PHASE 2 REPORT
MODULAR HYBRID PIER

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U.S. NAVY MODULAR HYBRID PIER – SUMMARY OF FEATURES

The Modular Hybrid Pier (MHP) is a breakthrough concept for replacement and new berthing piers built in support of a changing U.S. Navy fleet. The concept is applicable to any scenario of change and responds to the need for an economical solution to

- Future revisions in homeporting strategy
- The need to replace functionally obsolete Navy piers
- The need to dramatically reduce Navy pier maintenance cost
- The need to economically accommodate very significant future changes in cold iron utility requirements
- The need for a facility where many different vessel types can be efficiently berthed

The MHP is a 1,300- by 88-foot double deck floating pier constructed from identical 325-foot-long modules, as shown on the attached sheet. The facility has the following feature.

- A top deck designed to handle crane outrigger loads at any location
  Provides operational efficiency and the ability to use cranes with less reach
- A top deck completely free of utility hoses and cables
  Makes all operations deck activities more efficient
  Allows efficient delivery of materials by semi truck that can turnaround on the pier
- Below deck enclosed space (34,000 square feet) is available for ship and sailor support functions
  Equipment repair shop areas
  Training classrooms
  Recreation/laundry/personal gear stowage
- A unique mooring system that isolates the pier from earthquake effects
  Eliminates the premium for facilities built in earthquake areas
- Durable materials selection and simple details are used in construction
  Economy of construction
  Long-term durability leads to longer service life
  Simple details result in lower maintenance cost
- Compartmentation minimizes susceptibility to terrorist damage
  Mooring not accessible to mischief
  Ramps limit unauthorized access from shore
- A service level deck for all utility cable and hose handling
  Brings order and efficiency to the hookup and unhook process
  Open utility gallery area is 8 feet talk by 10 feet wide full length along each side of pier
  All utilities are surface mounted for easy access and maintenance
  Maximum area provided to add new utilities
  Surface mounting allows economical utilities upgrade

- An approach to utility design that can accommodate any surface combatant regardless of utility hookup configuration
  - Greatly increases the ability of Navy stations to accommodate variations in vessel types in double breasted configurations
  - Innovative use of portable receiving units and force mains avoids historical problems with gravity mains

- A facility that involves very little on-site construction
  - On-pier utilities installed off site
  - Minimizing on-site disruption
  - Providing flexibility to deal with environmental working restrictions
  - Minimizing field construction schedule

- A facility that moves up and down with the tide
  - Makes double-deck piers feasible for high tidal variation areas
  - Provides constant distance from ship deck to pier deck at all times
  - Eliminates the need to tend mooring lines, utilities, and gangways
  - Greatly simplifies fendering for even the most difficult to fender vessels
  - Common fendering system can be used for many different vessel types

- Allows relocation to a new port location at 10 percent of the cost of a new pier
  - Modules can be disassembled and towed to a new station

Opportunity for Systemized Planning Design and Construction

The fact that the facility can be floated from its construction location to the deployment location provides the opportunity for systematized planning, design, and construction and an off-site outfitting process.

- Modules are identical/interchangable allowing operational piers of
  - 650 feet (198 meters) (2 modules)
  - 975 feet (297 meters) (3 modules)
  - 1,300 feet (396 meters) (4 modules)
  - 1,650 feet (503 meters) (5 modules)

  to be construction by merely joining identical modules together at the deployment site.

- Modules are off-site prefabricated in a factory setting
  - Maximizing the opportunity for the higher quality
  - Minimizing the amount of field construction

- Construction can take place in a commercial rather than a Navy station environment
  - Resulting cost savings
  - Construction can be where labor costs are low
  - One construction site could serve east coast and one west coast

- Identical modules can be stockpiled
  - Longer production runs – reduced costs
  - Piers available on short notice
  - Allows a whole new approach to procurement

Site-Adapt Design Advantages

Concept maximizes the advantages of a site-adapt design approach, thus minimizing both the project-by-project design cost and greatly shortens the design schedule.

- Changes per design construction process from a one-of-a-kind custom activity to a standard production activity
- Floating module design is the same for all locations
- Utility design is the same for all vessels
- Mooring elements within the floating modules the same for all locations
- Access ramp designs vary only in span length and designs can be provided in 5-foot increments for direct use

Only two elements, mooring shaft support and ramp shore end abutment, are site-specific design.

- Mooring shaft support concept is same for all locations
  - Site-specific design of mooring to deal with site soils varies
    - Length and diameter of piles required
    - Number of piles required)
  - (typical 1,300-foot (396-meter) MHP requires 32 piles versus 1,500 for a fixed pier)
- Typical abutment designs can be prepared for a range of shore side conditions
  - Soil type variation
  - Yard elevation variation
- Greatly reduces the cost and schedule risk of a pier construction project
  - Floating module prices will be precisely known by the third project
  - Site-specific work becomes a very small percentage of the project

I. EXECUTIVE SUMMARY

The work to develop the modular hybrid pier (MHP) vessel berthing facility concept into a key element of the Navy's strategic response to the need to replace aging and obsolete berthing facilities around the world has progressed significantly with the results of this Phase 2 effort. As increased definition of the elements that comprise the MHP is developed, the benefits of the concept continue to increase in significance.

The MHP concept represents a breakthrough in the long-term operational efficiency of Navy berthing facilities. The concept also provides procurement and planning opportunities that have the potential to reduce both capital and life-cycle costs, while greatly increasing the flexibility and timeliness of responding to changes in mission and requirements among Navy stations around the world.

The objectives of the Phase 2 MHP efforts were to advance the preliminary design of four MHP systems: the mooring system, the module to module joining, the access ramps, and the vessel support utilities.

In order to accomplish these things, a major planning effort was devoted to refining the overall MHP configuration and verifying the configuration against both defined and practical operational requirements.

Considerable attention was given to the likely use scenarios for the operations deck. The decision was made to evaluate the minimum functional width and length of the MHP because these features are the primary determinants of the overall facility cost.

The layout of the service level of the MHP and the strategy outlined here for providing utility service to a wide range of vessel types is uniquely important and worthy of serious consideration by Navy operations personnel. The service level layout provides important benefits of operational efficiency, maintainability, and reliability to both the on-shore operations and vessel berthing functions.

The drawing set provided as part of the report provides an overview of the MHP configurations as currently developed in this preliminary design. The dimensions, material thickness shown, and construction concepts shown and discussed are viable and mostly employ construction concepts and methods that have been successfully used by the United States construction industry in the past.

Section V of the report further discusses the MHP features that have been developed in the Phase 2 effort. The main body of the report addresses general operational considerations in Section VI and then addresses, in sequence, each of the five MHP program elements investigated in Phase 2.

- The MHP Floating Pier Modules
- The MHP Module-to-Module Structural Joining
- The MHP Mooring
- The MHP Pier-to-Shore Access Ramps
- The MHP Utilities

The text is organized to first discuss the design criteria appropriate to each element and answers the question " What does this program element need to do?" Next is a design approach section that answers the question "How is this design requirement to be met?" This is followed by a more detailed discussion of the features of each MHP program element and supplements the preliminary design drawings by providing design intent information. Finally, a section is included that addresses the construction

considerations that apply to each program element. A series of appendixes contain the results of special studies and sample calculations that support the design.

Section XIII outlines some of the opportunities and benefits that the MHP concept brings to the overall Navy berthing facility program in terms of Navy-wide berthing facility upgrade planning.

Finally Section XV presents a description of the next step in the development of the MHP. The elements proposed to be addressed in a prototype testing phase are outlined for consideration. A necessary activity to further define the operational requirements in terms of the type of concurrent activity that must be accommodated is described. This is envisioned to take the form of structured interviews and workshops with ship officers and on-shore operating personnel, as well as visits to representative operational berthing facilities to document actual practices. At the end of the report, an approach to developing and using a Navy standard design for use in design/build or conventional design/bid/build procurement is discussed.

II. BACKGROUND

The ability to berth and serve the vessels of the fleet in Navy stations around the world is currently constrained by the characteristics of the aging facilities that are available to provide shore support.

A. Stated Navy Concerns

Fleet support operations personnel have expressed the following concerns.

1. They must work in conditions that are typified by clutter – even the cleanest piers are still unsightly and operationally inefficient due to the maze of shore power cables on deck that must be worked around.

2. They must moor ships as the piers dictate, not what is best for any given situation.

3. They must work around poorly designed utility areas that are different from pier to pier.

4. They are constrained from mooring certain ships in certain berths simply because a feature such as an accommodation ladder or brow/platform setup will not fit.

In order to improve the ability of the shore support operations to serve the vessels of the fleet in the most efficient and cost-effective manner, waterfront operations personnel have indicated they need new berthing pier facilities with the following characteristics.

B. General Technical Goals

1. A design approach that has maximum site adaptability, is minimally sensitive to local site geotechnical conditions, and differing site seismicity.

2. The ability to economically accommodate utility reconfiguration as new vessel types join the fleet.

3. An 80 percent reduction in baseline maintenance costs over the life of the new generation pier.

4. A service life approaching 140 years.

5. The smallest possible cost premium over conventional Navy pier structures.

C. Operational Goals

The following operational goals for new berthing facilities were recently developed by Navy personnel.

1. The ability to efficiently support

   - Vessel maintenance and light repair work
   - Personnel transfer
   - Crew training
   - Cargo transfer
   - Waste handling

2. The ability to have a totally clear operations deck

3. Standardized pier sizes to allow operations planning and berthing planning to be common from one pier to the next

4. Standardized berth water depths relative to MLLW

5. Standardized deck edges and berm heights

6. Standardized fendering system that accommodates both large vessels and smaller ships equally well

7. Standardized pier fittings, such as high-capacity bollards and cleats which have the same capacity from pier to pier

8. Standardized utilities stations with the flexibility of operation to permit bow-in and bow-out berthing while not interfering with brows located amidships, stern, and bow

9. Standardized lighting with the capability to dim as ship makes approach to pier

10. Standardized operations deck heights relative to vessel decks

11. The ability to position cranes out to deck edge

12. Efficient access to external transportation (e.g., truck access to all areas of operations deck)

13. All utility risers to be metered

14. All utilities feeding from below the operations deck with below-operations deck stowage for hoses and cables when not in use

15. Refuse handling by conveyor to street side containers

D. Navy Brainstorming Ideas

In early 2001, a Navy brainstorming session was held to define the most desirable characteristics of new-generation piers. The concepts listed below were judged to be the most important and significant when evaluated by the following criteria (in rough order of priority).

- Ability to accommodate as many different ship types as possible
- Applicable in multiple locations – site adaptable
- User friendly for operations
- Durability
- Highest payback in terms of both capital and life-cycle cost benefits
- Constructability
- Maximum use of composites in approvable applications

1. Navy Identified Top Ideas to Pursue

   a. Exploit all of the advantages of modularity

   b. Develop a two-layer pier with an optimized second layer

   c. Design to provide maximum versatility in accommodating ship classes

   d. Design utilities specifically for ease of upgrade to accommodate new vessel technology

   e. Design and construct the pier of low-maintenance materials

   f. Develop a prototype floating pier to confirm functional/operational concepts

   g. Use modular FRP cable ways for utilities

   h. Incorporate utility meters for all ship service utilities

   i. Pursue the development of FRP-reinforcing bar and prestressing tendons

   j. Investigate the use of composite bridge deck

   k. Incorporate load sensing and monitoring technology to aid operations

A listing of other ideas considered during the Navy brainstorming session and subsequently published on the NFESC Hybrid Pier web page is given in Appendix J.

III. OBJECTIVES OF THE PHASE 2 MHP PROGRAM

The objectives of the Phase 2 program were to develop preliminary designs for four aspects of the MHP facility that were generally defined in Phase 1 of this program. The design elements addressed in Phase 2 are as follows.

- The MHP floating pier mooring system
- The MHP module-to-module structural joining
- The MHP utilities to serve berthed vessels
- The MHP shore-to-pier access ramp system

In addition to the further definition for these elements, considerable effort was spent developing the detail configuration of the operational features of the pier as this was needed to support the preliminary design of the elements listed above.

A. Functionality

The overall plan size of the pier was set based on the length needed to berth the primary vessels as listed in Section VI.B.1. The width of the pier was set based on the space needed for mobile cranes and adjacent supporting laydown areas, combined with traffic lanes to allow the coming and going of support vehicles. The selected pier width was then checked to assure that it was sufficiently wide to support truck turnaround and that there was a viable approach to provision of low-angle mooring line bollards for mooring the alternate amphibious vessels. The approach taken was to limit the pier width and length to that necessary to support the primary vessel berthing and then check to determine to what extent alternate vessels could also be accommodated.

The elevation of the operations deck was developed from the elevation of the service-level deck, plus vehicle clearance and substation (electrical skid) replacement head room at the service deck, plus the structural depth needed for the operations deck and in the module-to-module joining area.

The elevation of the service deck was set to assure that the deck would remain above water level in the event of a two-compartment damaged condition.

Once the elevations of the service and operations deck were set, it was then possible to design the preliminary details of the mooring system and develop a ramp system that could accommodate the angular changes that result from tidal variations, wind and seismic movement, and from operational roll displacements of the MHP. The angular motion requirements for both the operations deck ramp and the service deck ramp were developed; however, the scope of work addressed only the preliminary design of the more heavily loaded operations deck ramp.

The effects of operational deck loads on the MHP were evaluated based on both the structural strength of the MHP and the hydrostatic properties of the MHP as a floating body.

The structural design approach was to design the pier for a high level of local load capability as outlined in the Section VII design criteria. Sufficient global strength was provided in the MHP so that acting as a large floating beam the pier can accommodate a wide range of expected deck-loading combinations. The design also assures that the module-to-module joint capacity is sufficient for both local and global load effects. Additionally, the global design of the MHP will accommodate the combinations of loads resulting from environmental effects and from berthed vessels.

The naval architecture design approach for the MHP was to evaluate the hydrostatic effects of various deck loadings based on the dimensions of the MHP that were otherwise derived from the functional considerations given above. Compartmentation of the perimeter watertight compartments was sized so that the condition with two-compartments damaged and flooded resulted in only a small compromise in operations so that operations could likely continue while the compartment damage was repaired.

The fact that the MHP is a floating body has significant advantages that were spelled out in the Phase 1 report and discussed elsewhere in this report. It is also true that since the MHP floats, more attention will have to be paid to the planning for and management of the operational loading of the main deck in those instances when the full operational capacity of the MHP is to be used. This issue is further discussed in Section VI.E., Operations Deck Functional Design Criteria.

B. Maintainability

One strategy for addressing the maintainability objective of this program is by keeping the various systems and the basic MHP structure as simple as possible. We have avoided the requirement for any underwater or in-water maintenance activities. Those elements of the mooring system, the ramp system, and the utilities systems that will require periodic inspection have been designed to be easily visible and very accessible should maintenance activities be required.

Much of the maintainability objective is addressed in the selection of materials that exhibit long-term durability. These materials are used in conjunction with details that generally have been shown to be durable and low maintenance in previous marine experience. Additionally, the major elements of the MHP are proposed to be fabricated off site in a controlled factory environment where those quality elements required for long-term durability can be more reliably controlled as compared to on-site construction.

C. Cost

The objective of the design has been to keep the initial cost of the MHP as low as possible so that the potential of its cost being competitive with a conventional Navy pier is maximized. Having said this, it is recognized that some of the materials used in the MHP design and some of the approaches to providing utilities support may be marginally more costly than the cheapest approach to providing a single-purpose berthing facility in a benign, nonseismic environment. The full cost advantages of the MHP systematized design approach will be captured by using the MHP concept to address new and replacement berthing facility requirements at multiple locations. This will allow the use of the basic MHP modular approach to avoid much of the site-specific design and construction that typify conventional Navy pier construction. The site-specific approach often compromises both the functionality and the long-term maintainability objectives simply because of the one-of-a-kind nature of these planning, design, and construction activities.

IV. PREVIOUS WORK RELATED TO PHASE 2 OF THE MHP PROGRAM

A. Navy/NFESC Programs and Publications

The following Navy documents were specifically used as background for this preliminary design effort.

- *Advanced Pier Concepts Users Guide*
  October 1985 No. UG 007
  Navy Civil Engineering Laboratory

- *LPD-17 Shore Power Design and Procedures*
  10 December 1999
  SUPSHIP, LANTDIV, NAVSEA, et al.

- *Piers and Wharves*
  30 June 1994 MIL-HDBK 1025/1
  Department of Defense

- *Mooring Design*
  1999 MIL-HDBK 1026/4A
  Department of Defense

- *Mooring Design Physical and Empirical Data*
  April 1986 DM 26.6
  Department of Defense

- *Seismic Criteria For California Marine Oil Terminals*
  1999 by J.M. Ferritto
  Navy Facilities Engineering Service Center

- *Safe Mooring of Ships*
  William Seelig NFESC 551 and
  R. David Curfman NAVFAC ENG/LANTNAVFAC 15

- *A Preliminary Assessment of Hurricane/Severe Storm Mooring at Navy Station Mayport/Jacksonville, FL*
  March 1977 Site Specific Report SSR-6078-OCN
  Navy Facilities Engineering Service Center

- *SURFLANT Heavy Weather Mooring Program Phase I Completion Report*
  April 2000 Site Specific Report SSR-6150-OCN
  Navy Facilities Engineering Service Center

- *Conceptual Development of Open Sea Module Connection Techniques*
  March 1995 Technical Memorandum TM-2067-AMP
  Navy Facilities Engineering Service Center

B. BERGER/ABAM MHP Efforts

The following BERGER/ABAM documents prepared under contract to NFESC were specifically used as background for this preliminary design effort.

- *Final Report Phase 1 – Concept Development Modular Hybrid Pier (MHP)*
  February 2000 Contract Report CR00-001-SHR
  Navy Facilities Engineering Service Center

- *Testing Report Phase 1A – Testing of Concrete Slabs*
  Modular Hybrid Pier (MHP)
  January 2001 Contract No. N47408-98-C-7529
  Navy Facilities Engineering Service Center

V. FEATURES OF THE MHP BERTHING FACILITY

A key concept of the MHP is to create a pier module that can be transported by water, assembled into piers of varying length, and deployed to any Navy station without changing the design of the basic MHP module. The general approach is to develop MHP configurations and systems so that the variable physical features from site to site can be handled by relatively simple site-adapt designs of the access ramp system, the MHP mooring system, and the on-shore hookup interface with the pier utilities.

The concept is deployable on a much shorter schedule than conventional fixed berthing piers, especially if standard modules stockpiled for future use can be employed in a specific project.

The MHP facility is a 1,300-foot (396-meter) long by 88-foot (26.8-meter) wide double-deck floating pier. The top deck is optimized for vessel maintenance and service operations, and all utilities service is provided from a special-purpose-designed service deck on the lower level.

The separation of the utilities and vessel maintenance functions means that utility cables and hoses are kept completely away from the operations deck, thus eliminating a major source of operational inefficiency with conventional piers where maintenance crews must work around utility cables and hoses.

The approach to planning for vessel utility support provides extreme flexibility in the ability to serve a wide range of surface combatants. The fact that the pier rises and falls on the tides with the berthed vessels eases the mooring of these vessels and eliminates the need to tend lines, gangways, and utility hookups.

For the site-specific elements addressed in this preliminary design effort, the San Diego site was used as the primary site and two other sites (Bremerton and Mayport) were used as alternative sites. These sites were selected as representative of a reasonable range of maximum tidal ranges, seismicity, and maximum wind conditions. The design of site-specific elements was developed with the idea in mind that the site variables would have to be accommodated as site-adapt designs with some minor modifications, which do not affect the basic MHP module design.

Table V.J.-1 shows tidal range, yard elevation, sea bottom elevation, soil condition, and special environmental and geotechnical considerations for the design site and each alternative site considered.

VI. MHP OPERATIONAL CONSIDERATIONS

The MHP physical configuration is shown on structural Drawings S-01 through S-29 and the utilities Drawings E-1 through E-4 and M-1 through M-4.

A. Design Criteria for Modularity and Standardization of Vessel Mooring Provisions

The modularity criteria for vessel mooring provisions is that the provisions be standardized to the maximum extent possible while still providing for all of the mooring needs of the primary and alternative vessels as listing in Section VI.B. below.

Layout of bollards, utilities, fenders, etc., are the same from one MHP facility to the next, easing the planning of the overall berthing operation and any maintenance activities that are to be performed.

TABLE V.J-1: SITE CRITERIA

Definition:

ELW = Extreme Low Water Level
MLLW = Mean Low Low Water Level
MHHW = Mean High High Water Level
EHW = Extreme High Water Level

Datum: MLLW = 0 ft (EL)	Desired Site				Optional Sites											
	San Diego				Bremerton				Newport				Norfolk			
Tidal Information Reference	NOAA/NOS Web Site				NOAA/NOS Web Site				NOAA/NOS Web Site				Deepening Pier and Dredging			
ELW	-2.88	ft	-0.88	m	-4.60	ft	-1.45	m	-3.20	ft	-0.98	m	-3.15	ft	-0.97	m
MLLW	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
MHHW	5.73		1.75		11.74		3.58		4.92		1.50		2.79		0.85	
EHW	8.35		2.55		15.10		4.60		7.50		2.29		8.43		2.57	
Tidal Difference																
EHW - ELW	11.23	ft	3.42	m	19.90	ft	6.07	m	10.70	ft	3.26	m	11.61	ft	3.54	m
Yard Elevation	Deepening Pier (Point Loma)				Dry Dock #3 Repair (Bremerton Ship Yard)				NFESC SSR-5078-OCN				*Pier 2 Replacement, Norfolk*			
	12.00	ft	3.66	m	17.60	ft	5.36	m	12.67	ft (est)	3.86	m	9.45	ft	2.88	m
Sea Bottom Elevation	Deepening Pier (Point Loma)				Dry Dock #3 Repair & Pier D				No Information				Deepening Pier and Dredging			
	-40.00	ft	-12.19	m	-43.50	ft	-13.26	m	-		-		-41.00	ft	-12.50	m
Soil Condition	(Ref: Pier 10 and 11 Soil's Report)				(Ref: Pier D Soil's Report)				No Information				Typical Norfolk Soil			
	Top Layer (~5 ft) - Bay Deposit Middle & Bottom - Dense Sand				Top Layer - Loose to medium dense sand Middle - Medium dense silt Bottom - Glacial till								Soft sediment over rock @ Approx. EL -90' (MLLW)			
Special Condition to be Considered																
	Possible Seismic Seiche				Possible Seismic Seiche				Possible High Storm Surge				Possible High Storm Surge			

Design Criteria Related to Vessels to be Berthed at the MHP

In the Phase 2 MHP preliminary design effort, the MHP vessel mooring system is designed for the primary vessels listed in Item 1 below. Optional vessels listed in Item 2 below can be accommodated with minor modification to the vessel mooring system without altering the MHP structure.

1. Primary Vessels – Surface Combatants Specifically Addressed in MHP Design

   Refer to berthing plan Drawing S-01. The following vessels are the primary vessels considered for berthing at the MHP. The berthing of these vessels was initially included in the agreed scope of work for this phase of the MHP program.

   - CG-47 (Ticonderoga class cruiser) – Two abreast
   - DDG-51 (Arleigh Burke class destroyer) – Two abreast
   - FFG-7 (Oliver Hazard Perry class fast frigate) – Two abreast

   Note: In the contract scope of work, the FFG-7 was the only vessel to be nested. However, the preliminary design has been updated to accommodate the other primary vessels nested due to progress review comments from the Navy.

2. Alternative Vessels – Surface Combatants for which the MHPs Berthing and Utilities may be Easily Modified

   Refer to berthing plan Drawing S-02. The following vessels are the alternate vessels considered for berthing at the MHP. The interest in berthing these vessels at the MHP was identified after this phase of the MHP program started and were not formally included in the scope of work for this phase of the program. We have addressed the berthing requirements for these vessels primarily as commentary; in some instances without performing supporting calculations.

   - DD-963 (Spruance class destroyer) – Two abreast
   - LPD-17 (New class landing dock ship)
   - LHA-1 (Tarawa class amphibious assault ship)
   - LHD-1 (Wasp class amphibious assault ship)

3. Vessel Characteristics Data

   Vessel characteristics data were obtained from the following resources.

   - *Ship Characteristics Database (Version 2.0)*
     Copyright 1997
     Department of the Navy
     NAVFAC Criteria Office

   - *Advanced Pier Concepts Users Guide*
     October 1985 No. UG 007
     Naval Civil Engineering Laboratory

   - *Jane's Fighting Ships*
     96th Edition
     Edited by Capt. Richard Sharpe

- *Draft - Facility Planning Criteria For LPD 17 Class Amphibious Transport Dock Ship*
  November 2000
  Naval Sea Systems Command

In Appendix A, the vessel characteristics data, which were used to calculate wind and current load on berthed vessels, is summarized.

4. Berthing Arrangement Criteria

The berthing plans and arrangements for the primary and alternative vessels are shown schematically in the attached plan drawings (S-01 and S-02). Typically, for the primary vessels, two berths (nested) on each side of MHP were investigated. For the alternative vessels, except for DD-963 (two abreast), one berth on each side of MHP was investigated.

As a result, among the primary vessels, nested CG-47s were the controlling case for transverse wind and longitudinal wind load cases. Among the alternative vessels, the LHA-1 was the controlling case for transverse wind, and nested DD-963s were the controlling case for the longitudinal wind load cases. The assumption for the design of the MHP floating pier mooring elements was that the alternative vessels, LHA-1, LHD-1, or LPD 17, would berth in the center portion of the pier. Therefore, if the amphibious vessels were to berth closer to one end of the berth, the selection of pier MHP mooring damping fenders would have to be updated. This would be needed to accommodate the increased proportion of the berthing loads they receive. Alternatively, the berth would have to be vacated earlier at a lower wind speed level in the event of an approaching heavy storm or hurricane. Details of the pier mooring design capacity is discussed in Section IX, MHP Mooring.

The controlling berthing arrangement for primary vessels is shown on Drawing S-09.

5. Berth Fendering Criteria

Berthed vessel fendering design for the MHP will be handled by NFESC. The selection of fenders by NFESC must be coordinated with the design of the MHP floating pier mooring system to assure that berthing forces are attenuated at least the extent assumed in the MHP floating pier mooring design.

a. Normal Conditions Berthing and Mooring Provisions

Fenders absorb the impact of vessels berthing against the pier and cushion the vessels when wind pushes them against the pier. Design criteria for fendering include berthing energy, static load from wind, and allowable pressure against ships' hull skins. Flare-sided ships, such as the DDG-51 Arleigh Burke class destroyers and ships with significant hull projections (several classes of amphibious assault ships), present special geometrical issues. While CVN berthing is not considered in this preliminary design effort, CVNs could be berthed at a MHP with consideration of the overhanging elevator sponsons. The hull sides of the MHP are designed to accommodate a wide variety of fendering concepts.

While development of the fendering design is tasked to NFESC, for preliminary design the fendering is assumed to be 8-foot (2.4-meter)

diameter foam-filled fenders spaced as needed between the MHP utility "windows."

6. Standard Outfitting Criteria

MHP modules will be outfitted with standard utilities and fittings that when, combined with the standard outfitting of the other modules that make up the MHP installation, will fully support the berthing of the primary vessels addressed.

a. Basic Vessel Mooring Bollards and Cleats

Ships are moored to bollards located on the operations deck. Cleats mounted in the utility window openings to the utility galleries are furnished for mooring smaller craft that are low to the water, such as tugs, yard maintenance barges, floating derricks, ships' boats, etc.

b. Basic Pier and Vessel Support Utilities

Utility support for moored vessels is provided in a manner that provides significant flexibility in the type of vessels that can be served by the pier. The vessel support utilities are discussed in more detail in Section XI. Additionally, the pier is outfitted with high-mast lighting on the operations deck, task lighting on the service deck, and with industrial power service available on both the service deck and the operations deck.

c. Optional Extras

For special purpose uses, it is possible to add special features to a basic MHP. For example, the approach taken to supplying utilities allows special utilities systems to be added to an MHP in a straightforward fashion.

It would, for example, be possible to replace one of the stairways with a freight elevator between the operations deck and the service deck if this were a special operational requirement.

Special fendering features for unique vessel fendering requirements will be straightforward to accommodate, as the MHP provides a continuous structural support surface at the waterline and large areas of structural support surfaces above the waterline that will allow the attachment and support of a wide variety of fender and camel arrangements.

B. Design Approach to Vessel Mooring at the MHP

Since the MHP deck levels relative to the berthed ship deck levels remain nearly constant throughout the full range of tidal variation, planning for mooring and maintenance of mooring lines becomes a more straightforward task.

1. Mooring Design Approach for Primary Vessels

The design berthing plans for primary vessels is shown on Drawing S-01.

a. Ordinary Operations

During ordinary operations, ships are moored to bollards located along the same edge of the pier the ships are berthed against. Pairs of lines at bow and stern act as both breasting and spring lines. These lines do not pass over the pier deck, and thus do not interfere with on-deck operations or vehicle access. Vertical mooring line angles are lower (and do not change due to tidal variations or storm surge) for the floating MHP than for conventional fixed, pile-supported, double-deck berthing piers. For fixed piers, wind and the combination of extreme tide and storm surge must be designed for. For the floating MHP, only wind and current is a design concern for ship moorings.

2. Mooring Design Approach for Alternative Vessels

The design berthing plans for alternative vessels is shown on Drawing S-02. Mooring for alternative vessels is as for the primary vessels except that the large LHAs [834-foot (254.2-meter) LOA] and LHDs [844-foot (257.3-meter LOA] are assumed for the calculation of MHP floating pier mooring loads to be moored symmetrically about the centerline of the MHP. This assumption should be further investigated to determine its validity prior to final design.

3. Design Approach to Mooring Hardware Provision

MHP modules will be outfitted with 200-kip (91-tonne) capacity bollards for primary vessel mooring line attachment at the edge of the operating deck on both sides of the pier. Bollards will be provided, spaced at 25 feet (7.6 meters) on center at module ends and at approximately 50-foot(15.2-meter) spacing in the central portion of each module. This arrangement is shown on Drawing S-01.

Provisions will be included in the basic MHP module design to attach inboard bollards for attachment of mooring lines from the alternative vessels (LPD–17s, LHA-1s, and LHD-1s). The inboard location of the bollards, combined with the constant vessel deck to MHP operations deck elevation difference, results in acceptable mooring line angles for these high sided vessels.

The location of these alternative vessel bollard attachment provisions is shown on Berthing Plan 2 on Drawing S-02. Further evaluation of the requirements for these bollards should be performed in advance of final design to determine if these bollard locations are actually necessary for the mooring of the alternative vessels, as the location of the bollards somewhat compromises the use of the operations deck space.

Cleats for small ship service vessels will be installed on top of the utility deck wave wall in the utility window openings. Two cleats will be installed on the wave wall in each opening.

4. Design Approach for Fendering Berthed Vessels

The detail fendering design for the MHP is tasked to NFESC because they have the in-depth background in Navy vessel fendering developed from recent fender system development programs.

The approach to fendering involves the use of large foam-filled fenders 8 to 10 feet (2.4 to 3.0 meters) in diameter and 14 feet(4.27 meters) long positioned at the waterline and located longitudinally between the utility windows in the MHP exterior service level wall as required to provide breasting for the moored vessels. The exterior service level wall will be designed to react fender forces over its surface between the waterline and the operations deck. The location of the berthed vessel fenders is shown schematically on Drawing S-06.

Located between the large foam-filled fenders will be a line of smaller fenders at or near the waterline to provide fendering for small vessels and protect the MHP from contact from barge corners. Ancillary fenders will be provided at the centerline of each utility window and above it to protect utility lines, cables, and hoses as they feed into the service-level utility gallery through the utility gallery windows.

In addition to requirements specified elsewhere, it should be pointed out that the fenders are directly supported by MHP primary structure. The fact that the primary structure is closer to the vessel berthing action requires that increased attention be paid to preventing unintended and unfendered MHP hull contact with barge corners, bulbous bows, tug bows, etc.

The channel end corners of the MHP will have special fenders designed to support small vessel turning in the event they use the corners as pivots.

C. Details of Vessel Mooring Provisions on the MHP

Preliminary design details for vessel mooring provisions are shown on Drawings S-01 and S-02.

1. Details of Mooring for Primary Vessels

In this preliminary design effort, vessel deck elevations for primary vessels to be moored have been compared with the MHP operations deck level and have been found to be reasonable for mooring. A regular spacing of bollards has been provided with a reduced spacing (more bollards) near the ends of each module. This results in more bollards concentrated near the ends and midships of the berthed primary vessels.

Prior to final design, the actual specified mooring arrangements for each of the primary vessels should be evaluated to assure that the proposed bollard arrangement is consistent with each vessel type's detailed requirements. Review of the specified mooring arrangements should be supplemented with interviews with representative mooring officers from the different vessel types to assure that the actual operational practices are reflected in the final provisions for mooring.

2. Details of Mooring for Alternative Vessels

In this preliminary design effort, vessel deck elevations for alternate vessels to be moored have been compared with the MHP operations deck level and have been found to have a significantly greater elevation differential (higher) above the MHP operations deck than do the primary vessels. For this reason, a regular spacing of deck attachments for additional bollards have been provided adjacent to the central vehicle drive aisles to reduce the mooring line angle to be more similar to

that for the primary vessels with a reduced spacing (more bollards) near the ends of each module.

Prior to final design, the actual specified mooring arrangements for each of the alternative vessels should be evaluated to assure that the proposed bollard arrangement is consistent with each vessel type's detailed requirements. Review of the specified mooring arrangements should be supplemented with interviews with mooring officers from the different vessel types to assure that actual operational practices are reflected in the final provisions for mooring.

3. Details of Mooring Hardware Provisions

Two cleats for small vessel temporary tie off and handling are provided on top of the service-level wave wall at each of the utility windows. Prior to final design the need for additional mooring hardware should be evaluated by review of the specified mooring arrangements for each vessel type. Review of the specified mooring arrangements should be supplemented with interviews with mooring officers from the different vessel types to assure that actual operational practices are reflected in the final provisions for mooring. In the case of auxiliary mooring hardware requirements, harbor tug captains and others responsible for waterfront operations and berthing activities should also be interviewed regarding requirements.

D. Operations Deck Functional Design Criteria

1. Design Approach to Operations Deck Function

The basic space layout of the operations deck is designed to provide the maximum amount of flexibility of use (see Drawing S-03).

a. The deck space is clear to the maximum extent possible. Vehicle traffic lanes, MHP mooring shafts, stairwells, and high mast lighting standards are located either on the pier centerline or adjacent to it to free up space near the pier edge.

b. Only mooring bollards are located at the pier edge. A removable bull rail can be provided if desired.

c. The operations deck is designed to resist the concentrated load from a 140-ton (127-tonne) crane outrigger (250 kips) (112 kN) at any location. This results in the minimum structural constraints on the placement of mobile cranes on the operations deck.

d. The operations deck is designed for high area loads (1,200 lbs per square foot) (57.5 kN per square meter), thus allowing large laydown loads to be arranged for best operational function with minimal structural constraints on placement of the laydown loads.

e. All utility cables, hoses, and lines are located in the utility gallery of the service-level deck and will never be located on the operations deck, allowing better operational deck access and management.

f. Vessel deck level versus MHP operational deck level - Relative deck levels of the highest deck primary vessel (DDG-51) and the lowest deck primary vessel (CG-47) are shown on Drawing S-06. The constant differential elevation between the ship's deck and the operations deck will ease the cargo transfer activity and the personnel gangway will not require tending.

2. Operational Loading - Draft Increase, Roll and Yaw

It is important to note that the MHP is also a floating body that has defined hydrostatic properties that influence the operational use of the MHP. For example, the plan size of the MHP results in a water plane area and associated center of buoyancy that determines how the loading of the MHP decks will affect the loaded draft roll and yaw of the MHP. The molded depth of the MHP determines the combination of the amount of live-load draft (draft in addition to the light-ship draft) and the amount of roll and yaw that can be accommodated while still maintaining the service deck with a sufficient margin above the waterline.

In some cases, the trim and draft effects, resulting from the hydrostatic properties of the MHP, will control the operational loading of the operations deck before the structural limitations are reached.

A primary issue for the MHP hydrostatic design is the size of the area over which the 1,200 lbs per square foot (57.5 kN per square meter) deck live load is applied. For example, a single 1,200 lbs per square foot (57.5 kN per square meter) live load applied over 250 square feet (23 square meters) equals 300,000 lbs (136 tonnes) total load can be applied at any location on the operations deck with only nominal effects on the MHP trim and live load draft. However, as the number and/or magnitude of high-deck loads associated with the 1,200 lbs per square foot (57.5 kN per square meter) loading increase, depending on where these loads are placed on the deck, they can result in trim and live-load draft combinations that represent operational limitations.

To provide a sense of the capacity of the MHP to handle a variety of deck loading configurations that can be accommodated are shown on Drawings L-02, L-03, and L-04.

Thus, while most vessel service operational scenarios can be carried out without concern for the overall structural and hydrostatic characteristics of the MHP, operations involving very large loads and operations involving large asymmetrical deck loading must be evaluated for their effect on the roll and yaw displacements of the MHP.

As part of the final design of the MHP, further consideration should be given to the full range of possible deck loading conditions associated with the various operational requirements. With this information, a handbook that can be used by the dock master to determine how unique loading situations are to be handled within the constraints of the MHP characteristics can be developed.

3. Operations Deck Space Allocation

Space allocation on the operations deck must support the requirements of vessel berthing and light maintenance activities. It is desired to be able to operate 140-ton (127-tonne) mobile cranes at capacity anywhere on the pier without

restriction. Additionally, it is required to provide laydown space for materials adjacent to the location of the mobile crane.

Space adjacent to the pier edge should be kept as clear as possible to allow maximum flexibility of operations. Vehicle access should be separated from the primary crane operations and laydown areas to the maximum extent possible.

Space allocation on the operations deck for light maintenance activities is shown on Drawings L-02, L-03, and L-04.

Personnel access provisions from the operations deck to the service deck should be provided so they do not interfere with the primary activity areas near the pier edge.

A vehicle turnaround should be located at the end of the pier to minimize impact on the high-activity vessel service areas.

4. Vehicles Requiring Operations Deck Access

There is no requirement for vehicle access between service and operations deck. In the unlikely event a van, small forklift, etc., were called down to the service deck, it would exit the pier via the operations deck ramp and reenter via the service deck ramp (see Table VI.E-1).

a. Personnel Transport Vehicles

- Auto – None, except for senior officers, chaplains, and ships' COs and XOs.

- Van – Full size, extended body, 15-passenger, such as a Ford Maxivan.

- Bus – Large school bus type, for transporting personnel on base. An example is a Bluebird TCFE 8400 cab forward (snub-nose conventional chassis), 84-passenger bus.

- Comment: The Bluebird bus has a 237-inch (6-meter) wheelbase with a 76 foot (23.2-meter) curb-to-curb (front wheel touches curbs) and 85-foot (25.9-meter) wall-to-wall (front corner of bus body touches walls) turning circles. The government often purchases this specific model. The 76-foot (23.2-meter) curb-to-curb circle is well within the 86-foot (26.2-meter) turnaround space provided As a check of the turnaround space provided, the AASHTO Green Book states a minimum design turning circle of 2 by 42 equals 84 feet (25.6 meters) for both their 240-inch (6.1-meter) wheelbase SU single unit truck and their 300-inch (7.6-meter) wheelbase city transit bus vehicles.

b. Maintenance Vehicles

- Ship-Related – Van-bodied and flatbed single-unit trucks, tractor, and van-bodied or flatbed semitrailers. No lowboys or dropped bed trailers allowed as these units may bottom out at access ramp break points.

- Pier-Related – Van delivery type trucks.

TABLE VI.E-1: EXAMPLE OF VEHICLE CHARACTERISTICS NEEDED

Vehicle	Model	O/A DIMS LxWxH	Wheel Base (ft)	O/S Corner Turning Circle	Gross Weight	Axle Load	Max Grade
Tractor and Semi Trailer	International 2574 6x4 Freshaof Trailer	24'-3"Lx8.5'Wx11'-10"H 45'Lx8.5'Wx13'-6"H	17' 37'	68'-10"	16,107 lbs	7,286 lbs / 8,821 lbs	16% N/A
Bus	School Bus etc	20'L	19'-9"	85'-0"	-	-	-
Truck Crane	DM 140T Crane	50'Lx24'-2"W	19'-2"		163,190 lbs	26,844 lbs / 141,976 lbs	-
Fork Lift	DM-20T ForkLift		9'-6"	28'-0"	20,000 lbs	2,500 lbs / 17,500 lbs	
Fire Truck	Basic Pumper	10' W X 10'-6"H (Some as 11'-6" W)	-	70' (Field Experience)	-	-	-
Aid Truck	Medic One Truck	9' W x 8'-6"H	-	70' (Field Experience)	-	-	-
Van	Ford "Maxi Van"	19'-4"Lx6'-7"Wx7'-0"H	11'-5"	46.3" (Dodge)	-	-	-
Pickup	Ford F250/ F350 4x4	18'-10"Lx6'-8"Wx6'-8"H	11'-5"	-	-	-	-
Tow Tractor and Steering Trailer	Toyota 02-2TD23 -	9'-11"Lx4'-8"Wx4'-6"H -	5'-4" -	10' -	- -	- -	16%ok (upto 18%) -

c. Freight and Equipment Vehicles

Ships' stores, equipment, and other freight are delivered by van- and flatbed-bodied single-unit trucks, and by van- and flatbed-bodied tractor and semitrailer trucks. Tractors and semis allowed on the operations deck are street rigs, not those optimized for interstate freeway operation (see Appendix C for AUTOTURN Truck Turning Analysis). The limitations are as follows.

(1) Street Tractor – Conventional (engine in front of cab) chassis short-cab tractor up to 208-inch (5.3-meter) wheelbase, flatbed, or van trailer up to 48-foot (14.6-meter) length with close-coupled dual axles.

Comment: A super-short snubnose yard tractor or COE (cab over engine) tractor will ease access and turning, but is not required. An example of a street tractor is an International 2594 6x4 with 204-inch (5.2-meter) wheelbase [midway in the 180- to 252-inch (4.6- to 6.4-meter) wheelbase range listed as available]. This tractor has a conventional chassis (engine in front of cab), a short cab (not a sleeper), and a space of 126 inches (3.2 meters) between the back of the cab and the fifth wheel. Curb-to-curb and wall-to-wall turning circles are 66.2 and 68.8 ft (20.2 and 21.0 meters), respectively. In theory, provided there is enough space between the back of the tractor cab and the nose of the trailer, turning circle is limited by the tractor and not by the trailer. For comparison with AASHTO and field experience data, an International 2594 with 180-inch (4.6-meter) wheelbase has turning circles of 59.2 and 61.7 feet (18.0 and 18.8 meters), respectively.

(2) Street Trailer – Flat bed or van type (not drop-frame or low boy), 53-foot (16.2-meter) maximum length, 13 feet 6 inches (4.1 meters) maximum height to top of van box, close- coupled dual axles spaced at 48 inches (1.2 meters) and centered 5 to 14 feet (1.5 to 4.3 meters) from end, no triple axle, no dolly, 3 feet (0.9 meters) from kingpin to nose of trailer, 24-inch (0.6-meter) minimum ground clearance under retracted stand located 44 inches (1.1 meters) maximum behind kingpin (generic Fruehauf).

(3) Interstate Tractors and Trailers – Not allowed on pier

Comment: These vehicles cannot go on the pier and may not even be capable of traversing the base roadways from the outside gate to the pierhead. These rigs are optimized for maximum gross weight under local state Department of Transportation permits. They turn very poorly. When loaded, tight turns will scrub the treads off the tires on dollies, wide-spaced dual axles, and triple axles. These rigs will not negotiate a turnaround within any reasonable pier width. Aerodynamic cabs with low-ground clearance and tight space between cab and trailer body severely limit pavement dip angles (where cab hits trailer) and breakover angles (where tractor skirt high centers). These rigs typically include a long 240-inch (6.1-meter) wheelbase tractor, aero-bodied sleeper cab on the tractor, cab sides tight to nose of trailer van body, wide-spaced duals or triples on trailer, dollies (extra axles) on tractor and/or trailer, etc.

(4) Street Combination (tractor and semitrailer) – Allowed on pier

Comment: Based on the theoretical tractor curb-to-curb turning circle, a space of only 66 feet (20.1 meters) curb-to-curb is required to turn a street combination rig (see discussion under Street Tractor above). The AASHTO Green Book lists a theoretical 80-foot (24.4-meter) design turning circle for their WB-40 Semitrailer AASHTO "intermediate vehicle" has a 156-inch (4.0-meter) tractor wheelbase and 40-foot (12.2-meter) trailer. The AASHTO computer simulation plot indicates a turning circle of 81.5 feet (24.8 meters). (Compare this with the discussion on street tractor, above). For a WB-67 [240-inch (6.1-meter) tractor wheelbase and 53-foot (16.2-meter) trailer, an interstate rig], the corresponding turning circles are 90 and 91.5 feet (27.4 and 27.9 meters), respectively.

Comment: These turning diameters are less than field experience indicates on two commercial breakbulk cargo finger piers for which reliable information is available. Both piers require turnaround by tractor and semitrailer combination rigs. One pier is 85 feet (25.9 meters) clear curb-to-curb. The other is 98 feet (29.9 meters) curb-to-curb. The stevedoring company that operates both piers states that their snub-nosed Mack tractor with 40-foot (12.2-meter) trailer can turn around in the 85 feet (25.9 meters) (in two passes). The tractor completes most of the turn, backs up a short distance so as not to upset the trailer, and then completes its turn. They state that a fully-loaded street rig (not an Interstate rig as discussed above) can easily turn around on the 98-foot (29.9-meter) pier, and that with care an unloaded long wheelbase interstate rig [248-inch (6.3-meter) wheelbase tractor and 53-foot (16.2-meter) trailer] can just turn around. The reason for unloading before turning, is that when unloaded scrubbing does not damage tire treads on wide-set triple-axle trailers.

(5) It is concluded that, since the 85-foot (25.9-meter) pier functions adequately for a high-frequency breakbulk cargo operation, the 86-foot (26.2-meter) curb-to-curb space furnished on the MHP is sufficient. Whether it is sufficient to turn a 208-inch (5.3-meter) wheelbase street rig is still an open subject. It may be that turnaround requires yard tractors rather than street tractors.

While it appears that the 86-foot (26.2-meter) curb-to-curb pier width is sufficient for trailer/trailer combinations that will be used on the pier, a wider pier will obviously increase the ease of turning and accommodate larger tractor/trailer combinations. Drawing S-07 shows the cross section of an optional wider MHP with an additional 20 feet (6.1 meters) added to the width. Since this increased width adds considerable cost to the facility, it is not desirable to add width beyond that which will be needed for turning of the actual type of vehicles that will be used on the pier.

d. Emergency Response Vehicles

(1) Fire Trucks – Standard pumper with no aerial capability.

Comment: Ships are expected to fight their own fires. There is nothing else on the pier requiring TeleSquirt or other aerial capability. Limiting dimensions (Tacoma Fire Department fleet) are maximum height 10 feet 6 inches (3.2 meters), and max width 10 feet (3.1 meters) mirror to mirror. Prior to final design, the range of dimensions for Navy fire trucks should be checked.

(2) Ambulances – Standard Medic-One-type truck with walk-through van-type body. Limiting dimensions (Tacoma Fire Department fleet) are maximum height 8 feet 6 inches (2.6 meters) over the lights, and maximum width 9 ft (2.7 meters) mirror to mirror.

e. Operations Deck Circulation Path for Vehicles

(1) Main Roadway – Dedicated space, full length of pier, for autos, buses, and single-unit trucks, tractor, and semitrailer trucks. Located along the centerline of pier, to allow crane operations on both pier faces at the same time. Two highway-standard 12-foot (3.7-meter) lanes are provided, divided to pass around the high-mast light poles and around the mooring shafts and stairwell doghouses. Because of the very low vehicle speeds and vehicle counts, dedicated shoulders or breakdown lanes are not provided.

(2) Vehicle Passing – Main roadway must be two-lane, to allow vehicles to pass another stalled or waiting vehicle. One lane is provided on either side of the pier centerline, to maximize the dedicated space available for crane operations.

(3) Vehicle Turnaround – Dedicated space, at the channel end of pier, for vehicles requiring large turning circles, such as buses, and tractor and semitrailer trucks. Turning circles of 86 feet (26.2 meters) curb-to-curb and 88 feet (26.8 meters) (hull width) equivalent wall-to-wall are provided. Traffic bollards will be provided in locations where the turning circle comes in close proximity to the operations deck edge to prevent accidents involving the pier edge.

(4) Vehicle Parking – No permanent parking spaces except for ships' COs and XOs. Temporary parking off dedicated main roadway and turnaround at locations not required by crane operations, heavy maintenance, or ships' stores.

5. Personnel Access to Operations Deck from Service Deck

a. Mooring Personnel Access

Doors on the stairwells' function as fire exits from the service deck, smoke barriers against fire on the service deck, and as a security barrier to prevent unauthorized access to the service deck from the operations deck. Doors to stairwells would be alarmed. Use by mooring and utility hookup crews would require the door alarms to be disarmed and the doors unlocked.

Comment: There may be a need for personnel to pass lines, hoses, or cables between service and operations decks during berthing and deberthing operation. Occasionally, personnel may need to go from one deck to the other during an operation. Generally, mooring personnel will be brought to and taken back from the pier by bus on the operations deck (using stairs to get to and from the service deck) or by van on the service deck directly to the berth (in which case access to the operations deck is not required).

b. Maintenance Personnel Access from Service Deck

If access to the operations deck is required, maintenance personnel will use the stairwells. There is no requirement for tools, ship-to-shore utility hookups, ships' stores, and utility repair parts access between service and operations deck. Generally, these items are carried by vehicle directly to the location on the service deck that they are needed. Under unusual circumstance, small toolboxes, utility maintenance parts, and utility hookups can be manually carried down or up the stairs. Note security considerations discussed above.

Comment: Generally, maintenance personnel will not need to go between decks, as they will be transported with their tools and supplies directly to the maintenance location via van or small utility truck traveling at service deck level.

c. Ships' Crews Access to Service Deck

For the baseline MHP, ships' crews would have little need to access the service deck, in which case they would use the stairwells located at the end of each MHP module (generally at the ends and middle of each berth).

Comment: The service-level deck can be readily expanded to accommodate additional functions having a high enough value to justify locating them on the pier rather than on the yard. Any of these additional functions will require significant access between service and operations decks. In this event, additional stairs and or elevators can be provided. Additional functions could include warehousing of critical ships' stores, maintenance shops and supplies, crew training classrooms, and crew amenities.

d. Firefighting Access to Service Deck

Firefighters access fires on the service deck via the stairwells from the operations deck or by van or small utility truck on the service level. Exit is to the operations deck via the stairwells. Fire truck access is limited to the operations deck.

Comment: If necessary, fire hoses can be routed over the side of the MHP and through the utility windows or down the stairwells to the utility deck.

e. Fire Exit, All Personnel

Fire exit for all personnel is via fire doors to stairwells to operations deck.

f. Medical Aid Access, All Personnel

Access is via stretcher through stairwells to ambulance on operations deck. Alternatively, via stretcher in van or on small utility truck or trailer to shore end of service level ramp to ambulance on shore.

6. Details of Operations Deck Function

The operations deck function is best shown on Drawings L0-2, L-03, and L-04 that describe how the space required for vessel maintenance activities with associated crane service can be handled for a variety of vessels berthed at the MHP (refer to Section VII.C. for a detailed description of vessel maintenance activity requirements).

Key to the function of the operations deck is the fact that the deck is designed to allow the location and operation of a 140-ton (127-tonne) crane at any location on the pier except in the 50-foot (15.2-meter) controlled loading areas at either end of the pier. Similarly, 250 square feet (23 square meters) of 1,200 lbs per square feet (57.5 kN per square meter) live load [300,000 lbs (136 tonnes) total weight] can be located anywhere on the deck surface except in the 50-foot (15.2-meter) controlled loading areas at either end of the pier. Multiple cranes and multiple areas of 1,200 lbs per square foot (57.5 kN per square meter) live load can be accommodated, but as mentioned in Section VII.E, as part of the final design of the MHP further consideration should be given to the full range of possible deck loading conditions associated with the various operational requirements.

The function of the operations deck is limited to repair and maintenance activities, and vessel mooring line attachment. All utilities functions are removed from the operations deck to ease the ability to manage the deck space.

As mentioned elsewhere, an 88-foot (26.8-meter) wide operational deck is proposed in the preliminary design. The likely requirements for deck space have been considered and it appears that this width will provide a functional MHP. However, to address interests in a wider pier, Drawing S-07 shows a 108-foot (32.9-meter) wide pier as an option. The pier function would remain the same in all respects, but there would be an additional 26,000 square feet (2,415 square meters) of space on the operations deck. The additional width would also provide small reductions in the hydrostatic displacements associated with asymmetrical loading of the MHP. This additional deck width would likely result in a construction cost premium of approximately 20 to 25 percent over that of the basic 88-foot (26.8-meter) wide MHP.

E. Service Deck Functional Design Criteria

1. Design Approach to Service Deck Function

The layout of the service deck is optimized around efficient function of the vessel utility hookup and disconnect activity. The area is organized to allow connection hoses and cables to be efficiently handled and organized in a straightforward manner, easing the organization of the area.

a. The service deck area is also planned to support efficient maintenance, replacement, and upgrade of utility systems by locating the utility systems within easy reach of maintenance personnel without use of lift equipment or special access devices. The liquid lines have sectionalizing valves that allow rerouting of fluids if a section of a line needs to be shut down for maintenance. Similarly, if a substation (electrical skid) requires maintenance, electrical service can be provided from one of the other MHP electrical substations (electrical skids).

b. Maintenance vehicle access is provided via a dedicated one-way vehicle lane immediately adjacent to all utility locations and immediately adjacent to substations (electrical skids). Vehicle turnarounds are provided at pier ends and at the mid point. Off-lane parking areas for maintenance vehicles are provided to avoid blocking the maintenance vehicle drive lane.

c. Vessel Deck Elevation versus Utility Deck Elevation – In every instance, the service deck level is below the ship's deck level. This allows for an efficient arrangement for transfer of utility lines from the vessel, through the utility gallery windows for hook up to utility lines on the service deck. The constant elevation between the service deck and the ships' decks means that the utility lines, once hooked up, will not require tending as tides change.

d. The location of the service deck also provides good load transfer structure to react fendering loads into the MHP structure.

e. Service Deck Level versus Water Level – The relationship of the service deck to the waterline will remain constant within close limits. Floating fenders will be accessible for inspection and minor maintenance from the service deck utility windows. Additional freeboard to protect the service deck area from spray is provided by the service level wave wall.

f. Key elements of the utility system are modular and can be removed from the MHP service deck level for major off-site maintenance or replacement.

2. Operational Loading Roll and Yaw

Service deck features will generally be located symmetrical to the center of buoyancy of the MHP and will, thus, not affect the roll and yaw displacement of the MHP. Movable items will consist of the modular mobile pumping stations and small vehicles that will have minimal effect on roll and yaw of the MHP.

3. Service Deck Space Allocation

Space for the following utility components, runs, and hookups is required (see utilities criteria for performance requirements and for hardware).

a. Hoses, cables, etc., to hook up the vessels' hoses, cables, etc., to the MHP utilities, for each vessel berthed.

b. Longitudinal runs of utility mains (cables, piping, and hoses) along both sides of the pier (mounted on underside of operations deck), sectionalizing valves, overhead crossovers between sides, and connections to shore via ramps.

c. Moveable floor-mounted equipment, such as portable receiver/duplex pumps for liquid wastes, and electrical and communications mounds (may be fixed or movable).

d. Electrical transformer and switchgear skids (skids)

Comment: The substations (electrical skids) are the largest and heaviest equipment to be located on the service level. They are located adjacent to the module to module joints so that a sufficiently large space can be efficiently developed to accommodate them. This location is out of the way of traffic, allowing normal operations, and is not subject to direct weather and sea conditions. Overhead clear height of 9 feet 8 inches (2.94 meters) minimum is provided in substation (electrical skid) installation area, giving a clearance of 1 foot (0.3 meter) above the skid unit.

e. Electrical turtlebacks (mounds) located adjacent to pier utility windows.

f. Transportation paths for removal and replacement of major electrical (skids, etc.) and mechanical (wet wells and pumps) equipment without jackhammering out concrete or major rigging operations. A clear height of 9 feet 1 inch (2.76 meters) is provided at the pier edge for installation/removal clearance.

In the event a substation (electrical skid) requires replacement the replacement unit, is delivered to the pier operations deck and lifted via crane from the operations deck to a temporary lifting platform located adjacent to the substation (electrical skid) area. The exterior parapet wall at substation (electrical skid) locations is designed to allow removal for substation (electrical skid) replacement. The substation (electrical skid) is then moved across the utility deck roadway to the replacement location. In the event a larger temporary substation (electrical skid) unit is used as an immediate replacement (MUSE unit), it can be temporarily located on the operations deck.

g. Available Service Level Space for Secondary Uses

Space below the operations deck and adjacent to the service deck is available for development to support MHP mission support activities, if desired. To use these spaces, they must be configured and conditioned to support the desired uses. Details of an approach to developing these areas is given in Section VI.F.6.

These activities include the following.

- Office and Training Areas for Ships' Crews – This would include typical office spaces and special training provisions that could include special audio visual equipment or direct communications ties to onboard ship equipment.

- Shops for Small Equipment Repair – With supporting equipment tailored specifically to accommodate repair of equipment from the class of vessels assigned to berth at the MHP.

- Electronic Shops – This could include the installation of diagnostic equipment that could be connected to ship board modules and used to troubleshoot equipment on-board the berthed vessels without removing the equipment from the vessel for maintenance.

- Crew Amenity Spaces

  Laundry – Laundry facilities could be combined with recreation game rooms, lounges, libraries, computer facilities, personal gear storage

- Storage Warehousing

  Ships supplies
  Replacement parts

Comment: It is envisioned at this time that only the floor at the elevation of the service deck would be developed to support secondary uses. It should be pointed out that there is space for an additional story below the service deck that could also be developed if necessary. While this would nearly double the space available for secondary uses, it would likely require some addition to the total depth of the MHP to accommodate the additional weight that would likely be associated with developing an additional level.

4. Vehicles Requiring Service Deck Access

The following vehicles require access to the service deck. Access to the service deck is limited to the type of vehicles outlined below.

a. Maintenance Vehicles

(1) Small battery-powered utility trucks with cab, service bodies, and roof racks, towing small four-wheel steering (tracking) trailers.

(2) Small propane or battery-powered forklifts and tractors towing small four-wheel steering (tracking) trailers.

(3) Full-size van (Ford Maxivan, etc.).

(4) No high-, wide-, or large-turning circle vehicles such as walk-through step vans, fire trucks, or walk-through van-bodied aid or trucks will be allowed on the service level.

b. Major Utility Element Replacement Vehicles

(1) Purpose-built, strap-on, air-bearing or caster-wheeled lowboy for moving substations (electrical skids) to and from their vaults.

(2) Gasoline- or propane-powered tow tractor for major utility lowboys.

c. Service Deck Circulation Path for Vehicles

(1) Turnaround

Maintenance vehicles follow a counter-clockwise circulation path (so that most turns are left turns, on the driver's side, to better clear obstructions). Turnarounds are provided at the center of the pier and at the end of the pier.

(2) Passing

Maintenance vehicles (small utility trucks, small tow trucks and forklifts, and small four-wheel steering trailers) are narrow. Parking spaces for maintenance vehicles are provided along the longitudinal aisles, so that maintenance activities can continue without disruption caused by vans and maintenance vehicles that wish to pass.

Comment: Parking spaces are not provided for vans. Vans can wait in turnarounds, allowing other vehicles to go past on the main aisle and use the next turnaround. Few vehicles of any sort are expected on the service deck, and traffic issues are not expected to be significant.

5. Personnel Access to Service Deck

a. Mooring Personnel Access from Operations Deck

Stairwells with fire doors and smoke enclosures are provided along the center of the pier, at both ends of each MHP module.

Comment: There may be a need for personnel to pass lines, hoses, or cables between service and operations decks during berthing and deberthing operations. Occasionally, personnel may need to go from one deck to the other during an operation. Generally, mooring personnel will be brought to and taken back from the pier by bus on the operations deck (using stairs to get to and from the service deck) or by van on the service deck directly to the berth (in which case, access to the operations deck is not required).

b. Maintenance Personnel Access

Maintenance personnel will access the service deck via van or small maintenance vehicle over the service level ramp to the service level drive aisle.

Comment: Generally, maintenance personnel will not need to go between decks, as they will be transported with their tools and supplies directly to the maintenance location via van or small utility truck traveling at service deck level.

c. Ships' Crews Access

For the baseline MHP, ships' crews would have little need to access the service deck, in which case they would use the stairwells located at the

end of each pontoon module (generally at the ends and middle of each berth).

Comment: The service-level deck can be readily expanded to accommodate additional functions of the MHP mission-support activities as outlined in Section VI.E.5. above. Any of these additional functions will require increased access between service and operations decks. In this event, additional stairs and/or elevators may be needed.

d. Firefighting Access

Firefighters access fires on the service deck via the stairwells from the operations deck, or by van or small utility truck on the service level. Fire exit is to the operations deck via the stairwells. Fire truck access is limited to the operations deck.

Comment: If necessary, fire hoses can be routed over the side of the MHP and through the utility windows or down the stairwells to the utility deck.

e. Fire Exit, All Personnel

Fire exit for all personnel is via fire doors to stairwells to operations deck.

f. Medical Aid Access, All Personnel

Access is via stretcher through stairwells to ambulance on operations deck. Alternatively, via stretcher in van or on small utility truck or trailer to shore end of service-level ramp to ambulance on shore.

6. Details of Service Deck Function

The details of the service deck layout are shown in Drawings S-03, S-04, and S-05. A key feature of the functional features of the service deck is the approach taken to the provision of utility services to berthed vessels.

Utility runs are located in a dedicated aisle on the service deck on each side of the MHP. The approach is that connections to all utilities, both electrical and mechanical, are provided at frequent and regular intervals within the utility aisle along the pier sides. Connections are made from the ships to the MHP utilities either by cable or hose plug-in for input services, such as electrical and compressed air, or by hose connection to mobile pump stations for output services, such as oily waste and CHT.

Lines from ships into the service level are run through large (6 feet 6 inches by 12 feet 16 inches) (2 by 3.8 meters) utility windows in the exterior side wall of the MHP at the service level. These windows are sized so that utility line handlers can easily man handle lines through these openings for connection to utility outlets on the service level.

Substations (electrical skids) are located on the service deck in a protected inboard location well above the waterline. Substation (electrical skid) locations allow feeds from installed substations (electrical skids) to be combined to provide the required power for a wide range of potential nested vessel combinations without alteration to any permanent electrical cabling.

A maintenance vehicle aisle is provided adjacent to the full length of the utility aisle so that maintenance personnel and tools can drive to any location requiring maintenance. Vehicle turnarounds are provided at pier ends and at mid pier.

Stairwell access is provided from the service level to the longitudinal centerline of the operations deck at intervals along the pier.

a. Service Level Interior Space Utilization

As mentioned previously, the possibility of developing the central interior space on the service level and below offers the potential of added functional benefits to the MHP. There are several approaches to developing this space. Two approaches are considered below.

b. Water Tight Floor versus Composite Floor Slab for Service Level Interior Space

Space for ancillary uses in support of vessel maintenance and/or ship crewmembers can be provided in the interior watertight cells at the level of the service deck. Two options for the floor system of the interior area were considered. Each has different consequences and benefits.

- Option 1 – Nonwatertight Composite Floor Slab System – Metal (or composite) decking with 4.5-inch (114-mm) concrete and steel beams

- Option 2 – Watertight Floor System – Structural concrete slab

(1) Benefits and Consequences for Option 1 – Nonwatertight Floor

One of benefits to the composite floor system is that a large ancillary use area [about 8,600 square feet (799 square meter) module – 34,000 square feet (3,159 square meter) for a four-module 1,300-foot (396-meter) pier] can be obtained with minimal effect on the MHP draft. In the preliminary draft calculations, the draft due to the composite system would be as shown below.

- Due to the slab weight (~40 psf) (1.92 kN per square meter): Weight adds approximately 0.25-foot (76-mm) draft

- Due to the reduced LL (50 psf) (2.39 kN per square meter): Weight adds approximately 0.3-foot (91-mm) draft

- Total additional draft = 0.55 feet (167 mm)

Another benefit to the composite floor system is the flexibility of construction. The only element that needs to be constructed during the initial MHP construction is the concrete corbel floor support that is cast integral with the longitudinal bulkhead. As long as these support elements are in place, the floor system can be economically constructed any time in the future.

One of the consequences of incorporating a nonwatertight composite floor system is the affect on the environment of the ancillary space. Since the space will be inside the watertight cells, the doors to the

area have to be watertight. Therefore, special provisions have to be made to make sure that the doors to this area are routinely closed to maintain the watertightness of the interior space. The watertightness of these cells is necessary for damaged condition hydrostatic performance.

(2) Benefits and Consequences for Option 2 – Watertight floor

By using a structural concrete watertight floor system, the watertight cells will be below the ancillary space area, so that the area is no longer a watertight space. Therefore, the doors to the area do not have to be watertight and, if desired windows and other openings can be added for the area, this may enhance the usefulness of this space for a wider range of uses.

However, one of the consequences of the watertight floor system is an increase in the cost and draft due to the increased weight of this type of floor system. Compared to the composite slab system, the draft due to the watertight slab is more than twice as much as the composite slab system [approximately 1.1 feet (335 mm)]. Therefore, if draft due to the floor were to be maintained at the same level of draft as that for the composite slab, the floor area would have to be limited to approximately 25 percent of the available area. If the floor area is to be maintained at the same level as that for the composite slab, the depth of the MHP may need to be increased, which means that cost of MHP will be somewhat more.

Another consequence of this option is that, for economy, the ancillary area floor should be built at the time of initial MHP module construction. This approach does not give the same flexibility to economically add the ancillary space in the future.

F. Criteria for MHP Maintainability

1. Identification of Maintainable Systems

The objective of the final design activities will be to complete the design and specification of materials and systems such that maintenance requirements for the various systems are minimized. For those elements of maintenance that are unavoidable, the involved system or feature should be designed such that maintenance can be performed with a minimum of equipment, materials, and labor.

The following elements of the various MHP facility systems will have maintenance requirements.

a. Shore-to-Pier Access Ramps

The operations deck access ramp has been designed using primarily steel tube for the truss elements. The possibility of galvanizing and painting the ramp structure will be explored as ways to minimize future maintenance requirements. The ramp deck structure has not yet been finalized; both a textured steel deck structure and a concrete deck structure will be evaluated in final design.

NFESC indicated an interest in consideration of FRP materials for the ramp structures for reasons of maintainability. The required loads that the operations deck access ramp structure is designed for are too large for FRP construction to be economical. The loads and span of the service deck ramp may be within the range of FRP construction. The preliminary design of the service ramp was not in the scope of this effort.

FRP cable and utility trays may be used on the operations ramp to support the utility runs that will cross this ramp. High voltage cables will be separated from other hoses, cables, and wires in a separate cable tray with appropriate safety separation distance.

The ramp end supports must accommodate a complex combination of displacements as defined elsewhere. Several alternative methods of handling these displacements were considered before the current steel wheel; steel rail/ torsionally compliant ramp approach was adopted. This approach was judged to be relatively the most maintenance free of the methods available for accommodation of the range of motions involved. It is likely that the ramp end support wheels and their bearings will require periodic lubrication (once per year) and periodic inspection to assure that everything is working as intended. It is proposed that the ramp motion accommodation design be tested in a prototype phase to assure that the mechanism functions as intended and has the desired low-maintenance characteristics.

b. MHP Mooring

The underwater dolphin portion of the MHP mooring should not require any maintenance over the life of the facility. Care will be taken in the specification of materials and construction methods for the piling and the pile cap to assure that the concrete structure has long-term durability characteristics.

The steel mooring guide shaft that is installed into the underwater dolphin is subject to corrosion and to wear as result of the fender system rubbing against it as the tide goes up and down. Final design activities should consider viable ways to protect this shaft from corrosion. Stainless-steel cladding in the underwater and splash zones should be considered, as should other coatings. The above water portions of the shaft can be periodically lubricated to protect from corrosion and reduce wear from fender contact. Passive corrosion protection measures are preferred over systems, such as an impressed current cathodic protection system, as these systems also require maintenance to assure their effectiveness.

The energy-absorbing compliant rubber fender portion of the mooring system is a potential maintenance item. The fenders have been located above the waterline and in an area shielded from the sun's ultraviolet exposure to reduce the potential for environmental degradation and allow for maintenance access for inspection and repair/replacement, if necessary. NFESC has expressed concern regarding the fender brand and type identified in this preliminary design. This expressed concern should be further addressed prior to final design. In most situations, these fenders are loaded well below their ultimate capacity. However, the performance of the mooring fender/steel mooring guide shaft interface

under design loads is an item that should be the subject of confirmation tests in the prototype phase of the MHP program.

c. Fendering/Ship Mooring

The design of fendering for berthed vessels is tasked to NFESC. Access to waterline fenders is possible through the utility windows. The MHP provides a solid wall of reaction structure to support fender reactions and the MHP outer wall can accept fender attach hardware. The final design of the vessel fendering system should consider appropriate fender connection provisions that are consistent with the MHP exterior wall structure. Standardized corrosion-resistant fender connection hardware should be cast into the exterior wall panels as part of the construction process.

Mooring provisions consist of a regular system of service-level, small-vessel cleats and high-capacity bollards on the operations deck level. No maintenance requirements for these features is anticipated.

d. Electrical Systems

There is a high-voltage feed system from shore power to the MHP substations (electrical skids) and a lower-voltage distribution system from the MHP substations (electrical skids) to the ship service turtlebacks. Power to berthed vessels is distributed by variable length cables from distribution turtlebacks to the ship's power hookup.

Primary maintenance requirements will likely stem from physical damage to electrical components as result of collision with equipment or rough handling. Substations (electrical skids) are located on the service level away from vehicle traffic routes. Turtle backs are located in the utility aisles of the service deck away from vehicles and potential adverse contact with cranes or other moving equipment. The utility aisles on the service deck provide an area for organized storage of pier-to-ship cables to prevent inadvertent damage to connectors or cables from vehicles or other equipment. Low voltage cables will be run in cable trays and separated from high voltage cable, which will be run in 5-inch-diameter (125-millimeter) conduit.

All electrical conduit is mounted overhead in exposed conduits that are directly supported from the underside of the operations deck on the service level and, thus, not exposed to inadvertent damage. The 10-foot 3-inch (3.1-meter) width of the dedicated utility gallery provides ample space to accommodate electrical conduits, electrical cable trays, and other utility runs. In the event maintenance is required, all electrical components are available to maintenance access in the most straightforward way possible. All on-pier electrical cables and equipment are accessible for maintenance without special equipment.

In the event substations (electrical skids) require replacement, an exit route for removal to a platform or a barge along side the substation (electrical skid) location has been designed and includes the required structural capacity and access provisions.

The pier to shore electrical cables have special provisions to accommodate the angular and translation motion that takes place at the pier-to-access

ramp joint and at the access ramp-to-shore joint. There are 15 KV cables, such as used for mining operations or high voltage crane reels (i.e., "mining" or "jumper" cables), which are manufactured for such use and are proven readily available technology. These areas are easily accessible for inspection and repair if necessary.

e. Mechanical Systems

Primary maintenance requirements will likely stem from physical damage to mechanical components as a result of collision with equipment or rough handling. All mechanical systems are located on the service level away from vehicle traffic routes. Attachment fittings and portable receiver/duplex pump units are located in the utility aisles of the service deck away from vehicles and potential adverse contact with cranes or other moving equipment. The utility aisles on the service deck provide an area for organized storage of pier-to-ship hoses to prevent inadvertent damage to connectors or hoses from vehicles or other equipment.

All mechanical piping is made from noncorroding or corrosion-resistant materials. Mechanical lines are all surface mounted above the utility aisle on the service deck level. The line location protects the lines from inadvertent damage from vehicles or moving equipment. Lines are fitted with clean outs as required for maintenance and have sectionalizing valves to allow any required maintenance to take place without curtailing ship service.

In the event maintenance is required, all mechanical systems are available to maintenance access in the most straightforward way possible. All on-pier mechanical lines, valves, and equipment are accessible for maintenance without special equipment.

All mechanical lines taking waste off the pier are low-pressure force mains and, thus, are not as subject to maintenance associated with incidental clogging as would be shallow-sloping gravity lines.

Portable receiver/duplex pumping units have wheels and can be transported off the pier for maintenance and replacement if necessary without any disassembly.

The pier-to-shore mechanical lines have special provisions to accommodate the angular and translation motion that takes place at the pier to access ramp joint and at the access ramp-to-shore joint. These areas are easily accessible for inspection and repair if necessary.

2. Maintainability objectives

The concept that the MHP is a standard-design pier allows for incorporation of lessons learned through incremental improvements as new "versions" of the MHP design are issued. Thus, systems can be optimized and refined over time by incorporation of operational experience into each new design without compromising the standardized modular concept.

The objective is continuous improvement of maintainability in the form of reduced maintenance cost, increased systems reliability, and longevity. This approach to continuous improvement will be implemented by preserving

excellent low-maintenance features and by making adjustments to the design of features that operational experience throughout the Navy shows can be improved. This process will begin with the prototype confirmation testing of selected elements of the overall MHP system. Any design improvements found to be beneficial would be made to the MHP site adapt design on a regular basis within the constraints of a configuration-control philosophy that maintains essential interchangeability among MHP facilities.

G. MHP Security Requirements

The MHP preliminary design addresses security of the pier from the shore-side access. A security guard house will be located between the two access ramps to control access. In addition to the guard house, it is possible to design the ramp transition hinge plates such that they can be maintained in a normally raised position so that vehicle access from the shore to the pier is denied until the pier guard lowers the hinge plate.

Pier mooring provisions will be enclosed within the structure of the MHP to reduce their exposure to threat of sabotage.

Pier lighting provisions will consider both operational lighting requirements and security lighting requirements.

The MHP is designed to be stable with two watertight compartments fully flooded. The completed 1,300-foot (396-meter) MHP contains 112 watertight cells, providing considerable redundancy against the threat of terrorist damage to one or more compartments.

Conventional pile-supported piers are sometimes configured such that small boats can go beneath the pier and potentially detonate explosives that could damage both the pier and adjacent berthed vessels. The MHP presents a solid concrete wall at the waterline and extending 12 feet (4 meters) below the waterline, thus making unobserved, unauthorized activities in the pier less likely.

H. MHP Functional Concepts Considered and Rejected

Several approaches to developing stationary double-deck piers using large modules, off-site prefabricated, and moved into place with offshore lifting equipment were investigated. The optimization of conventional pile-supported Navy double-deck pier design was also considered. None of the configurations explored exhibited the functional advantages of a floating double-deck facility and had the ability to minimize the negative effects of adverse site-specific conditions to the extent possible with a floating pier.

VII. MHP FLOATING PIER MODULES

A. Criteria for Modularity and Standardization of MHP Modules

The individual MHP module is the basic unit of the MHP systems design approach. The objective is that all modules are the same and can be integrated into an overall MHP berthing facility at any position in the pier installation (channel end, interior, shore end). The ability to make module-to-module connections, to accept a bolt on-ramp support, and accommodate pier-mooring elements is included in each module.

It is desired that modular design and quality assurance systems be such that modules manufactured by different contractors at different times, in different geographic locations, can be integrated together to construct an MHP berthing facility.

It is also desirable to be able to use two, three, and four, of five MHP modules integrated together to form viable floating piers that can support a variety of missions.

B. MHP Hydrostatic and Global Structural Design Criteria

1. Lightship Draft

The lightship draft criteria is dependent on the waterplane area of the MHP, the weight of the overall MHP structure, and the permanently installed features. The lightship draft, the differential draft resulting from the maximum loading of the MHP, and the damaged stability criteria determine the required molded depth of the MHP cross section. The calculation of the lightship draft requires that the weight of all of the elements of the MHP be determined within close limits. The preliminary design lightship draft of the MHP is shown on Drawing S-06. Background draft calculations are given in Appendix F.

2. Maximum Loaded Draft

The maximum loaded draft criteria is dependent on the waterplane area of the MHP, the lightship draft, and the maximum operational load to be carried by the MHP. The design loaded draft of the MHP is shown on Drawing S-06. The 3-foot (1-meter) difference between the maximum loaded draft and the lightship draft indicates a distributed loading capacity of 22,000 kips (98,000 kN), combined on the operations deck and the service deck. The preliminary assessment of the projected uses of the MHP indicate that this is a sufficient capacity. This should be further verified through analysis of actual berthing usage prior to final design.

Additional load carrying capacity can be provided by increasing the depth and/or the width of the MHP. Since this adds cost to the facility, it is not desirable to add depth or width beyond that which will be needed for operational loading.

3. Damaged Stability

The MHP is designed to be able to sustain two watertight compartments damaged and fully flooded without overstressing the structure or becoming hydrostatically unstable. The controlling condition for this check is shown in Figure 1 on Drawing L-01. The MHP is designed to accommodate one compartment damaged and fully flooded with full operational loading as shown in Figure 2 on Drawing L-01.

Access to interior compartments to inspect for damage or perform repairs is provided through watertight manholes in the floor of the utility aisle of the service deck for the perimeter compartments and through watertight doors on the service level to the interior compartments. Permanently installed FRP ladders are provided at each of the compartment entry locations.

The analysis to check damaged stability effects is given in Appendix B. The analysis included consideration of both rigid-body-hydrostatic effects and structural-deflection effects.

4. Roll and Yaw Characteristics

The MHP, as a floating body, is subject to roll and yaw displacements as a result of deck loading that is asymmetrical to the MHP center of buoyancy (see Figure VII.B.4). The more asymmetrical the deck loading, the more the roll and/or yaw displacement. The largest roll displacement calculated was 2.3 degrees for two ROH activities with two, 140-ton (127-tonne) cranes operating on one side of the MHP (deck slope of 4 percent). This loading condition is shown in Figure 2 on Drawing L-04. The preliminary assessment of the projected uses of the MHP indicate that the roll and yaw characteristics are acceptable. This should be further verified through analysis of actual berthing usage prior to final design.

The propensity to roll and yaw can be lessened by adding width and depth to the MHP. Since this adds cost to the facility, it is not desirable to add either width or depth beyond that which will be needed for operational loading.

5. Global Strength

The global strength required of the MHP is that required to resist the global stresses that result from the following global loading conditions

a. the application of loads to the decks

b. the transfer of transverse loads from the wind and current effects on berthed vessels to the MHP mooring system

c. seismic loading effects

d. wave bending effects

The bending, shear, and torsion stresses resulting from these loading conditions are, in some instances, combined and the MHP is designed to handle defined service level loading within service-level stress limits and other less likely but possible loading combinations within ultimate stress limits.

Service level stress limits for the MHP primary structural materials are as follows.

- Concrete compression — 0.4 f'c = 2,800 psi (19.3 MPa)
- Concrete tension — zero
- Prestressing steel — 0.6 fu = 162 ksi (1,117 MPa)

For service-level loading, there will also be a design criteria to control the distribution and crack width of any concrete cracking that may occur.

Ultimate strength stress limits for the MHP primary structural materials are as follows.

- Concrete compression — f'c = 7,000 psi (48.3 MPa)
- Concrete tension — 6 sq rt f'c = 502 psi (3.5 MPa)
- Prestressing steel — fu = 270 ksi (1,862 MPa)

See Appendix G for sample calculations supporting the global strength design.

Figure VII.B.4

All of the effects, except the detailed combinations of applied loads to the operations deck, are known within close limits. While the configuration of the MHP cross section allows very significant structural strength to be developed by increasing the amount of post-tensioning and increasing the required compressive strength of the concrete, this adds cost to the facility and it is not desirable to add structural capacity significantly beyond that which will be needed for factored operational loading.

As part of the final design activity, a detailed series of factored-load combinations for both service level and ultimate strength design will be developed.

C. Operations Deck Structural and Geometric Design Criteria

The design approach taken with the MHP has been to design the deck for the structural capacities required and to set the overall size of the facility based on the plan size requirements for operational laydown space and vehicle access.

1. Concentrated Area Loading

The MHP has the capacity to accommodate a wide range of deck loading configurations associated with the following selected maintenance activities (from MIL-HDBK 1025/1 Change 3, 30 June 1994).

a. Planned Restricted Availability (PRA)

PRA consists of limited repairs of shipboard equipment and systems by contract forces under Supervisor of Shipbuilding and Repairs (SUPSHIP) control, with a duration of 30 to 60 days. Gross deck area requirements are about 10,800 square feet (1,003 square meters) (35 by 310 feet) (10.7 by 94.5 meters) of command and storage area and could be on the lower level of a double-deck pier.

The preliminary analysis of this activity indicated an average operational deck loading of approximately 193 lbs per square foot (9.24 N per square meter), plus the supporting mobile crane(see Appendix G for the supporting tabulation used to develop this area loading).

b. Selected Restricted Availability (SRA)

SRA consists of expanded repairs and/or minor ship alterations to shipboard equipment and systems by SUPSHIP contract forces, with a duration of approximately 60 days. Gross deck area requirements are about 18,000 square feet (1,672 square meters) (35 by 515 feet) (10.7 by 157 meters). On a double-deck pier with adequate clearance, about 5,000 square feet (464.5 square meters) of command and operational area could be on the lower level.

The preliminary analysis of this activity indicated an average operational deck loading of approximately 205 lbs per square foot (9.82 N per square meter), plus the supporting mobile crane (see Appendix G for the supporting tabulation used to develop this area loading).

c. Regular Overhaul (ROH)

ROH consists of major repairs and ship alterations to shipboard equipment and systems by SUPSHIP contract forces, with a duration of six to eight months. Gross deck area requirements are about 23,000 square feet (2,137 square meters) (35 by 660 feet) (10.7 by 201 meters). In addition, there would be a requirement for turnaround areas on deck and warehousing off the pier. On a double deck pier, up to 8,000 square feet (743 square meters) of command and operational area could be on the lower level.

This preliminary analysis of this activity indicated an average operational deck loading of approximately 213 lbs per square foot (10.2 N per square meter), plus the supporting mobile crane (see Appendix G for the supporting tabulation used to develop this area loading).

The operations deck is structurally designed to accommodate a 1,200 lbs per square foot (57.5 kN per square meter) uniform load. The hydrostatic properties of the floating pier acting as a floating body defines the extent of area that can be loaded to 1,200 lbs per square foot (57.5 kN per square meter) in terms of its effect on MHP draft, and for asymmetrical loading on its yaw and roll. Drawings L-02, L-03, and L-04 show the assumed layout of deck areas with laydown space to support the above maintenance activities.

2. Crane Loading

Additionally, the MHP operational deck has been designed to resist 250,000 lbs (113.4-tonne) concentrated loads applied by the 30- by 30-inch (0.76- by 0.76-meter) crane outriggers of a 140-ton (127-tonne) crane as defined in MIL-HDBK 1025/1.

3. Other Load Effects

The facility has been designed to resist berthing, wind, and seismic global loading and to react the mooring line loads from all of the primary and alternate vessels considered. These loads also have an effect on the design of the operations deck as it acts as the top flange of the MHP acting as a box beam for global loading.

D. Service Deck Structural and Geometric Design Criteria

1. Concentrated Area Loading

The service-level deck is designed for HS–10 truck service and a 250 lbs per square foot (12 kN per square meter) uniform load.

2. Special Equipment Operational Loading

The heaviest equipment located on the service level are the electrical substations (electrical skids). The support structure in the substation (electrical skid) area is designed to accommodate the loads associated with the substations (electrical skids). The replacement access route from the substation (electrical skid) area transversely to the MHP service level removable parapet wall is also designed to support the loads associated with the substations (electrical skids).

E. MHP Module Construction

1. MHP Module Off-Site Construction Activities

The basic concept of the MHP is that the individual MHP modules are off-site prefabricated at a location ideally suited to this type of construction in the most economical manner. The modules are also outfitted with utilities at an off-site location. The fact that the modules can be wet towed from the fabrication site to the final deployment site means that the fabrication site can be far removed from the final deployment location as the towing costs are not a very significant part of the overall facility costs.

2. MHP Module On-Site Construction Activities

The on-site module construction activities should be limited to the absolute minimum to minimize on-site construction disruption and take advantage of the quality advantages of factory construction methods at an off-site location. While it is possible to do some aspects of module construction on site, there is no rationale for doing so.

3. Alternative MHP Module Construction Methods

Drawings S-16 through S-29 show a precast concrete approach to fabricating the MHP. It is also possible to construct the facility as a cast-in-place concrete construction effort. It is likely that the full objective of interchangeable modules would not be achieved with fully cast-in-place construction, unless special measures were undertaken to achieve the required tolerances for module-to-module mating.

VIII. MHP MODULE-TO-MODULE STRUCTURAL JOINING

A. Design Criteria for Structural Joining of MHP Modules

1. Structural Design Criteria

The structural requirements for the module-to-module joints are to provide sufficient global and local strength across the joints and within the overall MHP for design combinations of wave and still-water bending effects, and the interface shears and torsions associated with vessel berthing and deck loading.

2. Watertightness Criteria

Assure watertight integrity of the module-to-module joints and preserve essential MHP compartmentation to provide required damaged stability. The watertightness of the joint prestressing ducts at the module-to-module joint interface is to be specifically addressed.

3. Construction Tolerance Criteria

A plan is needed to achieve and control construction tolerances that will accomplish the relative alignment of the individual MHP modules to meet agreed project dimensional location tolerances in plan and elevation. This plan must also allow the installation of the structural and utility connections across joints.

Appendix D defines the tolerances requiring control for module-to-module joining.

4. Construction Operations Criteria

A construction approach is needed to allow the mating operation to safely and reliably take place in the wave and wind conditions typical of the Navy station joining sites. Temporary joining methods are needed to allow equipment and utility hookup and checkout to take place as soon as possible after initial joining is accomplished.

B. Design Approach to Structural Joining of MHP Modules

1. Design Approach to Providing Structural Capacity of Module-to-Module Joints

Final global strength across each of the joints between the MHP modules must be capable of handling the factored design loads resulting from appropriate combinations of the following.

- Vessel berthing effects

- Still-water bending effects, including shear and torsion from

  Dead loads
  Equipment loads
  Deck operational loading
  Deck storage loads

- Wave bending effects, including shear and torsion from

  Delivery voyage waves (if applicable)
  Design extreme waves
  Service level waves

- Mooring loads (seismic, wind, wave, and current effects)

  Temporary effects during installation
  Service-level mooring forces
  Design extreme mooring forces

- Delivery towing load effects (if applicable)

Local joint strength necessary to support large loads applied adjacent to joint locations will be provided by developing appropriately reinforced structural sections that can react the joint forces. Complete load paths from the point of joint force reaction through the module walls and into the top, bottom, and wall plates of the MHP platform will be provided.

2. Approach to Maintainability of Module-to-Module Joints

The resulting final module-to-module joints will behave essentially as monolithic joints. The design criteria selected will assure that the joints do not crack under all combinations of service loading. This means that there will be no relative motion across the joints as a result of design loads. Utility designers do not need to plan expansion capability in equipment and connection utility lines to

accommodate movement at the MHP module-to-module joints. The overall MHP will, however, expand and contract longitudinally due to seasonal variations in temperature. This expansion and contraction will be zero at the MHP midpoint and maximum at the pier ends.

Special design attention will be given to assuring that the prestressing steel ducts are watertight at the module-to-module connections. The joint outside of the prestressing steel ducts will be grouted in the region of the post-tensioning bars and the post-tensioning ducts for the joining bars will be filled with a corrosion-preventing material subsequent to stressing the bars.

3. Approach to Assembly and Disassembly of Module-to-Module Joints

High-strength bar post-tensioning was selected as the structural material to use to provide the necessary tension and precompression capacity at the module-to-module joint. This type of connection was selected to provide the opportunity of economical disassembly should that be required to allow deployment of MHP modules to a new location. Appendix D outlines the module-to-module joining process. To disassemble the MHP modules, the process, as described and shown pictorially in Appendix D, is performed in reverse.

C. Details of Structural Joining of MHP Modules

Details of the structural joining of MHP modules are shown on Drawing S-28 and further discussed in Appendix D. All of the joints from one module to the next are the same.

1. Tolerances for Module-to-Module Joints

The joining for the four MHP modules sequentially into a single large MHP facility, as shown on Drawing A-01, involves initially aligning the individual modules with respect to each other.

The approach presented in this preliminary design for the MHP involves making the module-to-module joint width as small as practically possible, thus limiting the amount of construction activity associated with finalizing the joint structure. With this approach, the issues of alignment of the two mating surfaces become more important (than in the wet cast-joint approach discussed in Section VIII.E).

The surfaces to be mated are typically 88 feet (26.8 meters) wide by 28 feet 10 inches (8.8 meters) deep. To construct a vertical wall of this size to an accuracy of +/- 0.50 inch (13 mm) from true perpendicular at the top, would require the wall to be constructed to a tolerance of +/- 0.08 degrees from true vertical. This would require special attention to detail and is likely not reliably achievable on a continuing basis in the heavy construction industry. Thus, for consideration of alignment requirements, an alternative to direct surface-to-surface mating of the entire surface is required. The possible consequences of variations in alignment tolerances are shown in Appendix D Drawing App D-1. Note that, unless controlled, the plan and elevation alignment tolerances can adversely accumulate during the joining operation, causing potential plan and elevation alignment problems.

To deal with the issue of angular alignment in plan and elevation, a joint clearance space of 4 inches (100 mm) is proposed. This clearance can be maintained within acceptable dimensional limits [(+/- 2 inches) (+/- 50 mm)],

and a system of contact plates on each of the two surfaces to be mated, as shown in Appendix D, are provided. The contact plates are relatively small surfaces that can be accurately set to form a plane that is perpendicular to the top deck plane and perpendicular to the longitudinal module centerline within close tolerances. When the contact plates on the mating surfaces are brought into contact, the top deck plane datum's of the mating MHP modules will be parallel and the plan alignment grid datum lines of the mating MHP module units will be perpendicular. The attachment for the contact plates will be an integral part of the MHP modules. The detail setting of the plates to a close planar tolerance (both horizontally and vertically) will be accomplished by precision surveying and plate adjustment after the MHP module is constructed to within the tolerances outlined above. The actual tolerance for setting the contact plates will be determined to provide relative final alignment among the MHP modules that is consistent with the overall joining activity, the joint seal design and the required alignment of utility features that must cross the joints from one MHP module to the next. Tolerances for the joining activity include the tolerances required for match up of the post-tensioning ducts at the joint interface.

Alignment of grid datum lines in plan and elevation will be accomplished by male/female pintle alignment boxes located near the operations deck above the waterline (see Appendix D). These boxes and the pintle that inserts into the box will be shaped in mating tapers to allow self alignment in plan and elevation as the MHP modules are drawn together while afloat. The male end of this assembly will be detailed so that it can be precisely positioned horizontally and vertically and then welded into place after the primary MHP module construction is complete.

The full range of construction and mating tolerances will require development of a comprehensive integrated tolerance control activity that will allow the joining process to proceed without dimensional interferences. Specified dimensional tolerance variations will need to be compared against realistic construction practices and the combination of tolerances for the various features and clearances required for fit-up will need to be developed into a tolerance system that can be documented, specified, implemented, and controlled by a tolerance quality assurance system.

Tolerances that will be important to the joining activity include the following.

- Local tolerances

  Squareness of ends
  End skew
  Local smoothness
  Prestressing duct location
  Location of plates

- Global tolerances

  Tolerances for two, three, and four modules joined together
  Effects of adversely combining local tolerances
  Global dimensional effects of tolerance accumulation

See Appendix D for a tabulation of the features that will require dimensional control as part of the joining tolerance system that will need to be developed as part of the final design.

2. Assembly of Module-to-Module Joints

The procedures for assembly of the module-to-module joints are outlined in graphic form in Appendix D. There are several issues that must be addressed in the design of the module-to-module joining activity. First, the mating surfaces must be moved close together to engage the passive alignment devices. Once the mating surfaces come into contact, sufficient structural capacity needs to be developed to prevent the joint from moving apart and possibly impacting one of the joining surfaces on the other. Secondly, the joining area must be made watertight so that it can be dewatered, properly connected, and then pumped with grout for load transfer between the structural elements of the interface.

a. Initial Ballasting for Trim Correction

For the individual MHP modules floating before being joined, the interior wall layout and location of the stair wells, mooring moonpools, and substations (electrical skids) cause the bare concrete modules to be somewhat out of level trim. Water ballast should be added to the perimeter compartments as required to trim the modules for joining. The individual modules should be ballasted to float level (+/- 1 inch) (+/- 25 mm) and each be at the same draft in the outfitted condition for joining.

b. Initial Positioning of Modules for Joining

The modules to be joined will be positioned using a system of winches, sheaves, and fairleads working from a winch barge as described in Appendix D. One of the modules being joined will be moored in position while the other is moved into place. The effects of these movements and the differential effects of wind, waves, currents, and mooring forces all must be accounted for when determining the level of temporary strength to be provided at the joints.

c. Temporary Global and Local Strength of Module-to-Module Joints

The strength of the module-to-module joint in the temporary condition, after initial mating but before the completion of the joint construction to the final configuration, must be sufficient to resist the effects of all loads that are applied at the joining site during the joining operation. Once the two MHP modules being joined come into contact, enough preliminary joint strength must be developed to prevent the joint from moving during the remainder of the construction process to complete the joint. The types of loads involved are as listed in Section VIII.B. for the final joint design. However, the magnitude of the temporary loads is limited by virtue of the assumed protected joining location, the short duration of the temporary condition, and the fact that the MHP is not subject to service loads at the time of joining.

As the MHP modules are brought together, it will be necessary to develop tension loads in structural ties at the deck level (see Appendix D).

d. Ballasting to Develop Temporary Joint Capacity

Once the deck tension ties have been established, the modules being joined will be ballasted to produce a hogging moment (tension in top – compression in bottom) at the joint. The walls in the individual MHP modules are configured to provide ballast tanks around the outside perimeter of the completed MHP facility. In the completed condition, the arrangement of the ballast compartments provides for maximum flexibility in ballsting in that the tanks are symmetrically located and are as far from the platform center of buoyancy as possible.

e. Watertightness During the Joining Operation

The ballasting activity will put the underwater portion of the module-to-module joint into compression against the lower contact plates and provide the reaction for an inflatable elastomeric water seal located on the perimeter of the mating surfaces. The inflation of this seal will allow the joint to be dewatered, which will result in additional hydrostatic pressure, pushing the individual MHP modules together at the joint.

The principal of developing a compression seal around the perimeter of the joint between the individual modules has been used successfully for joining operations with hydrostatic heads in the 10- to 15-foot (3- to 5-meter) range. The possibility of using only a compressible elastomeric joint seal as opposed to an inflatable joint seal should be further explored in final design.

f. Installation of Joint Post-Tensioning Bars

With the joint dewatered, post-tensioning bars can be threaded through the ducts at the joint, connecting the bottom plates of the individual MHP modules being joined. These post-tensioning bars will then be tightened to apply additional force across the joint, bringing the alignment plates mounted on the mating surfaces of the two individual modules into zero clearance contact. The amount of temporary tension capacity and resulting bending moment capacity to be installed across the joint will depend on the design temporary wave exposure at the joining location.

Once the temporary tension capacity is installed and joining bars nominally prestressed across the bottom of the joint, the construction activities required to finalize the joint can be undertaken. Because the joint at this point will be fixed and the construction activity to complete the joint will primarily take place below deck, the connection of selected utilities across the joint can begin.

3. Concrete Outline in Module-to-Module Joint Area

The concrete outlines in the module-to-module joint area are shown on Drawings S-22 and S-28. A series of concrete bosses have been configured to accommodate the transfer forces and moments and to provide space for both the typical module tendon post-tensioning anchors and the joint bar prestressing anchorages.

Special attention will be given to details that assure the water tightness of the module-to-module prestressing duct joints. Technology to reliably achieve

prestress duct watertightness at joints has been identified that is being developed for prestressing joints in segmental bridges and will be considered in final design for use in the MHP.

4. Post-Tensioning Across Module-to-Module Joints

Prior to final post-tensioning, the joint is filled with grout. In recent floating bridge construction, the nonload transfer areas of the joint are covered with a compressible foam and the joint grout forms a direct load transfer path only over the designed load transfer elements, the operations deck plate, the service deck plate, the keel plate, and the vertical walls and interior bulkheads.

The preliminary design proposes the use of a bagged grouting system for the module-to-module joint. This approach will positively contain the grout to the areas where load transfer is desired and increase the reliability of the overall joint grouting operation. The bags will be segmented into approximately 10-foot (3-meter) long sections and will be grouted using grout tubes accessed from the interior of the MHP modules above the waterline. This approach will allow sequential grouting at all levels of the MHP without a delay to allows lifts of grout to gain strength prior to placing the next lift above. It will also lessen the risk of a grout blowout of the module-to-module dewatering seal.

The selection of the bag material and design for the grout bags will require verification testing. Grout pressures in the bags will be limited to about 20 psi (138 KPa) using this approach. The grout bag material should be sufficiently strong and incompressible so that compression and shear forces can be reliably carried across the interface. Once the grout has attained its design strength, the post-tensioning across the joint will be stressed to its full design value, thus developing the required full global capacity of the joint.

It may be desirable to use pressurized flat jacks at the initial hard contact points used as reaction surfaces in the development of the temporary joint capacity. These jacks could be depressurized after the joint grout has attained its strength, but before final stressing of the joint permanent post-tensioning, thus avoiding the potential for attracting more load than desired to the contact plate supporting structure.

In final design efforts, avoidance of the use of the grout bags and flat jacks should be explored as a simplification of the joining process if equally reliable methods can be identified.

D. MHP Module-to-Module Joining at Construction Site

A possible module-to-module joining sequence is shown in Appendix D.

1. MHP Module-to-Module Joining Off-Site Construction Activities

The modules to be joined are completely prepared for joining at the off-site construction facility. Mating surfaces are dimensionally verified and passive alignment provisions are installed as part of the off-site construction process. The joint seal to allow dewatering is installed off-site as part of the module construction process. Any special provisions for towing are installed off site.

Module joining steel and associated anchorage hardware is positioned on the modules to be joined and shipped with the modules to the site so it can be conveniently installed.

2. MHP Module-to-Module On-Site Construction Activities

Depending on how long the modules have been in the water, it may be necessary to clean the mating interface surfaces in the load transfer areas to remove the beginnings of any marine growth. Prior to joining, the joint mating surfaces should be carefully inspected to assure that no damage has occurred in transit and that the seals and joint grout bags are in place. Incidental repairs to the mating surfaces can be made, if necessary, to repair damage.

Quality assurance measurement records of matching features for each set of matching surfaces should be reviewed as soon as possible after module construction to assure that there will be no fit-up problems. At the site, the fact that this comparison has been made should be confirmed prior to initiating the joining process.

3. Alternative MHP Module-to-Module Joining Construction Methods

The alternatives to the proposed grouted approach to joining are a wet-cast joint and a match-cast joint.

a. The wet-cast joint involves construction of a 6- to 8-foot (1.8- to 2.4-meter) wide joint structure between the two segments to be mated. Construction is accomplished in the dry after dewatering the joint area using a coffer dam attached to the temporarily mated modules across the open joint. Post-tensioning ducts are spliced within this joint region. Walls are formed and constructed only in the designated load transfer area. The advantage of this approach is that the module end and match-up feature tolerance can be somewhat less stringent than for the grouted approach. The disadvantage of this approach is that the amount of time and labor required to construct this type of joint is more than for a grouted joint. This type of joint is also more difficult to disassemble in the event the MHP is to be disassembled for relocation.

b. The match-cast approach involves precasting one matching surface and then using that surface as a form for casting the mating surface of the matching element. The pieces are then joined using only an epoxy adhesive to provide a measure of concrete tensile capacity across the joint. This approach assures that all of the matching post-tensioning ducts align and that the surfaces fit-up within tolerance. It does not result in modules that are interchangeable, and it is not a preferred method to accomplish in the water while the modules are afloat.

E. MHP Structural Joining Concepts Considered and Rejected

Several concepts were considered prior to adopting the approach presented in this preliminary design.

1. Limited number of large high-capacity, module-to-module connections. This approach, often proposed for open-ocean joining requirements, was found to result in significant structural requirements to transfer the forces involved. The

size of structure involved and the cost of the special fittings was felt to be an unnecessary extension of the state of the art.

2. Use of strand post-tensioning with a wet-cast, module-to-module joint. While this approach produces an excellent joint, it doesn't provide the same ability to disassemble for future relocation of the MHP that the joining method presented in the preliminary design does.

IX. MHP MOORING

A. Criteria for Modularity and Standardization of MHP Mooring

The important elements to be standardized for the mooring design are the steel mooring guide shafts that are supported by the site-specific dolphin structures and the load reaction elements within the mooring moonpool area of the MHP modules. Mooring shaft capacity can be varied by holding the exterior dimensions of the shaft the same, while using heavier plate to construct the shaft structure. The capacity of the energy absorbing fenders is increased by increasing the length of the energy absorbing fender element while the cross section of the fender element remains constant. These approaches allow changes in mooring capacity without changing the basic modularity of the MHP modules or the dolphin-supported shafts.

B. MHP Floating Pier Mooring Structural and Geometric Design Criteria

1. MHP Mooring Design Loads from Combinations of Berthed Vessels

The preliminary design of the mooring system is based on the primary vessels as defined in Section VIB.1. However, with some modifications, the mooring system is able to accommodate the alternative vessels (defined in Section VI.B.2.), as well. Vessel arrangements are important in determining the mooring design loads due to the design consequences of wind and current effects.

The design assumptions regarding the vessels to be berthed are as follows.

a. For the primary vessels, the following arrangements create the controlling conditions for the design of the MHP mooring system due to wind and current (see Drawing S-09).

- Transverse, Wind, and Current – Two berths of nested CG-47s on both sides of pier
- Longitudinal Wind and Current – Two berths of nested CG-47s on both sides of pier

b. For the alternative vessels, the following arrangements create the controlling conditions for the design of the MHP mooring system due to wind and current.

- Transverse Wind and Current – Two LHD-1s, one on either side of the pier
- Longitudinal Wind and Current – Two berths of nested DD-963s on both sides of the pier

2. MHP Mooring Design Loads from Wind and Current Effects

a. Nesting Vessel Distribution Factors

In order to determine the total mooring design load, not only the load distribution factors for nesting ships, but also the factors for the berthing arrangement, including wind and current effects on the pier, are important. The load factors for nesting ships due to wind and current are calculated based on the 1986 revision of DM1025 methods. These factors were checked against the 1999 revision of MIL HDBK-1026/4A. The somewhat more conservative values calculated using 1986 DM 1025 were used for preliminary design of the mooring system.

The load factors for the berthing arrangement due to wind and current were decided based on engineering judgment using the factor of the nesting vessels. MIL-HDBK 1026/4A does not have provisions for how to determine the overall berthing factor for nested vessels berthed on either side of the pier. Therefore, we used our best judgment to estimate the overall berthing factors to determine total mooring design load (see Appendix H for our assumption on the overall berthing factors).

b. Site-Specific Wind and Current Conditions

The basic design assumption for the MHP mooring for wind effects is that prior to an approaching tropical hurricane, typhoon, or large tidal surge, berthed vessels will leave the MHP. The MHP mooring system is designed for the following two conditions based on MIL-HDBK 1026/4 Table 7.

Pier with moored ships (Mooring Service Type II)

- Wind Velocity: 50-year recurrence (64 knots max)
- Current Velocity: 50-year recurrence
- Tidal Range: ELW to MHHW
- Wave: 1-year recurrence

Pier without moored ships (Mooring Service Type IV)

- Wind Velocity: 100-year recurrence
- Current Velocity: 100-year recurrence
- Tidal Range: Extreme experienced historically at site
- Waves: 100-year recurrence

The heavy weather mooring criteria (Mooring Service Type III) is not considered in the MHP mooring design at this point. If the scope of work were to change to accommodate Mooring Service Type III, further investigation is necessary to upgrade the design of both the MHP and its mooring system. Design loads for the mooring system would increase significantly in order to accommodate the moored ships under higher wind and current loads. However the concept of the MHP mooring system will be valid even for Mooring Service Type III condition.

The basic design of the MHP mooring system is based on the design site's (San Diego) physical and environmental conditions and, with some modification to the basic design, the MHP mooring system is also able to accommodate the optional sites' (Mayport and Bremerton) physical and environmental conditions. The wind and current loads used for the design site and the optional sites are summarized in Table IX.B-1. on the next page.

The wind and current loads were calculated using the 1986 revision of DM26.4 The result was also spot checked using the 1999 revision of MIL-HDBK 1026/4A methods and also by using the Navy's Mathcad loads program designed by W. Seelig from Navy Facilities Engineering Service Center.

According to the results of the analysis, the wind load on vessels contributes to the mooring load significantly more than does the current load on vessels. Therefore, the maximum combined wind and current loads for MHP mooring design are derived from light draft (maximum wind area) with extreme low water (ELW) (maximum current effects). Light draft creates the maximum wind exposure area for vessels and pier combined to maximize the wind load which is the primary load. ELW creates the greatest current load condition.

3. MHP Mooring Design Loads from Vessel Berthing Energy

Berthing energy from the vessels is absorbed by the vessel fender system that, in turn, exerts a reaction on the MHP as a concentrated load (uniform over the length of the fender element). The fender reactions are transmitted through the MHP structure to the mooring system and ultimately to the foundation soils. Because the ship berthing impact load is transient in nature and does not usually occur simultaneously with the maximum wind and current forces, berthing impact loads are not combined with the wind and current loads in the development of the mooring system design. According to the preliminary analysis, the mooring load, due to the wind and current loads on moored ships, governs the design over the loads resulting from ship berthing energy.

Preliminary vessel fendering is assumed to be 8-foot (2.4-meter) diameter foam-filled fenders spaced as needed between the MHP utility windows. Development of the fendering design is tasked to NFESC in future phases in order to draw on the experience NFESC staff have gained in the comprehensive fendering development program.

4. MHP Mooring Design Loads From Wave Effects

The placement of MHP is assumed to be in protected Navy station harbors with minimal fetch distance for wind waves. Primary waves are the result of vessel traffic. Since all berthing operations are tug assisted, the assumption for the preliminary mooring design is that wave loads do not govern the design.

5. MHP Mooring Design Loads from Seismic Effects

In the preliminary MHP mooring design, two levels of an earthquake were considered: a 500-year return earthquake and a 2,500-year return earthquake. For the preliminary design, the seismic spectra from San Diego and Bremerton, which are known to be high seismic zones, were investigated. The level of

earthquake for design of Navy facilities in San Diego and Bremerton is quite similar. Using

TABLE IX.B-1: SUMMARY OF MHP MOORING LOADS & SELECTION OF FENDERS

SUMMARY: Loads on MHP

Controlling Configuration:

[For Primary Ships]
Trans Wind & Current: 2 SETS OF NESTED CG-47 ON EACH SIDE
Long Wind & Current: 2 SETS OF NESTED CG-47 ON EACH SIDE

[For Optional Ships]
Trans Wind & Current: ONE LHA 1 ON EACH SIDE
Long Wind & Current: 2 SETS OF NESTED DD 963 ON EACH SIDE

SUMMARY of MOORING LOADS DUE TO WIND AND CURRENT

			TOTAL LOAD ON MHP (1)				Max. Load/shaft (2)		
			Service Load		Ult Load = 1.3 (Service Load)		Ult Load = 1.3 (Service Load)		
			Transv W+C kips	Long W+C kips	Transv W+C kips	Long W+C kips	Transv W+C kips	Long W+C kips	NOTE:
Design Site	Type II	Primary Vessels	1029	194	1337	252	669	126	[2 Mooring System]
		Optional Vessels	1499	149	1948	194	487	194	[4 Mooring System]
	Type IV	MHP only	249	15	324	20	162	20	[2 Mooring System]
Optional Site	Type II	Primary Vessels	1537	278	2000	362	500	362	[4 Mooring System]
		Optional Vessels	2293	226	2981	294	1162	294	[4 Mooring System]
	Type IV	MHP only	1447	76	1881	99	470	99	[4 Mooring System]

FENDER SELECTIONS : (These are notthe only options.)
See Definitions onthe next page

			TRANSV	LONG	TOTAL LOAD ON MHP Transv W+C kips	TOTAL LOAD ON MHP Long W+C kips	Max. Load/shaft Transv W+C kips	Max. Load/shaft Long W+C kips	
Design Site	Type II	Primary Vessels	No1, Opt B MV1450x2000 A	No1, OptA MV1450x1000B	1392	244	696	244	
		Optional Vessels	No1, Opt C MV1450x1500A	No1, OptA MV1450x1000B	2028	244	922	244	
	Type IV	MHP only	No1, Opt B MV1450x2000 A	No1, OptA MV1450x1000B	1392	244	696	244	
Optional Site	Type II	Primary Vessels	No1, Opt C MV1450x1500A	No1, OptA MV1450x1500B	2000	366	922	366	(3)
		Optional Vessels	No2, Opt C MV1450x1500B	No1, OptA MV1450x1500B	2928	366	722	366	(3)
	Type IV	MHP only	No1, Opt C MV1450x1500A	No1, OptA MV1450x1500B	2028	366	922	366	

Note:
1) Assuming that Vessels would be berthed symmetrically on the center
2) When the vessels are berthed closer to the Mooring only (for LHD and LHA and LPD) - See Calculation for the assumption of rotation
3) If vessels are allowed to berth closer to the mooring, it needs to be pointed to accommodate the value from the above.

TABLE IX.B-1: SUMMARY OF MHP MOORING LOADS & SELECTION OF FENDERS (CONTINUED)

DEFINITIONS:

Mooring System:

		Option A	Option B	Option C
		1 Mooring kips	2 mooring kips	4 mooring kips
MOORING No 1	2- (2)Trellex M/ units per shaft	2R	4R	8R
MOORING No 2	2 - (4) Trellex M/ units per Shaft	4R	8R	16R

Notation:

Mooring No 1: 2-Trellex per side of guided shaft
Mooring No 2: For Trass, 4 Trellex per side (Stacking 2-Trellex vertically)
For Long, 2 Trellex per side

OPTION A: Total Loads for 1 Mooring
OPTION B: Total Loads for 2 Moorings
OPTION C: Total Loads for 4 Moorings

Fenders:

			Mooring No 1		M	oring No 2		
			Option A	Option B	Option C	Option A	Option B	Option C
TRELLEX	Type	R, Reaction (kips)	1 Mooring kips	2 mooring kips	4 mooring kips	1 Mooring kips	2 mooring kips	4 mooring kips
M/ 1450 x 1000	B	122	244	488	976	488	976	1952
M/ 1450 x 1000	A	174	348	696	1392	696	1392	2784
M/ 1450 x 1500	B	183	366	732	1464	732	1464	2928
M/ 1450 x 1500	A	261	522	1044	2088	1044	2088	4176
M/ 1450 x 2000	B	244	488	976	1952	976	1952	3904
M/ 1450 x 2000	A	348	696	1392	2784	1392	2784	5568

Note: *: For MooringNo 2, Design bpile cap and piles have tobe changed.
**: M1450 was elected toaccommodate EQ displacementfor BREMERTON and SAN DIEGO.
***: M/ 1450x2000B isthe longestfender we can usefor M/ 1450

American Association of State Highway and Transportation Officials (AASHTO) 16th Edition Div 1A, Bridge Design Code, the following load factors and load combinations were established for design of the MHP mooring elements.

- Ultimate Load Case: DL + EQM
  [EQM = EQ / R, R = 1.0 for foundation design]

  DL is dead load
  EQM is the modified earthquake force
  EQ is the unmodified earthquake force
  R is the numerical coefficient response modification factor

AASHTO Div 1A requires that earthquake effects be combined for design using 100 percent of the factored forces in one direction and 30 percent of the factored forces in the other direction of the earthquake.

In order to meet the criteria for "Seismic Criteria For California Marine Oil Terminals" by J.M. Feritto, the following items have to be checked at the next phase of design.

- Effects of vertical EQ forces
- Serviceability limit state with 72 year return EQ

However, it is not likely that these items will affect the mooring concept that has been developed in Phase 2. The vertical dead load affecting the mooring system is only the self-weight of the mooring system. Therefore, it is unlikely that vertical earthquake effects would control the preliminary design of MHP mooring system. Regarding the serviceability requirements for a 72-year return EQ, the preliminary design of MHP mooring system should be able to accommodate the 72-year return level EQ displacement within service level allowable stresses, since the structure is designed to accommodate the 2,500-year return EQ displacement.

6. MHP Geometric and Tolerance Design Criteria

The mooring concept developed in this preliminary design involves the use of two vertical mooring shafts (four for alternative vessels) supported by pile dolphins that are installed at the site. The mooring shafts fit within mooring shaft moonpool housings that are an integral part of the floating MHP module structure. The shafts must match up closely with the as-built locations of the mooring shaft housings and the mooring shafts must be perpendicular to the waterline and parallel to each other.

In order to assure proper fit up of these features, the dolphins must be located to match the as-built dimensions between the mooring housings in the MHP. The installation details for installing the mooring shaft into the dolphin pile cap provide for significant tolerance adjustment, as do the details for installing the energy attenuation fender elements within the mooring housing in the MHP.

7. Local Tidal Variation

Tidal conditions, extreme high tides, and extreme low tides vary significantly among Navy stations in different geographic areas (see Table V.J-1). While a major advantage of the floating MHP is that the moored vessels and the pier rise and fall together with the tides, the differences in tidal extremes from location to

location may range from those that affect the mooring system design slightly to other areas where the load reaction elevation changes on the mooring structure are significant.

In addition to astronomic tidal variations, which can be closely predicted, some Navy stations are located in areas where significant water level changes associated with water level surges associated with major storms can be experienced. Other stations are located in areas where significant seismic seiche water level changes (both positive and negative) are possible. These conditions are generally addressed in ways that allow some repairable facility damage to occur while assuring the survival of the facility. Neither the effects of storm surge or seismic seiche were addressed in detail in this preliminary design. Strategies to address these issues in ways that do not compromise MHP modularity are available and should be further evaluated prior to final design as site-specific design issues.

8. Water Depth at Pier Location

For Pier 10/11 in San Diego, the design dredge depth for the vessel berths is –37 feet (-11.3 meters) MLLW with an over-dredge allowance of 1.7 feet (0.5 meters) for a maximum dredge depth of 38.7 feet (11.8 meters).

Differences in water depth at the MHP deployment location mainly affects the mooring system design. The mooring system dolphin pile cap must be set low enough so that there is always a clearance between the bottom of the MHP hull at the maximum operational draft of the MHP and the top of the pile cap at ELW.

Comment: Generally, if there is sufficient water depth for the vessels to be berthed, there will be sufficient water depth for the MHP. A clearance of approximately 3 feet (0.9 meter) between the MHP keel plate and the top of the underwater dolphin support structure at ELW is needed. Thus, for the preliminary design of the MHP for San Diego site conditions, the top of the dolphin support structure should be located at about – 22 feet (-6.7 meters) MLLW. The dolphin mooring structures will be located near the longitudinal centerline of the MHP. Thus, it will be possible to dredge MHP berths deeper, if required by future vessels, without concern for undermining the mooring structures

9. Environmental and Physical Design Conditions

a. Soil conditions affect the design of the pile system for the dolphin mooring shaft support structure. The number, size, and length of piles are all dependent on the actual soil conditions. Also depending on the site geotechnical conditions, the batter pile system shown in the preliminary design may not be the most cost-effective solution. If this proves to be the case for a specific site, then the pile system will be altered to suit local conditions.

b. Special environmental considerations, such as seismic seiche and storm surge, are a design issue for the mooring system. Seismic seiche may be possible for some West Coast locations as a result of a large offshore earthquake. Storm surge is a more likely event for some locations on the East Coast. These special events can cause abnormal water levels that

would affect the design of both the mooring system, the access ramps, and the shore utilities interface.

The basic floating pier structure is not affected by earthquakes. Only the moorings of the MHP and the access ramps are subject to earthquake loading. Both of these features are designed with significant motion capability to accommodate seismic effects. The earthquake criteria for final design will be developed from the publication "Design Criteria for Earthquake Hazard Mitigation of Navy Piers and Wharves" by J.M. Ferritto (TR-2069-SHR). The MHP mooring will be configured to minimize the design effects of varying levels of earthquake risk from site to site.

C. Design Approach to Standard MHP Floating Pier Mooring

1. Mooring Design Issues

The MHP mooring system design is influenced by site wind and current loads, site tidal ranges, the water depth at the deployment site, site geotechnical conditions, and local seismicity. The design is also dependent upon the operational and mission requirements for berthing vessels. One of the challenges for the design of mooring system is to develop a basic design that will accommodate various site-specific conditions and berthing vessel variations with minor modifications to the mooring system design while maintaining the benefits of the MHP modular philosophy.

The wind and current produce sustained and gust loads to the MHP mooring system, which are transmitted through the ship fendering system to the MHP and then to the MHP mooring system, and ultimately to the foundation soils, through the mooring shaft and its supporting dolphin structure. The vessel fender system does not reduce this load but rather distributes the load uniformly to the floating pier. The fendering system also acts to attenuate the peak values of the berthing forces so that the berthing forces do not design the overall mooring.

A unique design approach for MHP mooring system is used to minimize the design effects of varying levels of earthquake risk from site to site. In order to maintain the modular concept, the high level of potential seismic loading, such as exists in San Diego or Bremerton, have to be accommodated in the design of the MHP mooring system, even though on the East Coast, design site seismicity is much lower. To be cost effective in a system designed for broad site applicability, it is necessary to avoid over design of the MHP and its mooring system while still accommodating the worst-case, site-specific situations from site to site.

The approach selected of using a very flexible mooring system that incorporates force isolation fender elements to reduce the seismic effects to the level of wind and current force achieves this objective. However, as a consequence of this, the MHP mooring system has to accommodate significant seismic displacements. The details of this concept are explained in Section IX.D. of this report and shown on Drawings S-9 through S-12.

2. Design Approach to Floating Pier-Mounted Mooring Elements

The approach taken to the design of mooring elements contained in or part of the MHP module structure is that they will be the same for all modules. The dimensional opening and structural strength of the mooring reaction elements is the same for all MHP modules. The energy-absorbing elements are the same for

all modules, except that longitudinal acting energy absorbing elements are typically installed at only one mooring location.

The typical installation uses two of the four available mooring locations in the assembled MHP (each module has a mooring moonpool). For some alternative locations with high wind exposure or for alternative vessels, four mooring locations can be used to increase the capacity of MHP mooring to accommodate the increased wind and current loads on the berthed vessels.

The energy-absorbing elements (Trellex marine fender elements) are removable and replaceable. They are located within the MHP mooring moonpool above the waterline so that they are not exposed to saltwater and can be inspected and maintained if necessary without resorting to in-water or underwater activities.

3. Design Approach to Site-Specific Force Reaction Dolphin Elements

The force reaction dolphins are the primary site-specific design element of the MHP facility. They are basically lateral-force resisting pile caps designed to accept and react the primarily lateral forces and associated moments transmitted through the mooring guide shafts to the dolphin pile cap. The only vertical forces acting on the dolphin are dead load forces from the pile cap itself and from the mooring guide shaft. There are also small (in comparison to the capacity of the dolphin) frictional forces transmitted through the mooring guide shaft as a result of the motion of the MHP moving up and down with the tides while the mooring is under transverse or longitudinal load from wind and current effects.

The standard dolphin pile caps are envisioned to be precast caps that are partially completed at the time of installation. The caps are sized to accept the largest number of piles that may be required. If fewer piles are needed because of lower environmental loads or more competent soils, then fewer piles are used in the standard dolphin pile cap. The pile caps are used as driving templates for the dolphin piling. After driving of the piles, the mooring guide shaft is adjusted within a dry coffer dam constructed around the dolphin pile cap and the piles and mooring shaft are integrated with a concrete pour that completes the dolphin assembly. The mooring shafts are then removed, the MHP moved over the dolphins, and the mooring guide shafts are reinserted through the MHP module into the dolphin pile caps and secured. The construction process is further described in Section IX.E.

4. Design Approach to Site-Specific Mooring Elements

Standard mooring provisions have been developed that are applicable with minor modifications to the expected range of tidal variation and pier face water depths, a range of soil types, and the expected range of seismic loading. The MHP mooring system is designed to provide a lateral force-resisting system that accommodates loads applied to the floating pier in both the longitudinal and transverse directions.

a. Varying Seismic Conditions – The design of the mooring system will be configured to provide a measure of seismic isolation so that the mooring system need not be designed for the full range of potential seismic forces.

b. Tidal Variation – Mooring provisions for the MHP will be designed to accommodate its use in both low- and high-tidal variation areas as

represented by Mayport, San Diego, and Bremerton. Differences in tidal extremes are handled primarily by increasing or reducing the basic length of the mooring guide shafts. The increased moments associated with increasing the shaft length (and thus increasing the cantilever length of the mooring guide shaft) are handled by increasing the shaft material thickness without increasing the external dimensions of the guide shaft.

c. Water Depth – The approach to handing differences in water depth at the deployment site are handled in a manner similar to that described for tidal range variation

d. Soils – A pile-supported mooring dolphin that can be tailored to site soils conditions by using more or fewer piles as variations from the typical design will be used. Variations in soil profile will be accommodated by varying the pile length, pile size, and/or number of piles to suit local conditions.

The site specific information considered in the preliminary design is presented in tabular form in Table V.J.-1.

D. Details of Standard MHP Floating Pier Mooring System

Details of the MHP mooring system are shown on Drawings S-09 through S-12.

1. Details of the MHP Mounted Mooring Elements

The location of the MHP mooring system reaction points within the plan of the floating pier was selected to minimize the transverse flexural capacity requirement of the MHP. The concept of placing the MHP mooring at the ends of pier was investigated in Phase 1. However, even though there are some advantages to having the mooring location at the ends of pier, the consequences are the resulting significant increase in the transverse design moments for the MHP and the associated increase in cost. As a result, the location of mooring system reaction points was set to be at approximately the fifth points of the overall pier length to improve the efficiency of the global structural system.

One of the unique concepts of the MHP mooring system is the approach used to reduce the effects of the seismic force to the level of wind and current force effects. This was achieved by the use of the proven energy absorbing and damping features of rubber marine fender elements. Using the flexible fender as a spring connection between the MHP and the MHP mooring system increases the dynamic response period of the MHP structure to the extent that the structure experiences primarily the displacement effects of the design earthquake rather than the force effects of the design earthquake. In other words, the compliant nature of the mooring load reaction elements results in the base shear of the structure being minimized while the structure experiences a larger seismic displacement. As a result, the seismic loads developed will be limited to the reaction generated from the mooring fender displacement based on the computed earthquake displacement.

Criteria for selecting the rubber fender were that the fender should accommodate the forces associated with ultimate wind and current effects and also accommodate the calculated seismic displacement. The seismic displacement is calculated based on the period of the structure (which is in turn based on the stiffness of the rubber fender) and the seismic spectrum at the

specific site. The design earthquake spectrum for both San Diego and Bremerton shows that when the dynamic response period of the structure is greater than 4 seconds, the displacement of the structure will be constant. Therefore, it is important to select the rubber mooring reaction fender elements of the MHP mooring system such that they are flexible enough to provide the period of structure greater than 4 seconds.

In the preliminary mooring design, a Trellex Fender MV1450 was chosen to react the MHP mooring forces. According to the seismic calculations, based on the San Diego seismic spectrum, 30 inches (0.76 meter) of displacement is expected from 2,500-year return earthquake and 20 inches (0.50 meter) displacement is expected from 500-year return earthquake (see Appendix H for sample calculation). Trellex MV1450 fender units can displace about 33 inches (0.83 meter) (58 percent of fender height of 1,450 mm) before the fender becomes "solid" (completely compressed). Since the seismic spectra for Bremerton is very similar to that for San Diego, the expected displacement at Bremerton (optional site) should be similar.

The force resisting capacity of a given fender cross section is determined by the length of the fender. Thus, the length of fender required is determined depending on the wind and current loads from the vessels and pier structure. By changing the length of fender, the different wind and current forces at different sites and the different berthing vessel arrangements can be accommodated. Even though the longest Trellex fenders unit is 78.7 inches (2,000 mm), the Trellex fenders can be stacked up to meet the required capacity. As long as the height of the fender remains 4.76 feet (1,450 mm), the fender length changes required to accommodate higher and lower wind and current loads require no modification to the size of mooring opening in the MHP structure.

Several options for MHP mooring fender locations were investigated. For example

- Option A – Attaching the fender to the MHP pier at the utility deck level
- Option B – Attaching the fender to the steel mooring guide shaft

The suitability of fender locations was evaluated taking into consideration maintainability and functionality. Both options have advantages and disadvantages. Ultimately, Option A was selected. The advantages of this option can be summarized as follows.

a. Since fenders are always above the water, inspection and maintenance can be performed easily and this improves the durability and maintainability of system.

b. Because the vertical location of the MHP mooring fenders and the vessel berthing fender are relatively same in elevation, the potential for rolling displacement of the MHP due to the eccentricity of the applied and reacted loads is minimized. Since the MHP is a floating pier, it is important to minimize any rolling displacements to protect the operation of the deck activities.

2. Details of the Stationary Mooring Dolphin and Mooring Shaft

a. Mooring Guide Shaft Details

In the preliminary design a 7-foot 6 inch by 7-foot 6-inch (2.3- by 2.3-meter) square hollow steel shaft built up from steel plate was selected as the guide shaft for the mooring system. The advantages of the selection of this type of an element can be summarized as follows.

(1) One can easily increase capacity of shaft by increasing the thickness of the shaft plates without affecting the outer dimension of the shaft.

(2) Handling of the steel shaft during construction would be easier since the hollow steel shaft is light enough to be handled by a small crane.

The surface of the steel mooring shaft will be treated to minimize corrosion. In addition, the thickness of the steel shaft plating will be sized to accommodate the possibility of corrosion effects over time.

The length of mooring shaft is determined from the tidal range of the site. The shaft will be made long enough to accommodate the full vertical range of the MHP motion as it rises and falls with the tides. The foundation system (dolphin pile cap and pile design) is designed for the most adverse combination of elevations and loads at the specific site condition. In the basic design for San Diego, the shaft plating is 1.5-inch (38-mm) thick and the shaft is 41 feet (12.5 meters) long to accommodate the tidal range of 11.23 feet (3.42 meters).

b. Mooring Dolphin Details

The pile design portion of the mooring dolphin foundation design of the MHP mooring system is very much site specific. The concept of the basic design was to develop a versatile design that can accommodate the conditions found at different sites and berthing vessel variations with some minor modification. In the preliminary design, the use of a precast concrete pile cap is recommended to increase the underwater construction quality and long-term durability. In addition, the precast pile cap can also be used as a template for pile driving.

Precast concrete piles are used in the basic design. The main benefit of precast concrete piling is that for most conditions it is more economical compared to the steel piling and the concrete piles are often more versatile in various soil conditions. Conventional precast concrete piles were also selected in consideration of the cost consequences of equipment mobilization costs of large floating equipment. Such large equipment could drive a 15- to 20-foot (4.6- to 6-meter) diameter steel caisson that could replace the piles and pile cap shown in this preliminary design. A batter pile system was chosen because of the versatility of the system under various soil conditions compared to some other systems, such as plumb drilled shafts. In addition, by using different sizes and lengths of piles or changing the arrangement of piles, the capacity of the foundation can easily be changed to accommodate variations in foundation conditions (see Drawing S-11 for the pile arrangement and pile cap configuration for the San Diego design site).

The publication “Seismic Criteria For California Marine Oil Terminals” by Ferritto, requires special attention in design when batter pile systems are

employed. Designing a batter pile system per the requirements of this document requires a special study to avoid a severe design penalty. The study is "to ensure that the structure, including batter piles, will respond within the specified performance limit state." In the MHP mooring foundation design, the batter piles are significantly isolated from the seismic deflection of the MHP floating pier associated with a 2,500-year return earthquake. The energy absorbing mooring fender components of the system are placed to accommodate the seismic displacement. Therefore, use of a batter pile system can be justified for use in the MHP mooring system foundation.

c. Special Conditions to be Considered

For the design of the MHP mooring system, it is important to look into the special conditions at the specific sites. On the West Coast, seismic seiche may effect the water elevation more than the usual tidal range. On the East Coast, the storm surge may be the concern. For example, in Mayport there is the potential for positive storm surge of more than 15 feet in addition to the normal tide according to The Navy document SSR-6183-OCN titled "*Concept Study – Mooring Service Type III for a CVN-68 at Navsta Mayport, FL*" by NFESC. For these site-specific environmental conditions, special considerations have to be made for the mooring system to assure that any damage resulting from extreme events is either completely avoided or is a least reparable.

For additional positive tidal effect, the length of the mooring shaft can be made long enough to accommodate the additional range of MHP motion. However, since this is not the normal condition, the method of accomplishing the shaft extension can be developed to accommodate these rare conditions. For the additional negative tidal or seiche effect, the foundation of the mooring system pile cap and piles have to be placed below the range of MHP motion. If necessary, additional dredging may have to be done to place the foundation pile cap low enough to avoid bottoming out the pier in these situations.

E. MHP Mooring Construction

1. MHP Mooring Off-Site Construction Activities

Off-site activities associated with mooring construction include the fabrication of all of the mooring elements that are part of the MHP floating module, the precast concrete pile cap, the precast concrete piles, and the mooring guide shafts. The off-site fabrication reduces on-site construction disruption and provides the opportunity for improved quality associated with plant manufactured precast concrete. The off-site fabrication also provides opportunities for nonsite specific advance fabrication and stockpiling, with the resulting addition of considerable planning and schedule flexibility to the MHP implementation program.

2. MHP Mooring On-Site Construction Activities

The construction sequence shown on drawings S-10 is one of the possible ways to build the MHP mooring.

The construction of the mooring system is challenging because of the underwater construction involved and the required coordination of mooring

elements both within the MHP floating structure and elements which are pile supported at the final deployment site.

a. The objectives of the mooring construction are to achieve the following conditions.

(1) Each of four mooring shafts (two in some locations) must fit in the mating 15- by 15-foot (4.6- by 4.6-meter) square mooring opening of the MHP.

(2) The face of the mooring shaft must be parallel to the face of the MHP mooring opening, so that the mooring load reaction fenders can transfer the mooring, berthing, and seismic loads from the MHP to the mooring shaft most efficiently.

(3) The mooring shaft must be perpendicular relative to the waterline, so that the MHP can move up and down along the shaft smoothly to accommodate the elevation change associated with the site tidal range.

b. Tolerances and Adjustments for Mooring Shaft Installation

The proper placement of mooring shaft supporting pile caps is critical for the mooring construction. The pile cap placement controls the location of the mooring shaft, which has to fit properly inside of the MHP mooring openings. Therefore, the as-built surveying for coordinating the orientation and distance between MHP mooring openings within the assembled MHP is very important so that the location of pile caps and mooring shafts can be set to match the as-built dimensions of the mooring elements within the floating MHP or vice versa if the moorings are built in advance of the MHP module assembly.

In the design, the mooring installation tolerances are accommodated by providing adjustment capability at two locations: within the dolphin pile cap and the mooring reaction fender attachment within the MHP.

Because of the unique construction, it is necessary to provide a sufficient construction tolerance in the design. The preliminary design of the mooring system provides a tolerance of $\pm$ 9 inches (229 mm) in plan location of the dolphin pilecap with maximum of 8 degrees rotational tolerance and an approach to allow adjustment to attain the necessary tolerance for mooring guide shaft plumbness.

If a greater tolerance is desired for pile cap placement, it can be accomplished by enlarging the plan size of the pile cap and mooring shaft opening in the pile cap.

The following three items are incorporated in the design in order to provide the sufficient tolerances and adjustment capability.

(1) Oversized shaft opening in the pile cap: Allows the shaft to be adjusted in rotation up to 8 degrees. If the rotational tolerance is not needed, the plan location of shaft can be adjusted up to an additional 8 inches (203 mm). However, any rotational inaccuracy is first corrected at the pile cap level because the plan location can also be adjusted within the MHP.

(2) Shaft cap with leveling screws: The shaft cap with the leveling screws mechanism, as shown on Drawing S-12, is provided to allow adjustment of the plan location and initial plumbness of the mooring shaft. The shaft cap is premanufactured to match the steel mooring shaft, so that the cap and shaft will fit perfectly. Then, the leveling screws attached to the shaft cap can be used to adjust the plumbness of the mooring shaft without relying on the levelness of the pile cap. The limit of adjustment theoretically only depends on the length of leveling screws.

(3) Side adjustment plates: Four sets of plumbness adjustment plates are installed on top of each pile cap. The adjustment plates consist of a set of serrated embed plates and a matching set of loose serrated top plates. Because the rotational position of the mooring shaft relative to the as-built pile cap location is unknown before the installation of the shaft, the top adjustment plates may have to be trimmed after measuring the proper fit. The side adjustment plates, in combination with the shaft cap assembly, will hold the shaft in position within the pile cap during the MHP installation process.

c. Tolerance Adjustment for Mooring Fender Installation

Within the mating mooring reaction moonpools on the MHP, only the translation (plan location) tolerance is accommodated. By the time the pile supported mooring shaft system is in place, the rotation and plumbness tolerance should already be achieved for the shaft installation.

(1) Shim plates: Nine 1 inch (25 mm) shim plates are provided for use between the mooring fenders and their support surfaces on the MHP, which are located at service deck level in the mooring openings. By adjusting the shim plates, any inaccuracy of plan location up to up to $\pm$ 9 inches can be corrected in 1 inch (25 mm) increments.

d. Global Location of Dolphin Structures

In addition to the adjustment provisions incorporated in the preliminary mooring design, the following additional measures are proposed to increase the construction accuracy.

(1) Surveying posts for pile cap placement: Because the pile cap is placed underwater, surveying posts that can be seen above the water will be used to improve the accuracy of the placement of the pile cap.

(2) Steel template for pile driving: A steel template for pile driving will be connected to the precast pile cap and located above water to supplement the precast pile cap as a pile-driving template to make pile driving more accurate. These assisting mechanisms for pile driving are recommended to limit the pile cap movement, which may be caused by pile driving.

(3) Temporary bracing: Temporary bracing is provided to assist in positioning the mooring shaft in a plumb position.

Accurate surveying cannot be emphasized enough prior to construction, during construction, and just prior to finalizing each stage of construction.

Appropriate survey control will be a key to positioning the mooring system elements in the correct locations.

3. Alternative MHP Mooring Construction Methods

Local construction conditions, the local availability of specialized equipment, and the experience level of local contractors may have a significant effect on the most economical method of constructing the mooring dolphins. For example, the following concepts may be economically viable in certain situations.

a. Use of a single large caisson to replace the pile foundation shown in the preliminary design.

b. Use of three or four large drilled shafts to support the mooring dolphin.

c. The use of a lift in trussed steel jacket similar to a small oil drilling jacket.

F. MHP Moorings Concepts Considered and Rejected

Several approaches to accomplish the mooring of the MPH were considered and rejected, leading to the approach presented in this preliminary design. A number of these approaches were addressed in the document *Final Report Phase 1 – Concept Development Modular Hybrid Pier (MHP)*

1. Tight line mooring – This concept was initially rejected as the space constraints and water depths within a typical Navy station harbor were not consistent with the long scopes and cable lengths necessary with this type of mooring in high-tidal zones. It was also felt that the applicability of this system to a finger pier moored perpendicular to the shore would place additional demands on the access ramp system to accommodate longitudinal and transverse motions of the MHP.

   Potential users have expressed an interest in the ability to moor the MHP with line and anchor moorings. A rough comparison of the costs of a line and anchor mooring system indicates that the costs are comparable to those of the mooring dolphin and mooring shaft concept shown. An advantage of a line and anchor mooring system is that it would be faster and easier to construct, and the elements of the system (anchors, cable and chain) would be reusable at another location in the event the MHP facility were moved.

   It is estimated that, for the primary vessels considered, two transverse moorings with three 30,000-pound anchors each would be required on each side of the MHP. Additionally, two longitudinal moorings, one acting toward shore and one acting away from shore, would be required. Each of these moorings would have three 30,000-pound anchors. Moorings of similar capacity that we are familiar with would likely have dimensions similar to those shown in Figure IX.F.1 on the following page. In order to clear the bottom of ships berthed adjacent to the pier, a clump weight would be required on each mooring at the pier edge. Likely, the moorings would be pretensioned to assure that loading was equally shared by the multiple lines and anchors and to increase the mooring stiffness and, thus, reduce the displacement of the MHP under applied berthing and wind loads.

Figure IX.F.1

While the details of the a line and anchor mooring system would vary with the bottom conditions and the tidal variations that must be dealt with, this type of mooring may be viable in areas with sufficient space on either side of the pier to accommodate the scope associated with line and anchor moorings. Sufficient water depth to allow the catenary trajectory of the mooring line to clear the bottom of vessels moored adjacent to the pier is also required.

2. Large mooring dolphins at the pier ends – This concept was rejected after preliminary calculations indicated that a very high level of transverse strength was required to transfer vessel berthing forces through the central portion of the pier to the moorings at the ends. This strength requirement would have been the controlling condition for the design of the MHP and would have represented unnecessarily high costs for the facility.

X. MHP PIER-TO-SHORE ACCESS RAMPS

A. Criteria for Modularity and Standardization of MHP Access Ramps

The modularity of the access ramps should address the following things.

a. The load carrying capacity of the ramps (both dimensionally and structurally) should be the same for all lengths of ramp designed for different locations.

b. The interface with the MHP on the pier end of the ramp and the interface with the on-shore abutment at the shore end of the ramp should be the same from one installation to the next.

c. The details of supporting the utilities and accommodating the ramp angular movement with the utilities should be the same from one installation to the next.

Ideally, the structural system for the ramp structure should be the same from one installation to the next; however, for locations requiring very long ramps and those that can use shorter ramps there may be economic reasons to revise the structural system of the ramp.

It is envisioned that a series of typical ramp designs in 5-foot (1.5-meter) increments of span will be developed for use with the MHP site-adapt design package. The site-adapt work for the ramp would then be only the site-specific design of the abutment consistent with local geotechnical conditions.

B. Access Ramp Structural and Geometric Design Criteria

Each MHP facility has two ramps, one from the MHP operations deck to the yard, and the other from the MHP service deck to the yard. The operations deck ramp is centered on the MHP longitudinal centerline. The service deck ramp is offset to line up with the seaward-bound longitudinal service deck vehicle aisle.

The primary differences in access ramp design from one location to another is the access ramp length. This length is determined to maintain the ramp angles within the limit of motions and within the maximum grades for vehicular traffic. For a given tidal variation, the longer the ramp the lower the angular motions to be accommodated and the lower the grades. Also, the longer the ramp the greater is the ramp cost.

1. Operations Deck Access Ramp Design Criteria

a. The operations deck access ramp is designed to carry the loads associated with the following.

- 140-ton (127-tonne) mobile crane as defined in MIL-HDBK 1025/1
- 20-ton (18.1-tonne) fork lift as defined in MIL-HDBK 1025/1
- HS 20 Truck
- 100 psf (4.8 kN per square meter) uniform live load

The ramp is designed in accordance with AASHTO 16th Edition Bridge Design Code.

b. Ramp grade varies as the MHP floats up and down with the tide. Design criteria are as follows.

(1) Ramp width - One-way, single 12-foot (3.7-meter) lane, plus a 3-foot (0.9-meter) marked (no curb or raised walkway) pedestrian pathway, for a total pavement width between guardrails of 15 feet (4.6 meters).

Comment: This width is just sufficient for creeping-speed traffic with no abutting walls or high barriers to cause a vehicle driver to shy away to the other side of the pavement. Widths of limiting vehicles are street rig tractor and semi equals 8 feet 6 inches (2.6 meters) (plus mirrors (common), basic pumper fire truck equals 10 feet (3.0 meters) to mirrors (seldom, except usage in an emergency), 140-ton (127-tonne) crane equals 11 feet (3.4 meters) to fenders (seldom).

The ramps and their end bearings are also designed to accommodate motions of the MHP without binding and without pulling off the supports. The total ranges (plus to minus) of these motions are shown in Table X.B-1.

Table X.B-1

Item	**San Diego (Basic)**	**Bremerton (Optional)**	**Mayport (Optional)**
Transverse (feet)	2.5 ft (0.76 m)	2.5 ft (0.76 m)	N/A
Longitudinal (feet)	2.5 ft (0.76 m)	2.5 ft (0.76 m)	N/A
Roll (degrees)	2.1 deg	2.1 deg	2.1 deg
Vertical (feet) Tide and Draft	14.98 ft (4.57 m)	23.65 ft (7.21 m)	14.45 ft(4.40 m)
Total at Operations Ramp	**14.98 ft (4.57 m)**	**23.65 ft (7.21 m)**	**14.45 ft (4.40 m)**
Roll at Service Ramp	0.97 ft (0.30 m)	0.97 ft (0.30 m)	0.97 ft (0.30 m)
Total at Service Ramp	**15.95 ft (4.86 m)**	**24.62 ft (7.50**	**15.42 ft (4.70**

Item	San Diego (Basic)	Bremerton (Optional)	Mayport (Optional)
		m)	m)

2. Service Deck Access Ramp Design Criteria

The design of this ramp is not included in the scope of this preliminary design.

a. The service level access ramp is designed to carry the loads associated with light vans and light pick-up trucks and smaller vehicles (Ford Maxivan, etc.). The design loads include the following.

- H10 truck

The ramp is designed in accordance with AASHTO 16th Edition Bridge Design Code.

A weight limit posting and vehicle size restriction frame will be installed at the shore end of the service level ramp to prevent large and overweight vehicles from accessing the ramp.

b. Ramp Grade – The steeper the grade, the closer the MHP can be set to the seawall. Vehicles must be able to stop on the ramp and then start up again (gradability criterion). Gradability for gasoline or propane-powered vehicles is not an issue. Gradability for battery-powered vehicles is.

c. Ramp Width – One-way, single 10-foot (3.0-meter) wide lane with no pedestrian pathway (pedestrians walk in vehicle path), for a total pavement width between guardrails of 12 feet (3.7 meters). This is just sufficient for creeping-speed traffic with no abutting walls or high barriers to cause a vehicle driver to shy away to the other side of the pavement. Widths of limiting vehicles are full-size van equals 79 inches (2 meters), battery or propane powered tow tractor, small forklift, utility truck, and small steering trailers are narrower.

Comment: Traffic frequency is much less than for the operations deck ramp, so the inherent difficulties (poor sight distance at entrance and exit of ramp, and a confusing traffic pattern at the intersection at the yard roadway) matter less.

The service ramp is design to accommodate motions of the MHP as outlined for the operations deck ramp.

3. Yard Elevation Relative to MLLW (designated as MLW in some locations)

Yard elevation mainly affects the access ramp design. The access ramp is the only element that connects the yard and MHP floating pier. The yard elevation, pier operations, and service deck elevations at extreme tidal events set the extreme angles of the access ramps given the ramp lengths.

For the preliminary design, a shore side elevation of 11.6 feet (3.5 meters) above MLLW was considered. This elevation is the quay wall centerline elevation at Piers 10 and 11 in San Diego.

Comment: Yard elevation relative to MLLW will be a variable from site to site. Where conditions allow, the local elevations can be changed on shore to either ramp up from a low-yard elevation or ramp down from a higher-yard elevation. It is likely that revisions to on-shore elevations will not be practical in most typical Navy station situations. Therefore, the differential elevations resulting from the yard elevation and the variable tides will be handled by approach ramps that are either longer or shorter. Longer ramps will be used to limit the maximum grade of the ramp during extreme tidal variations (see Table X.B-2 for criteria for ramp vertical geometry).

4. Interface with On-Shore Facilities

Preliminary design will assume a roadway parallel to the shore with adequate space at the shore end of the pier to allow a turn that will result in alignment of vehicles with the longitudinal axis of the access ramps prior to entering the ramp (no turning flares will be provided on the access ramps) (see Table X.B-2 for criteria for ramp vertical geometry).

5. Local Tidal Variation

Tidal conditions, extreme high tides, and extreme low tides vary significantly among Navy stations in different geographic areas. A major advantage of the floating MHP is that the moored vessels and the pier rise and fall together with the tides. Small tidal extremes in some locations result in minor ramp motion. In other areas, the angular motions and grade changes associated with the tidal cycles are significant.

6. Environmental and Physical Design Conditions

a. Special Environmental Considerations (such as seismic seiche and storm surge)

Seismic seiche may be possible for some West Coast locations as a result of a large earthquake. Storm surge is a more likely event for some locations on the East Coast. These special events can cause abnormal water levels that would affect the design of the access ramps.

The basic floating pier structure is not affected by earthquakes. Only the moorings of the MHP and the access ramps are subject to earthquake loading. Both of these features are designed with significant motion capability to accommodate seismic effects. The earthquake criteria for design will be developed from the publication “Design Criteria for Earthquake Hazard Mitigation of Navy Piers and Wharves” by J.M. Ferritto (TR-2069-SHR).

C. Design Approach to MHP Pier-To-Shore Access Ramps

The MHP will be designed to accommodate standard access ramps to both the operating and utility deck levels. In areas of high-tidal variation, the ramps will be necessarily of longer span to allow high and low tidal ranges to be accommodated within limiting ramp grades. For the production MHP, it will be possible to design a series of different length ramps suited for different tidal variations that can be site adapted to a particular site. The primary site adaptation, other than ramp length, will consist of variable shore side abutment design and associated utility connections.

TABLE X.B-2: CRITERIA FOR RAMP VERTICAL GEOMETRY

ITEM	Reference Standard *	MHP Goal **	Remarks
Grade			
Normal Operations	12%	12%	MHHW/MLLW
Extreme Conditions	N/A	16%	EHW/ ELW
Transitions			
Blend Length	12'	16' - 17' (12' apron and 4 or 5' flapper)	Longer Vehicles
Approach Angle	14.0 degree	14.0 degree	
Departure Angle	8.0 degree	8.0 degree	
Breakover Angle	6.0 degree	6.0 degree	
Dip Angle	N/A	5.0 degree (Ops. Ramp)	Tractor and Semi
		N/A (Service Ramp)	

Notes:
Normal Operations = Ramp Grade between MHHW (Light) to MLLW (Loaded)
Extreme Conditions = Ramp Grade for EHW (Light) and ELW (Loaded) Condition. (Special Condition such as Storm Surge and Seismic Seiche are not considered.)
Blend Length, Approach Angle, Departure Angle, Breakover Angle, & Dip Angle - see sketch below

Reference Standard: Parking Garage Ramp Details From Ramsey and Sleeper
MHP Goal : MHP Ramp Design Criteria

1. Design Approach for Normal Access from Yard to Operations Deck

a. Yard Roadway – A generic yard is assumed, where the pier (finger type) is oriented perpendicularly to a seawall running along the edge of the yard. The main access road from the yard to the pier is assumed to be a two-lane roadway running along the seawall. This roadway has wide shoulders or breakdown lanes on both sides. The pavement is wide enough so that the limiting vehicle (a street rig tractor and semitrailer) can turn 90 degrees from the roadway onto the ramp joining the pier to the yard, without using the ramp as part of its turning radius.

b. Ramp – A ramp is provided between shore to the upper (operations) deck of the MHP. The ramp lands at the shore edge of the operations ramp and does not use up operations deck space to effectively lengthen the ramp.

Inherent difficulties include poor sight distance at junction of ramp with operations deck (top of ramp), and a confusing traffic pattern at the intersection at the yard roadway (bottom of ramp). Vehicle traffic on the one lane ramp is controlled via signals at top and bottom of the ramp, monitored via closed circuit TV (CCTV) by the security guard (see Table X.C-1 for vehicles using operational ramp during normal operations). Vehicle waiting space is provided on the pier operating deck and along the shoulder of the yard access roadway.

(1) Grade – Given the same tidal variations, the steeper the allowable ramp grade, the closer the MHP hull can be set to the seawall. Vehicles must be able to stop on the ramp and then start up again (gradability criterion). The limiting vehicle for gradability is an ordinary street rig tractor and semitrailer, which can start up on a 16 percent grade. Maximum grade is thus set at 16 percent for normal operations (MLLW with MHP at maximum draft) to MHHW with MHP at minimum draft). Grade criteria should be studied further prior to final design to assure there are no other vehicles that will constrain the ramp maximum grade to lower values.

(2) Transitions – Typically, transitions are provided between a ramp and the level pavements at top and bottom of the ramp. The purpose of transitions is to ease problems with breakover angle at the top of a ramp, where the vehicle's midbody tends to high-center between axles. The transition also deals with approach and departure angles at the bottom of a ramp, where the vehicle's ends tend to strike the pavement entering and leaving the transition. A third concern is with the dip angle (negative breakover), where the two parts of a tractor and semitrailer rig span the junction between pavement and transition (or ramp and transition) at the bottom of a ramp.

Comment: For tractor and semitrailer rigs, approach and departure angles do not generally limit. Breakover angles can be limiting. For this reason, long-wheelbase freeway tractors with aero-bodies and low skirts are not allowed on the pier. Still the ramp configuration must limit the break angle to avoid a semitrailer, high-centering on its retracted jack stand.

TABLE X.C-1: CRITERIA FOR RAMP VERTICAL GEOMETRY

RAMP	VEHICLES
Operation Ramp	
Extreme Conditions	Pumper Fire Truck Medical Aid Truck
Normal Operation	Auto, Vans, Pickups "Street" Tractor and 45' Trailer Bus (48 passengers) Truck Crane, 140T Forklift, 20T
Service Ramp	
Extreme Conditions	None
Normal Operation	Van (15 passenger) Pickup (1 Ton, Not Dually) Tow Tractor with Steering Trailer

Dip angle causes the clearance between the back of the cab and the front of a van-bodied trailer to close up. This is particularly critical with aero-bodied sleeper-cab tractors with tight cab-to-trailer clearance. This is another reason that these rigs are not allowed on the MHP.

Transition lengths were initially set by judgment at 12 feet (3.7 meters). This is the length commonly used in parking garages. A study to confirm the approach to transition design is presented on Drawings S-14 and S-15.

See Table X.C-2 for ramp length, transition grades, and variations with tide and draft of maximum grade. Prior to final design, transition lengths and angles should be studied further in conjunction with specific vehicles in use at representative Navy stations.

c. Security and Control

(1) Typical Operation – Typically, a vehicle approaches the pier along the yard roadway that runs along the seawall. The vehicle stops on the shoulder, while the driver walks over to the guard shack to show identification, waybills, etc., and to obtain permission to enter the pier. The guard shack can be located on the seawall between the operations and service deck ramps, on the seawall to either side of the ramps, or across the access roadway opposite the ramps. Direct view and CCTV are provided to assure sufficient visual control. After obtaining permission to enter the pier, the driver returns to the truck, the guard opens the remotely controlled barrier gate at the bottom of the ramp, sets the traffic control signal to green, and the vehicle goes onto the pier.

(2) Protection Against Terrorists – A threat to be guarded against is a truck loaded with explosives running the guard post and barrier gate. The barrier gate is kept closed except when an approved vehicle is actually in the gate opening, so that a terrorist cannot run the gate when it is open for someone else. Approach speed to the ramp is severely limited by the need to make a tight radius 90 degree turn from the yard access roadway along the seawall onto the ramp. Ramp hinge plates can be raised to form barrier gate that can stop low-speed impact from a heavy truck. If considered necessary, a second barrier gate could be provided at the pier end of the ramp.

2. Extreme Conditions Access from Yard To Operations Deck

a. Yard Roadway – Same as for normal access.

b. Ramp – Same as for normal access, except that ramp grades are more extreme, and only emergency vehicles (basic pumper-type fire truck and Medic-One-type ambulance, as shown in Table X.C-1) need negotiate the ramp. This situation occurs for short periods during the year when normal astronomical tides exceed the range of MLLW to MHHW, and for longer periods during major storms, when storm surge causes water levels to approach ELW and EHW (see Table X.C-2, which shows limiting grades at ELW and maximum MHP draft, and at EHW and minimum MHP draft).

TABLE X.C-2: AVERAGE RAMP SLOPE AND GRADES

		Operation Deck Ramp		Service Deck Ramp	
FLOATING PIER		Light Ship	Loaded Ship	Light Ship	Loaded Ship
Molded Depth to Operations Deck (at sides)	28.00 ft	28.00 ft	28.00 ft		
Add'l Operations Deck Crown (at transv CL)	1.00 ft	1.00 ft	1.00 ft		
Molded Depth to Service Deck (at sides)	16.67 ft			16.67 ft	16.67 ft
Light Ship Draft **	10.50 ft	(10.50) ft		(10.50) ft	
Service Draft ***	11.25 ft		(11.25) ft		(11.25) ft
Add'l Live Load Displacement	3.00 ft		(3.00) ft		(3.00) ft
Deck Height Above Water, MHP End	---	16.50 ft	14.75 ft	5.17 ft	2.42 ft

San Diego

Yard Elevation= 12.00

Span Length = 96.00

		ELW	MLLW	MHHW	EHW	RANGE
	Tide Water Elevation	-2.88 ft	0.00 ft	5.75 ft	8.35 ft	11.23 ft
Operation Deck	Deck Elevation Light	15.62 ft	18.50 ft	24.23 ft	26.85 ft	14.98 ft
	Deck Elevation Loaded	11.87 ft	14.75 ft	20.48 ft	23.10 ft	
	Δ Ramp Slope Light	3.62 ft	6.50 ft	12.23 ft	14.85 ft	
	Δ Ramp slope Loaded	-0.13 ft	2.75 ft	8.48 ft	11.10 ft	
	Avg. Limiting Grade	-0.13 %	2.81 %	12.48 %	15.15 %	
Service Deck	Deck Elevation Light	3.29 ft	6.17 ft	11.90 ft	14.52 ft	14.98 ft
	Deck Elevation Loaded	-0.46 ft	2.42 ft	8.15 ft	10.77 ft	
	Δ Ramp Slope Light	-8.71 ft	-5.83 ft	-0.10 ft	2.62 ft	
	Δ Ramp slope Loaded	-12.46 ft	-9.58 ft	-3.85 ft	-1.23 ft	
	Avg. Limiting Grade	-12.72 %	-8.76 %	-3.93 %	2.57 %	

Bremerton

Yard Elevation= 17.50

Span Length = 148.00

		ELW	MLLW	MHHW	EHW	RANGE
	Tide Water Elevation	-4.80 ft	0.00 ft	11.74 ft	15.10 ft	19.90 ft
Operation Deck	Deck Elevation Light	13.70 ft	18.50 ft	30.24 ft	33.60 ft	23.86 ft
	Deck Elevation Loaded	9.95 ft	14.75 ft	26.49 ft	29.85 ft	
	Δ Ramp Slope Light	-3.90 ft	0.90 ft	12.64 ft	16.00 ft	
	Δ Ramp slope Loaded	-7.65 ft	-2.85 ft	8.89 ft	12.25 ft	
	Avg. Limiting Grade	-5.24 %	-1.95 %	6.06 %	10.06 %	
Service Deck	Deck Elevation Light	1.37 ft	6.17 ft	17.91 ft	21.27 ft	23.86 ft
	Deck Elevation Loaded	-2.38 ft	2.42 ft	14.15 ft	17.52 ft	
	Δ Ramp Slope Light	-16.23 ft	-11.43 ft	0.31 ft	3.67 ft	
	Δ Ramp slope Loaded	-19.98 ft	-15.18 ft	-3.44 ft	-0.08 ft	
	Avg. Limiting Grade	-13.69 %	-10.40 %	-2.39 %	2.51 %	

Mayport

Yard Elevation= 12.57

Span Length = 104.00

		ELW	MLLW	MHHW	EHW	RANGE
	Tide Water Elevation	-3.20 ft	0.00 ft	4.92 ft	7.50 ft	10.70 ft
Operation Deck	Deck Elevation Light	15.30 ft	18.50 ft	23.42 ft	26.00 ft	14.45 ft
	Deck Elevation Loaded	11.55 ft	14.75 ft	19.67 ft	22.25 ft	
	Δ Ramp Slope Light	2.63 ft	5.83 ft	10.75 ft	13.33 ft	
	Δ Ramp slope Loaded	-1.12 ft	2.08 ft	7.00 ft	9.58 ft	
	Avg. Limiting Grade	-1.08 %	2.00 %	10.34 %	12.82 %	
Service Deck	Deck Elevation Light	2.97 ft	6.17 ft	11.09 ft	13.67 ft	14.45 ft
	Deck Elevation Loaded	-0.78 ft	2.42 ft	7.34 ft	9.92 ft	
	Δ Ramp Slope Light	-9.70 ft	-6.50 ft	-1.58 ft	1.00 ft	
	Δ Ramp slope Loaded	-13.45 ft	-10.25 ft	-5.33 ft	-2.75 ft	
	Avg. Limiting Grade	-12.94 %	-9.85 %	-5.13 %	0.95 %	

Notes:

Range = Difference between ELW and EHW

Deck Elevation = Tide Elevation + Deck Height Above Water

Δ Ramp Slope = Deck Elevation - Yard Elevation ("Positive "Up" to deck)

Shaded = Limiting Slopes and Grades

Avg Limiting Grade = Ramp Slope / Span Length (Ignores Transition)

** Light Ship Draft - Included only for concrete weight

*** Service Draft - LIGHT DRAFT including Concrete Wt and Utility (Service) Wt.

Comments:

1. Avg. Limiting Grade is a measure of ramp steepness. Grade in middle of ramp between transition is somewhat more.
2. Ramp length for each site (San Diego = Basic, Bremerton = Optional, Mayport = Optional) chosen to produce approximately equal grade severity
3. For San Diego and Mayport (Low tidal range sites), the grade for the optional ramp is steeper than for the service ramp. For Bremerton (High tidal range site), the service ramp is steeper.

c. Security and Control – Same as for normal access, except that guard prevents vehicles that will have problems with the ramp during these conditions from entering the pier.

3. Emergency Access from Yard to Operations Deck

a. Yard Roadway – Only emergency vehicles (basic pumper fire truck and Medic-One-type ambulance) enter or leave the pier. They can do so at any time, during normal or extreme conditions (see Security and Control below). Otherwise, same as for normal access.

b. Ramp – See Security and Control below. Otherwise, same as for extreme access.

c. Security and Control – Security guard gets vehicles, other than emergency ones, off the ramp and keeps them from blocking access or departure of the emergency vehicles. Otherwise, same as for extreme access.

4. Normal Access for Yard to Service Deck

a. Yard Roadway – The roadway is the same as described under Yard to Operations Deck above. The limiting vehicle is much smaller, an extended-body, full-size van (Ford MaxiVan), which requires much less space to turn.

b. Ramp – A ramp is provided between shore to the lower (service) deck of the MHP. Ramp grade varies as the MHP floats up and down with the tide. Design criteria are as follows.

(1) Vehicle traffic is controlled via signals at the entrance and exit to the ramp and is monitored via closed circuit TV (CCTV) by the security guard (see Table X.C-1 for vehicles using service ramp during normal operations). Vehicles waiting to leave the pier wait in the one-way aisle approaching the ramp. Vehicles waiting to enter the pier wait in the breakdown lane along the shoulder of the yard access roadway.

(2) Transitions – As for the operations deck ramp, transitions are provided between a ramp and the level pavements at top and bottom of the ramp. Ramp and transition lengths are set to match the ramp to the operating deck (see Table X.C-2 for ramp length, transition grades, variations with tide, and draft of maximum grade).

c. Security and Control

(1) Typical Operation – Same as for the operations deck ramp. One guard shack and one security guard handle both ramps.

(2) Protection Against Terrorists – Same as for the operations deck ramp. The confined space of the vehicle aisles and their proximity to ships' waterlines makes potential consequences of a truck bomb more serious.

5. Extreme Conditions Access from Yard to Service Deck

a. Yard Roadway – Same as for normal access.

b. Ramp – Personnel and maintenance vehicles need not access the service deck during extreme conditions (extremes of tidal range or during major storms). No vehicles use the ramp during extreme conditions.

c. Security and Control – Same as for ramp to operations deck, except that the guard will not allow any vehicles to enter or leave the pier.

6. Emergency Access from Yard to Service Deck

a. Yard Roadway – Emergency vehicles (basic pumper fire truck and Medic-One type ambulance) access only the upper (operations) deck. They do not enter the lower (service) deck under any conditions. Fires are fought and medical aid rendered from fire trucks and ambulances on the upper (operations) deck.

b. Ramp – Emergency vehicles do not use the ramp to the service deck.

c. Security and Control – The security guard keeps emergency vehicles from attempting to enter the service deck ramp.

D. Details of MHP Pier to Shore Access Ramps

Preliminary design details for the pier to shore access ramp to the operations deck are shown on Drawing S-13.

1. Details of Basic Ramp Requirements

The support requirements for both the operations ramp and the service ramp are similar. The preliminary design of the more lightly loaded service deck ramp was not included in the scope of this effort; however, much of the work on the operations deck access ramp applies to the service deck ramp, as well.

The ramps are designed to span from shore to the floating dock. These ramps and the required details are very similar to transfer spans used by ferry systems to load and unload vehicles. Ferry system ramps, however, are usually shorter and can have steeper slopes. In some instances the ferries can not be unloaded in extreme tidal events because of ramp operational limitations which results in a short waiting period for ferry patrons.

2. Details of Ramp Length and Slopes

Ramp lengths were determined for three candidate sites. In all cases, the length of the ramp was controlled by the maximum allowable slope of the service deck ramp. This is because the range of motion for this ramp was generally from the level position to a maximum downward angle versus the operations deck ramp, which has a range of motion both above and below the level position.

Ramp length was calculated for the extreme tidal ranges (no storm surge) assuming a maximum grade to start/stop a tractor/trailer rig of approximately 16 percent (9 degree angle). This allows for operations under any tidal conditions (no storm surge). Under normal conditions (MHHW/MLLW or

MHW/MLW) the grade of the ramps will be less than 13.2 percent (7.5 degree angle) (San Diego). These maximum grades occur for only a few hours of the day on those days with very high or low tides as the tidal elevation is constantly changing. If the berth length is limited by constraints at a particular site, a shorter ramp with steeper grades can be used, but this may limit truck operations for a short time each day.

The ramps are not used as part of the mooring system in this design. On other projects, the ramps have been used as compression struts to resist onshore loads and together with supplementary pretensioned cables, used to also provide a tension tie, to resist offshore loads. However, the ramps used as part of a mooring system in this manner have a flatter slope, typically 8 percent or less and hence would be much longer than those proposed for the MHP. Longer ramps also have other design implications including increased depth of structure, increased weight, and increased cost.

3. Details of Ramp Support System

It is proposed to hinge the ramp at the floating dock end and permit sliding perpendicular to shore at the shore end. This arrangement was chosen so as to minimize the space needed to land the ramp on the floating dock and also avoid special deck framing near the pontoon ends that would be required to support the large eccentric load from the ramp support designed to allow sliding at the pier end. The shore end support abutment will be a site adapt design for each project location because of varying geotechnical conditions and shore bulkhead conditions and hence any variations or unusual conditions can be taken up at this end. Sliding parallel to shore will be restrained at both ends; however, some rotation in plan and about the longitudinal axis of the ramp will be permitted at both ends of the ramp.

4. Details of Ramp Structure

The basic ramp structure selected for the preliminary design and developed for the San Diego site conditions consists of an orthotropic steel deck between steel trusses. This type of framing is torsionally flexible and can accommodate the roll displacement of the floating dock. For the operations deck ramp, a 12-foot-long hinged transition span would be provided at each end of the ramp to accommodate extreme motions above and below the horizontal position of the ramp. The shore side transition span is attached to the end of the ramp. The floating pier side transition ramp would be set into the ramp structure 12 feet from the end of the ramp. The support trusses carry through to the ramp support points but the transition element is hinged. With this detail the space required on the MHP to land the ramp is minimized. End details are similar for both the operations deck and service deck ramps except that in the service deck ramp the hinged transition ramp is deleted and only a hinged apron lip is required at the floating dock end.

The ramp structure has to accommodate not only the main three directions of displacement (transverse, longitudinal, and vertical), but also it has to accommodate the rolling displacement of the MHP due to possible asymmetrical deck loading. To absorb the rolling displacement of the MHP, the torsionally flexible, open-top pony truss structure, was chosen for the ramp structure.

Tubular sections were chosen for the truss members to minimize the surface area for painting and ease of maintenance purposes. The depth to span ratio of 1:10 was used for the truss structure based on the AASHTO Section 10.5.3 requirement that this span to depth ratio not be exceeded for this type of structure. Wide flange floor beams (W24) are placed at 10 ft (3.0 m) on centers. Orthotropic steel deck elements span between the floorbeams.

As a preliminary design, the following sizes of members were selected using a 100-ton (90.7 tonnes) (TM9100) crane load as the controlling design load.

- Top and Bottom Chord Members – TS 8x8
- Vertical Truss Members - TS 8x6
- Diagonal Truss Members - TS 8x4
- Floorbeams- W24x68

In the next phase of design, the member sizes should be reanalyzed for DM specified 140-ton (127-tonne) crane (see Appendix E for estimated member sizes for 140-ton crane).

Using the above member sections, the torsional flexibility of the ramp structure was verified using a computer model analysis by the program RISA-3D. In the computer model, the structure was analyzed with the load of single mobile truck crane (100-ton) (90.7-tonne) and support displacement [roughly 8 inches (203 mm)] to represent the MHP roll displacement. Two loading conditions of the truck crane (mid-span and near ends) were investigated.

As a result, it was determined that the member sizes selected were sufficient to support the design load within allowable stresses (see Appendix E for the results of the analysis). Additional stresses in the members due to the support displacements were very small, which confirms the required flexibility of the structure in torsion.

The stability of the top chord member against buckling was also checked by hand using a method from Timoshenko (reference: Theory of Elastic Stability by S. Timoshenko). From the hand analysis, the critical axial load for buckling of the top chord member was almost four times the design axial load in this member. Therefore, the stability of the top chord member should be sufficient and further confirms the preliminary design concept (see Appendix E for the calculation).

5. Details of Ramp Support and Support Bearings

As the MHP is located relative to shore by the mooring dolphins, the ramps and their bearings are designed to absorb the MHP motions while maintaining static determinacy, without developing binding forces. For both ramps, the concept is the same.

The ramp connection details and end bearings must allow for vertical motions of the MHP, horizontal motions perpendicular and parallel to shore, and roll of the floating dock. The ramp should not bind or lock up when subjected to extreme movements associated with extreme tidal events and extreme floating dock hydrostatic displacements.

The total ranges (plus to minus) of these motions are given in Table X.B-1.

Vertical MHP motions to be accommodated by ramp support result from tide elevation changes (ELW to EHW), and to changes in MHP draft (light ship to heavy ship). For the service deck ramp, which is offset from the centerline of the MHP, vertical motion also includes MHP roll effects. Transverse motions (parallel to the seawall) result from deflections of the mooring dolphin system, which are driven by the 2,500-year extreme earthquake or by storm wind on vessels moored to the MHP. Longitudinal motions (perpendicular to the seawall) result also from deflections of the mooring dolphin system, which are driven by the 2,500-year extreme earthquake or by storm wind on vessels moored at the MHP. Roll motions (rotation about the longitudinal centerline of the MHP) result from asymmetrical live loads (two truck cranes with their associated laydown areas on one side of the MHP).

The ramp is supported vertically at all four corners by standard double-flanged crane wheels running on short sections of crane rail. All four rails are oriented longitudinally, parallel to the ramp. The wheel axles form hinges at both ends of the ramp, to absorb changes in ramp grade resulting from vertical motions of the MHP. The wheel flanges locate the ramp transversely, and resist transverse lateral forces from the ramp itself.

At the MHP end, a vertical pintle locates the ramp longitudinally, and resists longitudinal lateral forces from the ramp itself, while allowing the ramp to pivot about the pintle centerline, thus absorbing transverse motions of the MHP. The corner wheels rotate in opposite directions to absorb the pivot rotation, functioning as a turntable in a railroad engine roundhouse.

At the yard end of the ramp, the ramp is designed to move back and forth longitudinally, in order to absorb the motions from longitudinal wind effects, from seismic effects, change in horizontal projected length resulting from vertical motion and changes in ramp grade. The two corner wheels roll back and forth in the same direction to absorb this longitudinal motion, functioning the same as the roller at the float end of a marina gangway. At the same time, the two corner wheels roll in opposite directions (or at different rates if combined with longitudinal motion) as at the upper end of the ramp, to absorb transverse motions.

The ramp structure is designed to assure continuous four-point support, as an open-top pony truss, so as to be deliberately torsionally flexible, thus absorbing roll motions without lifting one corner support wheel off its rail. A torsionally stiff ramp structure, such as a box girder, is subject to teetering impact when a heavy live load (such as a truck crane) moves from the triangular kern formed by one set of three wheels to the kern formed by the other set of three wheels, causing the previously lifted-off wheel to come down hard on its rail.

The four-point ramp support system proposed consists of two pinned bearings at the floating dock end and two rolling bearings at the shore end. Several bearing alternatives were investigated including cylindrical-type bearings and steel wheels on steel rails (similar to container or overhead crane runways). The steel wheel on steel rails solution was selected for this phase because it is a proven technology for reliably supporting heavy loads.

Crane wheels as proposed for the ramp support system are typically designed with a 3/4-inch (19-mm) gap [3/8 inch (9 mm) on a side] between the rail head and the inside faces of the wheel flanges. This gap absorbs the second order angular motions resulting from “pintle” rotation due to transverse motions.

With this arrangement of wheels and pintle, the motions of the MHP produce the wheel travel motions as shown in Table X.D-1 on the next page.

The drawings show the wheels to a conceptual level of detail. Wheels and rail are sized per the Crane Manufacturers Association of America (CMAA) 70 design guide, the industry standard specification (code) for the design and construction of overhead traveling bridge cranes. Conceptual level calculations indicate that for San Diego, 24-inch (610-mm) tread diameter wheels with case-hardened treads and flanges running on hardened 175 lbs (778 kN) ASCE crane rail will be adequate to support the combined dead and live (vehicle) loads. Wheels are normally purchased as an assembly of wheel, pressed-in axle, and cartridge tapered roller bearings, which is then inserted into a mounting slot in the crane truck and bolted in place. Because the rollers in the pier end wheel bearings rotate only when the MHP moves significantly in the transverse direction, which will be seldom, we will consider grease-lubricated bronze journal bearings for the wheels in this location. These bearings are in lieu of the current standard tapered roller bearings as the bronze bearings are likely to perform more reliably over a longer period of time in this situation.

The wheel assembly and rail indicated on the drawings is an industry standard, and would ordinarily not require testing to assure good performance. However, the type and extent of motion is not standard and will merit testing in the prototype phase of the program.

The drawings also show the wheels centered underneath the ramp trusses. This location eliminates vertical eccentricity. However, this makes the pit at the yard end deep enough so that the rail/wheel contact elevation is below the MHHW tide elevation (San Diego). While a curb would be provided to prevent water entry into the ramp support area it is possible that under some situations the wheel bearings would be under water at EHW. This is a likely maintenance problem for roller bearings. Since seals are not perfect, some water could possibly enter the bearings, and corrosion would be the result. Bronze journals would eliminate much of the concern.

Alternative solutions to locate the bearings up and out of the water will be investigated in final design. It is suggested that further design consider cantilevering the wheels outboard of the trusses, so that they can be raised up nearly level with the truss bottom chords. The eccentricity moments would be taken by a transverse beam between the two trusses. Also, the trusses (and the wheels) could be further raised relative to the ramp roadway surface. The design goal should be to raise the wheel/rail contact well above MHHW for the optional (Bremerton and Mayport) sites, as well as for the basic site (San Diego). Immersion of the wheel/rail contact and of wheel bearings would be accepted for EHW, which occurs very seldom in the life of the facility.

E. MHP Access Ramp Construction and Installation

1. MHP Access Ramp Off-Site Construction Activities

The ramps will be completely fabricated off site and brought to the site for assembly. It may be possible to load the ramp assemblies onto the operations deck of the MHP module and deliver them to this site in this manner.

TABLE X.D-1: WHEEL MOTION @ RAMP BEARINGS

	San Diego				Bremerton				Mayport			
RAMP Characteristics												
Length of Bridge	96	ft	29.9	m	146	ft	44.5	m	104	ft	31.7	m
Roll Angle - from LL	2.1	deg			2.1	deg			2.1	deg		
Angle - Transverse Motion	1.48	deg			0.98	deg			N/A	deg		
Wheels at MHP End,												
Transv. Disp. Due to Trans. Motion	0.31	in	7.8	mm	0.21		5.2	mm	N/A	in	N/A	mm
Total	0.31	in	7.8	mm	0.21		5.2	mm	N/A	in	N/A	mm
@ Operation Deck												
Wheels at Yard End, Due to												
**Long. Disp. Due to Long Motion	-30.0	in	-762.0	mm	-30.0	in	-762.0	mm	N/A	in	N/A	mm
Long. Disp. Due to Vertical Motion	-13.6	in	-344.4	mm	-10.6	in	-268.2	mm	-10.3	in	-261.6	mm
Long. Disp. Due to Transv. Motion	-0.004	in	-0.10	mm	-0.002	in	-0.04	mm	N/A	in	N/A	mm
Total	-43.6	in	-1106.5	mm	-40.6	in	-1030.3	mm	-10.3	in	-261.6	mm
@ Service Deck												
Wheels at Yard End,												
**Long. Disp. Due to Long Motion	-30.0	in	-762.0	mm	-30.0	in	-762.0	mm	N/A	in	N/A	mm
Long. Disp. Due to Vertical Motion	-9.5	in	-242.3	mm	-16.5	in	-419.1	mm	-10.5	in	-266.7	mm
Long. Disp. Due to Transv. Motion	-0.004	in	-0.10	mm	-0.002	in	-0.04	mm	N/A	in	N/A	mm
Long. Disp. Due to Roll Motion	-0.11	in	-2.8	mm	-0.72	in	-18.3	mm	-0.10	in	-2.5	mm
Total	-39.7	in	-1007.2	mm	-47.2	in	-1199.4	mm	-10.6	in	-269.2	mm

Notes:

Negative Motion: Motion towards MHP
Positive Motion: Motion towards Yard
**: Longitudinal Motion (due to EQ) can be positive or negative motion. However since other motions occur only to Negative direction, negative motion is specified to maximize the total motion.

The MHP end ramp support provisions will be constructed off site as part of the MHP module construction activity. The shore end support rail assembly can be made up off site in the proper gage and length for casting into the site built abutment.

2. MHP Access Ramp On-Site Construction Activities

The site-specific abutment for the shore end of the pier to shore ramps will be constructed on site. It may be possible to develop site adapt designs for the abutments that can be varied to suit local geotechnical and yard/bulkhead conditions.

It may also be possible to devise a way to economically launch the ramp from the MHP (if delivered by MHP) to the shore abutment in a way that minimizes the amount and size of floating construction equipment involved.

3. Alternative MHP Access Ramp Construction Methods

It is possible to build the ramps in place and shore up the water ends of the ramps to allow the MHP to be moved into position.

F. MHP Access Ramps Concepts Considered and Rejected

Initial thinking regarding the design of the access ramps focused on whether or not to make the access ramps part of the mooring system by reacting the dock mooring forces perpendicular to the shoreline through the ramp. Another focus was how short we could make the ramp span. For this design there is a high value of positive elevation differential of the operations deck from the nominal yard elevation and the high value of negative elevation differential from the service deck to the nominal yard elevation. This situation means that, unless the approach ramps are made with very long spans, the ramp slopes at the tidal extremes would be too steep to use the ramps as mooring force transfer elements.

A box beam ramp system with pot bearings and sliding surface supports was originally investigated. Because of the wide range and magnitude of motions involved, this approach was deferred in favor of the approach presented in the preliminary design.

XI. MHP UTILITIES

A. Criteria for Modularity and Standardization of MHP Utilities

The modularity and standardization for the utilities systems on the MHP should address the following things.

1. To the extent possible a minimum number of different components should be used.

2. Where multiple units of equipment are needed for capacity reasons, the equipment units should be the same brand, size, and capacity (e.g., substations, transformers, switchgear, portable receiver/duplex pump units, etc.)

3. Pipe splicing spool elements, where needed, should be the same to the maximum extent possible.

4. Arrangements and fixtures for utility outlets and valves should be the same for each location in each system to the maximum extent possible.

5. Hoses and cables should be configured to maximize the interchangeability of these items.

6. To the extent practical and advisable, utility elements that already have a good use history with the Navy should be used.

B. Design Criteria for MHP Utilities

1. Design Criteria for Utilities for Berthed Vessels

The design criteria for the MHP utilities are that the basic utilities are to be designed to serve the primary vessels to be berthed at the facility. The utilities should also be able to serve the alternative vessels by accessing electrical turtlebacks with auxiliary MHP to ship connection cables and by relocating hose connections and the portable receiver/duplex pump units to provide mechanical service.

2. Design Criteria for Utilities to Support Pier Operations

In addition, the facility should provide industrial power provisions to operate small tools on both the operations deck and service deck levels, high mast lighting capable of being dimmed upon vessel approach is provided on the operations deck, task lighting is provided on the service level. Lighting design is to consider both operational and security requirements so that separate systems do not have to be designed.

3. Interface With On-Shore Facilities

The interface with on-shore facilities relates to the requirement to connect the MHP utility systems to the corresponding supply or receiving systems on shore. This is a site dependent aspect of the design that is addressed by extending the on-shore utilities to a hookup location near the MHP ramp to shore abutment location.

4. Local Tidal Variation

Tidal conditions, extreme high tides and extreme low tides, vary significantly among Navy stations in different geographic areas. In some areas, the angular motions and grade changes associated with the tidal cycles are significant. The utility systems crossing the access ramps must be designed to accommodate the ramp angle changes resulting form tidal variations, as well as the ramp end translation resulting from wind and seismic effects. The material selection for utility lines crossing the ramp from the MHP to shore should consider the increased potential for damage at this location.

5. Environmental and Physical Design Conditions

Seismic seiche may be possible for some west coast locations as result of a large earthquake. Storm surge is a more likely event for some locations on the east coast. These special events can cause abnormal water levels that would affect the design of the shore utilities interface. Utilities systems will be designed with

disconnects in areas where storm surge warning would allow disconnection of utilities to prevent damage.

The basic floating pier structure is not affected by earthquakes. Only the moorings of the MHP and the access ramps are subject to earthquake loading. Both of these features and the utilities crossing the access ramp to shore are designed with significant motion capability to accommodate seismic effects.

C. Design Approach to MHP Vessel Support Utilities

1. Design Approach to Interface with On-Shore Utilities

The MHP site adapt design will include standard utility manhole designs and vault designs for connection of the MHP mechanical and electrical systems to on-shore utility systems. The site specific aspect of the utility hookup design will be limited to running the on-shore utilities to the MHP manholes and vault and hooking up with the standard MHP systems extending into the manholes and vaults. An optional design for on-shore pump stations will be provided as part of the standard designs in the event that direct access to on-shore gravity systems is not practical.

2. Design Approach to Utility Distribution to/from Berthed Vessels

The basic approach to the provision of utility services to berthed vessels is that either a hose or electrical cable extends from the vessel hookup point to the nearest MHP standard utility outlet. For wastes coming from vessels to the MHP the portable receiver/duplex pump stations are positioned to conveniently accept incoming hoses and transfer the waste materials to the overhead fixed MHP force main system for pumping to shore. Future design efforts should consider the possibility that flexible hoses from ships may require some type of additional intermediate support.

3. Design Approach to Flexibility of Utility Services to Berthed Vessels

Utility lines and electrical capacity are sized to allow a wide flexibility in meeting the utility needs of berthed vessels. Space for additional utility lines and empty conduits for additional electrical cables are provided in the basic design to allow for easy changes in response to changed utility requirements.

In the event a major utility upgrade is required, for example as a new generation of ships joins the fleet, the upgrade of all utility systems can be accomplished without demolition of any structural elements of the MHP. All utility systems are surface mounted out of the way of all operational activities, allowing major utility upgrade activity to be underway while the operations deck is still fully available for use.

4. Design Approach to Utility Maintainability and Upgrade Ability

The concept that the MHP is a “standard design” pier allows for incorporation of utility related lessons learned through incremental improvements to utility systems as new “Versions” of the MHP design are issued. Thus, utility systems can be optimized and refined by incorporation of Navy wide operational experience into each new design without compromising the standardized modular concept.

The objective is continuous improvement of both function and maintainability in the form of reduced maintenance cost, increased systems reliability, and longevity of utility systems. This approach to continuous improvement will be by preserving excellent low-maintenance features of the various utility systems and by making adjustments to the design of features that operational experience throughout the Navy shows can be improved. This process will begin with the prototype confirmation testing of selected elements of the MHP utilities systems. Design improvements would be made to the MHP site adapt design of the utilities on a continuing basis within the constraints of a configuration control philosophy that maintains essential interchangeability among MHP facilities.

D. Details of MHP Vessel Support Utilities

Details of the MHP vessel support utility systems are shown on Drawings E-1 through E-4 and M1 through M-4.

The following sections outline the details of the utilities to be provided on the MHP.

1. General

a. Utility requirements are based on data compiled from Military Handbook 1025/2 and NCEL UG0007. Where "nested" vessels are serviced, manifold outlets will be provided for individual connections, but a diversity factor will be included for non-concurrent continuous usage.

b. Piping distribution systems will be installed suspended below the operations deck, in the utility aisle on the service level deck. Piping will be individually supported from corrosion resistant threaded inserts cast into the bottom of the operations deck slab. Pipe hangers will be vinylester fiberglass or polyurethane with vinylester fiberglass or 316 stainless steel all-threaded rods. Where lateral access is required for substation (electrical skid) or large equipment replacement, removable spool pieces with isolation valves will be provided.

c. Piping connections between modular pier sections will offset from the overhead location and stack up in the reduced clearance area at the module-to-module joint. Isolation valves, air vents and drain valves with hose connections will be provided. Although the tolerance in alignment of the modular sections is extremely minor (± 1/4-inch) (+/- 6-mm), a flexible connection will be provided due to alignment requirements of the piping section flange bolt holes.

d. Utility services include potable water, compressed air, CHT, oily waste, phone, computer network, cable TV, and electrical. Space layout for the utility services will include provisions for two future services to be added. These systems could include steam and condensate, chilled water services, or other future requirements.

e. For the purpose of this study, where steam is required a portable steam generator will be used. This skid-mounted, packaged system would include an electric steam generator, a feedwater system and pump, water conditioners, and a skid-mounted fuel tank. The advantage of this approach is in the mobility of the system. The skid-mounted system could be placed on a flat-bed trailer and moved to the location required on the operations deck, with temporary water and power connections to the

utilities below. The disadvantages of this system are the size requirement and the quality of steam required shipboard. Water treatment would be required to pre-condition the make-up water to the boiler.

For the baseline facility criteria, steam is not a requirement. If the pier were located to a port where steam services are required, there is a good possibility that steam service would be available on shore. Another option is that an electric portable steam generator, not fuel fired, could be used. This has the disadvantage of increasing the electrical load on the pier electrical services.

f. Outlet locations for connection to vessels are based on a composite plan, locating the various outlet locations for the primary and alternate vessels, and standardizing the locations for the modular pier sections.

g. Piping materials (discussed with each service description) were selected based upon long term durability, strength of material, flammability, and chemical compatibility with fluid.

h. Present design will incorporate metering electrical (energy) usage only. Future capability will allow for controlling and measuring flow of other utility systems from a central location. SCADA (Supervisory Control and Data Acquisition) connections could be provided at individual utility outlets with electronic actuators integrated with isolation valves, and tied into a direct digital control system for remote monitoring and control of ship utilities.

i. Operations and utility deck stormwater, addressed in Section IX.E.7. of this report, will be integrated into the oily waste system design for conveyance of the stormwater to shore.

2. Details of Potable Water System

a. Based upon a total of 1,000 gpm (63.1 liters per second) for the entire MHP, including fire protection requirements for the MHP only. Main will be 8 inches (203 mm) in size with 5-inch (127-mm) risers/drops at utility outlets.

b. Utility outlet risers will have a manifold with three 2-1/2-inch (63.5-mm) connections; two “nested” vessels and onefire protection outlet. Each utility connection will have an isolation valve, a backflow preventor, and a quick-disconnect hose fitting.

c. Proposed piping material will be fiberglass reinforced thermosetting plastic (FRTP), with aromatic-amine cured epoxy resin. Fittings will be threaded or flanged (valves).

3. Details for Compressed Air System

a. All primary vessels require 1,000 cfm (472 liters per second) per ship. Alternate vessels require 1,500 cfm (708 liters per second) each, except the DDG-963 which requires 1,000 cfm (472 liters per second). Since the larger alternate vessels occupy the normal berthing for two of the primary vessels, the gross total will be based on any mix of (6) primary ships. For five or more vessels a diversity factor of 0.5 may be used, which provides

for a total of 3,000 cfm (1,416 liters per second) for the MHP. Main will be 6 inches (152 mm) in size with 3-inch (76-mm) riser/drops at utility outlets.

b. Utility outlet risers will have a manifold with three 1-1/4-inch (32-mm) connections and three 1/2-inch (12-mm) connections. Each utility connection will have an isolation valve and a quick-disconnect hose fitting.

c. Proposed piping material will be FRTP, with aromatic-amine cured epoxy resin. Fittings will be threaded or flanged (valves).

4. Details of Oily Waste System

a. All primary vessels require 100 gpm (6.3 liters per second) per ship, except the FFG-17 requires 17 gpm (1.1 liters per second).

b. Alternate vessel requirements are as follows.

LHA-1 at 126 gpm (8.0 liters per second)
LHD-1 at 162 gpm (10.2 liters per second)
LPD-1 at 54 gpm (3.4 liters per second)
DD-963 at 180 gpm (11.4 liters per second)

Worst case would be 400 gpm (25.3 liters per second) for the primary vessels and 720 gpm (45.4 liters per second) for four alternate DDG-963 vessels. A diversity factor of 0.31 may be used for the gross total, which provides for a total of 123 gpm (7.8 liters per second) [216 gpm (13.6 liters per second) optional] for the MHP.

Design will be based on 180 gpm (11.4 liters per second) maximum rate per riser and a total of 216 gpm (13.6 liters per second) for the main. Main will be 4 inches (100 mm) in size with 4-inch (100-mm) risers at utility connections.

c. Utility outlet risers will have a 4-inch (100-mm) connection and a bottom test port connection. Each utility connection will have a flanged isolation valve and a quick-disconnect hose fitting.

d. Piping material will be double-wall construction FRTP with aromatic-amine cured epoxy resin. Fittings will be bell and spigot ("clamshell") or flanged (valves).

e. For each section of modular pier (and on each side of each section), a portable oily waste receiver/duplex pump will be provided. Discharge from each vessel's hose will connect to the receiver. The duplex pump discharge will connect to a valved main line hose connection at each location. This portable assembly will relocate within each side of the utility service deck as required, with hold-down clips at each vessel service location and cord and plug electrical outlet boxes provided. CHT and oily waste portable receiver/duplex pump units will be interchangeable to provide operational redundancy.

5. Details of the CHT System

a. All primary vessels require a 4-inch (100-mm) hose connection per ship. Design will be based on 200 gpm (12.6 liters per second) maximum rate per ship and a transfer pump rated at 225 gpm (14.2 liters per second). Force main will be 6 inches (152 mm) in size on each side of the pier.

b. Utility outlet risers will have a 4-inch (100 mm) connection and a bottom test port connection. Each utility connection will have a flanged isolation valve and a quick-disconnect hose fitting.

c. Piping material will be FRTP with aromatic-amine cured epoxy resin. Fittings will be socket weld or flanged (valves).

d. For each section of modular pier (and on each side of each section), a portable CHT receiver/duplex pump will be provided. Discharge from each vessel's hose will connect to the receiver. The duplex pump discharge will connect to a valved main line hose connection at each location. This portable assembly will relocate within each side of the utility service deck as required, with hold-down clips at each vessel service location and cord and plug electrical outlet boxes provided. CHT and oily waste portable receiver/duplex pump units will be interchangeable to provide operational redundancy.

6. Details of Electrical System

a. Primary electrical service from shore-to-pier would be with modular splices or portable high-voltage cable couplers. This is to allow for quick disconnect for maintenance, repair, warned storm surge, impending hurricane, or other such condition. See Appendix M for cut sheets.

b. Primary and alternate vessels require shore power at nominal 480 volt, 3 phase, 60 Hz. This will be provided through receptacle assemblies (turtlebacks) located on the service deck level at the pier perimeter. The primary and alternate vessels require the following power in amperes:

(First number is maximum receivable/second number is design load.)
(P) = Primary, (A) = Alternate

CG-47 (P)	5,200A/4,100A, (1,200A is to serve tendered ship)
DD-963 (A)	3,200A/3,200A
DDG-51 (P)	4,800A/4,500A
FFG-7 (P)	2,800A/2,800A
LHA-1 (A)	7,200A/5,400A
LHD-1 (A)	8,000A/8,000A
LPD-17 (A)	8,000A/8,000A

c. For service to primary ships berthed the highest berth service requirement for a ships service would be 4800A. A 12-receptacle turtleback assembly from a 3,750 KVA substation (electrical skid) with forced air cooling for service in some locations would meet this requirement. Four 3,750 KVA electrical, transformer, and switchgear skids, each serving a 12-receptacle turtleback assembly, would serve any proposed berthing arrangement of primary vessels, with no nested ships with exception of FFG-7s which can be nested. Total ships power available with this arrangement is 19,200A. Connection to substations (electrical skids) is via plug/receptical connections to ease maintenance and assembly/disassembly.

d. For service to include alternate and nested ships berthed the highest berth service requirement for a ships service would be 8,000A. To serve any proposed alternate/primary berthing arrangement eight 3,750 KVA substations (electrical skids) serving 12, 12-receptacle turtleback assemblies would be provided. Four substations (electrical skids) will each serve a single 12-receptacle assembly. Four additional substations (electrical skids) will each serve two, 12-receptacle turtleback assemblies. Total ships power available with this arrangement is 38,400A. Note, worse possible case would be DDG-51s nested at four berths (i.e., 8 DDG-51s). This would require 36,000A using design load and no diversity.

The 3,750 KVA substation (electrical skid) and 12-receptacle turtleback assembly as standard is proposed for the following reasons:

The 3,750 KVA is a standard size transformer/substation (electrical skid). Switchgear is located adjacent to substation (electrical skid) to allow local switching and provide transformer protection.

It will provide 5,000A at nominal 480V, which is the largest standard secondary breaker available.

It is smaller, lighter, less expensive, and more easily handled than a larger substation (electrical skid).

It would have a lower available fault current than a larger substation (electrical skid).

It provides more flexibility than other arrangements.

Additionally, the fact that all ships (except tenders) can split their shore power loads so that common secondary source current does not exceed 5,000A lends itself to the 3,750 KVA.

There is no practical rationale for using larger or smaller substations (electrical skids)/transformers.

Transformers would be provided with forced cooling to increase rating.

- Substations (electrical skids) main and/or feeder breakers will be provided with metering for SCADA connections for monitoring of utilities if required. A time of use meter on the main 480 volt bus that provides volts, amps, KWH, power factor, and 15-minute information will be provided.

- Telephone, cable TV, and computer network systems can be provided tailored to users requirements and coordinated with existing or planned capabilities.

- Industrial power to serve mobile power units, such as commonly used at military and commercial locations, would be obtained from unused turtleback receptacles.

- To serve miscellaneous equipment and functions (such as classrooms, dayrooms, and the like, which may be created in the interior of the utility deck) the space in the center section of the pier can be used to locate

electrical support equipment as required with no adverse effect on other electrical systems.

- Energy efficient fluorescent lighting fixtures controlled from switches on the utility deck will be used to light the utility deck area.

- High intensity discharge lighting will be used to light the operations deck. This lighting will be controlled from switches on the operations deck and will allow dimming during vessel berthing operations.

7. Details of Deck Stormwater Collection System

Near the end of the Phase 2 report preparation period, NFESC requested that the design team address the potential requirement to capture and treat all stormwater falling on the operations deck. It was determined that this was likely to be a new requirement for new piers at some Navy stations.

There are several approaches that should be explored as ways to handle and treat the operations deck stormwater. We were provided with an intensity of 0.2 inch per hour (5 mm per hour) with a maximum design rainfall of 0.6 inch (15 mm) for San Diego. This amount of precipitation results in a total volume of water to be handled equal to 6,370 gallons (24,113 liters) accumulating at a rate of 212 gallons per minute (13.4 liters per second).

The operations deck and the service level deck both are designed to slope away from the pier centerline so that precipitation and spills drain to the outboard edges of the pier. A heavy duty spouting trough at the edge of the operations deck slopes from a high point each way longitudinally to downspout risers at 100 feet (30 meters) on center. The risers run through the wall and deliver the operations deck runoff to the service deck enclosed area.

There are two candidate approaches to handling this water that merit further consideration.

a. The first approach is to run the water from the downspout risers into individual filter/oil water separator units located adjacent to each of the 26 downspouts. These units would sit on the utility deck be sized to extend nearly full height of the service deck space and fit in the available space adjacent to the service level exterior walls. Water intake would be at the base of the unit with direct overboard discharge of treated water from an outlet located below the top water surface of each filter/oil water separator unit.

   With this alternative the service deck (which is expected to remain dry most of the time) would have a series of small drainless wet wells located at 25 feet (8 meter) on center to collect incidental spray and spills. These wet wells would be individually pumped into the oily waste piping system using a portable sump pump when a spills occurs or when the area is washed down.

b. The second alternative approach is to use a system of internal drain lines located below the service level deck. These lines would feed the stormwater to a central compartment holding tank where it could then be pumped into the oily waste piping system and then to shore. It would be pumped at a controlled rate over an extended period of time so as not to

overload the oily waste system. It is envisioned that if this approach is taken there would be two holding tanks per MHP module [eight per 1,300-foot (396-m) pier], one on either side in the midpoint compartment located below the service deck aisle.

If this alternative is used, the service deck could also be drained into this system through a series of floor drains at 25 feet (8 meters) on center, located near the outboard wall of the service deck.

This alternative requires further consideration as it adds to the complexity of the pier structure by introducing a sloping drain line that must penetrate watertight bulkheads below the service level deck. This approach also introduces the concern that a leaking drain line could potentially flood the buoyancy chambers of the MHP. Thus this approach may require that a water detection system be installed in the affected buoyancy chambers.

E. Utility Motions at Access Ramp Ends

1. Motion Requirements for Utility Design

Where utility services from the shore connect to the MHP services, consideration is required for vertical movement of the MHP due to tidal action and emergency situations. "Extreme" motion has been defined as +/- 15 feet (4.6 meters) maximum. This is the maximum vertical movement of the pier from the shore between extreme low tide (maximum pier draft) to extreme high tide (lightship pier draft). This would result in a maximum angular deflection of 9 degrees. There is also longitudinal motion and transverse movement [36 inches (1.0 meters) maximum each]. The calculated offset required by a combination of these two movements is approximately 50 inches (1.3 m) with a 45 degree angle.

The length of the connecting ramp, along with the angular movement required in the piping and electrical system cabling is indicated in Drawings S-13, S-14, and S-15.

2. Location of Services On Access Ramp

Utility services will be routed below the operations deck ramp, connecting from the shore services to the overhead distribution piping and electrical conduit system on the utility service deck. Provisions for isolation of these services in an emergency situation will be handled with a quick-closing isolation valve located adjacent to the ramp piping connections (both sides).

3. Proposed Approach to Accommodating Utility Motions

Braided 316 stainless steel flexible connector with a minimum length of 8 feet (2.4 meters) (looped for transverse expansion and contraction of the piping system) is proposed for connection to both the MHP piping and the shore service piping. The flexible section will have flanged connections (with a union or floating flange at one side to prevent torque on the flexible section) and be installed adjacent to the isolation valve. Where containment double-wall construction piping is required, containment basins can be installed at these flexible connections.

Flexible ball joints are an alternative to this arrangement. These require periodic lubrication and are more applicable where greater angles (up to 15 degrees) of offset are anticipated. Due to the lack of maintenance required, the flexible braided steel connections are considered more favorable.

F. MHP Utilities – Construction and Module-to-Module Hookup

1. MHP Utilities Off Site Construction Activities

The objective of the MHP modular approach is to outfit the modules with all of the required utilities at an off-site outfitting location that is selected by the contractor for convenience and his ability to control cost and quality. Thus, except for the module-to-module connections and the connections to shore, the majority of the utility systems will be installed on the modules prior to their delivery to the site.

This will help to control the overall cost and quality and will provide schedule advantages, especially if outfitted modules are available from an advance manufactured supply of stockpiled modules constructed to support the general nonsite-specific MHP program.

2. MHP Utilities On-Site Construction Activities

On-site utilities work on the MHP will involve pulling electrical cable that crosses module-to-module joints after the modules are joined. Cable that does not cross the joints will be installed off site. Mechanical systems will require connection across the three module-to-module joints and across the access ramp to the shore interface manholes. After hookup, the utilities will be checked out.

On-shore utilities activities will include extending shore utilities into the interface mechanical manholes and the on-shore electrical vault for connection with the utility runs leading to the MHP.

3. Alternative MHP Utilities Construction Methods

As an alternative the utilities could be installed on the MHP after the facility is installed on site. This approach would likely be used for any special utilities systems that are needed in addition to the basic utilities provided.

G. MHP Utilities – Concepts Considered and Rejected

Initial thinking regarding providing the ability to serve a wide range of alternative vessel types from the same pier involved providing many hook up points and over capacity of systems to accommodate all conceivable locations for ship service inlets/outlets.

These were rejected in favor of the system shown in the preliminary design that uses portable receiver/duplex pump units, force mains, and variable length hoses and cables to serve the full range of vessels from a standardized system of utility outlets.

XII. MHP CONSTRUCTION MATERIALS

A. Background

The primary focus of the MHP program is the reduction of overall program-level maintenance and operation costs associated with berthing facilities.

The MHP program began with a primary emphasis on finding ways to take advantage of the high-strength and noncorroding characteristics of advanced composite materials as a means of reducing maintenance and extending the useful life of berthing facilities. The materials include carbon fiber composites (CFRP), high-strength fiberglass, and other fiber-reinforced plastic (FRP) materials that were initially developed to serve aerospace and specialty industry applications and are starting to see greater application to civil engineering structures and facilities.

The Phase 1 MHP concept development effort included an assessment of the maturity of the various materials technologies for near term (1 to 3 years in the future) application in the MHP. It was concluded that for secondary structural applications, and some nonstructural applications there were composite products that used materials technology that was mature enough to provide long-term reliable service as was needed for the MHP.

Composite post-tensioning technology was determined as not sufficiently mature to use as a primary structural component. It was also found that the costs of these systems were not currently compatible with the cost goals of the MHP program. Phase 1A of the program focused on the use of CFRP grids as local reinforcement combined with a reduction in the concrete cover so that the total section thickness of plate elements could be reduced with the consequential savings in concrete material, reduced draft, reduced post-tensioning materials, etc.

A design methodology was developed and proven through a test program that takes advantage of the high strength of the CFRP material, while still controlling concrete flexural cracking to desired levels. However, the final conclusion of the Phase 1A effort was

> "The structural testing proved the design concept to be working in a manner as predicted with the analysis. A finer mesh in combination with a small concrete cover seems to be advantageous for the cracking behavior, but the dominating factor of the structural behavior of the slabs is the prestress level. The composite mesh reinforcement can be replaced by a high-strength stainless or corrosion-resistant steel mesh and achieve similar results.
>
> In terms of constructability and cost efficiency, the use of stainless steel reinforcement is advantageous over the composite reinforcement. At this time, it is recommended to proceed with the MHP with stainless steel or other corrosion-free steel reinforcement as a near future (five-year) program. The lightweight concrete should be made as three different mixes meeting the specific requirements for (1) precast, (2) cast-in-place, and (3) pumpable concrete with maximum durability. For the far future, it is recommended to further consider composite reinforcement as the costs of these materials drop and their durability in concrete exposed to marine environment is more explored."

B. Criteria for Material Selection

The desired performance goal for the overall MHP is zero maintenance over a 100-year (or more) life. This goal is constrained by a cost goal that requires the first costs of new MHP berthing facilities be reasonably competitive with conventional construction in order to be considered for inclusion in the MILCON budget decision-making process.

C. Basic Structure Materials

1. Cement – Cements with chemical compositions that are not susceptible to delayed ettringite formation or other acknowledged cement deterioration mechanisms.

2. Aggregate – Manufactured lightweight aggregates not susceptible to alkali silica reactivity and proven through test to have acceptable long-term creep and water absorption characteristics.

3. Water – With no chemicals that can cause premature concrete deterioration.

4. Admixtures – That have a long history of successful performance in marine environments and that have been shown by test and experience to have no negative effects on the durability of concrete.

5. Reinforcing – Corrosion-resistant steel with acceptable ductility and a history of successful use as concrete reinforcement in marine environments. This includes cold drawn 316 stainless steel and nitronic-50 stainless steel.

6. Reinforcing Chairs and Ties – Noncorroding material with a proven history of use in concrete structures exposed to marine environments, with sufficient strength to withstand construction operations while keeping reinforcement in proper position.

7. Prestressing Steel – Per current ASTM specification with the specification of a minimum bond length test for strand used in pretensioning.

8. Post-tensioning Ducts – Nonmetalic, noncorroding ducts with a history of proven performance in concrete structures.

9. Post-tensioning Grout – Pumpable grout with a proven history of long-term, corrosion-resisting performance as post-tensioning grout. Specifically designed to minimize grout settlement.

10. Miscellaneous Metals – All miscellaneous metals will either be fabricated from corrosion-resistant metals or will have corrosion preventative coatings that provide corrosion protection equivalent to corrosion resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

D. Mooring System Materials

1. Elastomeric Materials – Elastomeric materials for fender elements will be from established fender manufacturers. Fender material used will have documented evidence of a long history of successful performance in marine environments.

2. Wear Surfaces – Wear surfaces will use materials that have exhibited proven successful performance in similar situations. The requirement to lubricate wear surfaces will be avoided by design to the maximum extent possible.

3. Miscellaneous Metals – All miscellaneous metals will either be fabricated from corrosion-resistant metals or will have corrosion preventative coatings that provide corrosion protection equivalent to corrosion resistant metals. Use of any

nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

E. Joining Materials

1. Post-tensioning Steel – Corrosion-protected, high-strength steel bars with a successful history of use as post-tensioning.

2. Post-tensioning Ducts – Nonmetalic, noncorroding ducts with a history of proven performance in concrete structures.

3. Post-tensioning Grout – Pumpable grout with a proven history of long-term performance as post-tensioning grout. Specifically designed to minimize grout settlement and shrinkage. Selection of grout for module-to-module joining tendons will include consideration for potential disassembly of the joint in the future.

4. Joint Grout – Pumpable grout with a proven history of performance in marine environments. Designed to minimize shrinkage and of sufficient strength to provide required load transfer.

F. Utility System Materials

1. Ship-to-Pier Electrical Cables and Connectors – Cables with noncorroding connectors, not subject to kinking damage or damage from UV exposure.

2. Cable Supports and Trays – Noncorroding FRP materials with a proven long-term performance history in marine environments. Strength adequate for the purpose.

3. Substations (electrical skids) and Substation Housings – Housings will either be fabricated from corrosion resistant materials or will have corrosion-preventative coatings that provide corrosion protection equivalent to corrosion resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

4. Mechanical Piping – Will be fabricated from proven materials and will either be FRP of a formulation consistent with the use or corrosion resistant steel.

5. Mechanical Valves and Fittings – Will be fabricated from corrosion-resistant materials or will have corrosion preventative coatings that provide corrosion protection equivalent to corrosion-resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

6. Lighting – Housings and standards for lighting will be fabricated from materials and will use designs that have a history of successful performance in marine environments.

G. Access Ramp Materials

1. Ramp Steel – Will be fabricated from corrosion-resistant materials or will have corrosion-preventative coatings that provide corrosion protection equivalent to corrosion-resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

2. Ramp Support Wheels – Will be designed to minimize maintenance of the wheel bearings, wheel surfaces, and wheel support rails.

H. Miscellaneous Materials

1. Watertight Manholes Covers – Will be fabricated from corrosion-resistant materials or will have corrosion-preventative coatings that provide corrosion protection equivalent to corrosion-resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

2. Watertight Doors – Will be fabricated from corrosion-resistant materials or will have corrosion-preventative coatings that provide corrosion protection equivalent to corrosion-resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

3. Bollards – Navy standard bollards will be used or bollards will be fabricated from corrosion-resistant materials or will have corrosion-preventative coatings that provide corrosion protection equivalent to corrosion-resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

4. Cleats - Navy standard cleats will be used or cleats will be fabricated from corrosion-resistant materials or will have corrosion-preventative coatings that provide corrosion protection equivalent to corrosion-resistant metals. Use of any nonferrous metals will be evaluated to assure that accidental galvanic cells are not created.

XIII. SYSTEMATIZED PLANNING, DESIGN, AND CONSTRUCTION

A. Opportunities and Benefits to a Systems Approach to MHP Design

1. Systematized Planning, Design, and Construction of MHP Modules

The standardization of configuration for individual MHP modules has the following objectives and provides the advantages outlined below.

a. Standard Module Length – To make prefabrication more repetitive and to allow stockpiling of MHP modules, all modules are the same length and the same structural configuration, so as to be interchangeable. The advantages are

- Prefabrication: Off-site construction, easing schedule and permitting series production, thus, reducing cost of construction. Construction in a commercial rather than Navy environment, reducing costs.

- Stockpiling: Longer production runs, reducing unit cost. Parts available to assemble piers on short notice in unforeseen locations to satisfy new mission requirements.

- Interchangeability: Only one kind of module is required, reducing the number of modules needed in stock to that are needed for a minimum length pier.

b. Standard Module-to Module-Joining – The method of joining modules together is the same, regardless of where along the length of the pier they are located. Advantages are

- Module interchangeability.
- Ability to prefabricate and stockpile.

c. Standard Utilities Joining – The methods of joining utilities between modules and between the access module and the ramps to shore is the same, regardless of where along the length of the pier they are located. This allows utilities (substations, mounds, receiver/duplex pump units, etc., as well as much of the cable and piping runs) to be installed on modules off site, at a location most favorable to bid prices. This location could be where the modules are prefabricated or stockpiled, or could be at an outfitting dock selected by the utilities subcontractor, where his/her costs are optimized. On-site connections between modules and between pier and shore are standardized, simple, and do not require high levels of contractor skill. Advantages are

- Lower cost
- Shortened on-site schedule
- Ability to install most of the utilities on the prefabricated modules

d. Standard Deck-to-Deck Levels – As the MHP is a floating pier, elevations of service (utilities) and operations (upper) decks relative to the water and to ships' decks vary only with draft of the MHP, and not with tide. The MHPs draft varies on the order of 2 or 3 feet, depending upon deck and storage loading. Tidal variations can range from minimal to large. Examples of the range between extreme low water (ELW) and extreme high water (EHW) are shown in Table V.J.-1.

Comment: On fixed, pile-supported, double-decked berthing piers, the lower (service or utilities) deck must be set high enough so that critical items, such as substations (electrical skids) and electrical mounds, do not flood at EHW. The minimum story height between the lower (service) and upper (operations) decks is the headroom required by service or maintenance vehicles, plus the height required for utilities crossover (where they go over the service vehicle aisle), plus the structural depth of the operations deck. Substations (electrical skids) can be selected from standard, commercially available types such that they have a limited effect on story height. EHW and the story height, thus, set the elevation of the upper (operations) deck.

Fixed piers require a compromise between keeping the lower utility deck dry, while not placing the upper operations deck so high above the water that smaller vessels with low decks cannot be served. This compromise gets more difficult the greater the tidal range. The tidal range at Norfolk is at about the upper end of tidal range for an operationally viable fixed, double-deck berthing pier. The double-deck MHP floating pier requires no such compromise. The operating deck can be very close to the water, much closer to optimum for the many smaller ships. The double-deck concept, thus, becomes viable for high tidal-range sites. A comparison of elevations in feet (meters) between the proposed floating MHP and fixed, double-deck berthing piers at San Diego, Bremerton, Mayport, and Norfolk is given in the following Table XIII.A-1.

TABLE XIII.A-1: COMPARISON OF SHIP AND PIER DECK ELEVATION, FIXED vs MHP DOUBLE DECK BERTHING PIERS

	FIXED PIER												MHP FLOATING PIER			
	San Diego Estimated Info				Bremerton Estimated Info				Mayport Estimated Info				Norfolk Pier 2			
Service Deck																
Deck EL (ELW = 0)	12.14	ft	3.70	m	20.51	ft	6.34	m	11.51	ft	3.54	m	12.62	ft	3.82	m
Deck EL (MLLW = 0)	9.28	ft	2.82	m	18.01	ft	4.86	m	8.41	ft	2.56	m	9.34	ft	2.85	m
Deck EL (EHW = 0)	0.91	ft &	0.28	m	0.91	ft &	0.28	m	0.91	ft &	0.28	m	0.91	ft	0.28	m
Operation Deck																
Story Ht	12.09	ft	3.69	m	12.09	ft	3.69	m	12.09	ft	3.69	m	12.09	ft	3.69	m
Deck EL (MLLW = 0)	21.35	ft	6.51	m	28.1	ft	8.56	m	20.6	ft	6.25	m	21.43	ft	6.53	m
1. CG-47: Primary Vessels																
MHP Op. Deck EL (ELW = 0)	24.23		7.39		32.90		10.03		23.70		7.22		24.61		7.50	
CG-47 deck above water	15		4.57		15		4.57		15		4.57		15		4.57	
Max ht ship below open deck	9.23		2.81		17.90		5.46		8.70		2.65		9.61		2.93	
2. FFG-7: Primary Vessels																
MHP Op. Deck EL (ELW = 0)	24.23		7.39		32.90		10.03		23.70		7.22		24.61		7.50	
CG-47 deck above water	15.5		4.72		15.5		4.72		15.5		4.72		15.5		4.72	
Max ht ship below open deck	8.73		2.66		17.40		5.30		8.20		2.50		9.11		2.78	
3. DDG-51: Primary Vessels																
MHP Op. Deck EL (EHW=0)	13.00		3.96		13.00		3.96		13.00		3.96		13.00		3.96	
DDG 51 deck above water	21.83		6.65		21.83		6.65		21.83		6.65		21.83		6.65	
Max ht ship above open deck	8.83		2.69		8.83		2.69		8.83		2.69		8.83		2.69	
4. DDG-993: Alternative Vessels																
MHP Op. Deck EL (ELW = 0)	24.23		7.39		32.90		10.03		23.70		7.22		24.61		7.50	
DDG 993 deck above water	15.5		4.72		15.5		4.72		15.5		4.72		15.5		4.72	
Max ht ship below open deck	8.73		2.66		17.40		5.30		8.20		2.50		9.11		2.78	
5. LHA-1 & LHD-1: Alternative Vessels																
MHP Op. Deck EL (EHW=0)	13.00		3.96		13.00		3.96		13.00		3.96		13.00		3.96	
LHA-1 deck above water	60		6.65		60		6.65		60		6.65		60		6.65	
Max ht ship above open deck	47.00		14.33		47.00		14.33		47.00		14.33		47.00		14.33	

	MHP FLOATING PIER			
Service Deck				
Deck EL (ELW = 0)	2.42 ft Loaded 5.42 ft Light		0.74 m Loaded 1.65 m Light	
Deck EL (MLLW = 0)	2.42 ft Loaded 5.42 ft Light		0.74 m Loaded 1.65 m Light	
Deck EL (EHW = 0)	2.42 ft Loaded 5.42 ft Light		0.74 m Loaded 1.65 m Light	
Operation Deck				
Story Ht	11.33	ft	3.45	m
Deck EL (MLLW = 0)	13.75 ft Loaded 16.75 ft Light		4.19 m Loaded 5.11 m Light	
1. CG-47: Primary Vessels				
MHP Op. Deck EL (ELW = 0)	13.75 ft Loaded 16.75 ft Light		4.19 m Loaded 5.11 m Light	
CG-47 deck above water	15.00	ft	4.57	m
Max ht ship below open deck	-1.25 ft Loaded 1.75 ft Light		-0.38 m Loaded 0.53 m Light	
2. FFG-7: Primary Vessels				
MHP Op. Deck EL (ELW = 0)	13.75 ft Loaded 16.75 ft Light		4.19 m Loaded 5.11 m Light	
CG-47 deck above water	15.50	ft	4.72	m
Max ht ship below open deck	-1.75 ft Loaded 1.25 ft Light		-0.53 m Loaded 0.38 m Light	
3. DDG-51: Primary Vessels				
MHP Op. Deck EL (EHW=0)	13.75 ft Loaded 16.75 ft Light		4.19 m Loaded 5.11 m Light	
DDG 51 deck above water	21.83	ft	6.65	m
Max ht ship above open deck	8.08 ft Loaded 5.08 ft Light		2.46 m Loaded 1.55 m Light	
4. DDG-993: Alternative Vessels				
MHP Op. Deck EL (ELW = 0)	13.75 ft Loaded 16.75 ft Light		4.19 m Loaded 5.11 m Light	
DDG 993 deck above water	15.50	ft	4.72	m
Max ht ship below open deck	-1.75 ft Loaded 1.25 ft Light		-0.53 m Loaded 0.38 m Light	
5. LHA-1 & LHD-1: Alternative Vessels				
MHP Op. Deck EL (EHW=0)	13.75 ft Loaded 16.75 ft Light		4.19 m Loaded 5.11 m Light	
LHA-1 deck above water	60.00	ft	18.29	m
Max ht ship above open deck	46.25 ft Loaded 43.25 ft Light		14.10 m Loaded 13.18 m Light	

TABLE XIII.A-1: (CONTINUE)

ASSUMPTIONS:

TABLE XIII.A-1: (CONTINUE)

ASSUMPTIONS:

1 Tidal Information — See Table V. J -1

2 Vessels Deck EL:

Advanced Pier Concepts User Guides
Main Deck Height Above DWL:

FFG-7 @ Amidships =	15.5 ft
CG-47 @ Amidships =	16 ft
DDG-51 @ Amidships =	21.83 ft
DD-963 @ Amidships =	16.5 ft

Janes Fighting Ships (Scaled from the picture)
Main Deck Height Above DWL:

LHA-1 @ Amidships =	est 60ft
LHD-1 @ Amidships =	est 60ft

(No information about LPD-17)

3 MHP Draft:

(From our Primary Design)
LIGHT = 11.25 ft
LOADED = 14.25 ft (Allowing 3 ft LL Draft)
Service Level Deck EL = 16 ft (from Keel)
Note that there will be additional 3 ft of wall (Above the Service Slab) for Wave Protection.

4 Fixed Pier Information:
& :

Norfolk: Pier 2 (fixed pier)
Elevation of the Service Deck for Other locations were assumed to be similar to the Norfolk PIER 2.

COMMENTARY:

1. Story heights, fixed pier vs floating MHP, need study. Currently, the fixed pier allows for a tall maintenance vehicle, but does not allow for transverse crossover of bulky utilities between sides of the pier. The floating MHP postulates lower vehicles, but does allow for utilities crossover.

2. The service deck of the fixed pier is only slightly above EHW. Substructures are subject to flooding during combinations of high tide and storm surge. Also, service deck structure will be immersed in salt water at MHHW, a common durability issue for site-built piers with carbon steel reinforcing.

3. Double decked fixed piers are not suitable operationally for high tide-range ports, because the deck of the lowest design ship (an CG-47) is so far below the operations deck of the ship (17.9Ô at Bremerton). The comparable figure for a floating MHP is only 1.75Ô and is independent of the site Ô tidal range.

4. Maximum ship deck heights above the operating deck height (DDG-51) are comparable for fixed piers and for floating MHPÔ (5.5Ô fixed vs 5.1Ô MHP).

As the elevations above water of the MHP service and operations decks of a floating MHP are independent of tide, they become site independent. The elevation of the service deck on the MHP is set so that it will not flood from wave action. The story height from the surface of the service deck to the top surface of the operations deck is minimized. This is accomplished by selecting a thin structural concept for the operations deck, by standardizing utilities runs and using end of pier cross overs for mechanical services to minimize
crossover height, and by selecting service and maintenance vehicles to be used on the service level for minimum reasonable headroom needs. The same story height and MHP hull depth is used for all potential sites. Summarizing, the advantages of the floating MHP are

- Deck elevations above water and story height between service and operating decks independent of tidal range and site
- Operations deck is lower to the water for better service to the more numerous, smaller ships
- Service deck is always high enough above water to stay dry
- Same story height and hull depth for all sites, enabling a standardized hull cross section for all sites

e. Basic Modules

A MHP facility is composed of three module types, each of which is a minor variation of the typical interior module. The modules are off-site prefabricated and floated to the deployment site where they are joined together as part of the installation process to form the MHP.

(1) Access Module – The access module of the MHP is located at the yard end of the pier. A typical interior module is modified to accommodate

- Access ramps from yard to upper (operations) deck and from yard to utility (service) deck
- All modules contain an interior mooring moonpool that can be implemented to moor the pier. The access module includes an energy-absorbing mooring fender system that restrains the pier in the direction parallel to its length as well as transversely
- Connections of pier utilities to shore

(2) End Module – The end module is located at the channel end of the pier, at the opposite end from the access module. A typical interior module is modified to accommodate

- An interior mooring moonpool that restrains the pier perpendicular to its length
- Turnarounds for trucks and maintenance vehicles, and crossovers between utilities on the two sides of the pier

(3) Interior Module – Interior modules are located between the access and end modules. These are the basic modules and are modified with add-on elements to make access and end modules. All interior modules contain mooring moonpools.

f. Pier Sub Modules

Fully functional MHP installations of varying lengths can be developed using different configurations of modules.

- Functional pier at 2 module length (650 feet) (198 meters)
  Access + End Modules

- Functional pier at 3 module length (975 feet) (297 meters)
  Access + End + 1 Interior Module

- Functional pier at 4 module length (1,300 feet) (396 meters)
  Access + End + 2 Interior Modules

2. Systematized Planning Design and Construction of MHP Mooring System Elements

Except for the pile configuration (number, size, and length of piles) for the mooring shaft support dolphin, the mooring system for the MHP is typical from one site to the other.

The design of the mooring system was developed so that the changes in the system to accommodate the mooring loads that differ from site to site can be accommodated without affecting the MHP module design.

The benefits of this approach to the mooring design is that all MHP moorings are the same throughout the program. The amount of site-specific design and construction is minimized. Mooring system elements can be prefabricated and stockpiled in support of the program.

There are three methods to increase the capacity of the MHP mooring system.

a. Use Four Mooring Locations Rather than the Minimum Two Locations

Large increments of mooring capacity increases can be made by outfitting and mobilizing an additional two mooring locations. All MHP modules have mooring locations (if they are not needed to provide the capacity required they are not outfitted). Use of four mooring locations doubles the MHP mooring capacity without changing the basic preliminary design of any of the mooring elements (fenders, mooring shafts, dolphin pile cap, dolphin piles).

b. Increase the Capacity of Each Mooring Location

Overall mooring capacity can be increased from the minimum initially by stacking additional fender elements within the MHP mooring moonpool with attendant increases in the strength of the mooring shaft and its support structure as required. The steps involved are as follows.

(1) Increase the fender capacity by choosing a longer fender with harder rubber or, if necessary, stack up the fenders to meet the required capacity.

(2) Increase the mooring shaft capacity by increasing the thickness of the shaft plating.

(3) Increase the pile-cap capacity by increasing the thickness of the cap and, if necessary, to accommodate more piles, increase the dimensions of the cap.

(4) Increase the pile capacity by increasing the number of piles, the size of the piles, and or the arrangement of the piles.

c. Increase capacity by using a combination of Items 1 and 2 above.

In Table IX.B-1, the mooring fender selections for the alternative sites and the alternative vessels is shown.

3. Systematized Planning Design and Construction of MHP Module-to-Module Joining Features

The configuration of all module-to-module joints are the same. Joints will all be designed to provide the capacity needed by the highest loaded joint. This will make the joint installation typical and avoid any problems with confusion regarding required capacity of the joints based on position within the MHP.

Joining bars and anchors will all be the same and will use the same type of equipment for stressing. This will allow optimization of procurement and assure that the joining operation is straightforward.

4. Systematized Planning Design and Construction of MHP Vessel Berthing Features

The approach to vessel berthing is that the vessel fendering, bollards, and cleat provisions will be typical from one MHP to the next. This will allow for ease of planning in berthing. The flexibility of the utility service approach means that vessel location for mooring is not dictated by the location of utility hookup points on the pier. This also increases the flexibility of planning for vessel berthing.

5. Systematized Planning Design and Construction of MHP Shore to Pier Access Ramps

Pier-to-shore access ramps will be a series of standard designs for the operations deck ramp and the service deck ramp that vary only in span. Support details will be typical for all ramps. All ramps will have the same load carrying capacity and dimensional clearances for vehicles.

Maintenance requirements for ramps will be typical for all ramps and, thus, can be part of a common maintenance program.

XIV. PRELIMINARY COST CONSIDERATIONS

In determining the costs of a facility like the MHP at the preliminary design stage, it is not possible to be as precise as one can be with a more conventional structure for which there is actual historical bid price information available. The costs issues associated with each of the major facility elements are discussed below. Tabulations of preliminary construction costs are given in Appendix L.

A. Basic MHP Structure

1. The Potential of Off-Site Prefabrication

On a baseline of 100, construction cost index factors for U.S. cities with waterfront access to the ocean tow routes, there is a considerable variation from one of the lowest cost locations to the highest. For example, Shreveport, LA, has an index of 80.9 and the New York City area has a cost index factor of 133.8. What this means is that in general terms, the cost difference in site construction between Shreveport and New York is 133.8/80.9 = 165 percent. Similarly the cost difference between construction at Norfolk and San Diego is 106.6/82.5 = 129 percent.

With a project that can be off-site prefabricated and open to bidders nationwide, the possibility is that contractors can take advantage of local labor rates and economic conditions and build the module elements of the MHP in locations where the modules can be produced most economically.

2. The Influence of Towing Costs from Fabrication Site to Deployment Site

Medium powered coastal tugs would be able to tow the MHP modules at speeds between 2 and 3 knots. Assuming a 2-knot towing speed, towing progress would be at the rate of 55 miles per day. Towing costs would be in the following range.

Number of tugs required =	4
Mobilization of four tugs =	$93,600
Per day per tug all inclusive =	$7,800

With the above costs, a 500-mile tow from fabrication site to the deployment site would cost $374,400 or about 1 percent of a $42 million facility cost. With similar assumptions, a 1,000-mile tow would cost $748,800 or about 2 percent of a $42 million facility cost.

The cost of towing is such that the economic advantages of off-site prefabricating the modules in one of the low-construction cost index areas of the country and towing them to a deployment site in a higher construction cost index is not lost.

3. Concrete Element Costs

In the Phase 1A effort, the total raw material cost of the lightweight concrete used was $122 per cubic yard. The total in-place cost of the hull concrete will be on the order of $810 to $1,160 per cubic yard. Thus, there is significant opportunity to reduce cost by saving labor, formwork, and equipment costs.

4. Special Reinforcing Steel Costs

The use of stainless steel reinforcing in the way we propose to use it represents a cost uncertainty. Stainless steel material costs range from $1.15 per pound to $1.82 per pound, as opposed to conventional steel reinforcement costs of about $0.23 per pound. To date, we have not been successful in locating a supplier that will quote a cost for a high-strength stainless or nitronic steel drawn wire fabricated into mats. We know that Florida Wire and Cable has in the past drawn nitronic steel for use in seven-wire strand, but they have not quoted a price to us for this material.

5. Prestressing System Costs

Encapsulated 270 ksi seven-wire post-tensioning is a product that is used in the industry. Thus, costs are available for this material.

B. MHP Mooring System

1. Site Mooring Shaft Support Dolphin Structure

The approach to minimize the on-site construction activity means that construction of the mooring shaft support dolphins is a relatively small construction effort when compared to the construction of a typical Navy pile-supported berthing pier. While this provides overall project economy, it means that the mobilization of crews and equipment is spread over a smaller construction activity and, thus, the unit prices for these elements of the project can be expected to be relatively high. It also means that the high costs of mobilization for specialized equipment aimed at replacing material or labor costs for these elements may not be warranted.

2. MHP Mounted Elements

The mooring elements installed in the MHP will be prepared for installation at the off-site fabrication site. They will not be installed until the final installation of the mooring shafts into the mooring shaft support dolphins. An approach to limit the amount of crane support needed will improve the economy of this construction activity.

C. Structural Module–to-Module Joining

The structural joining concept presented minimizes the use of tugs and other heavy floating equipment. Joining equipment can be reused for each module joint to be completed. Preparations for joining should be made to the maximum extent possible at the off-site fabrication site to minimize the amount of on-site labor and equipment necessary to support the on-site joining activity.

D. Utilities and Appurtenances

To the maximum extent possible, the utilities and appurtenances will be installed on the MHP modules at the off-site construction site. It may be advantageous for the modules to be moved from the concrete structure fabrication site to an outfitting site for installation of utilities.

E. Ramps

Ramps should be off-site prefabricated in the largest pieces that can be transported to the site. It may be possible to transport fully assembled ramps to the site using the MHP modules as transport vehicles.

Methods to launch and erect the ramps from the MHP modules to the shore abutment should be explored to identify the most reliable and economical method to do this. It may be possible to erect the units with minimal use of cranes.

XV. DEFINITION OF FUTURE PHASE ACTIVITIES

A. Prototype Testing

Prototype testing is recommended for those critical aspects of the MHP facility that represent a significant program risk. A significant program risk is one that, if the risk event occurs, will result in the program not proceeding or not meeting one of its primary objectives. Risks to be considered include, technical risks, operational risks, maintainability risks, and cost risks. Proposed mitigation methods for all significant program risks should be confirmed either by analysis or test as valid.

Technical risks include those issues related to design and specification that have unknown aspects that must be either confirmed or developed in order to provide confirmation that the design will reliably perform as intended.

Operational risks include those aspects of the project design that have unknown operational performance characteristics that must either be confirmed or developed in order to provide confirmation that the design will meet all operational and functional requirements.

Maintainability risks include those aspects of the project for which maintenance requirements are uncertain to the extent that they represent a significant life-cycle cost risk or an operational risk. The maintenance characteristics of these items must either be confirmed or developed in order to provide confirmation that the design will provide the desired low-maintenance performance.

Cost risks include those elements of the project for which cost information is unknown and which represents the potential of cost increase to the extent that the costs objectives of the project will not be met. The cost content (labor, materials, equipment) for these items must either be confirmed or developed in order to provide confirmation that the MHP will meet the program cost objectives.

The following are subjects to be considered for the prototype testing phase of the MHP program.

1. Design and construction a scaled MHP prototype that allows evaluation of as many of the typical MHP construction operations as possible. Proposed is a two-module, 50- by 100-foot (15.2- by 30.4-meter) double-deck floating pier. This would allow prototype construction of the following elements.

    - Two mooring dolphins with mooring shafts
    - The module-to-module joining operation
    - Construction of near full-scale utility galleries
    - Small-scale ramp-to-pier interface

- Construction of the modules using precast flat wall panels
- Construction of the module keel using cast-in-place concrete
- Use of lightweight concrete to construct all elements of the prototype
- Connection of the precast elements using cast-in-place joints
- Testing of prestressing details for module-to-module joining
- Testing of details of module longitudinal and transverse post-tensioning
- Prototype installation of the joined floating modules with the dolphin/mooring shaft mooring system
- Evaluation of utility hookup functionality (assuming mock utility hookup installed in the prototype facility)

2. Development of an MHP Development Information Presentation

This item addresses the significant risk that the MHP concept will not be sufficiently understood by those that must fund the concept and support its deployment. Development of this presentation will include

a. Scale model of pier – as basis of video presentation
b. Operational simulation
c. Video presentation of design

Scale model of joining
Scale model of mooring
Scale model of ramps
Scale model of utilities

d. Video presentation of results of prototype test program

3. Materials Prototype Testing

This item addresses the performance prequalification of key materials toward meeting the objective of a maintenance free service life of more than 100 years.

a. High Strength Stainless Steel (or corrosion resistant) Reinforcing

(1) Steel Selection Task

Contract identified steel suppliers and consult the available literature on corrosion-resistant reinforcing steel. Identify two or three candidate steels [high as possible strength up to 150 ksi (1,034 MPa) while still having acceptable cost, ductility and corrosion resistant characteristics]. We are looking for No. 3 or No. 4 bars in high strength steel. We will want other bars that are galvanically compatible that can be bent into conventional hooks for corners, joints, etc.

Collaborate with NFESC regarding the selection of the reinforcement steels.

(2) Steel Performance Confirmation Task

Once the candidate reinforcing steels have been selected, collaborate with NFESC to develop a simple confirmation test to assure that the steel is, in fact, sufficiently corrosion resistant in concrete. This will involve corrosion testing in concrete with cracked specimens exposed to a corrosive agent or sea-water. Evaluate bend areas and perhaps at reinforcing bar welds to assure that the steel selected performs as intended. Develop understanding of how to use the steel in combination with other steel embeds (angles, weld plates, hatch frames, post-tensioning anchors, etc.) to avoid accidentally establishing galvanic cells.

Collaborate with NFESC for the development and performance of these tests.

(3) Possible Bond Strength Test Task

Assuming that high-strength, corrosion-resistant deformed bars with obvious good bond characteristics can be procured, bond testing may not be required. If the bars selected are available only as smooth wire rather than deformed bars, it may be necessary to develop bond strength tests for hooks and laps.

b. Double Protected Electrically Isolated Post-Tensioning Systems

(1) Protection of Anchor Areas

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two systems that meet the criteria.

(2) Tendon Splice Areas

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two systems that meet the criteria.

c. Post-Tensioning Grout

(1) Grout Settlement Prevention

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two products that meet the criteria.

(2) Confirmation of Post-Tensioning Grout Corrosion Protection

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two post-tension grouting systems that meet the criteria.

d. Concrete Mix Constituents

(1) Cement

Develop prequalification criteria, including grind and chemical composition, for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two widely available cements that meet the criteria.

(2) Aggregate

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two manufactured aggregates that meet the criteria.

(3) Admixtures

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two brands of each admixture type, including chemical composition and maximum dosing amounts required for the project that meet the criteria.

4. Module-to-Module Joining Prototype Testing

This item addresses the operational procedures for achieving a watertight module-to-module joint that reliably transfers design joint loads.

a. Post-Tensioning Duct Splicing

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two splicing systems that meet the criteria.

b. Dewatering Seal

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two seal types that meet the criteria.

c. Grouting Operation

Develop prequalification criteria for this element of the MHP that is consistent with the 100-year plus zero maintenance objective and prequalify at least two systems that meet the criteria.

d. Operational Scale Model Development

Build an operational scale model that can be used to develop a video presentation showing how the module to module joining is accomplished.

5. Mooring System Prototype Testing

This item addresses the installation procedures and operational performance of the MHP floating pier mooring system.

a. Operational Scale Model Development

Build an operational scale model that can be used to develop a video presentation showing how the MHP mooring system operates.

b. Confirm installation procedures for MHP mooring dolphin and mooring guide shaft by design and construction a full scale prototype dolphin installation. Address the following items.

- Confirmation of viability of proposed installation method
- Installation to required tolerances
- Operation of proposed adjustment methods

c. Testing of mooring fender/guide shaft performance while moving under load. Develop test to confirm performance of mooring guide shaft/fender system under worst-case loading and under service-level loading. Consider dynamic and cyclic testing as well as static testing.

6. Ramp System Prototype Testing

This item addresses the motions accommodation provisions for the MHP access ramps.

a. Operational Scale Model Development

Build an operational scale model of the ramp system that can be used to confirm expected performance of the ramp support system under various combinations of motions. Develop a video presentation showing how the MHP ramp system operates to accommodate MHP motions.

b. Confirm Brake-Over and Dip Angle Effects on Design Vehicles

Build a full-scale model of breakover and dip angle geometry (geometry only, not the ramp) suitable to test the effects of break over and dip angles. Perform tests with vehicles currently in use on Navy piers. Document and video tape tests.

c. Confirm Ability of Design Vehicles to Operate on Maximum Ramp Grade

Build a full-scale model of grade geometry suitable to test the on-grade stopping and uphill start-up tests for the design vehicles. Perform tests with vehicles currently in use on Navy piers. Document and video tape tests.

d. Confirm Ability of Design Vehicle to Enter Ramps

Build a full-scale model of the ramp geometry (geometry only not the ramp) that a vehicle can be driven into to confirm the ability of the largest design vehicles to enter the ramp without difficulty from a typical approach roadway situation. Perform tests with vehicles currently in use on Navy piers. Document and video tape tests.

- Shore end
- Pier end

e. Environmental Exposure Testing of Movable Ramp Support Details

Subject movable ramp support details to accelerated environmental exposure testing in an aggressive corrosion environment to qualify the various details in the design for long term durability.

7. Standard Utilities Module Layout

This item addresses the confirmation of operational performance of the standard utilities module layout.

a. Build a utility station scale model suitable for planning the utility layout in three dimensions and for showing how the utility system hook up is to operate. Document and video tape different types of operations.

b. Construct a nonoperational full-scale mock-up of a utility station installation (one berth hookup). Outfit the mock-up with utility systems as proposed for the MHP. Invite Navy operations and fleet personnel to visit the mockup and provide comments and input regarding the proposed layout and design. The mock-up should include the following things.

(1) Standard Berthing Utility "Station"

- Utility window
- Turtleback
- All mechanical hookups
- Portable receiver/duplex pump

(2) Module-to-Module Spooling of Lines

c. Perform a simulated utility hookup and disconnect at the mock-up, and videotape the operation to show the operation of the utility system hookup/disconnect.

d. Build an operational prototype of the portable receiver/duplex pump and put it through a series of qualification tests to confirm its long-term performance.

(1) Document performance
(2) Identify any design improvements required
(3) Revise design based on recommended improvements

8. On-Pier Vehicle Movement Confirmation

This item addresses the ability of vehicles to efficiently make the required movements on both the operations deck and service deck of the MHP. These tests are performed in a parking lot with parking cones, layout lines, and actual design vehicles to be used on the pier. Tests are video taped as documentation.

a. Confirm capability of design truck to turnaround on operations deck
b. Confirm adequacy of vehicle drive space adjacent to stairs.
c. Confirm vehicle turning and passing movements on service deck

B. User Input

The preliminary design of the MHP has raised two important questions that should be addressed prior to final design.

1. Question 1. Is the MHP operations deck large enough to meet all functional vessel berthing requirements now and in the foreseeable future? This question is in the context that each additional square foot of deck space results in an added cost for each additional unit of area added. The deck can be made larger, but with a consequent increase in cost, and, thus, should not be made larger than functionally necessary.

2. Question 2. Are the MHP global structural capacity, structural stiffness, and hydrostatic properties (roll, yaw, and live-load draft sinkage) adequate to support all functional berthing requirements now and in the foreseeable future? The MHP structural capacity and stiffness can be increased and the hydrostatic motion characteristics can be improved, but with a consequent increase in cost, and, thus, should not be made stronger or more hydrostatically stable than functionally necessary.

As mentioned elsewhere in this report, the design team set the size and strength of the MHP at levels judged to be adequate for the defined functional berthing purposes. However, since the MHP has a global response to deck loading acting as a floating body with both global floating beam structural deflection characteristics and global floating beam hydrostatic properties, the issue of likely deck loading combinations has increased functional and operational significance as compared to the importance of this information for the design of a conventional pile-supported pier. Answers to questions of the level of deck loading associated with the various multiberth uses, both in terms of the magnitude of the loads, the distribution of loads and the number of loads, were not available from existing information.

The following prefinal design tasks should be accomplished so that deck loading design criteria can be refined into loading combinations that encompass the actual usage that the MHP operations deck is required to support.

1. Interview a representative sampling of berthing facility operations staff to develop and document an accurate understanding of the loading character and spatial requirements of the highest level of deck utilization likely to be found in practice.

a. Loading associated with activities at a single berth

b. Loading associated with activities at multiple berths that could be expected at the same time.

c. Space requirements for different types of maintenance and berthing activities (compare with DM defined activity space requirements)

d. Determine types of vehicles that must access operations and determine the turning characteristics of the largest trucks that must turnaround on the deck.

2. Visit a representative sampling of Navy berthing stations and view and document operations to verify results of interviews performed in Task 1 above.

3. Compare results of interviews and visits with published criteria for the design of Navy berthing pier facilities and resolve any differences. Document the results of this review and resolution activity.

4. Based on the results of Tasks 1 through 3 above, develop a series of deck loading combinations (both the load levels and the spatial distribution of the loads) and space requirements that represent the range of operational loadings and space requirements that the MHP is likely to experience.

5. Check the current MHP preliminary design against the loading combinations and the space requirements defined in Task 3 above.

a. Check global structural capacity against required strength

(1) Still water bending plus mooring and wave effects
(2) Combined bending, shear and torsion effects

b. Check global structural deflections against operational requirements for berthing.

(1) Global bending deflections acting as a beam on elastic foundation
(2) Global torsional deflections acting as a beam on elastic foundation

c. Check rigid body hydrostatic motions against operational requirements for berthing

(1) Roll as result of asymmetrical deck loading
(2) Yaw as result of asymmetrical deck loading
(3) Total draft increase as result of maximum loading of operations deck

d. Check the dimensional space allocation against any revised operational space requirements developed from interviews and site observations.

6. Revise the preliminary design of the MHP if indicated by the results of Task 4 above.

a. Revise deck width for turnaround if found to be necessary.

b. Revise deck length to provide additional area if found to be necessary

c. Revise hydrostatic properties by adding depth and width to the MHP hull if found to be necessary.

d. Revise global structural capacity by adding depth and width to the MHP hull if found to be necessary.

7. Document any differences between the current MHP preliminary design and final preliminary if any. Define the consequences of any differences in terms of cost and functional/operational performance of the MHP facility.

The results of this effort will either confirm that the size and capacity of the current preliminary design MHP design is adequate for all current and foreseeable future Navy berthing purposes or it will identify the revisions needed to assure functional adequacy of the MHP facility.

C. Final Design

1. Discussion of Procurement Issues

In order for the Navy to capture the full range of advantages associated with the deployment of a "fleet" of MHP floating pier facilities as replacements for obsolete fixed pier berthing facilities, the possibilities and opportunities for procurement should be acted on.

If MHP facilities are procured as one-of-a-kind facilities, as Navy berthing facilities are today, it is likely that the economic objectives of the program will not be met and the reliability of meeting long-term durability and low-maintenance objectives will be reduced. This is because the design and construction of floating facilities is new technology for most of the heavy construction industry. Projects involving new technology in any industry are subject to higher overall cost, schedule, and quality risks than are projects involving mature technologies. If the facilities are procured as one-of-a-kind facilities, MHP's will remain new technology for many years to come as each new group of designers and contractors approaches each MHP project for the first time.

The modularity, standardization, and nonsite-specific approach taken with the MHP concept provides the possibility of procuring standard MHP modules from several centralized factory sources, delivered by self-floating tow, and incorporated in MHP facility projects at Navy deployment sites throughout the world. Operators of these centralized factory sources would be specialists in prefabricated concrete construction and could be awarded competitive multi-year contracts to produce MHP modules on a work order basis to meet the needs of the berthing facility replacement program. The procurement contracts could include mobilization tasks that involve the development and qualification of quality assurance programs, construction of government designed formwork, and other tooling necessary to assure module interchangeability and high quality.

The modules could be fabricated from government furnished materials (cement, prestressing steel, aggregates, admixtures, etc.) procured from prequalified sources under special specifications designed to assure ultra-long durability and provided to the factory for use in construction.

With this procurement approach, MHP modules would become, over time, an industry standard product subject to the lower commodity pricing as opposed to special project premium pricing that is typical of one-of-a-kind design and construction activities.

2. Development of a "Site Adapt" Design

The approach taken with the development of the MHP concept lends itself to procurement as a site-adapt design. The standard MHP modules, complete with all utilities, on-board mooring provisions, and joining provisions, would be final designed and the completed design documents would form the basis of multiple site-adapt contracts.

The interface details for the MHP floating pier mooring would be final designed. A series of sample designs for the site-specific mooring guide shaft support dolphins would be developed to show designers how to design these lateral load reaction elements for different geotechnical conditions. Design loads for the mooring dolphins would be calculated for all different combinations of vessels to be moored for a wide range of possible deployment sites and provided to designers as design input for the mooring dolphin design.

A series of pier-to-shore access ramps for both the operations deck ramp and the service level ramp would be final designed in 5-foot (1.5-meter) span increments starting at 80 feet (24.4 meters) so that a ramp design could be specified from a set of standard drawings. Ramp support details would be final designed as part of the site adapt package and are the same for all installations.

The interface details for the ramps and the on-shore abutment would be final designed as part of the site-adapt package. A series of sample designs for the site-specific abutment designs would be developed to show designers how to design for different geotechnical conditions and different shore bulkhead conditions. Ramp support loads would be calculated for all different combinations of ramp length and provided to designers as design input for the abutment design.

A standard mechanical hookup manhole design and a standard electrical hookup vault would be final designed as part of the site-adapt package. Site-adapt work would include running on-shore utilities from where they exist on site to the MHP standard manhole and vault.

Thus, the typical site adapt design would include only site specific designs for either two or three mooring dolphins (depending on the wind exposure of the site), the site-specific design of the ramp abutments, and the extension design for extending on shore utilities to the MHP hook up points. All other elements of the project would be standard design elements. Standard modules completely outfitted could be provided to installation contractors as government furnished equipment.

XVI. PRELIMINARY DESIGN DRAWINGS

See Drawing A-01 for a list of drawings.