National Museum of the Marine Corps

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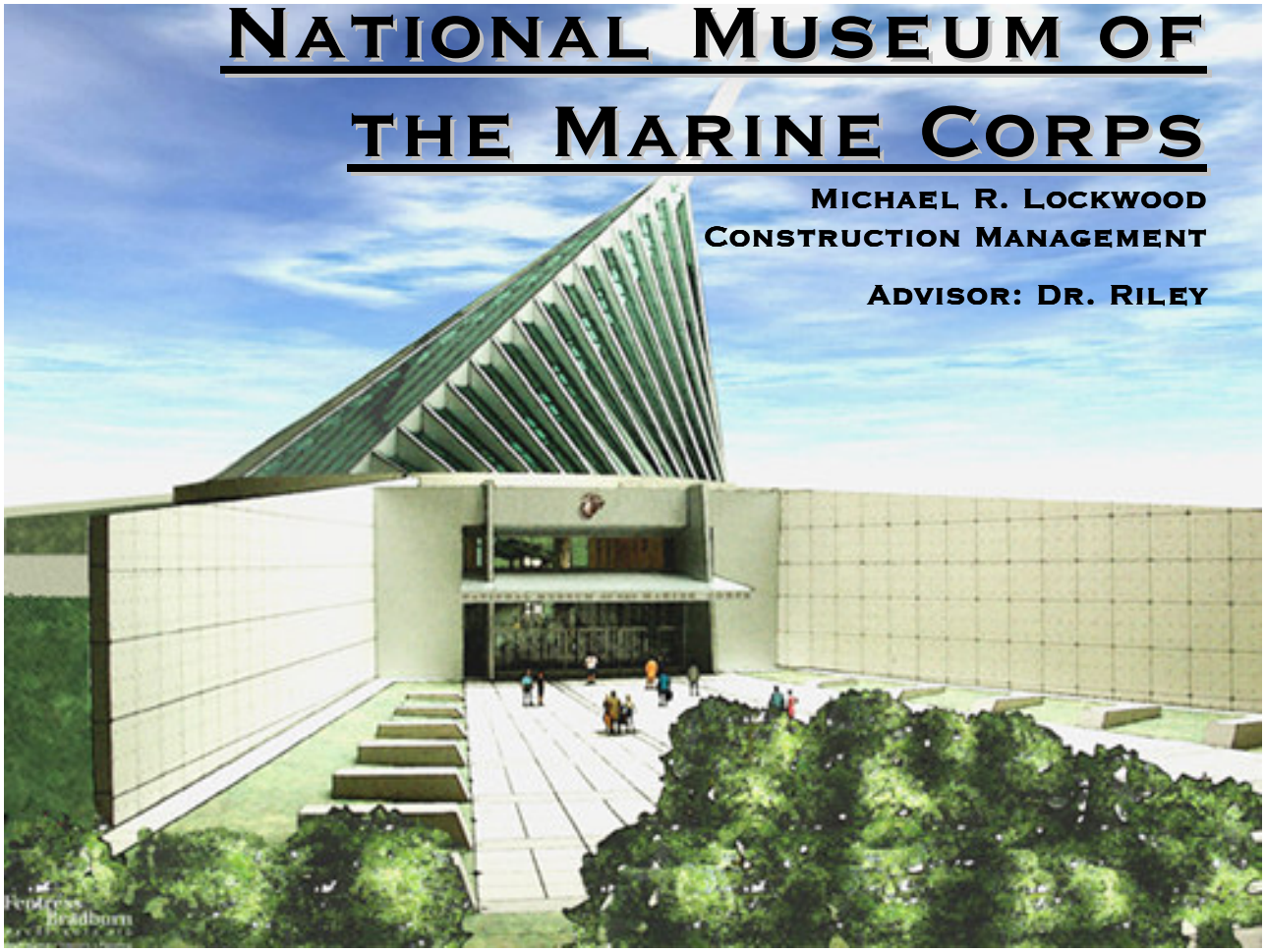

Technical Assignment I – Existing Construction Conditions

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

Executive Summary

The National Museum of the Marine Corps was designed using the LEED rating as a framework for sustainable design. The architects have incorporated several sustainable design features to improve load reduction, enhance renewable energy strategies, and high efficiency mechanical and electrical systems. Some of the design features are the large skylight system located above the Central Gallery space, retained earth on the exterior of the façade, and high performance glazing throughout. The project contains both cast-in-place and steel structural systems.

A traditional design-bid-build delivery approach has been undertaken for the project. The owner utilized a best value procurement method to obtain a contractor for the project. This method allowed for the best possible value delivery, which is important considering the high-level of quality expectations. The contractor was announced and given notice to proceed on April 12, 2004. The project is scheduled to be completed on April 12, 2006. A brief summary of the construction schedule shows the key activities durations, and time frame within the project as a whole.

A unique shear key footing system has been designed to carry the load imposed by the cast-in-place concrete walls and the earth berm backfill. The skylight consists of structural steel trusses, plate girders, and beams. The exterior ring of the building consists of structural steel columns and beams with a slab-on-metal deck floor system. Two large architectural concrete walls will funnel visitors to the main entrance of the museum.

The overall project cost is approximately $42,000,000 with the actual building cost around $35,000,000. Multiple estimating methods were developed to verify the cost and determine the reason for any potential difference in actual costs versus the estimated cost. The building is located on a formerly wooded area with mostly clayey soils. Site utilization and accessibility will not be a major concern due to the vast size of the project site, as the museum is only the first phase of an overall Marine Corps campus facility.

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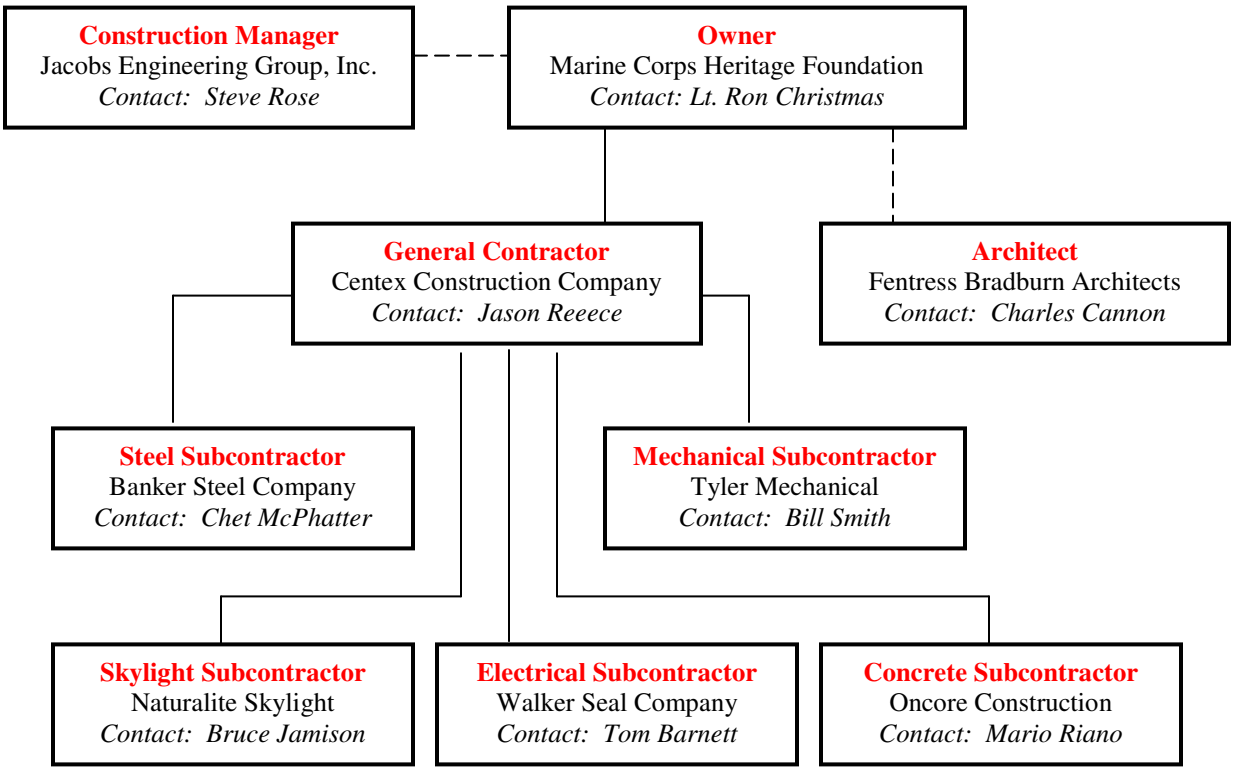
Project Delivery System

The National Museum of the Marine Corps project is being delivered as a design-bid-build traditional arrangement. The architect for the project was chosen as a result of a design competition in which 30 companies were invited to compete. The design competition allowed the owner to find the design that best portrayed the heritage of the Marine Corps. The owner also selected a best value procurement method for the project. This allowed the owner to choose the company that provided the best overall value instead of the lowest bid due to the high level of quality expected on the project.

The following summary diagram illustrates the contractual relationships on the project. (Note: a full version of the organizational chart can be seen in Appendix A). Under this arrangement, the owner holds contracts with the general contractor, architect, and construction manager, acting as the owner's representative. The owner holds a lump sum contract with a general contractor (Centex) and a fee based contract with the architect (Fentress Bradburn). The construction manager (Jacobs) was hired with a fee based contract by the owner to assist in managing the architect and general contractor, and monitoring the construction work to ensure quality. The general contractor holds a number of lump sum contracts with numerous subcontractors to perform the specialty work required to construct the building.

Organizational Chart[1]

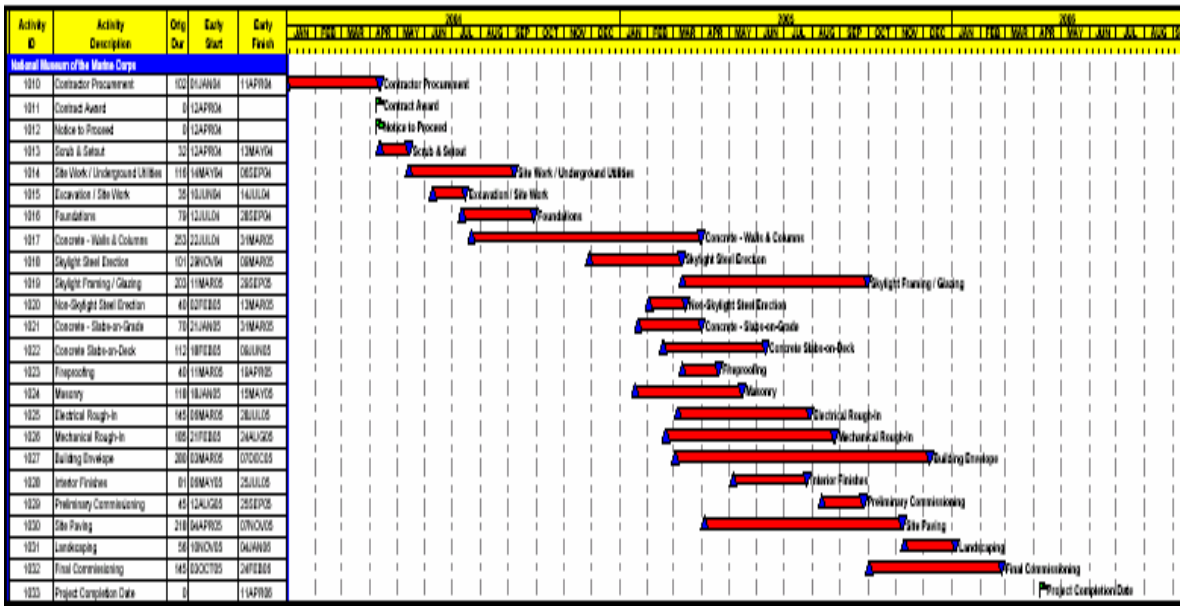


[1] This is only a partial project organization chart. Reference Appendix C for a full version.

Project Schedule Summary[2]

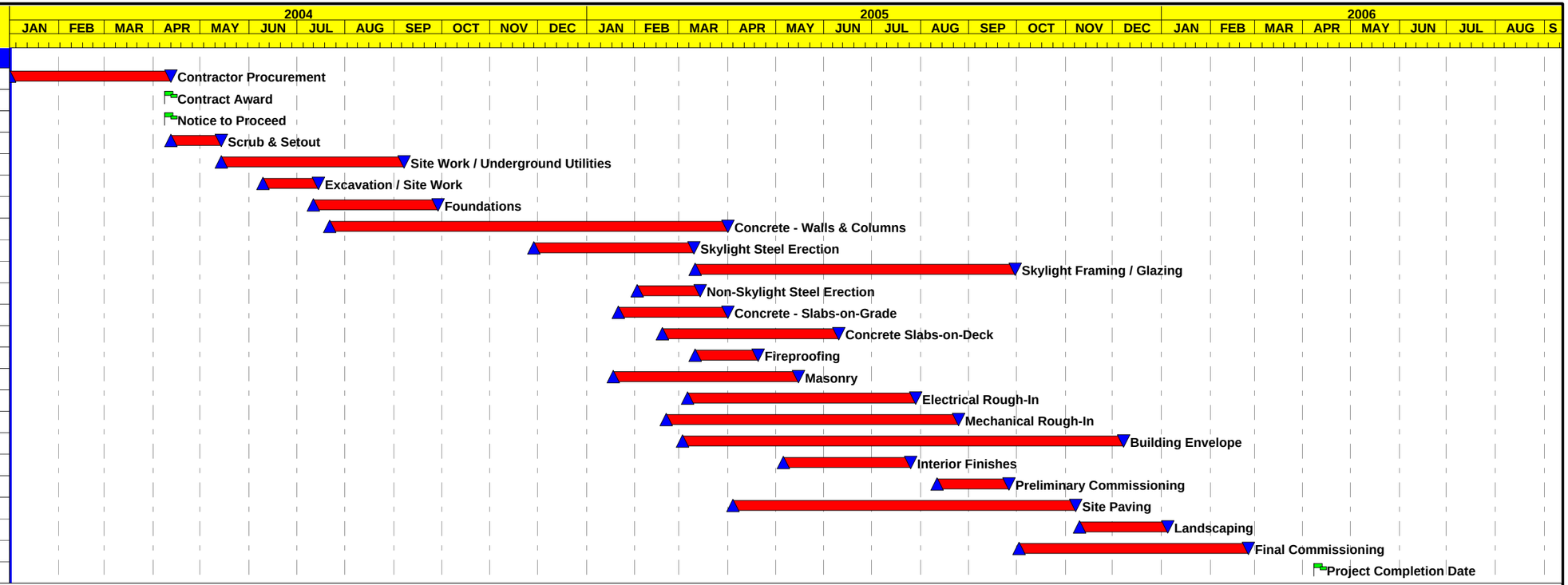
The schedule located in Appendix D provides a summarized view of the activities related to the overall development of the museum project. On April 12, 2004 the general contractor was awarded the contract and given the official notice to proceed. The project duration is two years and is scheduled to be competed on April 12, 2006.

Site work and foundations will be completed by mid-September 2004. A major milestone will be the erection of the 210-ft. mast section of the skylight system. The steel erection for the skylight is scheduled to begin in early December 2004 and continue until March 2005. Therefore, the weather during the winter months could have a significant impact on the structural steel erection. As can be seen from the summary schedule, commissioning is a key activity in turning over the completed project. For this project, there are two separate commissioning phases, a preliminary phase in which the subcontractor and general contractor will go through the commissioning steps to be sure everything is in order, and then a final commissioning stage which is an extensive program to turnover the project to the owner.



[2] Full version of the project summary schedule is located in Appendix D.

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
National Museum of the Marine Corps				
1010	Contractor Procurement	102	01JAN04	11APR04
1011	Contract Award	0	12APR04	
1012	Notice to Proceed	0	12APR04	
1013	Scrub & Setout	32	12APR04	13MAY04
1014	Site Work / Underground Utilities	116	14MAY04	06SEP04
1015	Excavation / Site Work	35	10JUN04	14JUL04
1016	Foundations	79	12JUL04	28SEP04
1017	Concrete - Walls & Columns	253	22JUL04	31MAR05
1018	Skylight Steel Erection	101	29NOV04	09MAR05
1019	Skylight Framing / Glazing	203	11MAR05	29SEP05
1020	Non-Skylight Steel Erection	40	02FEB05	13MAR05
1021	Concrete - Slabs-on-Grade	70	21JAN05	31MAR05
1022	Concrete Slabs-on-Deck	112	18FEB05	09JUN05
1023	Fireproofing	40	11MAR05	19APR05
1024	Masonry	118	18JAN05	15MAY05
1025	Electrical Rough-In	145	06MAR05	28JUL05
1026	Mechanical Rough-In	185	21FEB05	24AUG05
1027	Building Envelope	280	03MAR05	07DEC05
1028	Interior Finishes	81	06MAY05	25JUL05
1029	Preliminary Commissioning	45	12AUG05	25SEP05
1030	Site Paving	218	04APR05	07NOV05
1031	Landscaping	56	10NOV05	04JAN06
1032	Final Commissioning	145	03OCT05	24FEB06
1033	Project Completion Date	0		11APR06



Start Date 01JAN04
Finish Date
Data Date 01JAN04
Run Date 30SEP04 17:07

Early Bar
Progress Bar
Critical Activity

MIKE

Sheet 1 of 1

Michael R. Lockwood

National Museum of the Marine Corps

Classic Schedule Layout

Date	Revision	Checked	Approved

Building Systems Summary[3]

***Refer to Appendix C for a key plan to reference the building locations referenced in the following building system summaries.

Foundation System

The foundation system consists of deep shear key footings, spread footings, and grade beams. The footings all have a 4000 psi design strength.

The inner ring consists of a deep shear key footing topped with a 15' wide x 60" deep ring footing to support the load of the cast-in-place concrete wall and the earth backfill against the wall. Both components of the inner ring footing system are poured against the earth. The adjacent figure 1 represents an excavated portion of the shear key footing system during construction.

Figure 1 – Shear Key Footing System

A large spread footing located in the center of the inner ring carries the load for the mast portion of the skylight system. Four grade beams extend from the mast footing to the inner ring footing to carry a portion of the load of the 150' diameter slab-on-grade in the Central Gallery.

The remainder of the building consists of spread footings. The size of the spread footings depends on the bearing capacity of the excavated soil: 3000 psf or 5000 psf. All of the columns can have two distinct footing sizes depending on the bearing capacity of the soil.

[3] Refer to Appendix C for a key plan illustrating the building sections.

Structural System

The structural system for the museum is a combination of systems: cast-in-place concrete columns and walls, structural steel columns and beams, and load bearing masonry walls.

Cast-in-Place Concrete

The inner ring of the museum is constructed using cast-in-place concrete. One third of the inner ring consists of a 45' high, 2' thick concrete wall with integrated columns. The remaining portion of the inner ring consists of cast-in-place concrete columns. A ring beam sits atop the wall and columns around the entire inner ring to distribute the loads created by the massive skylight system. Figure 2 shows the formwork and rebar being constructed along the inner ring wall.

Rodbuster tying steel at central gallery wall - August, 2004

Figure 2 – Inner Ring Wall

Four cast-in-place wing walls extend from the inner ring area. These walls carry the load of the backfilled earth along with framing members throughout the building. The two wing walls adjacent to the main entrance will be architectural concrete. Therefore, a unique and specialized formwork system will be used to create the design pattern and expansion and construction joints in the walls.

Structural Steel

The outer ring portions of the building consist of structural steel columns and beams. The steel members are ASTM A992 grade steel. The crane will be located in the main entrance area of the building in order to erect all the members in the outer ring.

The skylight framing system consists of a large mast-truss extending from the center of the inner ring area. Four plate girder ridge beams connect the mast-truss to the ring beam. The remaining skylight structure consists of rib beams

connecting the mast to the ring beam. Wind bracing rods and sag rods provide the support necessary to carry the loads imposed on the structure. The crane will be located on the outside of the inner ring wall to erect the skylight structural steel.

Load Bearing Masonry

The exterior wall of outer ring section #4 of the exhibit gallery is a built up 12" load-bearing masonry wall. The wall carries the load imposed by the steel beams, the roof slab-on-deck, and the green roof components.

Floor System

The floor system consists of slab-on-grade on the first floor of the building and a combination of a cast-in-place slab and slab-on-metal deck on the second floor. The cast-in-place slab is a suspended walkway around the exterior of the inner ring. The remainder of the second floor is slab-on-metal deck in the outer ring portions of the building.

Skylight System

A unique element of the museum project is the large skylight system. The design of the skylight system reflects the flag raising at Iwo Jima. A 210-ft. mast extends from the main skylight system. The skylight soars 160' above ground consisting of structural steel framing members and high-energy efficient glazing. The skylight system is one of many sustainable design features of the building. The following graphics depict the skylight system

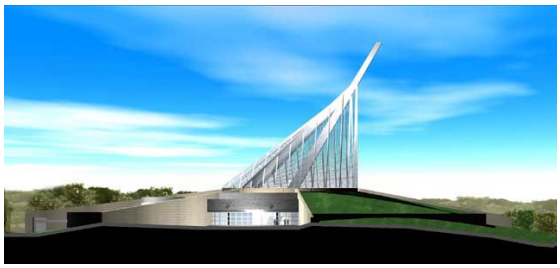


Figure 3 – Skylight System Elevation 1

Figure 4 – Skylight System Elevation 2

Mechanical System

The mechanical system for the museum consists of four air handling units (AHU) located in the mechanical room, outer ring-section #2. One AHU distributes air through exterior, buried ductwork located outside of the inner ring wall that supplies air to the central gallery space. The return air flows from the floor level and up the wall cavity to a large return air duct that returns to the AHU. The other AHU's distribute air throughout the remainder of the building. Two cooling towers are located on the exterior of the mechanical room. Variable air volume (VAV) are located throughout the building to monitor air flow into spaces and provide temperature adjustments where required.

Curtain Wall System

The majority of the building is an earth backfilled berm; therefore, there is not a significant amount of curtain wall in the building. However, the main components of the curtain wall are masonry walls with a metal panel system. The second floor has some high efficiency glazing and the main entrance way is a unique, removable, glass storefront.

Excavation Methods

The existing soil conditions on the site allowed for excavation of the building footprint and the foundation systems to be done without use of any special earth retaining methods. In some areas, stepped excavations were used for safety reasons to reduce the risk of potential collapse or earth movement of the soils.

Demolition Requirements

There are no demolition requirements for this building because this is a new site in an undeveloped location.

Project Cost Evaluation

Project Cost Breakdown

Building Construction Costs (CC): **$35,000,000**

(Note: Construction Cost excludes earthwork, permitting, land costs, etc.)

Total Building Square Feet: **120,000 ft^2**

Building Construction Cost per Square Foot: **$292 / ft^2**

Overall Project Cost: **$42,000,000**

Overall Project Cost per Square Foot: **$350 / ft^2**

Major Building Systems Costs:

Structural System: **$13,000,000**

MEP Systems: **$6,000,000**

Skylight System: **$5,500,000**

Design Cost:

* No information regarding design costs could be obtained, nor could it have been posted had it been obtained due to a confidentiality request.

Cost Estimates

D4 Cost Estimate[4]:

***Three Project Average*:** **$24,331,598**

***Two-High Average*:** **$30,596,450**

Square Foot Estimate:[5]

	SF Area	Cost / SF	Total Cost
Office	120000	$95.75	$11,490,000
Auditorium	120000	$106.5	$12,780,000
Student Union	120000	$110.6	$13,272,000
			$37,542,000

Location Factor Modifier: 0.91 * $37,542,000 = $34,163.220

Total SF Cost Estimate: **$34,163,220**

Analysis of Actual Cost vs. Estimate Cost

The total building construction cost for the project is about $35 million. Using average costs of three projects from the D4 Cost database, a total building construction cost estimate of $24,331,598. Referring to Appendix D, there is a significant differences between all three projects used for comparison. The range of costs for the different divisions is significantly differently with each project. Therefore, the average was not a true average because some of the projects had no costs for divisions while others had large costs. Therefore, in order to generate a more accurate estimate, the two higher costs associated with each division were used to generate a new estimate of $30,596,450. The difference between this cost and the actual building cost is approximately $5,000,000.

One of the possible reasons for the slight difference in cost is the large skylight system in the project. The skylight system is approximately $5,500,000 of the overall building cost, thus the difference in the two estimates. The Marine Corps project also

[4] Breakdown of D4 Cost Estimate located in Appendix D
[5] Cost information from R.S. Means Cost Data

contains added security features, unique terrazzo floor finishes and vast interior stone facing which could escalate the price immensely.

The square foot estimate above was a modified version of a true square foot estimate using R.S. Means Cost Data. There is no cost data specifically regarding museums; therefore, multiple building types were utilized to come up with the estimate. Since the building has similar features of an office, auditorium, and student union building (kitchen/cafeteria area), these buildings were used to model the square foot cost of the building. Using the 120,000 ft^2 building size and the unit cost per square foot from R.S. Means, the information in the table above was obtained. By applying a multiplication factor for the location, the final estimate was calculated to be $34,163,220.

Similar to the D4 Cost estimate, the number was slightly lower than the actual building cost. The main reason for the cost difference is a result of the very inaccurate method used to obtain the square foot cost because of lack of information for a museum or similar type project in the R.S. Means Cost Data.

Therefore, the estimate developed using the D4 Cost program would the more reliable estimate. Based on the estimate developed using D4 Cost, the reasons for the lower cost can easily be targeted, whereas the square foot cost estimate is too abstract to really determine the cost differences.

Site Plan of Existing Conditions[6]

A site plan for the site utilization / excavation phase is shown in Appendix D. The main components of the site plan consist of construction trailers, excavation stockpiles, site layout, and underground utility locations.

[6] Site Plan located in Appendix E

INTERSTATE - RT. 95

JOPLIN ROAD - RT. 619

TEMPORARY RETAINING POND

TEMPORARY RETAINING POND

174′

182′

198′

BACK SLOPE OF HILL GRADED TO PROPOSED SUBGRADE

STAGING, STORAGE & PARKNG AREA

STOCK OF UNUSABLE SOIL REMOVED

TEMPORARY RETAINING POND

PERMANENT RETAINING POND

TOPSOIL STOCKPILE

SUBCONTRACTOR TRAILERS

STAGING, STORAGE & PARKNG AREA

BUILDING SITE EXCAVATED TO 174′ FOR FOUNDATION CONSTRUCTION

1:1.5 SLOPE

LIMITS OF FOUNDATION WALLS

174′

STAGING, STORAGE & PARKNG AREA

STABALIZED CONSTRUCTION ROAD

BACKFILL STOCKPILE

CENTEX & OWNER TRAILERS

STRUCTURAL BACKFILL STOCKPILE

WEB CAMERA POLE

TRAILER PARKING

REMOVABLE FENCE & 15′ GATE TO ACCOMODATE INSTALATION OF UTILITIES

TEMPORARY ABOVE GROUND POWER & PHONE

TEMPORARY RETAINING POND

MAIN CONSTRUCTION ENTRANCE LOACKABLE GATE

UTILITY KEY

- STORM WATER SYSTEM
- SANITARY SEWER
- GAS LINE
- UNDERGROUND ELEC
- WATER LINE
- UNDERGROUND TEL

TRUE NORTH

100′ 60′ 20′ 50′ 200′

80′ 40′ 0 100′

NO SCALE

MICHAEL R. LOCKWOOD
CONSTRUCTION MANAGEMENT
ARCHITECTURAL ENGINEERING

NATIONAL MUSEUM OF THE MARINE CORPS

SITE PLAN: EXCAVATION & SITE PREPARATION PHASE

REVISIONS:

PAGE

MRL-1

Local Conditions

The site of the National Museum of the Marine Corps is located adjacent to the main entrance to the Quantico Marine Corps Base in Quantico, VA. The site was originally a wooded area with approximately a 50' varying elevation changes. The location of the building on the site will result in cuts up to 45' deep. Figure 5 below show the existing site conditions and figure 6 shows the construction site conditions.

Figure 5 - Existing Site Conditions

Figure 6 – Construction Site Conditions

Subsurface exploration done through twenty-three testing borings provided information regarding the existing soil conditions. The result indicated surficial soils containing root and other organic material approximately 0.5 to 1.5 feet. The alluvial soils were classified using the Unified Soil Classification system as sandy clay (CL), clayey sand (SC), and silty sand (SM). The geotechnical findings determined that rock excavation should not be expected, and it was not. The depth of groundwater on the site ranged from 29 to 47 feet, below existing elevations.

Based on the location and size of the site, there are no restrictions for construction parking and site accessibility.

The preferred construction method in the DC area is to use a cast-in-place structural system. However, this in not in the DC market. Therefore, no particular methods are preferred. As mentioned previously, the building has a variety of structural system components.

Client Information

"Established in 1979, the Marine Corps Heritage Foundation is a private, non-profit, organization dedicated to the preservation and promotion of Marine Corps history and tradition." [7] The Marine Corps Heritage Foundation supports the historical programs of the Marine Corps that are not able to receive government funding.

The vision statement behind the National Museum of the Marine Corps is "to tell, and preserve forever, this uniquely American story of contribution and sacrifice, valor and victory…through the eyes of the marines." [7]

The project is highly focused on quality; however, cost restrictions do exist. Since the Marine Corps Heritage Foundation is a private, non-profit organization, project funding is critical emphasis. The foundation has obtained a thousands donations to help fund the project. The museum at this time is the first part of a marine heritage campus. The project is being constructed in phases as the funding becomes available.

Cost and quality are very important expectations for the project. As a result, the owner chose to use a design competition to find the best quality design for the museum and a best value procurement method for selecting the contractor. Quality is of utmost concern of the owner because of the high profile nature of the project and the future contents of the museum in regards to the heritage of the Marine Corps.

[7] Information obtained from the Marine Corps Heritage website http://www.marinecorpsheritage.org

Appendices

Appendix A: Project Organization Chart

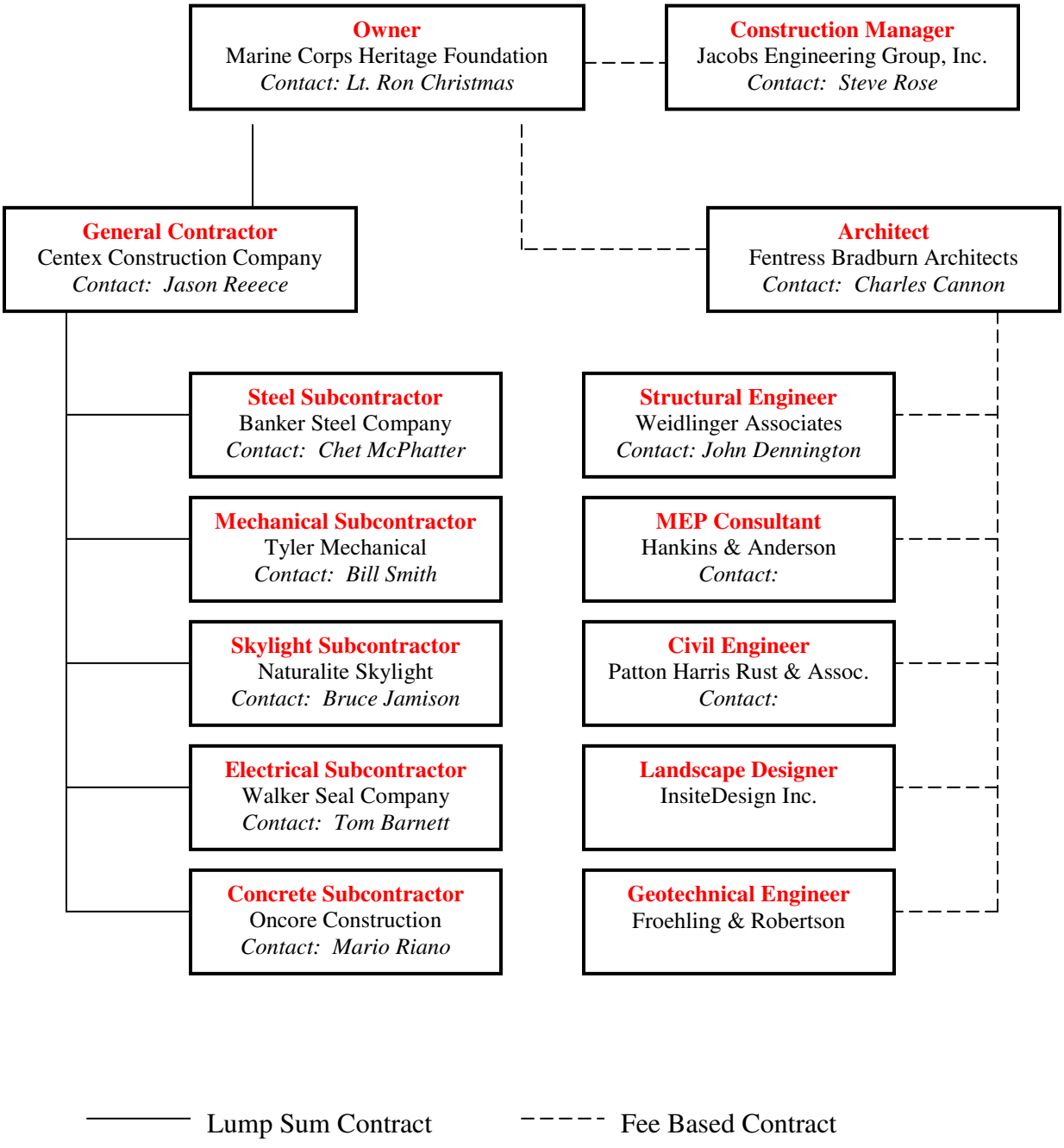
Appendix B: Project Summary Schedule

Appendix C: Key Plan

Appendix D: D4 Cost Estimate

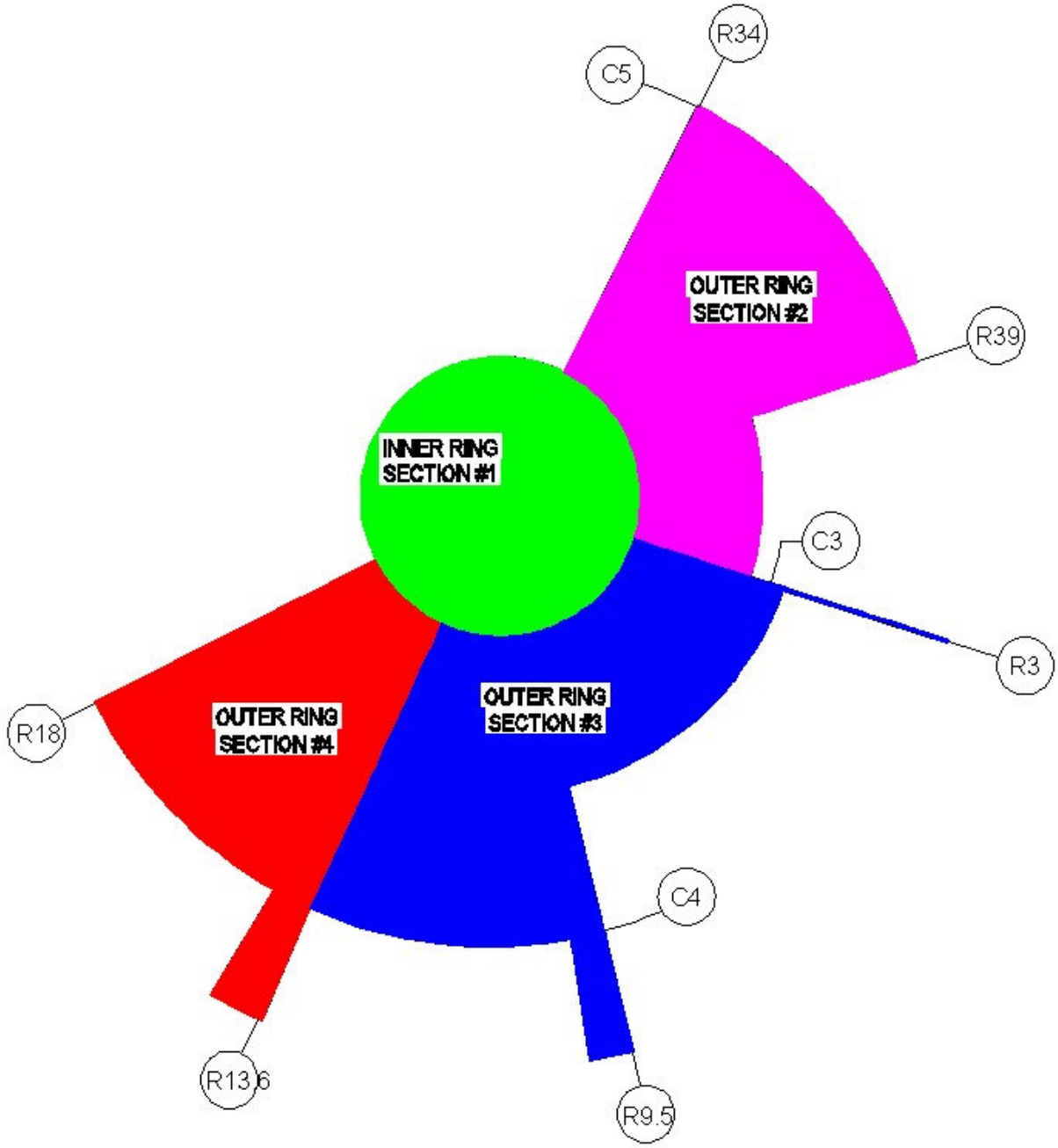
Appendix E: Site Plan

Appendix A: Project Organization Chart



Appendix B: Project Summary Schedule

Appendix C: Key Plan



Appendix D: D4 Cost Estimate

D4 Cost Estimate for National Museum of the Marine Corps Project

	Polk Art Museum		Creative Discovery Museum		Moody Gardens Discovery Museum		Adjusted Average of Projects		Two-High Adjusted Average of Projects	
Division Name	**SF Cost**	**Projected**	**SF Cost**	**Projected**	**SF Cost**	**Projected**	**SF Cost**	**Projected**	**SF Cost**	**Projected**
General Requirements	10.94	1,312,286	0.49	58,531	5.06	607,481	5.50	659,433	8.00	959,883.50
Concrete	12.07	1,448,816	39.83	4,780,065	24.30	2,915,907	25.40	3,048,263	32.07	3,847,986.00
Masonry	8.88	1,065,817	18.70	2,243,704	2.35	281,650	9.98	1,197,057	13.79	1,654,760.50
Metals	24.06	2,887,708	7.11	853,583	24.07	2,888,294	18.41	2,209,862	24.07	2,888,001.00
Wood & Plastics	12.40	1,487,679	32.01	3,841,124	1.79	215,380	15.40	1,848,061	22.21	2,664,401.50
Thermal & Moisture	26.43	3,171,240	5.69	682,866	1.10	132,541	11.07	1,328,882	3.40	407,703.50
Doors & Windows	8.28	994,149	17.65	2,117,642	35.62	4,274,455	20.52	2,462,082	26.64	3,196,048.50
Finishes	6.41	769,185	22.80	2,735,890	37.09	4,451,176	22.10	2,652,084	29.95	3,593,533.00
Specialties	0.94	112,962	28.20	3,384,091	1.56	187,767	10.23	1,228,273	14.88	1,785,929.00
Equipment	0.00	0	1.46	175,106	3.04	364,488	1.50	179,865	2.25	269,797.00
Furnishings	0.62	74,774	1.31	157,059	0.00	0	0.64	77,278	0.97	115,916.50
Special Construction	0	0	1.18	141,451	0.00	0	0.39	47,150	0.59	70,725.50
Conveying Systems	0	0	2.32	278,024	2.72	325,831	1.68	201,285	2.52	301,927.50
Mechanical	18.23	2,187,576	46.25	5,549,465	39.35	4,721,781	34.61	4,152,941	42.80	5,135,623.00
Electrical	14.24	1,708,824	28.37	3,404,577	33.37	4,003,850	25.33	3,039,084	30.87	3,704,213.50
Total Building Costs	**159.84**	**19,181,168**	**253.36**	**30,403,178**	**211.42**	**25,370,601**	**202.76**	**$24,331,598**	**254.98**	**$30,596,450**

* All data was obtained using D4 Cost 2002 Version.
** Costs for each case study example were adjusted based on location, time, and square footage of building

Appendix E: Site Plan