# National Museum of the Marine Corps


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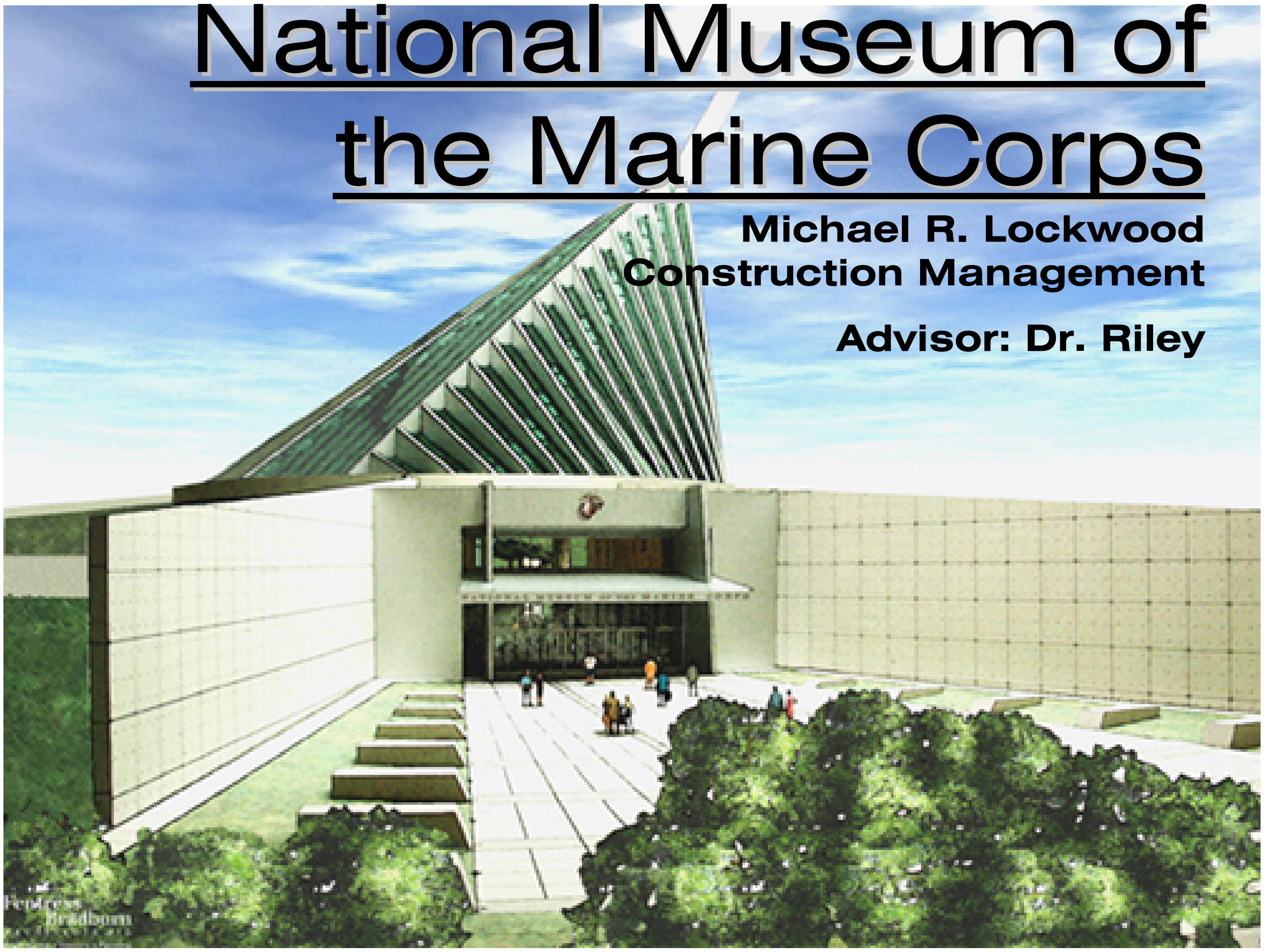

## Technical Assignment II – Analysis of Key Construction Issues

http://www.arche.psu.edu/thesis/2005/mrl185

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## Executive Summary

The information contained in the following document was compiled to analyze the key features of the National Museum of the Marine Corps project that affect project execution. An analysis of the schedule and costs of key building components is presented. A detailed investigation in the contract types and relationships between the project players was conducted and the results are presented. An overview of the design coordination and project staffing was done to further understand the project execution. And finally, a brief description of current construction industry issues and comparison to the project is presented.

The analysis of the schedule and costs of key building components provided a better understanding of the important attributes when executing the requirements of a project.

The detailed investigation of the contract types, contractor selection, and delivery system provides a better understanding of the responsibilities and scope of work of the project players. An assessment also presents the reasons why the delivery approach and contract types work well for a project of this nature.

A look into the general contractors project staffing provides a better understanding of the necessary members of a project team to complete a project of this nature. The current project staff was compared to that of the proposed staffing plan and was found to be relatively the same with only a couple minor exceptions.

The design coordination for the project has not begun at this time; however, the preliminary plan was established and discussed based on typical projects and information available at this time. A few potential problem areas requiring extensive coordination were addressed.

Finally, the brief description of current industry issues was presented and compared with components of this project to show the direct relationships between the rest of the industry and the project at hand.

## Assemblies Estimate

In order to determine a more detailed cost of the structural system of the National Museum of the Marine Corps, an assemblies estimate was performed. The following is a breakdown of the systems components and the resulting costs from the estimate. In order to provide the most accurate cost representation, location and other modification factors were used as appropriate. The location modification factor was already taken into account by the Means software for Alexandria, VA, which is the closest location in the Means database to Quantico, VA. Following the detailed breakdown of the estimates are a set of estimate summary tables. The first set of tables shows the unit costs for the assemblies used in this estimate and the second set of tables shows the estimated numbers calculated out with the respective values.

*Structural System Assemblies Estimate Details*

*Cast-in-Place Columns, Beams, Walls, and Slab-on-Grades*

- Columns:

  Means: 10’ Story Height, 24” x 24” Column

  Actual: 45’ Height, 24” x 48” Column

  Result: 1 actual column = 9 columns in means

  Modification Factors: 2 for size

  38 actual columns @ 45’ high

  38 *45 * 2 = 3420 V.L.F.

  **Total Estimated Cost = $3,723,314.14**

- Ring Beam:

  Means: 4” Beam/Slab Combination

  Actual: 10’ Thick Beam

  Modification Factor: 30 (4” * 30 = 10’)

  Area = 5026.5 $ft^2$ * 30 = 150,796 $ft^2$

  **Total Estimated Cost = $1,589,389.84**

- Walls:

  Means: 8' High, 12" Thick

  Actual: 45' High, 24" Thick

  Modification Factors: 2 for thickness

  Total Area = 43110 $ft^2$ * 2 = 86220 $ft^2$

  **Total Estimated Cost = $1,401,075.00**

- Slab-on-Grades:

  Means/Actual: 6" Thick

  Central Gallery Area = 17671.5 $ft^2$

  Outer Ring Area = 67858.4 $ft^2$

  Total Area = 85530 $ft^2$

  **Total Estimated Cost = $325,869.30**

*CMU Wall Assemblies*

- CMU Load Bearing Walls

  Means/Actual: 12" Block w/ reinforcing

  Area = 13552 $ft^2$

  **Total Estimated Cost = $132,852.40**

*Steel Columns (Non-Skylight)*

- Steel Column w/ Approx. 300 k Load

  Means: 300 k, 20' height

  Actual: 150-325 k range, 30' height

  Total V.L.F. = 1120 L.F.

  **Total Estimated Cost = $68,320.00**

- Steel Column w/ Approx. 200 k Load

  Means: 200 k, 20' height

  Actual: 125-225 k range, 20' height

  Total V.L.F. = 260 L.F.

  **Total Estimated Cost = $12,090.00**

*Skylight Steel Members*

- Ridge and Rib Beams

  **Total Estimated Cost = $1,379,560.00**

  The skylight steel estimate number was directly from the actual cost of the skylight members. This was due to uniqueness and complexity of system which could not be estimated using the assemblies methods developed by Means. The skylight is made of plate girders, beams, wind bracing rods, and sag rods.

*Slab-on-Metal Decks w/ Steel Beams*

- Composite Slab-on-Metal Deck w/ Beams

  Means: 75 psf w/ 5” Slab (Slab includes deck)

  Actual: 3” Deck w/ 3’1/4” Slab (Slab does not include deck)

  Total Area = 74490.4 $ft^2$

  **Total Estimated Cost = $825,353.63**

*Unit Price Assemblies Estimate Tables*

**CIP Concrete Columns, Walls, Ring Beam, & Slab-on-Grade Assemblies Estimate**

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | B10102033400 | CIP col, sq tied,900 K,10' sty ht,24" col,560 PLF wt,4000 PSI conc | V.L.F. | 32.50 | 86.50 | 119.00 | 223 | Union | 2004 | |
| 1.000 | B20101017600 | Conc wall reinforced, 8' high, 12" thick, plain finish, 5000 PSI | S.F. | 5.30 | 10.95 | 16.25 | 223 | Union | 2004 | |
| 1.000 | B10102193200 | CIP bm & slb,1 way,15x15',125PSF supimp,12" col min,4" slb,188PSF tot | S.F. | 2.89 | 7.65 | 10.54 | 223 | Union | 2004 | |
| 1.000 | A10301204480 | Slab on grade, 6" thick, non industrial, reinforced | S.F. | 1.93 | 1.88 | 3.81 | 223 | Union | 2004 | |
| | | **Totals** | | **$42.62** | **$106.98** | **$149.60** | | | | |

**CMU Wall Assemblies Estimate**

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | B20101115540 | Reinf conc blk W,rglrwt,hol,12x8x16",2000 PSI,#5@16"vert reinf&gt sp | S.F. | 3.50 | 6.45 | 9.95 | 223 | Union | 2004 | |
| | | **Totals** | | **$3.50** | **$6.45** | **$9.95** | | | | |

**Steel Wide-Flange Columns - (Non-Skylight)**

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | B10102085600 | Steel col,300 KIPS,20' unsupported height,79 PLF weight,12" wf | V.L.F. | 55.50 | 5.50 | 61.00 | 223 | Union | 2004 | C1, C2, C3, C6, C7 |
| 1.000 | B10102085000 | Steel col,200 KIPS,20' unsupported height,58 PLF weight,12" wf | V.L.F. | 41.00 | 5.50 | 46.50 | 223 | Union | 2004 | C4, C5, C8 |
| | | **Totals** | | **$96.50** | **$11.00** | **$107.50** | | | | |

**Concrete Slab-on-Metal Deck w/ Steel Beams**

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | B10102540560 | Wf,cmpst dk&slb,15x20',75PSF supimp,5" slb,1'-9"tot d,125PSF tot | S.F. | 6.45 | 4.63 | 11.08 | 223 | Union | 2004 | |
| | | **Totals** | | **$6.45** | **$4.63** | **$11.08** | | | | |

*Assemblies Estimate Summary Tables*

### *CIP Concrete Columns, Walls, Ring Beam, & Slab-on-Grade Assemblies Estimate*

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 3,420.000 | B10102033400 | CIP col, sq tied,900 K,10' sty ht,24" col,560 PLF wt,4000 PSI conc | V.L.F. | 111,150.00 | 295,830.00 | 406,980.00 | 223 | Union | 2004 | |
| 86,220.000 | B20101017600 | Conc wall reinforced, 8' high, 12" thick, plain finish, 5000 PSI | S.F. | 456,966.00 | 944,109.00 | 1,401,075.00 | 223 | Union | 2004 | |
| 150,796.000 | B10102193200 | CIP bm & slb,1 way,15x15',125PSF supimp,12" col min,4" slb,188PSF tot | S.F. | 435,800.44 | 1,153,589.40 | 1,589,389.84 | 223 | Union | 2004 | |
| 85,530.000 | A10301204480 | Slab on grade, 6" thick, non industrial, reinforced | S.F. | 165,072.90 | 160,796.40 | 325,869.30 | 223 | Union | 2004 | |
| | | **Totals** | | **$1,168,989.34** | **$2,554,324.80** | **$3,723,314.14** | | | | |

### *CMU Wall Assemblies Estimate*

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 13,352.000 | B20101115540 | Reinf conc blk W,rglrwt,hol,12x8x16",2000 PSI,#5@16"vert reinf&gt sp | S.F. | 46,732.00 | 86,120.40 | 132,852.40 | 223 | Union | 2004 | |
| | | **Totals** | | **$46,732.00** | **$86,120.40** | **$132,852.40** | | | | |

### *Steel Wide-Flange Columns - (Non-Skylight)*

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 1,120.000 | B10102085600 | Steel col,300 KIPS,20' unsupported height,79 PLF weight,12" wf | V.L.F. | 62,160.00 | 6,160.00 | 68,320.00 | 223 | Union | 2004 | C1, C2, C3, C6, C7 |
| 260.000 | B10102085000 | Steel col,200 KIPS,20' unsupported height,58 PLF weight,12" wf | V.L.F. | 10,660.00 | 1,430.00 | 12,090.00 | 223 | Union | 2004 | C4, C5, C8 |
| | | **Totals** | | **$72,820.00** | **$7,590.00** | **$80,410.00** | | | | |

### *Concrete Slab-on-Metal Deck w/ Steel Beams*

| Qty | Assembly Number | Description | Unit | Mat. | Inst. | Total | Zip Code Prefix | Type | Release | Note |
|---|---|---|---|---|---|---|---|---|---|---|
| 74,490.400 | B10102540560 | Wf,cmpst dk&slb,15x20',75PSF supimp,5" slb,1'-9"tot d,125PSF tot | S.F. | 480,463.08 | 344,890.55 | 825,353.63 | 223 | Union | 2004 | |
| | | **Totals** | | **$480,463.08** | **$344,890.55** | **$825,353.63** | | | | |

*Summary of Assemblies Estimates*

The estimates provided above were based on R.S. Means data and were modified based on location and other necessary factors to determine a relative cost of the given assembly. Although this provides a representative breakdown, it is not the best method to estimate because the most buildings have unique elements to them that do not necessarily fit into a “typical” Means assembly. Alterations can be made to adjust for these changes, but it ultimately could take more time to try and manipulate an assembly in Means than it would be to do a detailed takeoff and obtain unit prices for the materials, labor, and equipment for the individual system components.

*Proposed Scope of Work*

The superstructure for the National Museum of the Marine Corps consists of two distinct systems: cast-in-place concrete and structural steel. Below is a listing of the main components of each system which describes the scope of work and the items that will be estimated in the next technical assignment:

**Cast-in-Place Concrete Structure**

- 45’ high , 2’ thick CIP Walls
- Sloped CIP Wing Walls (42’ to 30’ high, 2’ thick
- 24” x 48” CIP Columns – 45’ high
- Elevated hanging CIP slab
- 6” Slab-on-grade
- Two 200’ exposed sloped architectural concrete walls

**Structural Steel Structure**

- Wide-flange steel columns
- HSS steel columns
- Wide-flange beams
- Plate Girders
- Wind bracing rods
- Slab-on-Metal Decks

## Contracts

The following chart is a graphical representation of the contract relationships for the National Museum of the Marine Corps project. Following the diagram, there is a description of the main contracts on the project and the roles associated with each contract holder.

*Project Organization Chart*

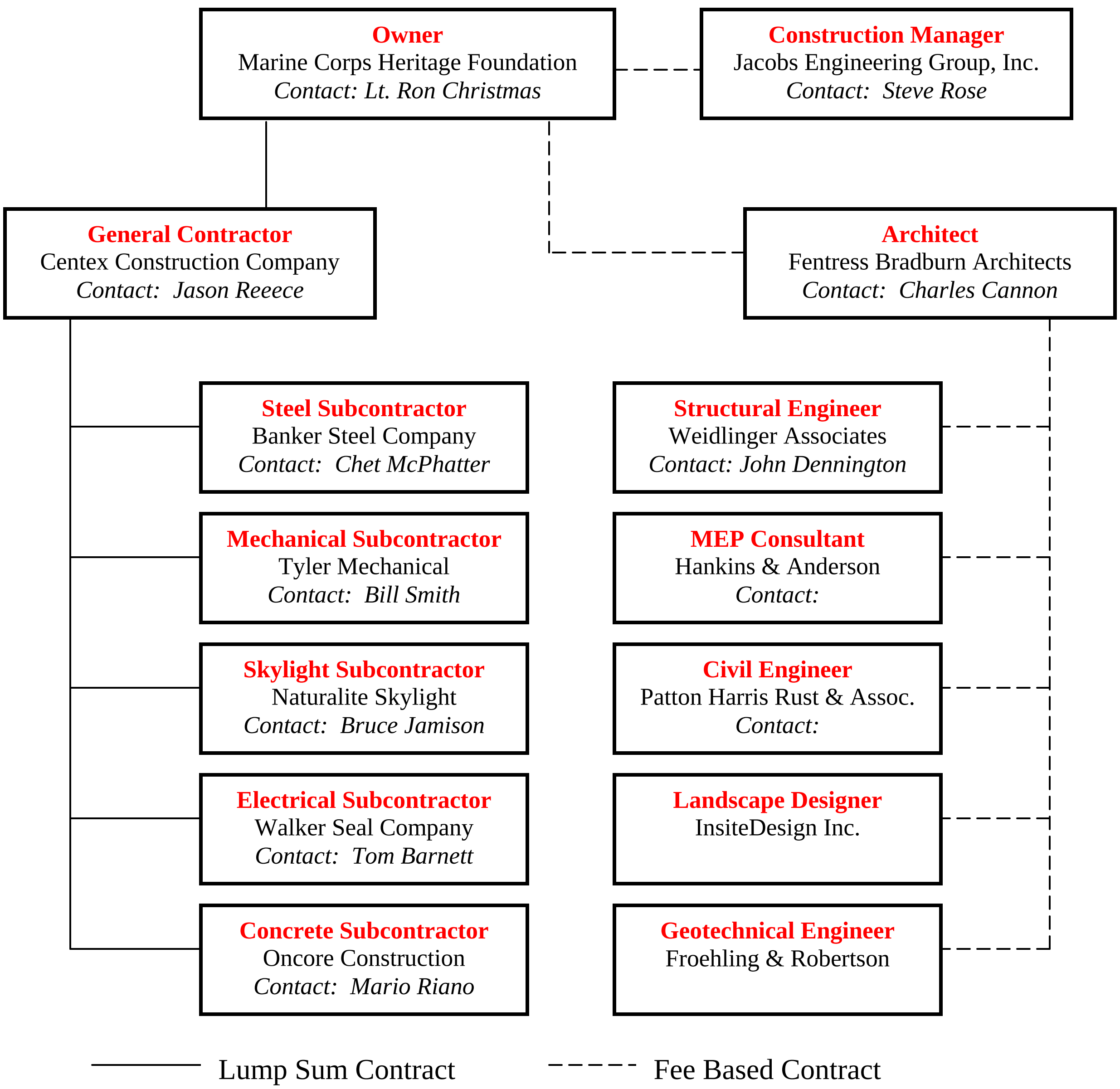



**Figure 1 – Project Organization Chart**

*Owner – Architect*

Contract Type: Fee Based Contract

Role of Owner:

- Provide architect with building program
- Approve/Disapprove architects plans for building

Role of Architect:

- Verify and Approve submittals
- Answer Requests for Information (RFI's)
- Approve Change Order Requests
- Update drawings per changes in design

The Owner carries a fee based contract with the Architect during the design and construction phases of the projects. During the design phase, the architect submitted percent complete drawings to the owner for approval until the final drawings were complete. Once the design was complete, the architect became the project consultant to the design. The architect was responsible for answering RFI's regarding the contract documents, approving change order requests, and approving submittals.

*Owner - Construction Manager*

Contract Type: Fee Based Contract

Role of Owner**:**

- Approve the payment requests
- Submit payment to CM and GC

Role of Construction Manager:

- To coordinate all information flow from GC to Owner
- Review monthly payment requests from GC to Owner
- Verify construction quality in field routinely
- Manage information flow to GC from the Owner

The owner hired a construction manager on a flat-fee contract to manage the general contractor throughout duration of the project. The construction manager is the owner's representative and is the direct contact between the owner and the general contractor. Essentially the construction manager performs document control, performs additional quality control, and reviews the general contractor's monthly payment requests.

*Owner – Contractor*

Contract Type: Lump Sum

Role of Owner:

- Furnish survey documents
- Provide site boundaries and access
- Direct the contractor of acceleration of schedule or changes
- Make monthly payments to contractor

Role of Contractor:

- Overall construction of project
- Buy and manage subcontractors
- Develop and maintain cost-loaded construction schedule
- Coordinate work between trades
- Develop and implement Quality Control Program
- Develop and maintain Safety Program

The owner established a lump sum contract with the general contractor on the project. The contractor was procured using a best value selection method. *Note: Further discussion to follow regarding contractor procurement*. The contractor for this project is responsible for the overall construction of the project, managing and coordinating work between subcontractors, developing and maintaining a cost-loaded construction schedule, implementation of Quality Control and Safety programs.

*Contractor – Subcontractor*

Contract Type: Lump Sum

Role of Contractor:

- Coordinate work between trades
- Review submittals and change order requests
- Develop and manage construction schedule

Role of Subcontractor:

- Perform contract scope of work
- Submit necessary requests for information
- Develop and submit shop drawings (As required)
- Develop submittals
- Perform work according to the GC's construction schedule
- Perform Quality Control inspections of work
- Abide by the GC's Safety Program
- Manage risks associated with contract

The general contractor holds a lump sum contract with all the subcontractors on the project. The general contractor's main role is to manage and coordinate the different trades on the project in order to enforce the construction schedule and get the project completed on time and in the most efficient manner. The subcontractors are responsible to perform all the duties of their individual scopes of work, prepare shop drawings (as required), develop submittals and perform quality control inspections on their work as part of the overall Quality Control Program.

*Bonds and Insurances Required*

The following is a list of the minimum insurance requirements specified by the contract documents:

- Comprehensive General Liability: $500,000
- Automobile Liability: $200,000 per person, $500,000 per occurrence for bodily injury, $20,000 per occurrence for property damage
- Workmen's Compensation: As required by Federal and State laws
- Employer's Liability: $100,000
- Others required by Virginia State Law

At this time, the others required by the Virginia State Law are not known as the contractor has been unable to provide me with the information required. Along the same lines, the information regarding the bonding requirements also has not become available from the contractor and is not specified in the contract specifications.

The following is a list of the typical bond requirements for various construction projects:

- Bid Bond
- Payment and Performance Bond
- Labor and Material Payment Bond

The payment and performance bond is the only bond known to be required on this project as the information has not become available from the contractor. It can be assumed however, that the other bonds are also required.

*Contractor Selection*

The National Museum of the Marine Corps project is a very high profile, high quality project. For this reason, the owner chose to use a best value contractor procurement method. A best value method allows the owner to select the contractor that will perform at the highest quality on the project. This varies from the typical low-bid selection process where the lowest bid contractor is awarded the project. A best value bid does not necessarily go to the lowest bidder. For this project, each of the qualified bidders was required to submit their bid and then present a proposal to the owner. A unique feature of this procurement selection was that the general contractor was required to have the three key subcontractors on board during the proposal stage: concrete subcontractor, skylight subcontractor, and steel subcontractor. Based on the bid and the proposal, the best contractor was selected for the job. Centex utilized the new 4D technology to illustrate the sequencing of the project and to show the owner exactly how things would be constructed and at what point certain activities would be completed. This is something that was very important to the owner.

*Assessment of Contract Types and Project Delivery System*

The National Museum of the Marine Corps developed as a design competition among nationally renowned architecture firms. Once the firm was selected, the designs became complete and the project essentially took on a design-bid-build delivery system. Therefore, when the owner invited the contractors to bid on the project, the design was already complete. The use of the best value procurement method allowed the owner to select the best contractor. A lump sum bid was used established between the general contractor and owner. This type of contract is very effective when the design is complete prior to obtaining the contractor. Also, the funding for the project was based on large donations from various sources; therefore, a lump sum provided the owner with a number that they could work with to obtain the necessary funding and let out more phases of the overall project as funding became available.

The traditional delivery system with a construction manager as the owner's representative was the most sensible choice because of the lack of construction experience by the owner and the geographic isolation of the architect (Colorado) to the project (Virginia). This delivery system allowed the construction manager to act as the owner's representative on-site while the architect made scheduled periodic site visits.

**Staffing Plan**

The following page illustrates the general contractor's project staffing plan. The project relationships are shown from the CEO down to the Field Engineers for the project. The Vice President of Operations is the figurehead of the project. The Project Executive reports directly to the V.P. of Operations. The QC Manager also directly reports to the V.P of Operations, but has a more unique roll on this project that will be discussed later. Under the Project Executive, there is the Project Manager and Superintendent who report direction to the Project Executive, and there is a QC Manager who does not report to the Project Executive. Essentially, the Project Executive's role is to oversee both the field and management facets of the project. The Project Manager has an Office Engineer along with an Office Manager to assist him on the project. The Superintendent is responsible for the Field Foreman, Chief Field Engineer, and, in this instance, is also the acting Site Safety and Health Officer. As the Site Safety and Health Officer, the Superintendent must report directly to the Safety Manager, who in turn reports directly to the Executive Vice President of the company.

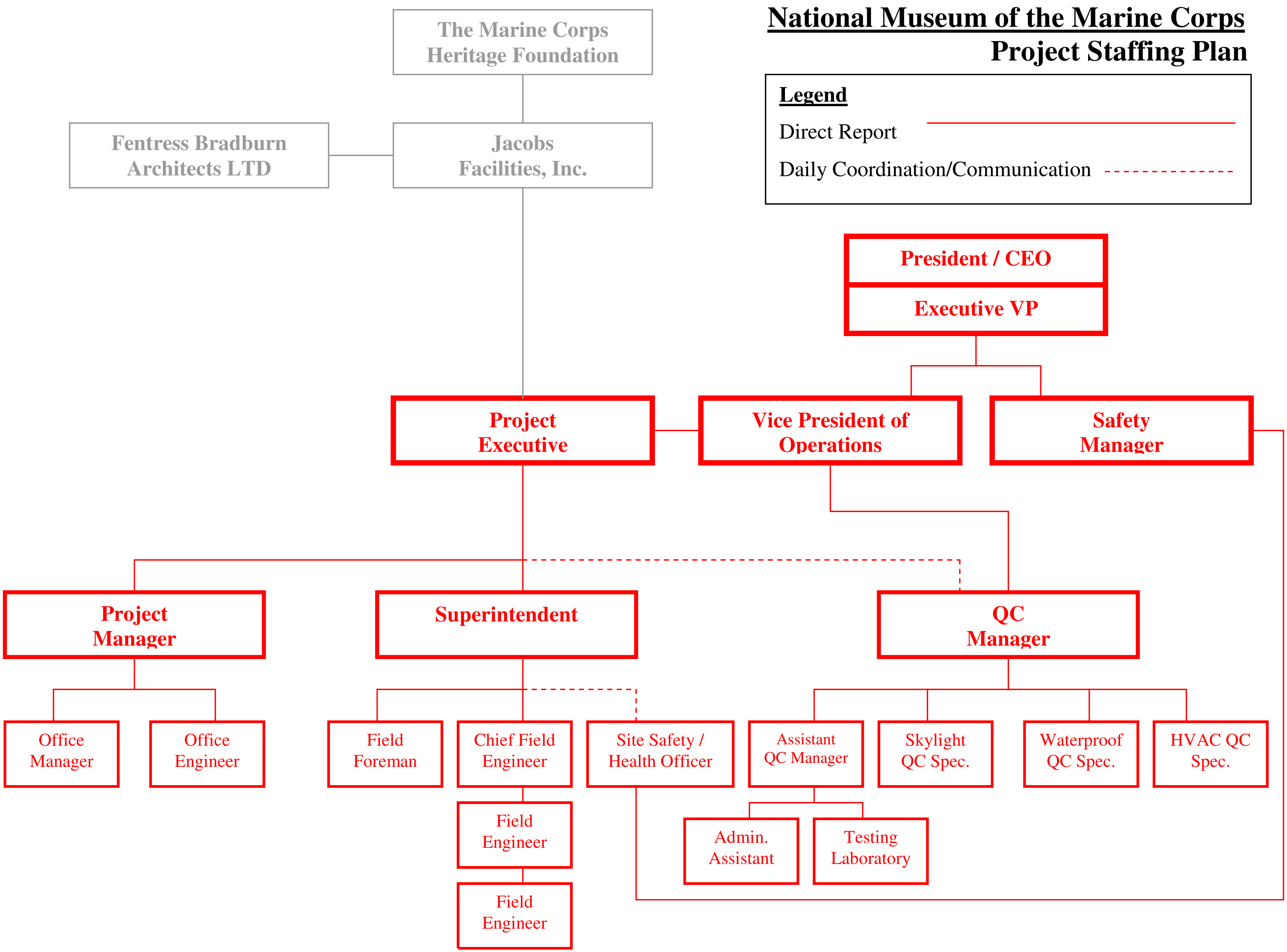



**Figure 2 – General Contractor Project Staffing Plan**

The role of the Quality Control Manager is unique for this project due to the high expectation of quality on the project. Section 01450 of the Contract Specifications requires the contracting officer to:

> "…establish and maintain a Quality Control (QC) program…consisting of a QC organization, a QC plan, a QC plan meeting, a coordination and mutual understanding meeting, QC Meetings, three phases of control, submittal review and approval, testing, completion inspections, and QC certifications and documentation…" (Specifications – Section 01450)

This section of the specifications details the role and responsibilities of the QC Manager. It also requires the QC Manager to have an Assistant QC Manager and an Administrative Assistant to help implement and manage the QC Program. Within the QC program, the contractor has established QC Assistants from the main subcontractors to provide quality control on their given field of work. The project staffing plan only represents a couple of these individual trades; however, there is a certified representative who reports directly to the general contractors QC Manager. This quality control program establishes a great deal of trust with the subcontractors which ultimately could result in a higher quality of workmanship from the given trades because they are being inspected by three levels of quality control. The representatives from the given trade must provide the most efficient inspections and do not want to overlook anything because a member of the quality control team or the construction manager will also be overlooking the work. At any time during the project, the QC Manager may terminate one of the certified QC representatives from their tasks and responsibilities if he/she is not conducting his/her given tasks according to the quality control program.

The project organization shown in the project staffing plan is a replica of the organization chart included with the proposal to the owner by the contractor. At this stage in construction, the project staff is set up as proposed to the owner with the one exception of the administrative assistant to the QC Manager. Currently, the Office Manager handles any duties that may have been the responsibility of the Administrative Assistant. During the summer months of construction, an intern also assisted the QC Manager and Assistant QC Manager with the tasks associated with the Quality Control

Program. Also added to this diagram were the two field engineers. These individuals were added to the project to conduct field layout and establish control points in the field. They do not have to lay out the work for the given trades; however, they must provide a check to all work before it is in place to assure things are being constructed according to the contract documents.

*Overall Project Staffing*

| **Project Staff Member** | **Project Phase** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Procurement** | | **Start-Up** | | **Excavation - Structural Phase** | | **Interior Phase** | | **Close-Out** | |
| Executive Vice President | | | | | | | | | | |
| Vice President of Operations | 1 | 1 | 1 | | | | | | | |
| Estimators | 1 | 1 | 1 | | | | | | | |
| Purchasing | | | 1 | 1 | | | | | | |
| Project Executive | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Project Manager | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| QC Manager | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Assistant QC Manager | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Superintendent | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| Chief Field Engineer | | | 1 | 1 | 1 | 1 | 1 | | | |
| Office Engineer | | | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 |
| Office Manager | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Project Engineer | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Safety Carpenter | | | | 1 | 1 | 1 | 1 | 1 | | |
| Field Engineer | | | | | 1 | 2 | | | | |

**Figure 3 – Overall Project Staffing Chart**

Figure 3 above illustrates the projected project staffing throughout the duration of the project. The project has been broken out into five distinct phases: procurement, start-up, excavation-structural, interior and close-out. Each of these phases is divided into two segments (or halves) to better illustrate when different staff members come on board the project and when they are removed from the project. Each segment represents the first and second half of a given phase.

A projected staffing chart such as this helps the contractor determine the personnel costs in the general conditions throughout the duration of the project. It also displays the level of involvement of the different staff members on the project and how the project develops.

## Design Coordination

Design coordination is one of the most important events that must take place on a construction project in order to successfully complete the project. Design coordination consists of coordinating trades and the systems in which those trades plan to install throughout the building.

The National Museum of the Marine Corps is currently in the initial structural phase with steel erection set to begin in mid-December 2004. Therefore, the design coordination process has not fully surfaced at this point. Based on discussions with the project staff, a detailed design coordination plan has yet to be established at this time. However, as with many projects, they plan to utilize the use of AutoCAD drawings and layers to coordinate the work between trades.

Typically, the electronic CAD files are developed by the contractors and then, one by one, laid on top of one another in AutoCAD. This technique allows individuals to determine any physical conflicts or lack of space in a given area for all of the systems components. The use of electronic drawings provides a quick and painless way to fix any conflicts or problem areas all at one time without numerous meetings to compare individuals revised drawings. One of the most important reasons for conducting design coordination prior to commencing work in the field on the given trades is to avoid potential conflicts/problems when work is physically being installed. If coordination is not done prior to construction of these systems, problems can arise in the field and could become very costly. The use of design coordination of trades ultimately reduces the potential conflicts and costs associated with them.

For this project, the mechanical contractor will have priority over the other trades in order to fit the ductwork and gravity lines in where they are required throughout the building. The sprinkler contractor will follow the mechanical contractor. And finally, the electrical contractor will be the last one in a space and is forced to fit the necessary conduit runs in the remaining space in a given area.

Considering the stage of the project at this point, there have been no problems with coordination and conflicts in the field because MEP work has not begun (other than embeds in concrete). One of the potential challenges on this project is the unique exterior buried supply ductwork to the Central Gallery space. This ductwork will provide a challenge of coordinating trades that tend not to work in the same areas as one another. The mechanical, electrical, excavation, concrete, damp-proofing, and stone contractors will be required to coordinate the work around this system. The ductwork penetrates the exterior cast-in-place wall and travels along the wall and then penetrates the wall at particular locations to diffusers located in the interior stone faced wall. The work will have to be carefully sequenced in order to reduce any conflict or delays with one subcontractor created by another.

Another area that will require a great deal of coordination is the mechanical room. The amount of equipment in the mechanical room and the runs of ductwork, piping, and conduit around and out of that room create an area of organized chaos. Without extensive coordination of trades in the mechanical room, there would be a very high potential for conflict and delay caused by other trades' work being in the wrong place or in too early for another's.

## Critical Industry Issues

*Integrated Design Management – Role of CM in Design*

An emerging construction delivery method is the early involvement of a construction manager or contractor in design. Contractors believe the earlier they can be involved, the more beneficial it can be for owners. This difficult task has become convincing the owners that their early involvement can in fact add value to the project. Based on the comments of the industry members during the discussion, once they have completed a project with an owner in which they were involved early, the owner was very pleased with this method and pursued it in their future projects.

The main issue that came of this discussion was how to measure the value added of having a construction manager on board early in design. As a contractor, they knew the value they could bring; however, portraying that value to an owner has been a challenge and needs more research to be done.

Based on this discussion, my research topic has begun to develop. I would like to pursue research in the area of the benefit of construction managers in the design process. My research will be based on interviews with design team members (architects, owners, and contractors), case study projects, and surveys to determine the real value of contractor involvement in design.

*Integrated Design and Construction II – Role of Technology*

As expected, the role of technology discussion was dominated by the student's participation. There were only three industry representatives in this discussion. The main concern regarding 3D/4D technology was the cost-benefit to the contractor. At this point in time, they do not see the benefit of the technology as compared to the costs of implementation. Until a case study project is complete to see the value of 3D/4D technology, it will be difficult to convince contractors to adapt this technology. Contractors need to see the real results of the technology on a project to see if it could be a useful tool for their projects.

Currently, Penn State has begun a case study project of the use of 3D/4D technology throughout the construction phase of a project. The case study is on the

National Museum of the Marine Corps. Therefore, it will be something I will be involved in and will have a direct effect on my thesis project. The results of this case study will be able to provide contractors with concrete results as to how this technology can add value to projects and if it would be a worthwhile investment for a company.

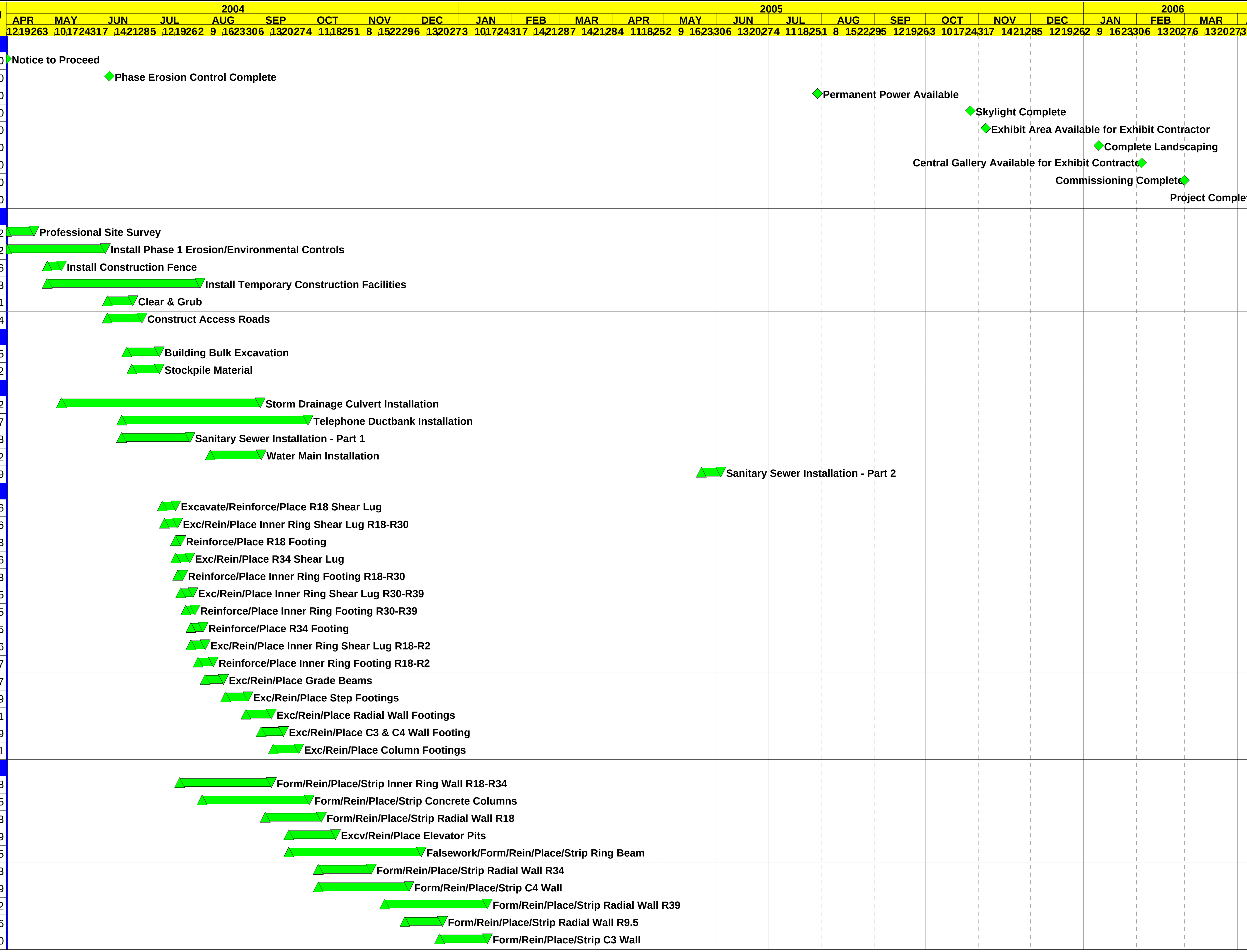
*Key Contacts*

- Bob Grottenthaler – Barton Malow.
    - Bob has a great deal of experience with the design-build market of construction as well as integration of design and construction. As Vice President of Barton Malow, he has been involved with numerous projects in which the CM was part of the design phase early in construction. Bob will be a great contact and source of information for my research.

- Howard Howe – Toyota Motor Sales U.S.A. Inc.
    - As part of Toyota Motor Sales construction division, Howard had a lot of good things to offer regarding the role of CM in design and has been able to wear both hats in this process as an owner and contractor. Howard will be able to provide great insight about the integrated design and construction process.

- Ray Sowers – Oncore Construction
    - Ray is a Senior Vice President of Oncore construction who is the concrete subcontractor on the National Museum of the Marine Corps project. Therefore, he will be a good source of knowledge regarding any critical issues or concerns of the concrete work on my project or the methodologies behind the approach to a complex project such as the museum project.

| Activity ID | Activity Description | Early Start | Early Finish | Orig Dur |
|---|---|---|---|---|
| **Milestone Activities** | | | | |
| 1000 | Notice to Proceed | 12APR04 | | 0 |
| 1010 | Phase Erosion Control Complete | | 10JUN04 | 0 |
| 1020 | Permanent Power Available | | 29JUL05 | 0 |
| 1030 | Skylight Complete | | 26OCT05 | 0 |
| 1040 | Exhibit Area Available for Exhibit | | 04NOV05 | 0 |
| 1050 | Complete Landscaping | | 09JAN06 | 0 |
| 1060 | Central Gallery Available for | | 03FEB06 | 0 |
| 1070 | Commissioning Complete | | 28FEB06 | 0 |
| 1080 | Project Complete | | 12APR06 | 0 |
| **Sitework** | | | | |
| 1090 | Professional Site Survey | 12APR04 | 27APR04 | 12 |
| 1120 | Install Phase 1 | 12APR04 | 08JUN04 | 42 |
| 1110 | Install Construction Fence | 06MAY04 | 13MAY04 | 6 |
| 1130 | Install Temporary Construction | 06MAY04 | 02AUG04 | 63 |
| 1100 | Clear & Grub | 10JUN04 | 24JUN04 | 11 |
| 1140 | Construct Access Roads | 10JUN04 | 29JUN04 | 14 |
| **Excavation** | | | | |
| 1150 | Building Bulk Excavation | 21JUN04 | 09JUL04 | 15 |
| 1160 | Stockpile Material | 24JUN04 | 09JUL04 | 12 |
| **Utilities** | | | | |
| 2420 | Storm Drainage Culvert | 14MAY04 | 06SEP04 | 82 |
| 2390 | Telephone Ductbank Installation | 18JUN04 | 04OCT04 | 77 |
| 2400 | Sanitary Sewer Installation - Part | 18JUN04 | 27JUL04 | 28 |
| 2430 | Water Main Installation | 09AUG04 | 07SEP04 | 22 |
| 2410 | Sanitary Sewer Installation - Part | 23MAY05 | 02JUN05 | 9 |
| **Foundations** | | | | |
| 1170 | Excavate/Reinforce/Place R18 | 12JUL04 | 19JUL04 | 6 |
| 1190 | Exc/Rein/Place Inner Ring Shear | 13JUL04 | 20JUL04 | 6 |
| 1180 | Reinforce/Place R18 Footing | 20JUL04 | 22JUL04 | 3 |
| 1210 | Exc/Rein/Place R34 Shear Lug | 20JUL04 | 27JUL04 | 6 |
| 1200 | Reinforce/Place Inner Ring | 21JUL04 | 23JUL04 | 3 |
| 1230 | Exc/Rein/Place Inner Ring Shear | 23JUL04 | 29JUL04 | 5 |
| 1240 | Reinforce/Place Inner Ring | 26JUL04 | 30JUL04 | 5 |
| 1220 | Reinforce/Place R34 Footing | 29JUL04 | 04AUG04 | 5 |
| 1250 | Exc/Rein/Place Inner Ring Shear | 29JUL04 | 05AUG04 | 6 |
| 1260 | Reinforce/Place Inner Ring | 02AUG04 | 10AUG04 | 7 |
| 1270 | Exc/Rein/Place Grade Beams | 06AUG04 | 16AUG04 | 7 |
| 1280 | Exc/Rein/Place Step Footings | 18AUG04 | 30AUG04 | 9 |
| 1290 | Exc/Rein/Place Radial Wall | 30AUG04 | 13SEP04 | 11 |
| 1300 | Exc/Rein/Place C3 & C4 Wall | 08SEP04 | 20SEP04 | 9 |
| 1310 | Exc/Rein/Place Column Footings | 15SEP04 | 29SEP04 | 11 |
| **Concrete** | | | | |
| 1340 | Form/Rein/Place/Strip Inner Ring | 22JUL04 | 13SEP04 | 38 |
| 1320 | Form/Rein/Place/Strip Concrete | 04AUG04 | 05OCT04 | 45 |
| 1350 | Form/Rein/Place/Strip Radial | 10SEP04 | 12OCT04 | 23 |
| 1330 | Excv/Rein/Place Elevator Pits | 24SEP04 | 20OCT04 | 19 |
| 1430 | Falsework/Form/Rein/Place/Strip | 24SEP04 | 09DEC04 | 55 |
| 1360 | Form/Rein/Place/Strip Radial | 11OCT04 | 10NOV04 | 23 |
| 1390 | Form/Rein/Place/Strip C4 Wall | 11OCT04 | 02DEC04 | 39 |
| 1370 | Form/Rein/Place/Strip Radial | 19NOV04 | 17JAN05 | 42 |
| 1400 | Form/Rein/Place/Strip Radial | 01DEC04 | 22DEC04 | 16 |
| 1410 | Form/Rein/Place/Strip C3 Wall | 21DEC04 | 17JAN05 | 20 |




Start Date 12APR04
Finish Date 12APR06
Data Date 12APR04
Run Date 21OCT04 10:58



Early Bar
Progress Bar
Critical Activity

NMMC

Sheet 1 of 4

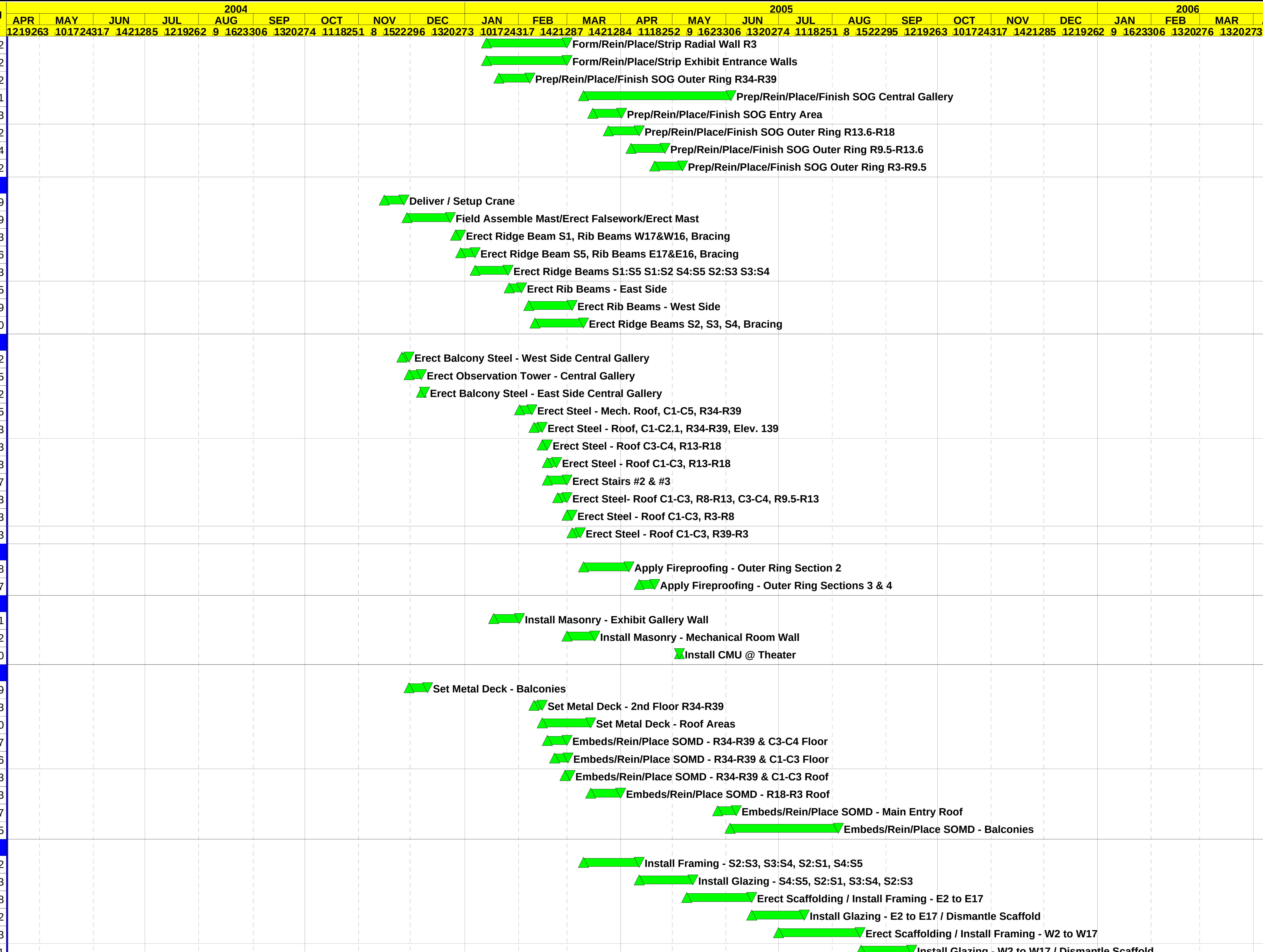
Michael R. Lockwood

National Museum of the Marine Corps

Classic Schedule Layout

| Date | Revision | Checked | Approved |
|---|---|---|---|

| Activity ID | Activity Description | Early Start | Early Finish | Orig Dur |
|---|---|---|---|---|
| 1380 | Form/Rein/Place/Strip Radial | 14JAN05 | 28FEB05 | 32 |
| 1420 | Form/Rein/Place/Strip Exhibit | 14JAN05 | 28FEB05 | 32 |
| 1460 | Prep/Rein/Place/Finish SOG | 21JAN05 | 07FEB05 | 12 |
| 1440 | Prep/Rein/Place/Finish SOG | 11MAR05 | 03JUN05 | 61 |
| 1450 | Prep/Rein/Place/Finish SOG | 16MAR05 | 01APR05 | 13 |
| 1470 | Prep/Rein/Place/Finish SOG | 25MAR05 | 11APR05 | 12 |
| 1480 | Prep/Rein/Place/Finish SOG | 07APR05 | 26APR05 | 14 |
| 1490 | Prep/Rein/Place/Finish SOG | 21APR05 | 06MAY05 | 12 |
| **Skylight Steel** | | | | |
| 1500 | Deliver / Setup Crane | 16NOV04 | 26NOV04 | 9 |
| 1510 | Field Assemble Mast/Erect | 29NOV04 | 23DEC04 | 19 |
| 1520 | Erect Ridge Beam S1, Rib Beams | 27DEC04 | 29DEC04 | 3 |
| 1530 | Erect Ridge Beam S5, Rib Beams | 30DEC04 | 06JAN05 | 6 |
| 1540 | Erect Ridge Beams S1:S5 S1:S2 | 07JAN05 | 25JAN05 | 13 |
| 1550 | Erect Rib Beams - East Side | 27JAN05 | 02FEB05 | 5 |
| 1560 | Erect Rib Beams - West Side | 07FEB05 | 03MAR05 | 19 |
| 1570 | Erect Ridge Beams S2, S3, S4, | 11FEB05 | 10MAR05 | 20 |
| **Non-Skylight Steel** | | | | |
| 1650 | Erect Balcony Steel - West Side | 26NOV04 | 29NOV04 | 2 |
| 1660 | Erect Observation Tower - | 30NOV04 | 06DEC04 | 5 |
| 1670 | Erect Balcony Steel - East Side | 07DEC04 | 08DEC04 | 2 |
| 1580 | Erect Steel - Mech. Roof, C1-C5, | 02FEB05 | 08FEB05 | 5 |
| 1590 | Erect Steel - Roof, C1-C2.1, | 10FEB05 | 14FEB05 | 3 |
| 1600 | Erect Steel - Roof C3-C4, | 15FEB05 | 17FEB05 | 3 |
| 1610 | Erect Steel - Roof C1-C3, | 18FEB05 | 22FEB05 | 3 |
| 1680 | Erect Stairs #2 & #3 | 18FEB05 | 28FEB05 | 7 |
| 1620 | Erect Steel- Roof C1-C3, R8-R13, | 24FEB05 | 28FEB05 | 3 |
| 1630 | Erect Steel - Roof C1-C3, R3-R8 | 01MAR05 | 03MAR05 | 3 |
| 1640 | Erect Steel - Roof C1-C3, R39-R3 | 04MAR05 | 08MAR05 | 3 |
| **Fireproofing** | | | | |
| 1870 | Apply Fireproofing - Outer Ring | 11MAR05 | 05APR05 | 18 |
| 1880 | Apply Fireproofing - Outer Ring | 12APR05 | 20APR05 | 7 |
| **Masonry** | | | | |
| 2270 | Install Masonry - Exhibit Gallery | 18JAN05 | 01FEB05 | 11 |
| 2260 | Install Masonry - Mechanical | 01MAR05 | 16MAR05 | 12 |
| 2280 | Install CMU @ Theater | 05MAY05 | 04MAY05 | 0 |
| **Slab-on-Metal Deck** | | | | |
| 1690 | Set Metal Deck - Balconies | 30NOV04 | 10DEC04 | 9 |
| 1700 | Set Metal Deck - 2nd Floor | 10FEB05 | 14FEB05 | 3 |
| 1710 | Set Metal Deck - Roof Areas | 15FEB05 | 14MAR05 | 20 |
| 1720 | Embeds/Rein/Place SOMD - | 18FEB05 | 28FEB05 | 7 |
| 1730 | Embeds/Rein/Place SOMD - | 22FEB05 | 01MAR05 | 6 |
| 1740 | Embeds/Rein/Place SOMD - | 28FEB05 | 02MAR05 | 3 |
| 1750 | Embeds/Rein/Place SOMD - | 15MAR05 | 31MAR05 | 13 |
| 1760 | Embeds/Rein/Place SOMD - | 27MAY05 | 06JUN05 | 7 |
| 1770 | Embeds/Rein/Place SOMD - | 03JUN05 | 04AUG05 | 45 |
| **Skylight Framing and Glazing** | | | | |
| 1780 | Install Framing - S2:S3, S3:S4, | 11MAR05 | 11APR05 | 22 |
| 1790 | Install Glazing - S4:S5, S2:S1, | 12APR05 | 12MAY05 | 23 |
| 1800 | Erect Scaffolding / Install Framing | 09MAY05 | 15JUN05 | 28 |
| 1810 | Install Glazing - E2 to E17 / | 16JUN05 | 15JUL05 | 22 |
| 1820 | Erect Scaffolding / Install Framing | 01JUL05 | 16AUG05 | 33 |
| 1830 | Install Glazing - W2 to W17 / | 18AUG05 | 15SEP05 | 21 |

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Early Bar
Progress Bar
Critical Activity



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Classic Schedule Layout

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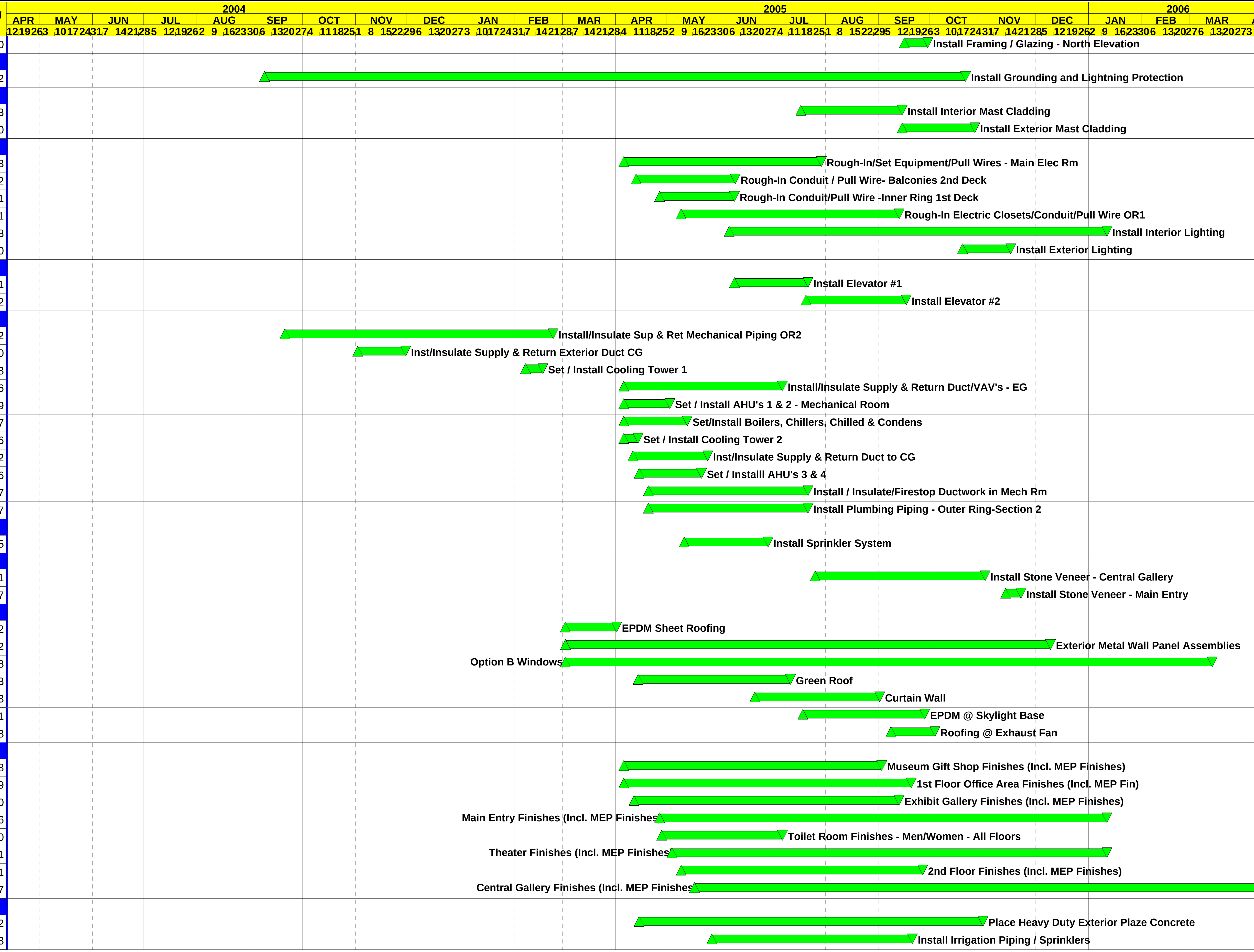
|---|---|---|---|

| Activity ID | Activity Description | Early Start | Early Finish | Orig Dur |
|---|---|---|---|---|
| 1840 | Install Framing / Glazing - North | 16SEP05 | 29SEP05 | 10 |
| **Grounding and Lightning Protection** | | | | |
| 2060 | Install Grounding and Lightning | 09SEP04 | 21OCT05 | 292 |
| **Mast Cladding** | | | | |
| 1850 | Install Interior Mast Cladding | 18JUL05 | 14SEP05 | 43 |
| 1860 | Install Exterior Mast Cladding | 15SEP05 | 26OCT05 | 30 |
| **Electrical** | | | | |
| 1910 | Rough-In/Set Equipment/Pull | 06APR05 | 29JUL05 | 83 |
| 1920 | Rough-In Conduit / Pull Wire- | 13APR05 | 09JUN05 | 42 |
| 1890 | Rough-In Conduit/Pull Wire -Inner | 27APR05 | 08JUN05 | 31 |
| 1900 | Rough-In Electric | 09MAY05 | 12SEP05 | 91 |
| 1930 | Install Interior Lighting | 06JUN05 | 11JAN06 | 158 |
| 1940 | Install Exterior Lighting | 20OCT05 | 16NOV05 | 20 |
| **Elevators** | | | | |
| 2290 | Install Elevator #1 | 09JUN05 | 21JUL05 | 31 |
| 2300 | Install Elevator #2 | 21JUL05 | 16SEP05 | 42 |
| **Mechanical** | | | | |
| 1990 | Install/Insulate Sup & Ret | 21SEP04 | 23FEB05 | 112 |
| 1950 | Inst/Insulate Supply & Return | 02NOV04 | 29NOV04 | 20 |
| 2030 | Set / Install Cooling Tower 1 | 08FEB05 | 17FEB05 | 8 |
| 1970 | Install/Insulate Supply & Return | 06APR05 | 06JUL05 | 66 |
| 2010 | Set / Install AHU's 1 & 2 - | 06APR05 | 02MAY05 | 19 |
| 2020 | Set/Install Boilers, Chillers, | 06APR05 | 12MAY05 | 27 |
| 2040 | Set / Install Cooling Tower 2 | 06APR05 | 13APR05 | 6 |
| 1960 | Inst/Insulate Supply & Return | 11APR05 | 24MAY05 | 32 |
| 2050 | Set / Installl AHU's 3 & 4 | 15APR05 | 20MAY05 | 26 |
| 1980 | Install / Insulate/Firestop | 20APR05 | 21JUL05 | 67 |
| 2000 | Install Plumbing Piping - Outer | 20APR05 | 21JUL05 | 67 |
| **Sprinklers** | | | | |
| 2310 | Install Sprinkler System | 11MAY05 | 28JUN05 | 35 |
| **Interior Stone Facing** | | | | |
| 2070 | Install Stone Veneer - Central | 26JUL05 | 01NOV05 | 71 |
| 2080 | Install Stone Veneer - Main Entry | 14NOV05 | 22NOV05 | 7 |
| **Building Envelope** | | | | |
| 2190 | EPDM Sheet Roofing | 03MAR05 | 01APR05 | 22 |
| 2230 | Exterior Metal Wall Panel | 03MAR05 | 09DEC05 | 202 |
| 2240 | Option B Windows | 03MAR05 | 13MAR06 | 268 |
| 2250 | Green Roof | 14APR05 | 11JUL05 | 63 |
| 2220 | Curtain Wall | 21JUN05 | 01SEP05 | 53 |
| 2200 | EPDM @ Skylight Base | 19JUL05 | 27SEP05 | 51 |
| 2210 | Roofing @ Exhaust Fan | 08SEP05 | 03OCT05 | 18 |
| **Interior Finishes** | | | | |
| 2130 | Museum Gift Shop Finishes (Incl. | 06APR05 | 02SEP05 | 108 |
| 2140 | 1st Floor Office Area Finishes | 06APR05 | 19SEP05 | 119 |
| 2160 | Exhibit Gallery Finishes (Incl. | 12APR05 | 12SEP05 | 110 |
| 2180 | Main Entry Finishes (Incl. MEP | 27APR05 | 11JAN06 | 186 |
| 2110 | Toilet Room Finishes - | 28APR05 | 06JUL05 | 50 |
| 2150 | Theater Finishes (Incl. MEP | 04MAY05 | 11JAN06 | 181 |
| 2120 | 2nd Floor Finishes (Incl. MEP | 09MAY05 | 26SEP05 | 101 |
| 2170 | Central Gallery Finishes (Incl. | 17MAY05 | 12APR06 | 237 |
| **Landscaping** | | | | |
| 2320 | Place Heavy Duty Exterior Plaze | 15APR05 | 31OCT05 | 142 |
| 2340 | Install Irrigation Piping / | 27MAY05 | 20SEP05 | 83 |

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Early Bar
Progress Bar
Critical Activity

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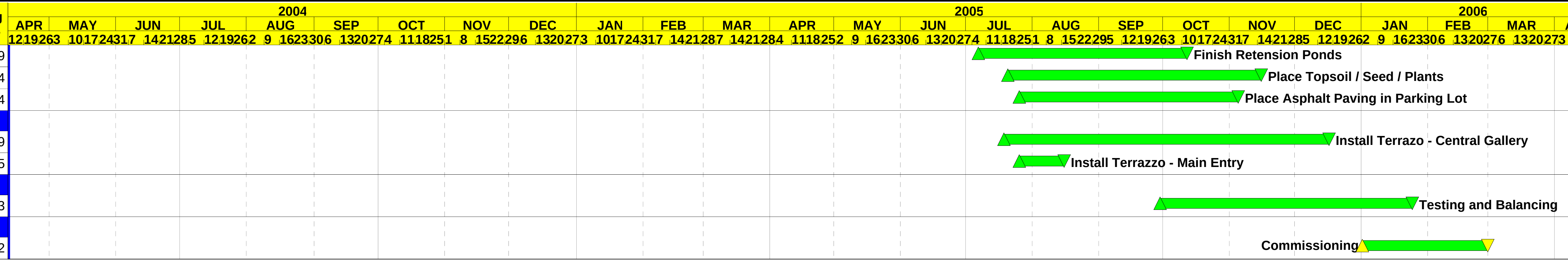
National Museum of the Marine Corps

Classic Schedule Layout

| Date | Revision | Checked | Approved |
|---|---|---|---|

| Activity ID | Activity Description | Early Start | Early Finish | Orig Dur |
|---|---|---|---|---|
| 2360 | Finish Retension Ponds | 07JUL05 | 11OCT05 | 69 |
| 2350 | Place Topsoil / Seed / Plants | 21JUL05 | 15NOV05 | 84 |
| 2330 | Place Asphalt Paving in Parking | 26JUL05 | 04NOV05 | 74 |
| **Terrazzo Flooring** | | | | |
| 2090 | Install Terrazo - Central Gallery | 19JUL05 | 16DEC05 | 109 |
| 2100 | Install Terrazzo - Main Entry | 26JUL05 | 15AUG05 | 15 |
| **Testing and Balancing** | | | | |
| 2370 | Testing and Balancing | 30SEP05 | 24JAN06 | 83 |
| **Commissioning** | | | | |
| 2380 | Commissioning | 02JAN06 | 28FEB06 | 42 |

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|---|---|
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