**IAP/MASSACHUSETTS INSTITUTE OF TECHNOLOGY**
**Department of Mechanical Engineering**

**2.704 PROJECTS IN NAVAL SHIP CONVERSION DESIGN**
IAP / Spring 2024

# Heavy Lift Heroes
# Final Report

## EXECUTIVE SUMMARY

This project underscores a significant advancement in the U.S. Navy's operational capabilities, specifically focusing on enhancing the Navy's ability to recover, transport, and swiftly redeploy battle-damaged vessels. By exploring the feasibility of retrofitting the *USNS Montford Point*, an existing Expeditionary Transfer Dock (T-ESD), to accommodate heavy lift operations for a Flight III Arleigh Burke class destroyer, this initiative addresses a crucial logistical and strategic need. Through comprehensive engineering assessments, it was determined that the *Montford Point* is suited for such heavy lift tasks in its current state, requiring only minor structural modifications to ensure the safety and efficiency of operations. The project's success in this regard highlights the potential for rapid response and redeployment capabilities, crucial not just in times of conflict but also for peacetime operations.

The project's technical analysis delved into the specific requirements for adapting the *Montford Point* to handle the distinct dimensions and features of the target cargo, including challenges posed by the sonar dome's projection and the propellers of the Arleigh Burke class destroyer. Utilizing software such as the Program of Ship Salvage Engineering (POSSE) and MAXSURF for deck strength evaluation and seakeeping analysis, the team devised strategies to manage the vessel's ballasting for submergence, lifting, and transit phases, ensuring stability and adherence to design load capacities. Moreover, the introduction of innovative solutions such as propeller pits and a continuous blocking scheme enabled the vessel to accommodate the destroyer without necessitating the removal of critical components, thus maintaining the integrity and operational readiness of both the *Montford Point* and the destroyer. This initiative not only demonstrates the Navy's dedication to enhancing its logistical capabilities but also sets a new standard for maritime engineering and strategic planning, ensuring the fleet's resilience and adaptability in facing future challenges.

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## SECTION 1: PROJECT OVERVIEW

### Motivation

To improve the U.S. Navy's battle-damage repair capabilities, this project assessed the feasibility of converting an existing T-ESD into a heavy lift-capable ship. The recovery, transportation, and redeployment of damaged naval vessels stand as critical competencies during times of peace and armed conflict. The swift repairs of the USS Yorktown before the Battle of Midway in World War II underscore the strategic necessity of promptly restoring damaged warships, emphasizing the significance of each vessel in times of war. Furthermore, recognizing the cumulative strategic impact of returning damaged ships to fighting condition, the ability to repair ships provides enduring benefits over the long term.

### General Concept of Operations

The Heavy Lift Vessel (HLV) is conceived as an integral asset within the U.S. Navy, specifically designed to recover and transport damaged naval assets at sea. Tailored to lift a Flight III Arleigh-Burke class destroyer, the HLV prioritizes the safe lifting and transportation of these vessels. The operational workflow entails meeting a damaged warship at sea, facilitating docking, preparing it for transport, and subsequently relocating it to a secure area for repairs. This strategic approach ensures the HLV's adaptability, swiftly removing damaged vessels from harm's way, and facilitating efficient repair and reintegration into operational service across a diverse range of global regions.

It's essential to note that while the HLV is expected to operate in areas where it may be exposed to potential threats, it will not be equipped with advanced defensive weapons. The provision of defensive capabilities will be coordinated with other warships, acknowledging that the associated risk is deemed acceptable within the broader naval operational context.

The purpose of this project was to determine the ability of an T-ESD, specifically the *Montford Point*, to lift and transport a damaged Arleigh-Burke class destroyer. If the *Montford Point* was unable to lift and transport a damaged DDG as is, structural modifications would then be made to ensure safe lifting and transport operations. The goal was to enhance naval operations' flexibility and adaptability, with the overall objective to assess the feasibility and benefits of the upgrade, while also identifying potential issues. This report discusses the Heavy Lift Heros design approach and decision framework, the various analyses that were conducted, the technical challenges with carrying out this project as well as lessons learned. Subsequent sections detail each of these areas of study in further detail.

### Study Objectives

Projects in Naval Ship Conversion Design, MIT Course 2.704 builds on pre-requisite naval ship design subjects (2.701-2.703) in the MIT 2N Program. Major requirements and objectives include:

(a) Application of naval architecture and ship design knowledge/skills to complete a conversion/modified-repeat ship concept design project;

(b) Ability to plan and execute work as part of a design team; and

(c) Demonstration of effective communications, in both written reports and oral presentations.

These objectives must be considered in specifying requirements and planning the project.

This study aimed to convert the *Montford Point* into a heavy lift capable vessel. The project focused on specifications necessary for accommodating the at sea docking and transport of an Arleigh-Burke class destroyer, and the project utilized the ship's ballasting systems and ship structure for this purpose. Notably, logistics associated with repairs at sea were excluded from the analysis. The study conducted structural, stability and seakeeping analyses and addressed any identified deficiencies through appropriate modifications.

**Customer Requirements**

The mission statement for this project was to transport a damaged Flight III Arleigh-Burke class destroyer by recovering it at sea using a converted T-ESD with heavy lift capability. From this mission statement, the following sponsor requirements were obtained:

| | **Threshold** | **Objective** |
|---|---|---|
| **Lifting Capacity** | 9,000 tons | 10,000 tons |
| **Sea State (Transporting)** | 3 | 5 |
| **Range** | 8,000 nm | 10,000 nm |
| **Classification Authority** | ABS | - - - |

From the sponsor requirements, the following derived requirements were obtained:

(a) Incorporate into the design necessary operational equipment and monitoring devices to support at sea operations.

(b) Provide necessary support services to the hosted vessel, such as fire prevention and electricity.

(c) Ensure adequate accommodation, sanitation, and messing spaces for additional crew and passengers.

**Major Assumptions**

The following major assumptions were made for this project:

(a) *Montford Point* as Starting Point. The study assumed that the *Montford Point* served as the starting point for the conversion project. The design retained the existing hull form and propulsion system layout, with modifications limited to what was necessary for the mission of lifting and safely transporting a damaged Arleigh-Burke class destroyer.

(b) Limited Changes to Accomodate Mission. It was assumed that changes to the vessel's design were minimal, focusing only on modifications necessary to fulfill the mission (i.e. additional ballasting capability). The number of crew and passengers that can be accommodated will be a consequence of this mission-centric approach.

(c) Commercial Standards for Classification: The study assumed that the heavy lift vessel will be modified to conform to commercial standards, specifically those of the American Bureau of Shipping (ABS). Deviations from commercial standards to U.S. Naval standards were considered in mission-specific areas such as services provided to the hosted vessel.

(d) Exclusion of Secondary Missions. No secondary missions were assumed for the heavy lift vessel (e.g. repair of the damaged vessel during transport). The vessel was tailored exclusively for the mission of lifting and transporting damaged Arleigh-Burke class destroyers.

(e) Simplified Structural Analysis. This study utilized the U.S. Navy's Program of Ship Salvage Engineering (POSSE) in order to conduct a structural analysis for the heavy lift vessel, which incorporates simple beam theory for calculations instead of finite element analysis (FEM) used by other programs like MAESTRO. While not as accurate as FEM, POSSE is used by the U.S. Navy for salvage operations around the world and was thus deemed appropriate to use for the purposes of this project.

These assumptions provided a foundational framework for the study, guiding the overall design process and operational considerations for the conversion of the T-ESD vessel into a heavy lift vessel.

The following margins were considered throughout this project:

(a) Design Margins for New Systems. Design margins of 20% were applied to the new system electrical loads and air conditioning loads associated with systems in the changed regions of the baseline ship. This ensured a margin of safety for the electrical and air conditioning systems affected by modifications.

(b) Ship Weight. A service life allowance of 5% was applied to the ship's weight to accommodate potential changes and additions during its operational life.

(c) Ship Vertical Center of Gravity. An allowance of 0.5 feet was provided for potential variations in the ship's vertical center of gravity over its service life.

(d) Ship Service Electric Load. A service life allowance of 20% will be applied to the ship's service electric load to account for potential changes in electrical demands over time.

These margin considerations provided a safety buffer and flexibility for the heavy lift vessel, accounting for potential variations and ensuring the vessel's robustness over its operational life.

No speed or powering margins were applied since the hull form and propulsion systems were not modified from the baseline T-ESD design. It is acknowledged that the removal of cargo and cargo handling loads may result in a significantly shallower draft.

**Information Resources**

Former NAVSEA 05D (Dr. Norbert Doerry) sponsored this project and provided insight and feedback throughout the design and conversion process. Other representatives from the following organizations were utilized for support as needed:

(a) Military Sealift Command

(b) SUPSALV

(c) NAVSEA 05D, 05C, 05H

**Process Overview**

To begin, a heavy lift analysis was performed using POSSE. Models of the *Montford Point* and an Arleigh-Burke class destroyer were input into the program and the heavy lift sequence was conducted. This analysis was utilized to evaluate the vessel's deck strength during ballasting to a 9m submergence depth, deballasting with the asset on the deck as well as during transit. The analysis included considerations for additional ballasting to achieve the required submergence depth for heavy lift operations. This detailed examination of the *Montford Point*'s ballasting and lifting capabilities revealed critical stress points on the heavy lift vessel's deck, where solutions were proposed in order to distribute the load more evenly during submergence and lifting operations.

Following the heavy lift and deck strength analyses, a detailed approach to sea fastening and block loading was undertaken so as to guarantee the safe transportation of the destroyer by the Montford Point. This included the calculation of dynamic forces due to the vessel's pitch and roll, alongside the expected accelerations, to ensure compliance with the requirements for Sea States 3 and 5, while also preparing for conditions as severe as Sea State 7. The resilience of the sea fastening and block loading systems under these conditions was affirmed through seakeeping analysis with MAXSURF, which verified the vessel's stability and adherence to loading parameters for Sea State 7. This thorough and strategic methodology underscored the commitment to maintaining the vessel's structural integrity and operational safety across a range of sea states.

Finally, additional consideration was given to support services that the destroyer would require during transport to include electricity, sanitation, firefighting, hotel services, etc. All of these areas of study are detailed further in the sections below.

## SECTION 2: BASELINE SHIP AND TARGET CARGO DESCRIPTION

### 2.1 Baseline Ship

*USNS Montford Point (T-ESD 1) was selected for this conversion project. The ship was placed in a reduced operating status in 2022 after several years of inactive service.*

The ship selected for conversion was the *USNS Montford Point* (T-ESD 1). It was constructed in 2013 by General Dynamics NASSCO, based on the hull design of the civilian Alaska-class oiler tanker. The ship was designed to be a versatile, semi-submersible platform which can perform large-scale logistics movements for the U.S. Navy. Its intended purpose was to reduce reliance on foreign ports and enable the seabasing of an amphibious landing force.

*USNS Montford Point demonstrating its capability to support logistics movements and sea base amphibious landing forces.*

*Montford Point*'s sister ship, the *USNS John Glenn* (T-ESD 2), was delivered to the Navy in 2014 but had design changes that reduced its payload capacity to reduce costs. As such, T-ESD 2 was not included in the scope of this project.

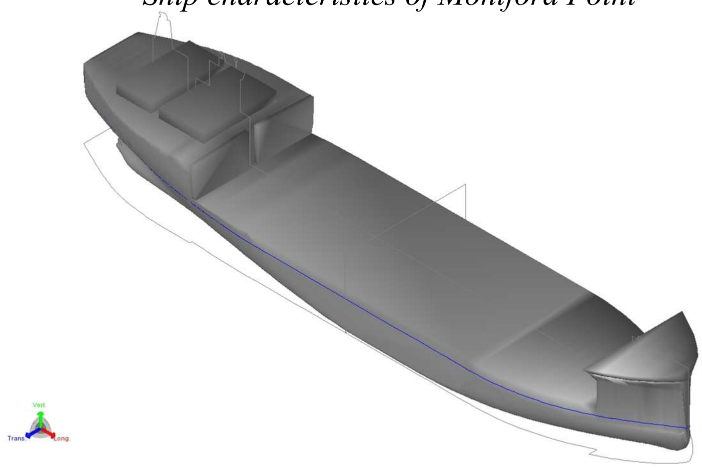
In 2022, after several years of inactive service, the Marine Corps proposed to retire both vessels. Congress, however, rejected this proposal, and the ships were instead placed in a reduced operating status.

The ship characteristics for *Montford Point* are summarized in the table below. These characteristics were determined by data available from the ship's technical drawings and computer aided modeling using POSSE.

| ***USNS Montford Point* Ship Characteristics** | | |
|---|---|---|
| LOA | 239.325 | m |
| LBP | 233.215 | m |
| Beam | 50 | m |
| Moulded Depth to Cargo Deck | 15.468 | m |
| Draft FP | 6.7818 | m |
| Cargo Capacity | 40000 | MT |
| Max Cargo Deck Loading | 20 | $MT/m^2$ |
| Gross Cargo Deck Area | 7490 | $m^2$ |
| Max Submerged Depth of Cargo Deck | 9 | m |
| Trim Limit | 7 | m |
| List Limit | 5 | deg |
| Design Draft | 12 | m |
| Displacement | 107,000 | MT |

| | | |
|---|---|---|
| LCG | 120.045 | m-AP |
| VCG | 9.174 | m-BL |
| KM | 22.837 | m-BL |
| GM | 12.747 | m-BL |

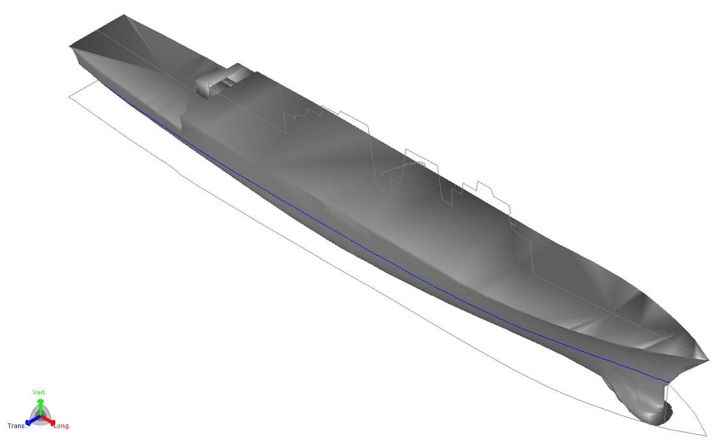
*Ship characteristics of Montford Point*



*3D view of USNS Montford Point POSSE model*

## 2.2 Target Cargo

The target cargo largely influences the design of heavy lift ships. For this conversion project, the target cargo was chosen to be an operational Flight III Arleigh Burke class destroyer. The characteristics of the target cargo is summarized in the table below and determined by data available from the ship class technical drawings and POSSE model.



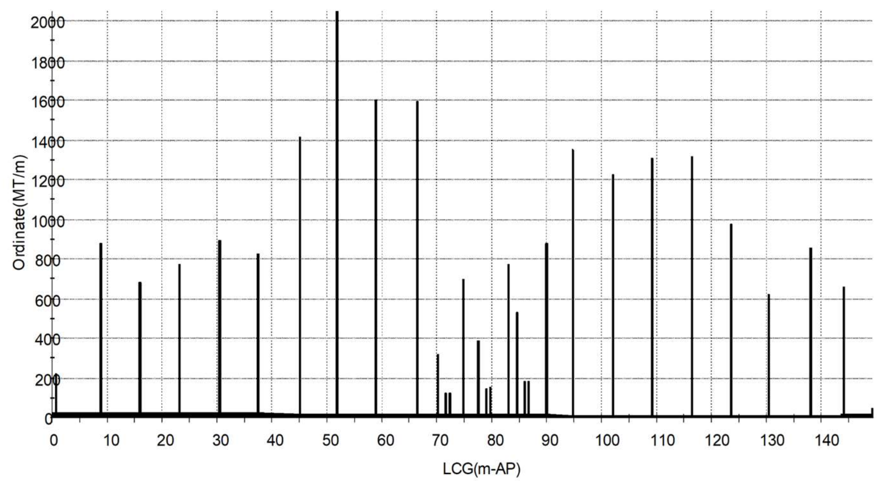
*3D view of target cargo (Flight III Arleigh Burke class destroyer) POSSE model*

| Target Cargo Characteristics<br><br>Flight III Arleigh Burke Class Destroyer | | |
|---|---|---|
| LOA | 155.296 | m |
| LBP | 143.561 | m |
| Beam | 20.269 | m |
| Moulded Depth | 12.497 | m |
| Draft FP | 6.782 | m |
| Draft MS | 6.654 | m |
| Draft AP | 6.523 | m |
| Trim at Perpendiculars | 0.259 | m |
| Heel Angle | 0.000 | deg |
| Displacement | 9259.264 | MT |
| LCG | 71.476 | m-AP |
| VCG | 7.925 | m-BL |
| KM | 8.912 | m |
| GM | 0.988 | m |
| LCB | 71.274 | m-AP |
| LCF | 64.797 | m-AP |
| Draft LCF | 6.642 | m |

| | | |
|---|---|---|
| Wind Area | 2362.746 | m |
| Wind Area VCG | 9.254 | m-BL |
| Projection Sonar Dome | 9.830 | m |
| Projection Propellers | 8.047 | m |

*Target cargo characteristics (operational Flight III Arleigh Burke Class Destroyer)*

The target cargo’s longitudinal weight distribution was based on the available lightship weight information of a Flight I Arleigh Burke class destroyer. A 2,157 MT additional load was evenly distributed to achieve a full load total weight of 9,260 MT, consistent with that of an operational Flight III Arleigh Burke destroyer. This weight distribution results in a LCG of 71.476 m forward of the aft perpendicular (AP). A VCG equal to 7.925 m above baseline was conservatively selected based on Flight I VCG data. By modeling the target cargo in POSSE, drafts at the forward and aft perpendiculars of 6.782 m and 6.523 m, respectively, were obtained with a 0 degree list.




*Longitudinal weight distribution of target cargo*

For comparison, the *USS Cole* (DDG 67) after being badly damaged off the coast of Yemen in 2000 was recorded as having a displacement of 8,316 MT, a VCG of 7.379 m, and forward and aft drafts of 8.077 m and 6.706 m, respectively. Prior to being loaded onto the Blue Marlin for transport, the ship’s list was reduced to 1 degree and the heavy lift vessel adjusted its trim and list to align with the *Cole*’s keel. The table below summarizes the differences between the selected target cargo for this project and the damaged *USS Cole* prior to being docked onto a heavy lift vessel.

| | **Displacement [MT]** | **VCG [m]** | **Forward Draft [m]** | **Aft Draft [m]** | **List [deg]** |
|---|---|---|---|---|---|
| Target Cargo (As Modeled) | 9260 | 7.925 | 6.782 | 6.523 | 0 |
| Damaged USS Cole (DDG 67) | 8,316 | 7.379 | 8.077 | 6.706 | 1 |

*Comparison between target cargo and damaged USS Cole (DDG 67)*

*USS Cole after sustaining bomb damage off the coast of Yemen in 2000.*

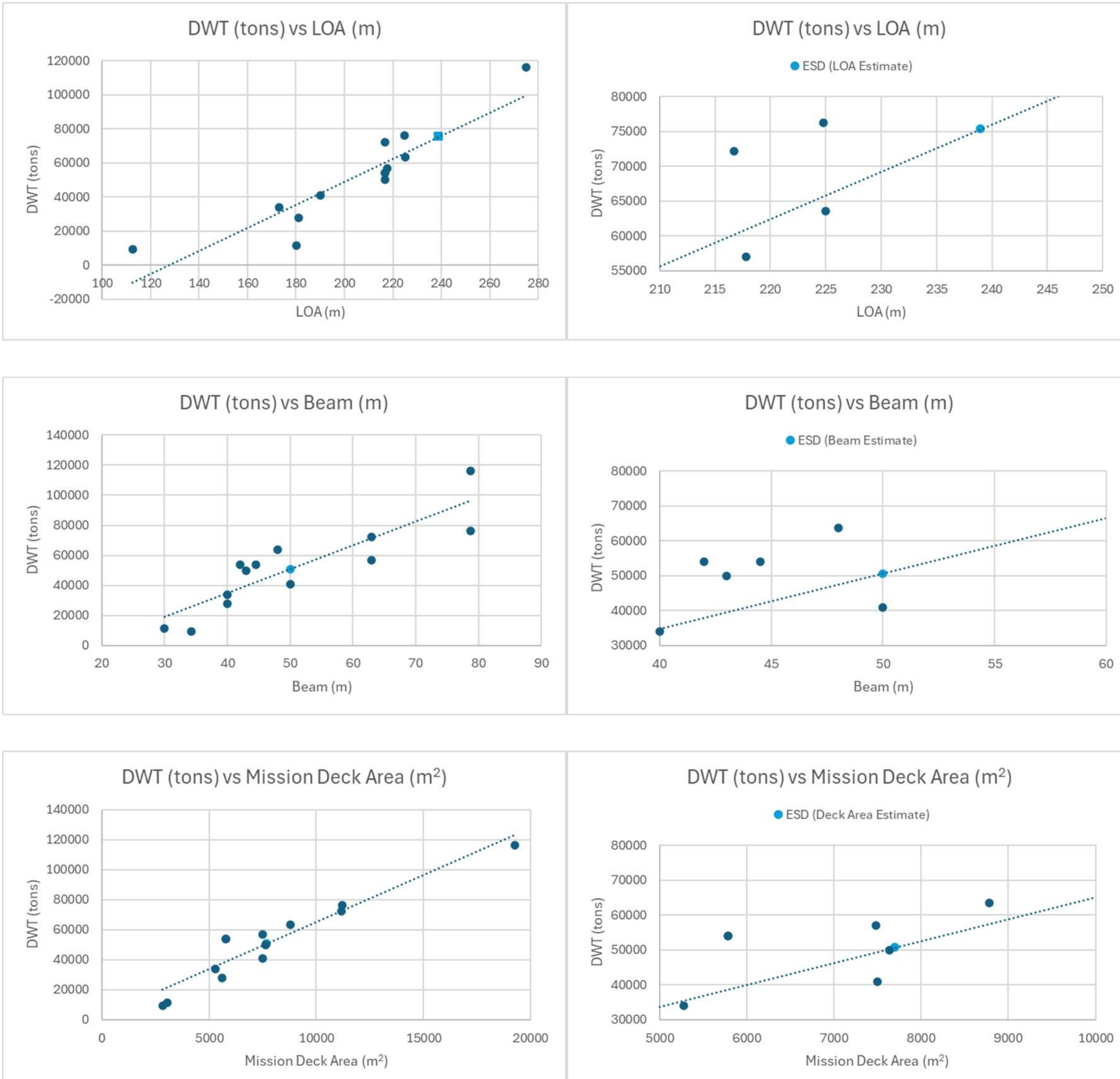
## SECTION 3: CONCEPT DEFINITION AND FEASIBILITY ANALYSES

### 3.1 Gross Assessment of Lifting Capacity Using Comparative Naval Architecture

Early in the project, a gross assessment of the *Montford Point*'s deadweight tonnage (DWT) was made using comparative naval architecture techniques to get a sense of its overall lifting capacity. Using the ship characteristics of 13 heavy lift ships, three estimates of *Montford Point*'s DWT were calculated based on its LOA, beam, and cargo deck area. The results of these estimates indicated that the DWT fell between 50,000 and 75,000 tons and was sufficiently adequate to accommodate the lift of a target cargo of approximately 10,000 tons, assuming sufficient deck strength. The table below provides a summary of *Montford Point*'s estimated DWT.

| Company Name | Vessel Name | LOA [m] | Beam [m] | Mission Deck Area [$m^2$] | DWT LOA Estimate [tons] | DWT Beam Estimate [tons] | DWT Cargo Deck Estimate [tons] |
|---|---|---|---|---|---|---|---|
| USNS | Montford Point (T-ESD 1) | 239 | 50 | 7,700 | 75311 | 50,651 | 50,647 |

*Using comparative naval architecture techniques, Montford Point's DWT was estimated to be between 50,000 and 75,000 tons, indicating adequacy for 10,000 ton target cargo.*




*Scatter plots of heavy lift vessels used to interpolate Montford Point's DWT*

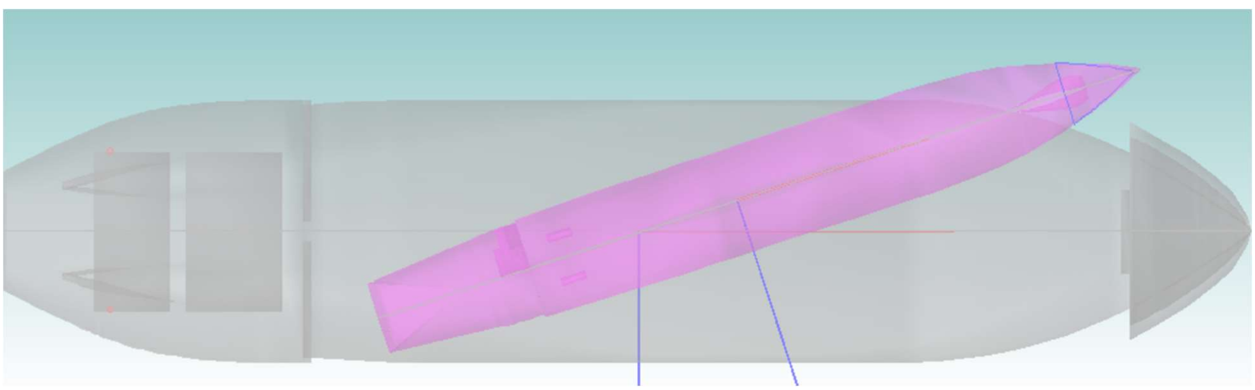
| Company Name | Vessel Name | LOA [m] | Beam [m] | Mission Deck Area [$m^2$] | DWT [tons] |
|---|---|---|---|---|---|
| Eide Marine Engineering | TRADER | 113 | 34 | 2,844 | 9,424 |
| Boskalis | TRANSSHELF | 173 | 40 | 5,280 | 34,030 |
| Eide Marine Engineering | TRANSPORTER | 180 | 30 | 3,060 | 11,435 |
| Boskalis | MIGHTY SERVANT 3 | 181 | 40 | 5,600 | 27,720 |
| Boskalis | MIGHTY SERVANT 1 | 190 | 50 | 7,500 | 40,910 |
| Boskalis | WHITE MARLIN | 217 | 63 | 11,189 | 72,146 |
| Boskalis | FORTE | 217 | 43 | 7,637 | 50,000 |
| Boskalis | TRIUMPH | 217 | 42 | 5,785 | 54,000 |
| Boskalis | TRUSTEE | 217 | 45 | 5,785 | 54,000 |
| Boskalis | BLACK MARLIN | 218 | 63 | 7,484 | 57,021 |
| Boskalis | BLUE MARLIN | 225 | 79 | 11,227 | 76,292 |
| GPO Heavy Lift | GRACE | 225 | 48 | 87,84 | 63,581 |
| Boskalis | BOKA VANGUARD | 275 | 79 | 19,250 | 116,175 |

*Heavy lift ship data used to estimate Montford Point's DWT using comparative naval architecture techniques*

## 3.2 Target Cargo Docking Arrangement

Although designed to ballast down to allow for 5 m above the cargo deck, with fixed ballast installed the *Montford Point* can achieve a depth of 9 m above the deck. Due to the target cargo's sonar dome having a projection of 9.83 m, a canted docking arrangement with the sonar dome hanging over the side of the *Montford Point* would be required. Furthermore, with the target cargo's propellers having a projection of 8.047 m and assuming for at least 0.3 m (1 ft) of clearance, the docking plan would be restricted to a maximum block height of 0.65 m. However, without removing the target cargo's propellers before docking or canting the cargo sufficiently that the propellers overhang the side of the *Montford Point*, they will interfere with the cargo deck, even with the aforementioned maximum block height. Removing the propellers from the target cargo was not considered due to the expediency desired for docking a damaged warship. Having both the sonar dome and propellers hanging over the side of *Montford Point* was undesirable due to the large cant angle required resulting in abnormal accelerations on the cargo during transport, reduced keel block area afforded for distributing loading across the cargo deck, and potential difficulties in longitudinal traversing of the cargo deck. This issue, however, can be remedied using propeller pits by making cuts in the cargo deck, ensuring no significant structural interference. This option was selected for further analysis due to *Montford Point* having a simple, segregated, upper ballast tank in the anticipated region that appeared promising for such a modification. With an estimated block height of 0.5738 m, the propeller would project approximately 0.95 m beneath the cargo deck and into the upper ballast tank. Because the upper ballast tank has a distance of 1.824 m from its bottom deck to the cargo deck, the arrangement would be sufficiently adequate.

To determine the cargo's cant angle and location on the *Montfort Point*, models based on respective ship drawings were used. Careful consideration was given to ensure that no interference would occur between the overhanging sonar dome and *Montford Point*'s hull, in which case the propeller pits would be roughly centered on the starboard half of the upper ballast tank SWB 3-65-0. Additionally, the length available for keel blocks was maximized to reduce deck loading. Ultimately, the team opted for a 18 degree cant angle to port with the point marking the midsection and centerline of the cargo at 18.851 m forward of *Montford Point*'s midsection and 5.745 m port of centerline.



*POSSE model showing desired docking arrangement*

For comparison, the docking arrangements for U.S. warships that were transported via heavy lift ships were reviewed. The intended docking arrangement most closely resembled that of the MV Blue Marlin when it transported the *USS Cole* in 2000, having a 17 degree cargo cant angle, a slightly greater deck strength (27.5 $MT/m^2$), similar physical dimensions, and propeller pits cut into the cargo deck.

*USS Samuel B. Roberts, USS Cole, USS McCain, and USS Fitzgerald (from left to right) transported via heavy lift ships after sustaining damage at sea .*

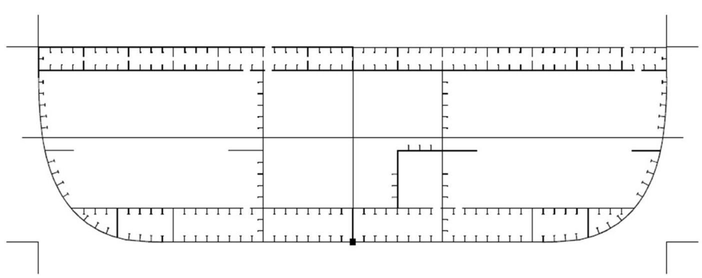
| U.S. Warships Transported via Heavy Lift Vessels | | | | | |
|---|---|---|---|---|---|
| **Year** | **Warship** | **Location** | **Nature of Damage** | **Heavy Lift Vessel** | **Cargo Cant Angle [deg]** |
| 1988 | USS Samuel B. Roberts (FFG 58) | Persian Gulf | Mine | Mighty Servant 2 | 0 |
| 2000 | USS Cole (DDG 67) | Aden, Yemen | Bomb | MV Blue Marlin | 17 |
| 2017 | USS John S. McCain (DDG 56) | Singapore | Collision | MV Treasure | 22 |
| 2017 | USS Fitzgerald (DDG 62) | Yokosuka, Japan | Collision | MV Transhelf | 0 |

*Summary of U.S. warships transported via heavy lift vessels*

### 3.3 Lifting Analysis

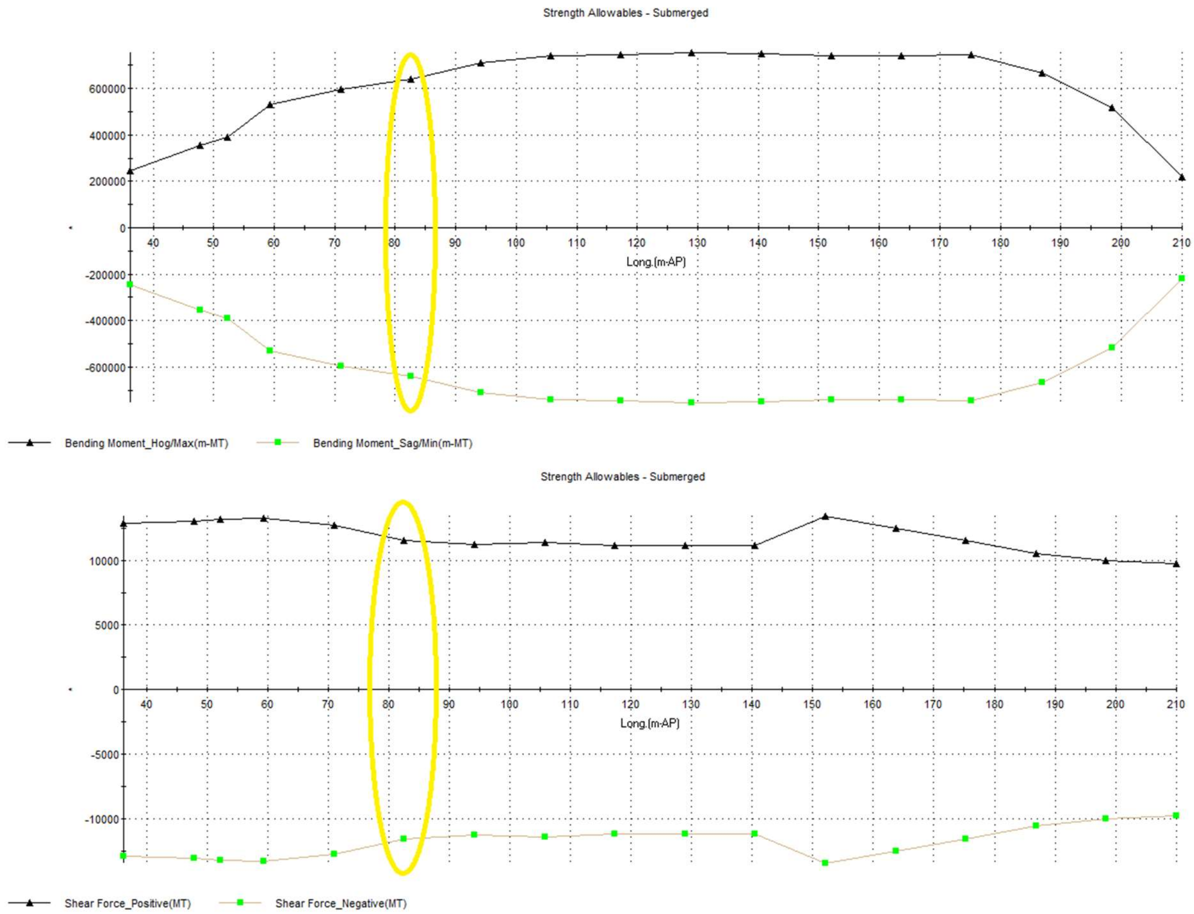
### 3.3.1 POSSE Model for Heavy Lift

To analyze the *Montford Point* for lifting conditions, the POSSE model of the ship was used. To accurately account for the strength of the ship in the condition it would be subjected to, the strength stations of the model were updated to account for deck cuts made for propeller pits.



*Station 13 Section*

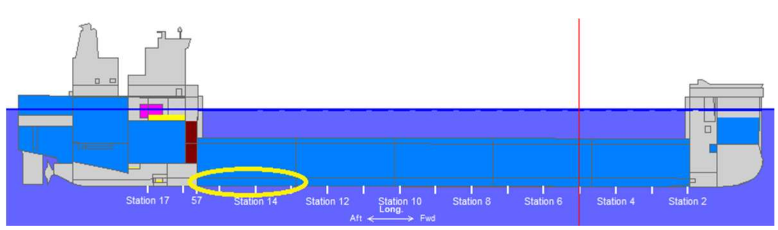
Given the geometry of the lift, the screw placement was determined to be in strength station 13 of the POSSE model. This station was conservatively modified to account for this by removing two 3 m sections from the mission deck structure. The cuts accounted for 4.6% of the total section area, and 6.2% of the section moment of inertia about the horizontal axis. The resulting allowable shear and bending stresses can be seen below. All subsequent stress plots are expressed as a percentage of these allowable values.




*Strength allowables with propeller pit cuts in station 13*

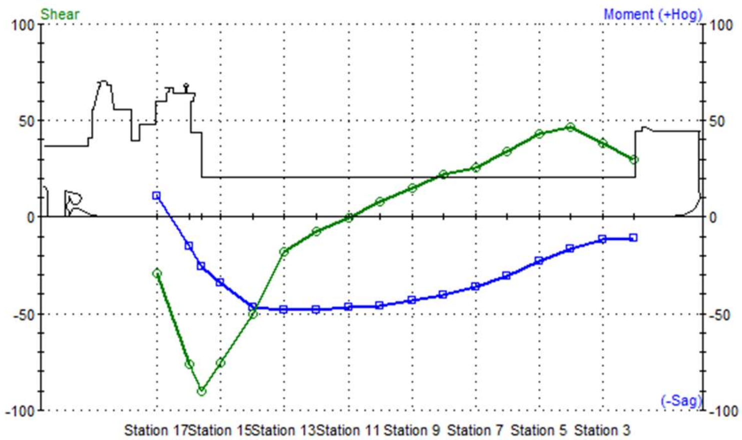
### 3.3.2 Ballasting Plan Analysis

The seawater ballast tanks of the vessel alone will not provide sufficient weight to submerge the mission deck low enough for the target cargo to be floated on. With all ballast tanks 100% full, the Montfort Point's cargo deck is limited to a 7 m submergence. In order to submerge the vessel to the required depth for a target cargo heavy lift, additional fixed ballast must be used. The ballasting plan included a 9 m submergence depth plan, where 13,208 MT of fixed ballast is loaded into the bottom tanks in the aft most section of the mission deck.



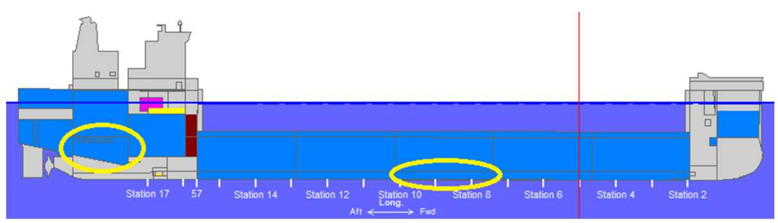

*Profile view of Montford Point at 9m submergence with fixed ballast locations per ballasting plan identified*

The 9 m ballasting plan was assessed in POSSE at all critical points during the submergence and subsequent lift. The most limiting condition during the ballasting was found to be when the vessel is at the full 9 m submergence depth, where the shear stress peaks at the joint between the buoyant aft structure and ballasted cargo deck.



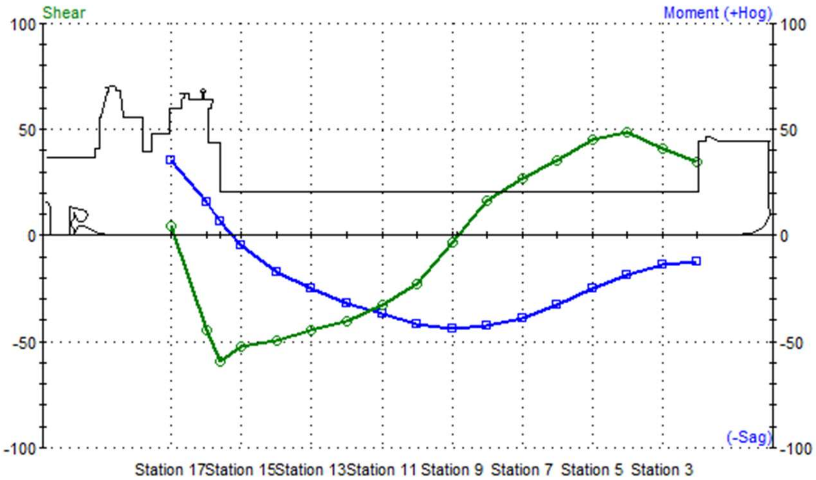

*9 m submergence percent allowable shear and moment from ballast plan*

The shear stress at frame 57, while acceptable in the current condition of the *Montford Point*, was at 86% of the allowable. Exploring the relocation of ballast to two longitudinal locations on the ship, as demonstrated in the figure below, was found to effectively even out the loading during submergence and reduce the shear loading on the ship to approximately 60%.




*Profile view of 9 m submergence with distributed fixed ballast*

The figure above shows the fixed ballast split with 7,162 MT beneath the center of the cargo deck, and 6,046 MT in aft ballast tanks. This is possible in many configurations, with any weight placed under the aft structure increasing the margin to limiting shear loading. The figure below shows the loading in this configuration.




*9 m submergence percent allowable shear and moment with distributed ballast*

Relocating the fixed ballast presents multiple trade-offs, including stress reduction without incurring additional costs, an increase in the ship's Vertical Center of Gravity (VCG) due to the aft tanks being higher than those on the inner bottom mission deck, and limits using additional tanks as movable ballast.

### 3.3.3 Ballasting Time Requirements

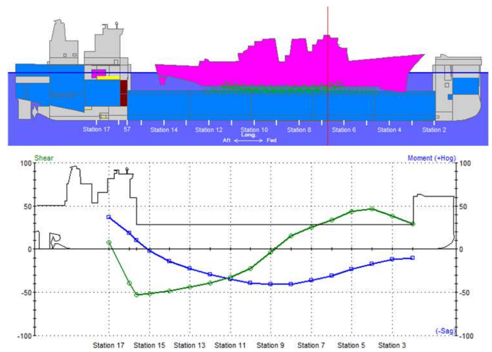
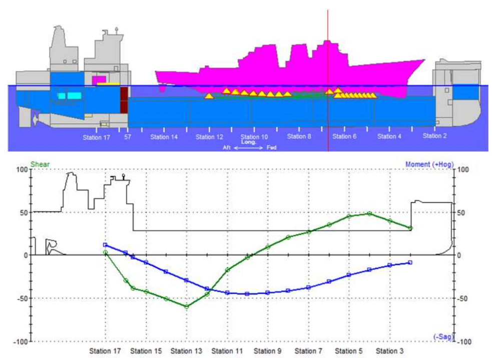
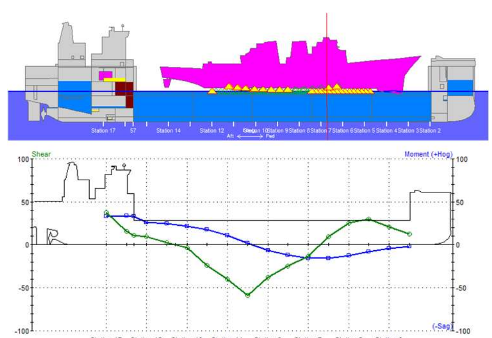
The full ballasting of the ship from the transit condition to reach the 9 meter submergence depth takes 21.4 hours of continuous pumping operation. To de-ballast the ship and lift the DDG, another 20.9 hours of pumping are required. This would suggest a three day timeline to submerge, place, and lift a DDG. With weather windows and other operational requirements it would be beneficial to reduce these times. Of note, Lamb’s chapter 52 suggests a time of no more than 16 hours for the entire time to ballast down and de-ballast heavy lift ships. With a faster lift, risk is greatly reduced. 16 hours would allow the entire evolution to be complete within a single day.

After the team’s visit to the ship and discussion with the crew, it was discovered that these ballasting times are limited by issues with the ballast tank venting systems, specifically the venting pipes diameters. A proposal has already been submitted to update the venting system, which will reduce the ballasting time by improving the venting capabilities of the ship.

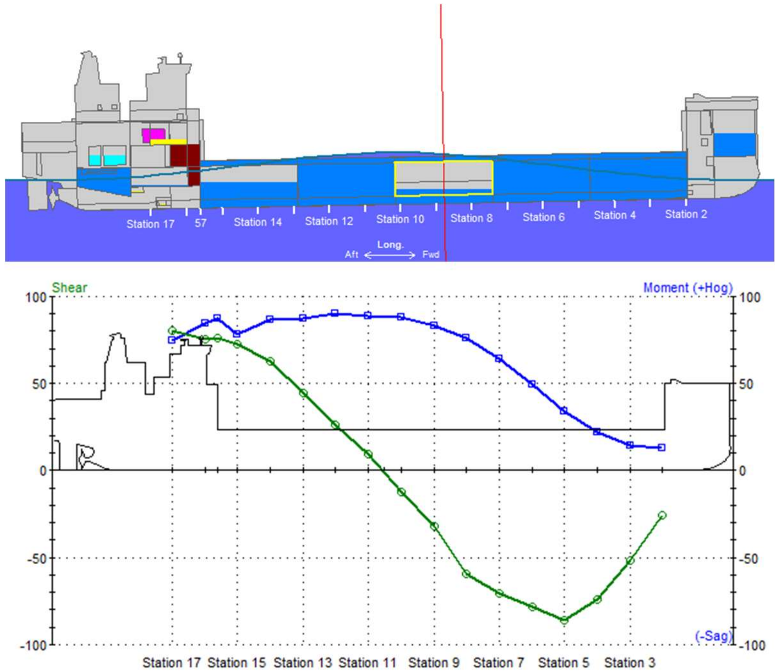
### 3.3.4 Lifting Strength Analysis

The lift was modeled in POSSE at important points during the lift sequence to ensure adequate stability and strength throughout the lifting process. To prove adequacy for all conditions, the lift was modeled with a block height of 0.57 m with the target cargo.

While the lift of the target cargo does affect the stress on the Montford Point’s hull, the resulting stresses are impacted more by the planning and operation of the ballast tanks. The total weight of target cargo lifted is on the same order of magnitude as a single ballast tank filled with seawater. A summary of strength conditions at various deck submergence depths is shown below.

| Deck Submergence | Rendering and Stress Plot | Summary |
|---|---|---|
| Full Submergence (9 meters) |  | GM: 2.2 meters<br>Max Shear: 53%<br>Max Bending: 41% |
| Initial Loading (5.5 meters) |  | GM: 1.7 meters<br>Max Shear: 60%<br>Max Bending: 45% |
| Least Stability (0.1 meters) |  | GM: 1.1 meters<br>Max Shear: 58%<br>Max Bending: 34% |
| Full Lift (-3.2 meters) |  | GM: 11.5 meters<br>Max Shear: 61%<br>Max Bending: 64% |

The transit condition of *Montford Point* with fixed ballast installed was analyzed in POSSE for hogging and sagging conditions using the 9.27 m wave derived from the ship's length. These conditions were analyzed both with and without the target cargo loading present, in the transiting condition. The most limiting condition was found to be when *Montford Point* is transiting, unloaded, with fixed ballast installed, with a standard hogging wave. This most limiting condition shown below presented the ship with a max shear stress of 86% and max bending of 90% of their allowable values. The stress of this condition can be reduced by further ballasting, with a tradeoff between draft and stress.




*Loaded Hogging Analysis*

### 3.4 Keel Blocks Sizing and Deck Strength

Although the cargo capacity of the *Montford Point* is 40,000 MT, more than four times that of the target cargo, deck strength limits must also be considered. *Montford Point*'s max cargo deck loading is 20 $MT/m^2$. The blockable length of the cargo extends from just aft of the sonar dome to about frame 385, where the skeg begins. The required block widths to achieve a 20 $MT/m^2$ loading on the *Montford Point*'s cargo deck were calculated in POSSE and can be seen in the table below. The maximum block width to accommodate a destroyer at full load is 5.21 m located by the skeg. By assuming standard side blocks placed 3.429 m off of the centerline, a max block width of 6.096 m can be achieved. Therefore, the required blocking widths are feasible. By assuming a continuous blocking scheme with a block system length of 97 m, maximizing block widths where possible, and a conservative full load cargo of 10,000 MT with side blocks assuming no load, approximately 572 $m^2$ of weight distributing area can be achieved, resulting in average deck pressure of 17.5 $MT/m^2$. Therefore, the intended block arrangement is adequate and deck strengthening initiatives are not necessary.

| Required Blocking Width [m] | | | |
|---|---|---|---|
| Frame Number | Full Load | Half Load | Lightship |

| | | | |
|---|---|---|---|
| 65 | 4.05 | 3.72 | 3.23 |
| 85 | 4.11 | 3.78 | 3.29 |
| 105 | 4.21 | 3.87 | 3.35 |
| 125 | 4.27 | 3.93 | 3.41 |
| 145 | 4.33 | 3.99 | 3.47 |
| 165 | 4.42 | 4.08 | 3.54 |
| 185 | 4.48 | 4.15 | 3.60 |
| 205 | 4.54 | 4.24 | 3.66 |
| 225 | 4.63 | 4.30 | 3.72 |
| 245 | 4.69 | 4.39 | 3.78 |
| 265 | 4.79 | 4.45 | 3.84 |
| 285 | 4.85 | 4.54 | 3.90 |
| 305 | 4.91 | 4.60 | 3.96 |
| 325 | 5.00 | 4.69 | 4.02 |
| 345 | 5.06 | 4.75 | 4.08 |
| 365 | 5.15 | 4.82 | 4.15 |
| 385 | 5.21 | 4.91 | 4.24 |

*Required blocking widths to achieve a maximum 20 $MT/m^2$ loading on the Montford Point's cargo deck*

### 3.5 Block Loading and Seakeeping Analysis

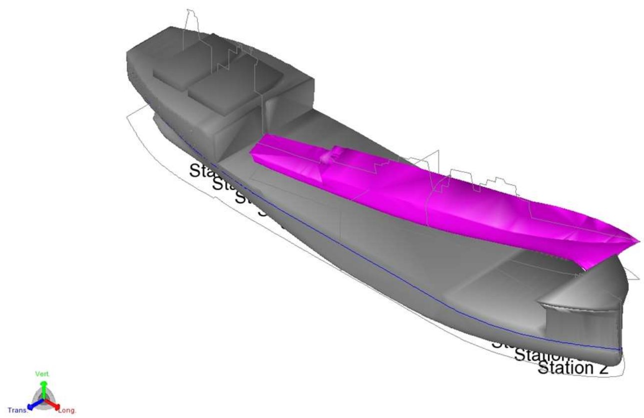
To ensure safe and secure transportation of the target cargo and *Montfort Point*, it was imperative to implement proper sea fastening and block loading. The design of sea fastening is done by calculating load forces that account for the vessel's roll and pitch movements. The U.S. Navy has developed a set of formulas to accurately assess these dynamic forces, which are outlined in DOD-STD-1399-301A, Ship Motion and Attitude. These equations integrate the impact of dynamic motion with the static force exerted by the cargo's weight to derive a comprehensive load factor. Notably, these formulas employ predetermined maximum values for roll and pitch in various sea states to estimate the forces involved.

The stress exerted on the blocks and sea fastening systems are influenced by both the loading state of the asset and the dynamic movements of the loaded heavy lift vessel. To accurately assess the stress levels on the blocks and sea fasteners during transit, an examination of these motions was required. To accommodate the possibility of encountering short-term periods of unexpectedly higher wave heights during transport, a dynamic analysis was conducted for a sea state two levels higher than the predicted maximum. As outlined in Section 1.2, Sea States 3 and 5 were set as the threshold and objective requirements, respectively, for safe transport. To adhere to these standards, the block loading and sea fastening systems were engineered to withstand all expected accelerations in conditions up to Sea State 7 (9m significant wave height), thereby ensuring they exceeded the necessary requirements for stability and safety. This approach ensures preparedness for variations in sea conditions beyond the threshold and objective requirements. It should be noted that reduced stresses can and should be achieved with sound voyage planning. Using POSSE to model *Montford Point* transporting the target cargo, several important parameters were determined and are summarized in the table below.

| **Characteristics of Montford Point while Transporting Target Cargo** | | |
|---|---|---|
| MS Draft | 38.41 | ft |
| Displacement | 100,270 | LT |
| VCG | 33.49 | ft-BL |
| LCG | 393.09 | ft-AP |
| TCG | 0.04 | STBD ft-CL |
| GM | 40.33 | ft |
| Roll Period ($T_R$) | 10.33 | s |
| Distance between Cargo and Heavy Lift Vessel VCG (z) | 20.71 | ft |
| Distance between Cargo and Heavy Lift Vessel LCG (x) | 53.05 | ft |

| | | |
|---|---|---|
| Distance between Cargo and Heavy Lift Vessel TCG (y) | 20.86 | ft |

*Characteristics of Montford Point while transporting target cargo used to determine keel block stresses*



*3D view of USNS Montford Point transporting target cargo*

Data tables and equations from DOD-STD-1399-301A provided the basis for analyzing the ship motions specific to the loaded heavy lift vessel in Sea State 7. Additionally, the MAXSURF software suite was employed to validate these assessments, ensuring a comprehensive understanding of the stress dynamics at play.

| **Sea State Wave Heights for Dynamic Loading** | |
|---|---|
| **Sea State Number** | **Significant Wave Height [m]** |
| 1 | 0.1 |
| 2 | 0.5 |
| 3 | 1.25 |
| 4 | 2.5 |
| 5 | 4 |
| 6 | 6 |

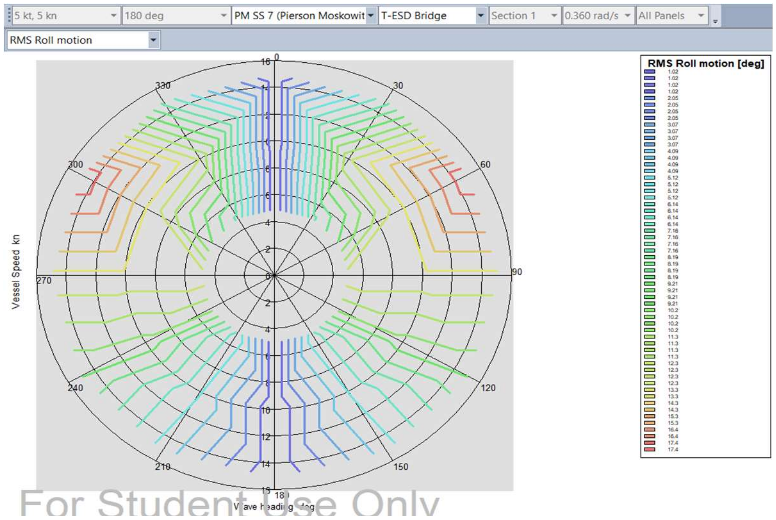
| | |
|---|---|
| 7 | 9 |
| 8 | 14 |

*Sea States and corresponding significant wave heights as defined in DOD-STD-1399-301A*

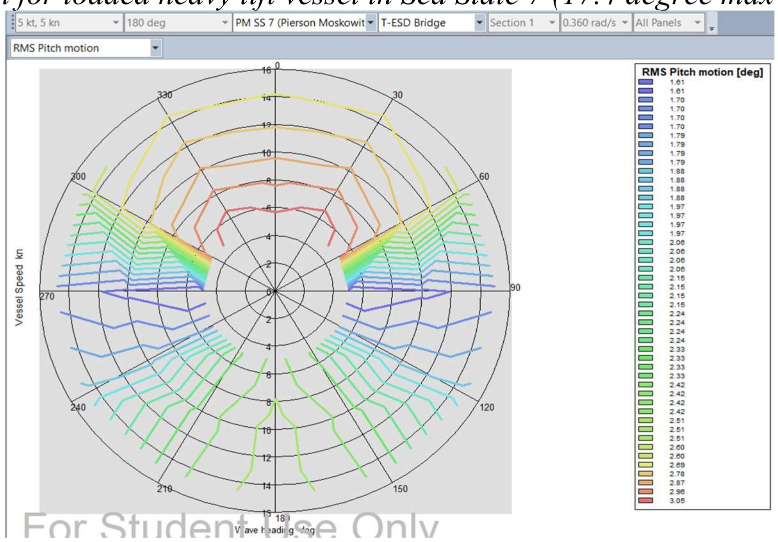
| Sea State 7 Ship Motion Parameters for Dynamic Loading | | |
|---|---|---|
| (For Ships with LBP Greater than 213 m) | | |
| Heave Acceleration (h) | 0.2 | g |
| Pitch Angle (P) | 3 | deg |
| Pitch Period ($T_P$) | 8 | s |
| Roll Angle (R) | 20 | deg |

*Relevant ship motion parameters for dynamic loading for Sea State 7 as defined in DOD-STD-1399-301A*

After inputting the loaded heavy lift vessel into MAXSURF and running the seakeeping analysis for Sea State 7, polar plots were generated. The wave heading angle is given as the angle around the plot, the radius of the polar plot represents the speed of the ship, and the color of the lines represent the magnitude of the root mean squared (RMS) response (responses being roll angle, pitch angle or acceleration). The polar plots generated from MAXSURF illustrate the loaded heavy lift vessel's roll angle to be 17.4° and the pitch angle to be 3.05° in Sea State 7, validating the above table's motion parameters. These plots are shown in the figures below.




*Roll motion for loaded heavy lift vessel in Sea State 7 (17.4 degree max roll angle)*




*Pitch ship motion analysis for loaded heavy lift vessel in Sea State 7 (3 degree max pitch angle)*

After identifying the ship's motions in Sea State 7, the acceleration factors arising from these movements must be calculated in order to understand the dynamic forces at play during the vessel's operation. The following equations from DOD-STD-1399-301A were used to determine the vertical and athwartships/lateral acceleration factors on the loaded heavy lift vessel during Sea State 7:

$$\mathbf{a_z = 1 + h + 0.214\ P\ x\ T_P^{-2} + 0.0214\ R\ y\ T_R^{-2}}$$

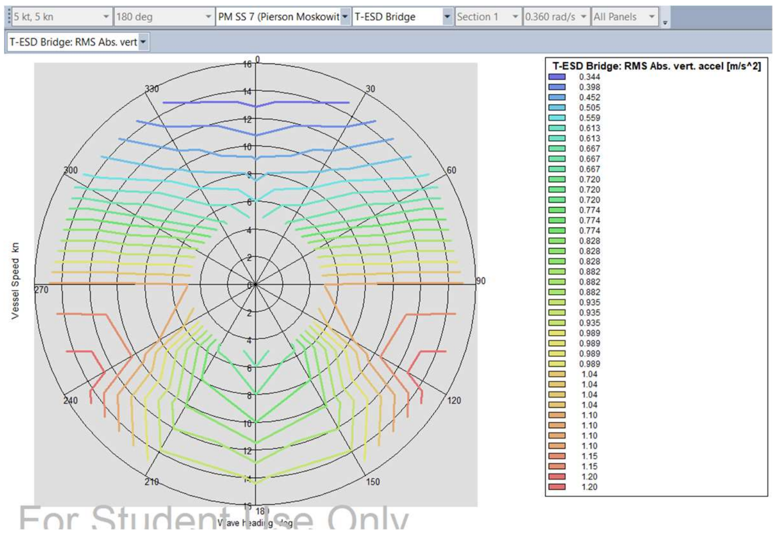
$$a_z = 1.38\ g$$

where:

| | | |
|---|---|---|
| $a_z$ | = | vertical acceleration factor [g] |
| h | = | heave acceleration [g] |
| P | = | maximum angle of pitch [degrees] |
| x | = | distance of center of gravity of asset forward or aft from center of gravity of heavy lift vessel [ft] |

R = maximum angle of roll [degrees]
y = distance of asset off centerline of heavy lift vessel [ft]
$T_P$ = period of pitch [s]
$T_R$ = period of roll [s]

The vertical acceleration factor ($a_z$) was calculated to be 1.38 g. The following plot from MAXSURF Motions, shown below, shows the maximum acceleration experienced during Sea State 7 for the loaded heavy lift vessel is 1.20, validating the calculation.




*Vertical ship acceleration ship motion analysis for loaded vessel in Sea State 7 with max value of 1.20 g, validating the 1.38 g calculated using equations in DOD-STD-1399-301A and conservatively selected for subsequent analysis*

By selecting the more conservative vertical acceleration of 1.38 g, the maximum dynamic loading ($DL_K$) on the keel blocks could be calculated, using the equation below.

$$\mathbf{DL_K = w\ a_z}$$

$$DL_K = 12{,}542 \text{ LT}$$

where:

w = Cargo weight in long tons (9,113 LT)

By modeling the weight distribution of the cargo using the trapezoidal approximation method, the maximum (LoadMax) and minimum (LoadMin) loads were calculated using the equations below.

$$\mathbf{LoadMax = DL_K\ L_K^{-1}\ (1 + A\ B^{-1})}$$

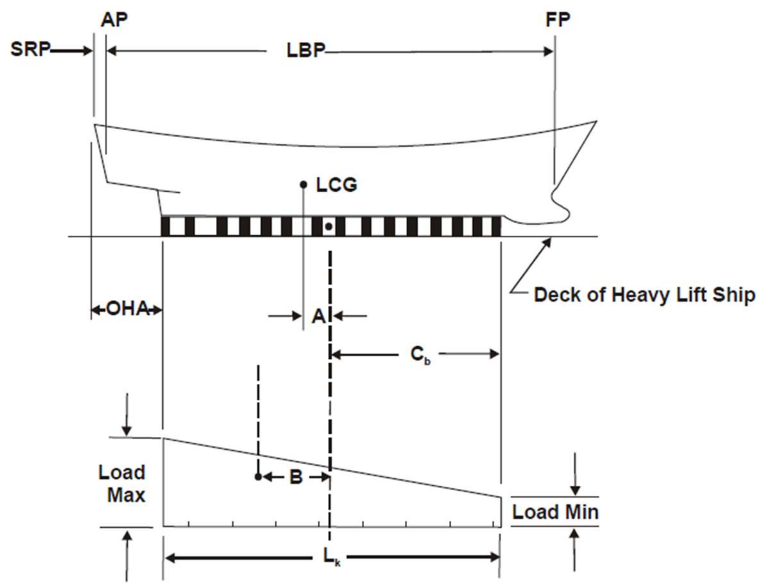
$$LoadMax = 47.67 \text{ LT/ft}$$

$$\mathbf{LoadMin = DL_K\ L_K^{-1}\ (1 - A\ B^{-1})}$$

$$LoadMin = 31.17 \text{ LT/ft}$$

where:

$L_K$ = Length of keel blocking (318.2 ft)
A = Distance from the cargo's LCG to center of blocking (11.1 ft)
B = Approximate center of trapezoidal weight distribution ($L_K/6$ = 53.0 ft)




*Graphical representation of weight distribution using trapezoidal approximation method*

To calculate the maximum stress (S) on the last section of keel blocking, the following equation was used.

$$S = LoadMax / A_e \cdot (2240\ \text{lb/LT})$$

where:

$A_e$ = Effective block area in square inches

Three effective block areas were used to get a sense of maximum stress experienced by the keel blocks. The first was based on effective block dimensions of 36" x 12" (432 $in^2$). For this effective block area, an effective block width of 36" was selected due to this value being the width of the target cargo keel for the majority of its length. The second was based on effective block dimensions of 18" x 12" (216 $in^2$). For this effective block area, an effective block width of 18" was selected due to this value being the width of the target cargo keel towards the end of the skeg. The third was based on effective block dimensions of 234" x 12" (2808 $in^2$). For this effective block area, it was assumed that steel plates were installed on top of the keel block to effectively distribute weight across an 19.5 ft wide keel block (the maximum keel block size accounting for 2 ft x 3 ft side blocks located 11.25 ft off centerline per class docking drawing). The results are summarized in the table below.

| Case Description | $A_e$ [in$^2$] | S [psi] |
|---|---|---|
| 36" Keel Width (Majority of Length) | 432 | 247 |
| 18" Keel Width (Near Skeg) | 216 | 494 |
| Steel Plate Installed (Maximum Keel Block Width) | 2808 | 38 |

*Summary of maximum keel block stresses based on effective block area*

Because the compressive limit of Douglas Fir (a commonly used blocking material) is 370 psi, steel plates should be incorporated into the keel block design to reduce maximum stresses near the cargo's skeg. Additional techniques for reducing maximum stresses include changing block locations such that the end of the cargo skeg lands over a transverse bulkhead and use of spreader beams to spread the load.

*Keel block arrangement with steel cap over soft wood used for transport of USS John S. McCain (DDG 56) aboard MV Treasure*

The max cargo deck loading limit of 20 MT/m$^2$ was also reconsidered based on the vertical dynamic loading under worst case transit. A dynamic load of 12,743 MT distributed across a 572 m$^2$ keel block arrangement will result in cargo deck loading of 22.3 MT/m$^2$, exceeding the limit. However, this loading condition is momentary in nature and does not account for any side block loading. Assuming side blocks support 10% of cargo load, then the deck loading limit will not be exceeded. This assumption is reasonable as side blocks tend to carry about 15% of total weight in practice.

### 3.6 Side Blocks and Sea Fastening

Calculating the number of side blocks required was performed in two steps. The first step determined the minimum number of side blocks required for docking the cargo. The second step determined the number required for transit.

To determine the number of side blocks for docking, the dead load was first considered. The dead load was assumed to consist of two components, the static vertical load ($DL_s$), estimated at 15% cargo load, and an additional load due to heels and rolls during docking ($DL_r$). A worst case environment of Sea State 4 was assumed for docking the vessel and a 5 degree roll amplitude for the *Montford Point* was considered (as defined by DOD-STD-1399-301A for a ship with LBP greater than 213 m). Additionally, the target cargo was assumed to be at a 2 degree list to account for possible damage, resulting in a 7 degree worst case roll amplitude (θ) which was used for calculations. Standard side block dimensions of 2 ft x 3ft made predominantly of Douglas Fir were also assumed. The equations below were used to calculate the number of side blocks needed to support the cargo dead load ($N_d$).

$$\mathbf{DL_s = 0.5 \cdot 0.15 \cdot w}$$

$$DL_s = 683.5 \text{ LT per side}$$

where:

w = Cargo weight (9113 LT)

$$\mathbf{DL_r = w \, Sin(\theta)}$$

$$DL_r = 1{,}110.6 \text{ LT per side}$$

where:

θ = 7 deg

$$\mathbf{N_d = (DL_s + DL_r) / (S_p \cdot A_e)}$$

$$N_d = 5.8$$

where:

$S_p$ = 800 psi (Douglas Fir)
$A_e$ = 24” x 36” = 864 in$^2$

Next, the number of blocks needed for wind loading ($N_w$) and dynamic loads from ship motions during transit ($N_r$) were calculated.

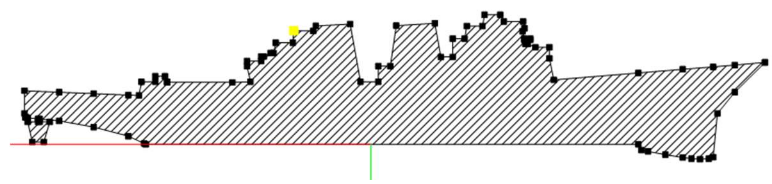
The moment from the wind forces was found using a standard 86.8 knot wind speed, multiplied by a gust factor of 1.21, resulting in speeds of 105 knots during transit. The POSSE model of the target cargo was used to determine its cross sectional area presented to beam winds ($A_s$) and moment arm from the deck of the *Montford Point* to the center of the projected area ($L_3$). The moment from the wind forces was calculated using the following equation.

$$\mathbf{M_w = 0.004\ A_s\ L_3\ V^2}$$

$$M_w = 34{,}068{,}993 \text{ ft-lbs}$$

where:

| | | |
|---|---|---|
| $A_s$ | = | 25432.4 $ft^2$ |
| $L_3$ | = | 30.36 ft |
| $V^2$ | = | 105 knots |



*POSSE model used to determine cargo's cross sectional area presented to beam winds and moment arm from Montford Point's Deck to center of projected area*

The number of side blocks needed for wind loading was then calculated using the following equation.

$$\mathbf{N_w = M_w / (A_e\ S_p\ L_2)}$$

$$N_w = 3.8 \text{ blocks per side}$$

where:

| | | |
|---|---|---|
| $L_2$ | = | Side block offset from centerline (17.5 ft) |

These side blocks should be installed immediately after docking the target cargo in case weather becomes worse during the period of final side blocking and seafastening.

Next, the side blocks required to account for the ship's motion during transit were determined. As with the calculations used to assess keel block strength during transit, a worst case environment of Sea State 7 was assumed. The acceleration in the athwartships direction was calculated using the method found in DOD-STD-1399-301A and is shown in the equation below. Results were validated with ship motion analysis performed using MAXSURF Motions.

$$\mathbf{a_y = Sin(R) + 0.0107\ P\ x\ T_P^{-2} + 0.0004\ R^2\ y\ T_R^{-2} + 0.0214\ R\ z\ T_R^{-2}}$$

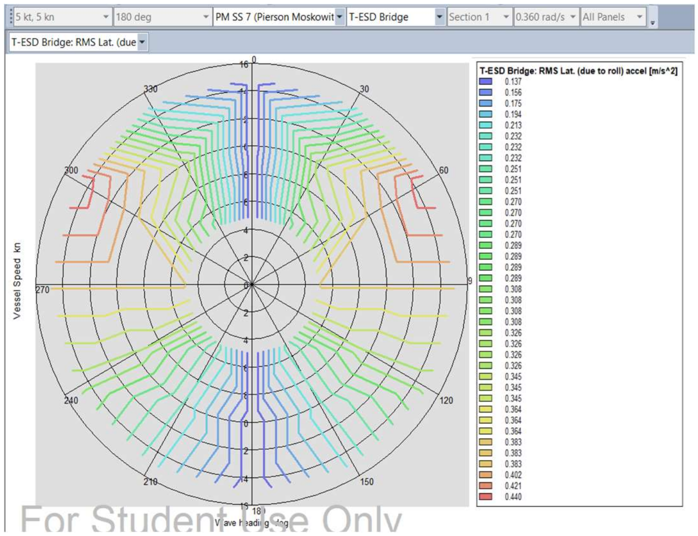
$$a_y = 0.49 \text{ g}$$

where:

| | | |
|---|---|---|
| $a_y$ | = | athwartships acceleration factor [g] |
| R | = | maximum angle of roll [degrees] |
| P | = | maximum angle of pitch [degrees] |
| x | = | distance of center of gravity of asset forward or aft from center of gravity of |

heavy lift vessel [ft]

| | | |
|---|---|---|
| y | = | distance of asset off centerline of heavy lift vessel [ft] |
| z | = | distance the asset's center of gravity is above the center of gravity of the HLV [ft] |
| $T_P$ | = | period of pitch [s] |
| $T_R$ | = | period of roll [s] |




*Athwartships ship acceleration ship motion analysis for loaded vessel in Sea State 7 with max value of 0.44 g, validating the 0.49 g calculated using equations in DOD-STD-1399-301A and conservatively selected for subsequent analysis*

The moment associated with rolling was calculated using the following equation.

$$\mathbf{M_r = w\ a_y\ KG \cdot (2240\ lb/LT)}$$

$$M_r = 258{,}474{,}726 \text{ ft-lbs}$$

where:

KG = Target cargo VCG (26 ft)

With the moment known, the number of side blocks required to resist that moment can be found using the following equation.

$$\mathbf{N_r = M_r / (A_e\ S_p\ L_2)}$$

$$N_r = 21.4 \text{ blocks per side}$$

The combined total number of side blocks ($T_{SB}$) then can be calculated using the equation below.

$$\mathbf{T_{SB} = N_d + N_w + N_r}$$

$$T_{SB} = 30.9 \text{ or } 31 \text{ blocks per side}$$

The total number of side blocks, however, is problematic because the class docking drawing for the target cargo provides up to only 21 side block locations. This means that spur shores will have to be used to resist the worst case moments generated by wind and transit conditions.

To determine the number of shores required, the number of side blocks required for ship's motion was reassessed. To determine the number of side blocks to support the static angle of roll, a maximum static angle of 17.4 degrees was assumed based on the ship's motion analysis results from MAXSURF. The number of side blocks to account for this condition was recalculated using the following equation.

$$\mathbf{N_r = w\ Sin(R) / A_e\ S_p} \cdot \mathbf{(2240\ lb/LT)}$$

$$N_r = 8.8 \text{ blocks per side}$$

where:

R = 17.4 degrees

Because side blocks on the docking drawing are designed to resist angles of roll up to 15 degrees, the spur shores must resist all greater angles. The number of shores required to resist the dynamic loading during transit was calculated based on the number of side blocks and the maximum allowable reaction of the shores. The number of shores required ($N_s$) was calculated using the following equation.

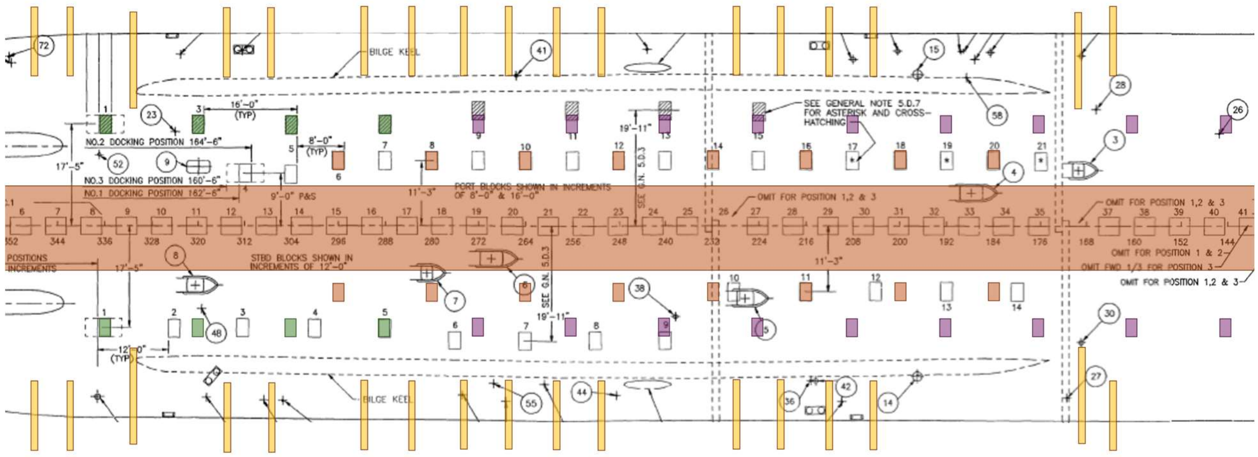
$$\mathbf{N_s = (M_r - w\ Sin(R)\ L_2) / (\sigma_s\ L_3)}$$

$$N_s = 16.5 \text{ or } 17 \text{ per side}$$

where:

$\sigma_s$ = Design loading per shore (195 LT)
$L_3$ = Average distance off centerline for shore locations against the hull of target cargo (21 ft)

By incorporating the additional 17 spur shores, the total number of side blocks required for transit was reduced from 31 to 18.4 or 19 per side. For additional redundancy, two additional side blocks located 11.25 ft off of centerline were incorporated into the blocking plan to make use of the available side block locations afforded by the docking drawing. The blocking plan with suggested spur shore locations overlaid on the docking drawing for the target cargo is shown below.




*The blocking plan for target cargo involves 8 inner side blocks per side with approximate 2 ft block heights. These side blocks will be present when cargo lands on blocks and is docked. After Montford Point completes deballasting, 13 outer side blocks (4 for wind loading and 9 for transit loading) per side will be installed. 17 spur shores per side, located approximately 21 ft off centerline will be installed, mindful of any features on the target cargo hull that would not be suitable for loading.*

### 3.7 Spur Shore Design

The max allowable stress of spur shores are dependent on material and geometry. The spur design considered for this application is based on steel I-beams with an assumed max loading (P) of 195 LT per shore (as was specified by NAVSEA 05P during the transport of *USS Cole* in 2000). To ensure that the spur shore can develop its full compressive yield strength ($\sigma_y$ = 32 Ksi for mild steel) without experiencing column buckling, the slenderness ratio (length to radius of gyration) was limited to 40. The minimum cross sectional area (A) of the shore was calculated by the following equation.

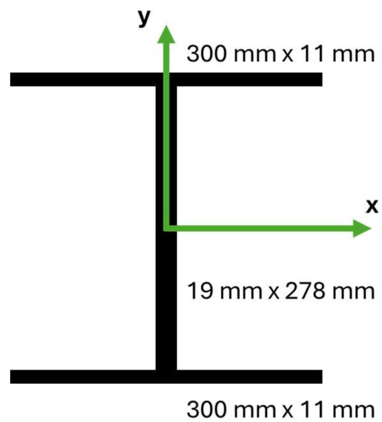
$$\mathbf{A = P / \sigma_{cr}}$$

$$A = 13.65 \text{ in}^2$$

where:

$\sigma_{cr}$ = Compressive yield strength ($\sigma_y$) if slenderness ratio is less than or equal to 40 (32 Ksi)

The dimensions of the I-beam considered for this application were 300 mm x 300 m x 11 mm x 19 mm, resulting in a cross sectional area of 18.417 in$^2$, thus satisfying the minimum limit. The figure below illustrates the I-beam geometry.




*I-beam geometry and dimensions for spur shore design*

To ensure spur shore design remains within slenderness ratio limits, the minimum radius of gyration must be determined, with moments of inertias calculated as intermediate steps. The results of calculations made for the x and y directions are shown below.

| **For x Axis** | **A [mm2]** | **X [mm]** | **M = A X [mm$^3$]** | **$I_x$ = M X [mm$^4$]** | **$I_y = bd^3/12$ [mm4]** |
|---|---|---|---|---|---|
| Upper Flange | 3300 | 294.5 | 971,850 | 286,209,825 | 33,275 |
| Web | 5282 | 150 | 792,300 | 11,8845,000 | 34,017,840.67 |
| Lower Flange | 3300 | 5.5 | 18,150 | 99,825 | 33,275 |
| Total | 11882 | N/A | 1,782,300 | 405,154,650 | 34,084,390.67 |
| $I_N = I_x + I_y - M^2/A$ | 171,894,040.7 | mm$^4$ | | | |
| $r = (I_N/A)^{1/2}$ (Radius of Gyration) | 120.277 | mm | | | |

| **For y Axis** | **A [mm2]** | **Y [mm]** | **M = A Y [mm$^3$]** | **$I_x$ = M X [mm$^4$]** | **$I_y = bd^3/12$ [mm4]** |
|---|---|---|---|---|---|
| Upper Flange | 3,300 | 150 | 495,000 | 74,250,000 | 24,750,000 |
| Web | 5,282 | 150 | 792,300 | 118,845,000 | 158,900.1667 |
| Lower Flange | 3,300 | 150 | 495,000 | 74,250,000 | 24,750,000 |

| | | | | | |
|---|---|---|---|---|---|
| Total | 11,882 | | 1,782,300 | 267,345,000 | 49,658,900.17 |
| $I_N = I_x + I_y - M^2/A$ | 49,658,900.17 | $mm^4$ | | | |
| **$r = (I_N/A)^{1/2}$ (Radius of Gyration)** | **64.647** | **mm** | | | |

Knowing the defined slenderness ratio and minimum radius of gyration, the maximum unsupported spur shore length was calculated using the following equation.

$$\mathbf{L_{Max} = 40\ r}$$

$$L_{Max} = 2.586 \text{ m} = 8.5 \text{ ft}$$

Supported spur shores (illustrated below), then, are afforded a max length of 17 ft.


*Supported spur shores*

Spur shore locations and geometries must be assessed to ensure they are able to overcome the overturning moment ($M_O$) which is generated by the transverse dynamic force working through the target cargo's center of gravity. It can be calculated using the following equation.

$$\mathbf{M_O = w\ a_y\ L_O}$$

$$M_O = 70{,}477 \text{ ft-LT}$$

where:

| | | |
|---|---|---|
| $\mathbf{a_y}$ | = | 0.44 g from motion analysis |
| $L_O$ | = | Target cargo's VCG + Keel block height ($H_{kb}$) - Shore average height ($H_s$) |
| | = | 15.88 ft (with average shore angle at 45 degrees with average height of 12 ft) |

The righting moment is developed by the resultant force that the spur shores can create in the transverse direction against the hull. The lever arm ($L_r$) is the distance between the line of action of the downward force through the center of gravity of the cargo and the position of the shore on the hull in the transverse direction. The lever arm and righting moment can be calculated using the following equations.

$$\mathbf{L_r = 26\ ft - Sin(R)\ (VCG_{cargo} + H_{kb} - L_O)}$$

$$L_r = 21.25\ ft$$

where:

26 ft was determined by section view geometry of target cargo
R = Max static angle of roll (17.4 degrees)
$VCG_{cargo}$ = Target cargo's vertical center of gravity (26 ft)
$H_{kb}$ = Keel block height (1.88 ft)

$$\mathbf{M_r = w\ (2 - a_z)\ Cos(R)\ L_r}$$

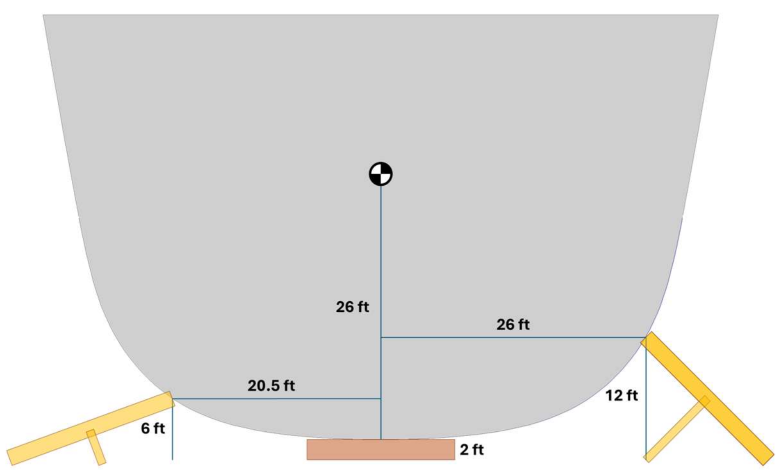
$$M_r = 147{,}840\ ft\text{-}LT$$

where:

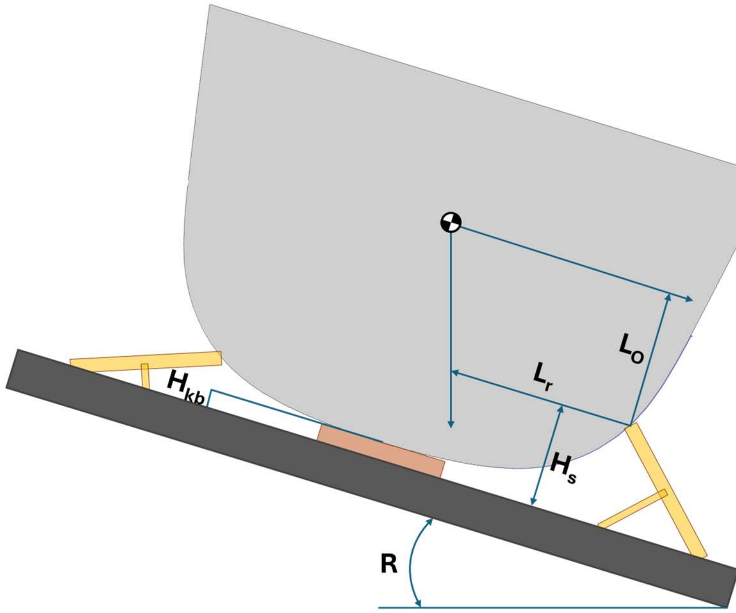
$a_z$ = 1.20 g from motion analysis

For this arrangement, the righting arm is greater than the overturning moment indicating that the average shore height is acceptable. By setting the equations for the two moments equal to each other, a maximum static roll angle of 47.5 degrees is obtained.

It is recommended that a good mix of angles between 20 degrees and 45 degrees be used in shoring plans with at least two at each angle. The figures below represent expected geometries for use of 20 degree and 45 degree supported spur shores.




*Representative geometries for 20 degree and 45 degree supported spur shores*



*Overturning moment geometry*

### 3.8 Target Cargo's Draft-at-Instability

During the docking evolution, the *Montford Point* will deballast to dock the target cargo on blocks and lift it out of the water. As the target cargo is lifted out of the water, it will experience an abnormal stability condition due to the docking blocks progressively assuming more and more of the cargo's weight. As the blocks take up more load, it will have the effect of raising the cargo's center of gravity and reducing its metacentric height (GM), thereby reducing its stability. At some draft in this process, the blocks will assume enough weight that the cargo's GM reaches zero, becoming unstable. This draft is known as the draft-of-instability and is hazardous. Once the draft-of-instability is reached, the buoyancy moment is insufficient to counter the gravitational moment, and the vessel will topple without side blocks. This condition occurs when the following equation holds true:

$$\mathbf{KM\ (\Delta - R_{KN}) = \Delta \cdot KG_O}$$

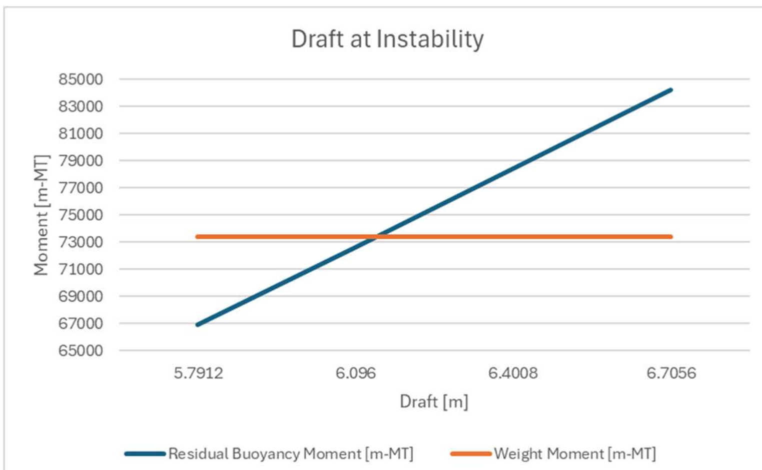
where:

| | | |
|---|---|---|
| KM | = | Height of the metacenter |
| $\Delta$ | = | Cargo's afloat displacement |
| $R_{KN}$ | = | Reaction at the keel blocks |
| $KG_O$ | = | Cargo's afloat center of gravity (VCG) |
| $(\Delta - R_{KN})$ | = | Displacement at reduced draft (residual buoyancy after keel contact) |

Using the POSSE model for the target cargo, the values of relevant variables were obtained for various drafts. The draft at instability for the target cargo was found to be 6.13 m by linear interpolation and is illustrated graphically at the intersection of the two lines below.

| Draft [m] | (Δ - $R_{KN}$) [MT] | KM [m] | KM (Δ - $R_{KN}$) [m-MT] | Δ · $KG_O$ [m-MT] |
|---|---|---|---|---|
| 5.79 | 7,558.06 | 8.85 | 6,6907.00 | 7,3377.81 |
| 6.10 | 8,185.98 | 8.87 | 7,2641.23 | 7,3377.81 |
| 6.40 | 8,813.91 | 8.90 | 7,8402.51 | 7,3377.81 |
| 6.71 | 9,441.83 | 8.92 | 8,4190.64 | 7,3377.81 |
| Interpolation of Draft at Instability: **6.13 m** | | | | |

*Table: Data used to calculate the target cargo's draft at instability*




*The target cargo's draft at instability is graphically represented by the point where the residual buoyancy moment and weight moment are equal.*

### 3.9 Target Cargo's Draft at Landing Forward and Aft

The target cargo will land on the forward and aft blocks when the moments created by the buoyancy force acting through LCB equals the displacement force acting through LCG. This condition occurs when the following equation holds true.

$$(\Delta - R_{KN})(LCB - x_{knuckle}) = \Delta (LCG - x_{knuckle})$$

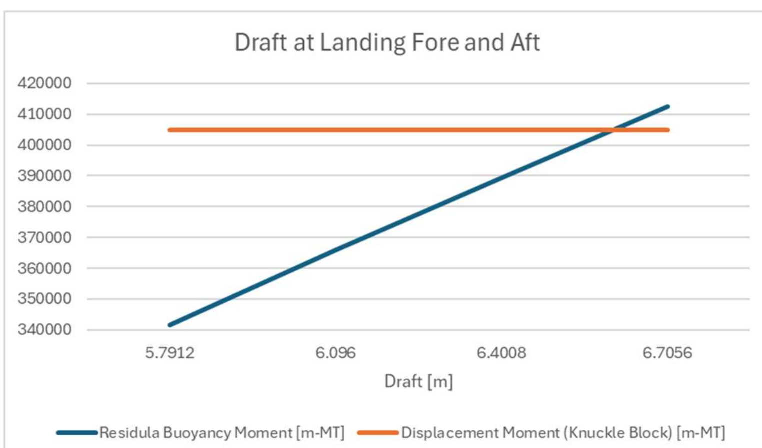
where:

LCB = Longitudinal center of buoyancy
$x_{knuckle}$ = Longitudinal location of aftmost keel block
LCG = Longitudinal center of gravity

By assuming that the *Montford Point* will trim itself such that the knuckle block will be the aftmost keel block, located near the skeg of the target cargo, and using the POSSE model for the target cargo, the values of relevant variables were obtained for various drafts. As with calculating the draft at instability, a similar method was used to calculate the draft at landing forward and aft. A draft of 6.61 m was determined by method of linear interpolation and is illustrated graphically by the intersection of the two lines below. Because the draft at landing forward and aft occurs 0.48 m before reaching the draft at instability, the target cargo will remain stable throughout the entirety of the docking evolution.

| **Draft [m]** | **($\Delta$ - $R_{KN}$) [MT]** | **(LCB - $x_{knuckle}$) [m]** | **($\Delta$ - $R_{KN}$) (LCB - $x_{knuckle}$) [m-MT]** | **$\Delta$ (LCG - $x_{knuckle}$) [m-MT]** |
|---|---|---|---|---|
| 5.79 | 7,558.06 | 45.21 | 341,730.58 | 404,969.15 |
| 6.10 | 8,185.98 | 44.70 | 365,922.07 | 404,969.15 |
| 6.40 | 8,813.91 | 44.19 | 389,467.11 | 404,969.15 |
| 6.71 | 9,441.83 | 43.67 | 412,369.97 | 404,969.15 |
| Interpolation of Draft at Landing: **6.61 m** | | | | |

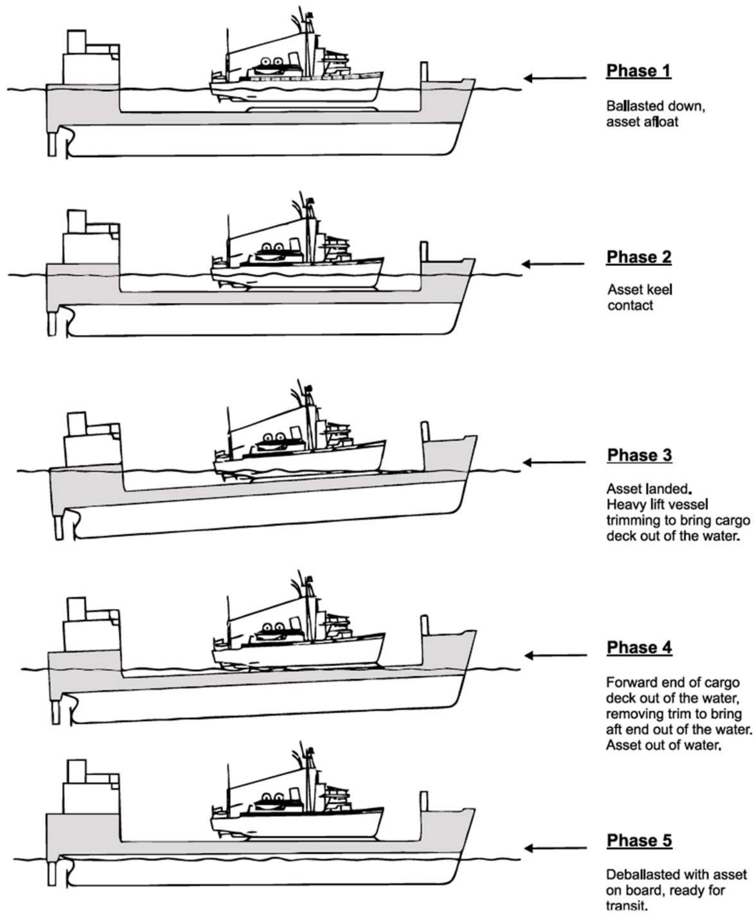
*Table: Data used to calculate the target cargo's draft at at landing forward and aft*




*The target cargo's draft at landing forward and aft is graphically represented by the point where the residual buoyancy moment and displacement moment about the knuckle block are equal.*

### 3.10 Stability During Deballasting

Using POSSE to model the docking evolution, the GMs of the combined heavy lift vessel - target cargo system at discrete midsection drafts were obtained to ensure stability was maintained throughout the entirety of the operation. The deballasting operation can be categorized with five phases, as illustrated below.

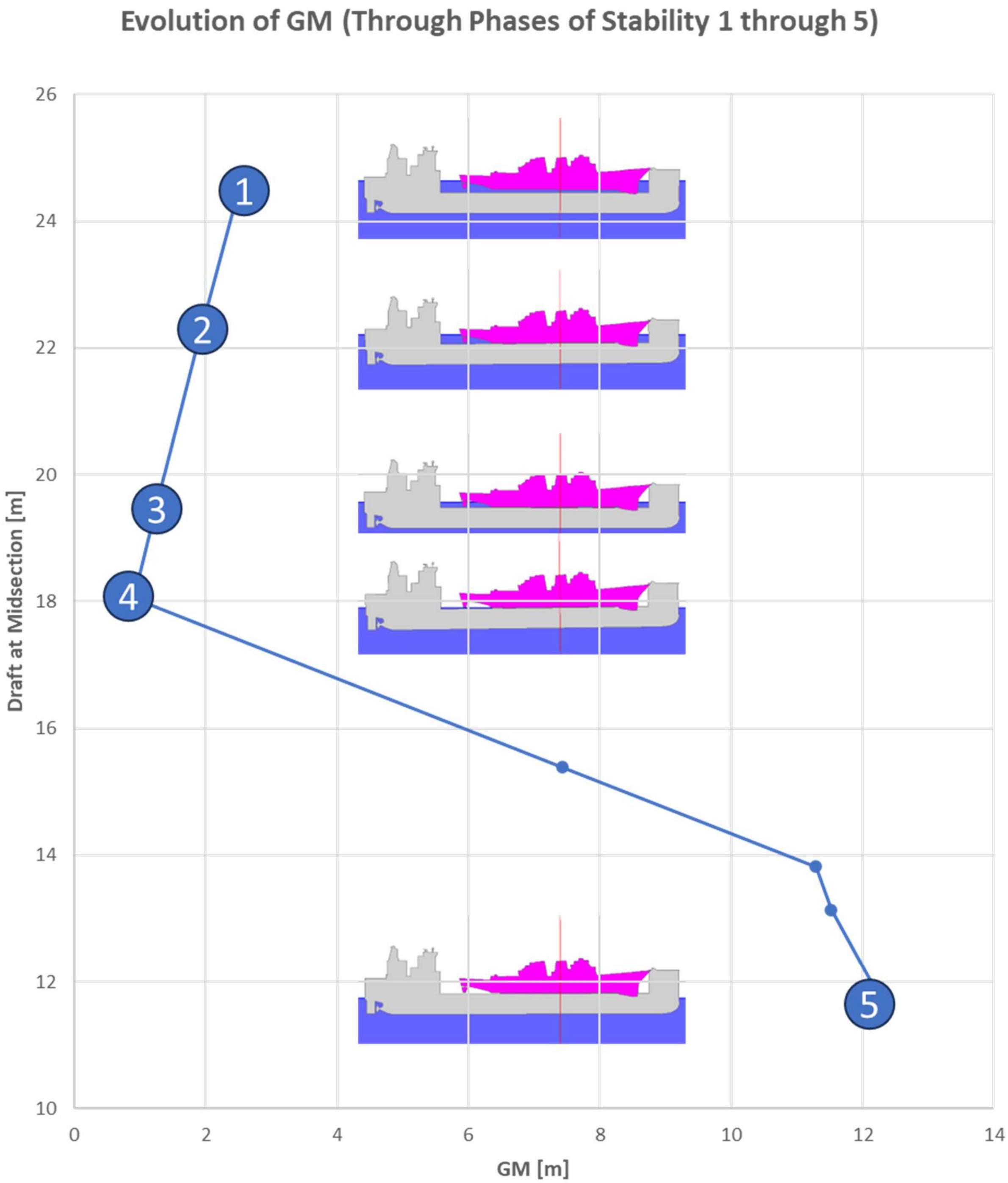



*Five phases of stability for a heavy lift drydocking*

The table below provides the GM and draft of each phase of stability and is shown graphically in the following figure.

| Phase of Stability | Draft at Midsection [m] | GM [m] |
|---|---|---|
| 1 | 24.43 | 2.476 |
| 2 | 22.238 | 1.919 |
| 3 | 19.525 | 1.253 |
| 4 | 18.052 | 0.907 |

| | | |
|---|---|---|
| 5 | 11.708 | 12.293 |

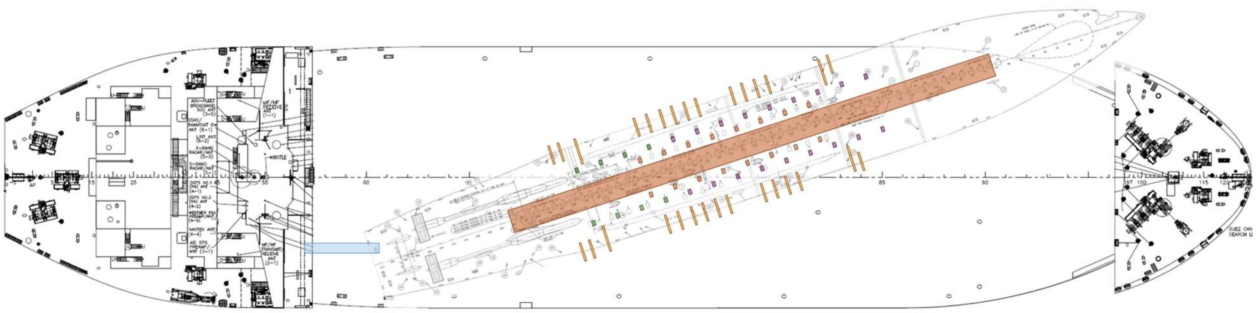



*Representative sampling of data points used to monitor evolution of GM throughout docking evolution. A minimum GM of approximately 1 m occurs during phase 4 when the waterplane area is lowest.*

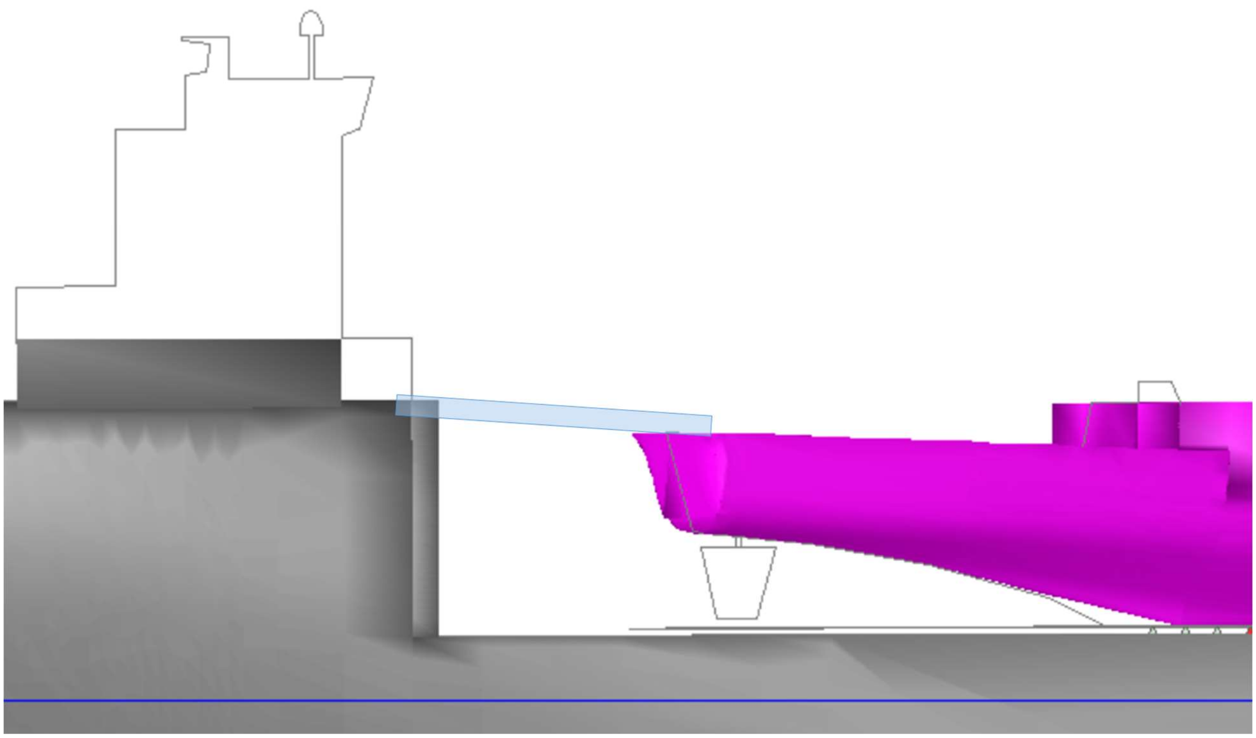
During phase 4 a minimum GM of 0.907 m occurred. In accordance with the U.S. Navy Towing manual, a NAVSEA waiver is required for evolutions where GM under 1 m occurs. However, a minimum GM of 1 m can easily be obtained by reducing the target's VCG of the from 7.925 m to 7.62 m. This can be accomplished in a large number of ways to include weight removal/addition and transfer techniques.

**3.11 Support Services and Equipment**

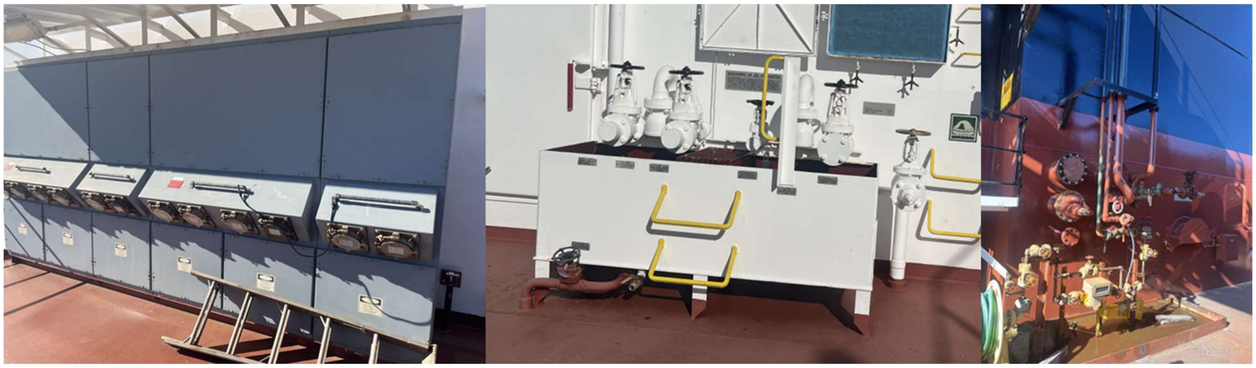
The blocking and sea fastening plan supports placing an access/service brow connecting the *Montford Point*'s aft upper deck to the target cargo's flight deck. Fire fighting hoses, standard shore power cables, freshwater hoses, and gray/black water removal hoses can be easily routed via this brow location due to conveniently located service hubs located on the aft end of *Montford Point*. The forward spaces are spacious and available to store additional equipment to support docking operations, such as welding gear and carpentry tools.



*Final topside arrangement showing locations of keel blocks, side blocks, spur shores, and access/service brow*



*Brow connecting Montford Point's upper deck to the target cargo's flight deck enables flow of personnel, equipment, and services*



*Conveniently located service hubs located on Montford Point's aft upper deck and cargo deck*

By assuming that *Montford Point* has a 10.57 turns per knot ratio (per shaft), typical of vessels of its size and category, a 15 knot transit speed can be achieved when both propulsion motors are operated at 80 RPM. At this speed, its motors draw approximately 15,000 kW of the 25,000 kW generated. Hotel loads account for approximately 16% of total generated power, or 4,000 kW. Assuming that the target cargo will draw approximately 1,000 kW (as was the case for the *USS Cole* when provided for by MV Blue Marlin) approximately 5,000 kW will remain in reserve. Therefore, while transiting at approximately 15 knots, the *Montford Point* will be able to provide electrical power to the target cargo while not exceeding 80% of its total generated electrical power.

Additionally, by changing the mission of the *Montford Point* to heavy lift and transport of damaged warships, it no longer requires storing JP-5 fuel used to support amphibious landing craft. These storage tanks store up to 2,000 MT of liquid and are rated to instead store fuel supporting *Montford Point*'s diesel generators. Doing so will increase the diesel fuel capacity from approximately 3,000 MT to 5,000 MT increasing the range of *Montford Point* by 60%. Said differently, by using the JP-5 fuel tanks to instead store diesel fuel for its generators, the *Montford Point*'s range will increase from 9,000 nm to approximately 15,000 nm.

## SECTION 4: CONCLUSIONS AND RECOMMENDATIONS

To enhance the U.S. Navy's capabilities for safely recovering battle-damage vessels, this project investigated the feasibility of retrofitting an existing T-ESD, specifically the *Montford Poin*t, into a vessel capable of heavy lifting a Flight III Arleigh Burke class destroyer. This initiative aims to facilitate the recovery, transportation, and swift redeployment of damaged naval vessels, a crucial capability both in peacetime and armed conflict. **Through rigorous engineering analysis, the team ultimately determined that the *Montford Point* is not only structurally capable of performing the aforementioned heavy lift in her present condition, but that minimal modifications need to be incorporated to ensure safe lifting and transport operations.**

The design considerations for enabling the *Montford Point* to be a steadfast HLV revolved around accommodating the specific dimensions and requirements of a Flight III Arleigh Burke class destroyer, factoring in challenges such as the sonar dome's projection and the ship's propellers. This section of the project also detailed the precise calculations for the destroyer's cant angle and positioning on the *Montford Point*, aiming to optimize the available space for keel blocks, minimize deck loading to be within the *Montford Point*'s design standards, and to increase the stability of the vessels during lift and transit. Modifications such as propeller pits were introduced to avoid significant structural interference, ensuring the destroyer could be docked rapidly without removing critical components.

In analyzing the *Montford Point* for lifting the target asset, POSSE was utilized to evaluate the vessel's deck strength during ballasting to a 9m submergence depth, deballasting with the asset on the deck as well as during transit. The analysis included considerations for additional ballasting to achieve the required submergence depth for heavy lift operations, highlighting the logistical and technical challenges involved in submerging the vessel to the appropriate depth and the subsequent lifting process. This detailed examination of the *Montford Point*'s ballasting and lifting capabilities revealed critical stress points and areas that would exceed the *Montford Point*'s design deck strength. However, by implementing a continuous blocking scheme over a length of 97 meters, optimizing block widths, and incorporating steel plates on the aft portion of the keel blocks to uniformly distribute the loading, it was possible to distribute the weight of a conservatively estimated full load of 10,000 MT over approximately 572 square meters. This distribution strategy results in an average deck pressure of 17.5 MT/m$^2$, which falls comfortably within the *Montford Point*'s loading capacity of 20 MT/m$^2$.

To guarantee the safe transportation of the destroyer by the *Montford Point*, a detailed approach to sea fastening and block loading was undertaken. This included the calculation of dynamic forces due to the vessel's pitch and roll, alongside the expected accelerations, to ensure compliance with the requirements for Sea States 3 and 5, while also preparing for conditions as severe as Sea State 7. The resilience of the sea fastening and block loading systems under these conditions was affirmed through seakeeping analysis with MAXSURF, which verified the vessel's stability and adherence to loading parameters for Sea State 7. Additionally, the operational planning considered the number of side blocks necessary for docking and transit, factoring in dead load, roll amplitudes, and forces induced by wind and motion. Addressing the limitation of side block locations, the project incorporated spur shores to counteract extreme moments from wind and transit conditions, ensuring the *Montford Point*'s preparedness for diverse maritime scenarios. This thorough and strategic methodology underscored the commitment to maintaining the vessel's structural integrity and operational safety across a range of sea states.

Finally, the blocking and sea fastening plan incorporates the strategic placement of an access/service brow to connect its aft upper deck with the target cargo's flight deck, facilitating the easy routing of firefighting hoses, shore power cables, and water management hoses due to conveniently located service hubs. Performance-wise, the *Montford Point* is capable of achieving a 15 knot transit speed at 80 RPM of both propulsion motors, utilizing about 60% of her available capacity. This operational efficiency allows for the accommodation of the target cargo's electrical needs, approximately 1,000 kW, alongside the ship's hotel loads, while maintaining a substantial reserve of power, thereby ensuring seamless support and power provision to the target cargo during transit without overtaxing the ship's electrical generation capabilities.

The primary recommendation for enhancing the *Montford Point* involves a detailed examination and upgrade of the ballasting system, particularly focused on the venting of the ballast tanks. The venting system limits the capability of the *Montford Point* to ballast and deballast from submergence depth, thereby increasing heavy lift operation times to undesirable levels. Retrofitting the venting system with larger diameter glass reinforced plastic (GRP) piping and installing adequate check valves could significantly enhance the vessel's timeline and performance for both its current operations and the proposed heavy lift mission.

Additionally, a separate study should consider the suitability of T-ESD 2 (*USNS John Glenn*) for undertaking the heavy lift mission. Implementing deck strengthening measures would be essential, given that the deck strength of the *John Glenn* is only 25% that of the *Montford Point*. However, incorporating another vessel capable of heavy lifting within the fleet would expand operational coverage and reduce reliance on foreign-flagged ships for executing such missions.

In summary, the detailed engineering analysis and operational planning undertaken for the *Montford Point*'s conversion for heavy lift operations underscore the Navy's commitment to adaptability and safety in maritime logistics. By combining theoretical formulas with practical adjustments, innovative solutions, and software programs such as POSSE and MAXSURF, the project team has laid a robust foundation for the *Montford Point* to perform its heavy lift mission, ensuring that it meets the stringent requirements for the secure transportation of critical naval assets under varying sea conditions. This holistic approach, leveraging both established standards and creative problem-solving, exemplifies the meticulous preparation required to enhance the Navy's operational capabilities and readiness.

## APPENDIX A: STUDY GUIDE

**IAP/MASSACHUSETTS INSTITUTE OF TECHNOLOGY**
**Department of Mechanical Engineering**

**2.704 PROJECTS IN NAVAL SHIP CONVERSION DESIGN**
IAP / Spring 2024

### Heavy Lift Heroes Study Guide

### I. Introduction

a. This document outlines the plan to upgrade an Expeditionary Transfer Dock (T-ESD) for heavier loads, specifically to transport a damaged Arleigh-Burke class destroyer. The goal is to enhance naval operations' flexibility and adaptability. The document covers expected performance improvements, and potential technical challenges. The objective is to assess the feasibility and benefits of the upgrade, while also identifying potential issues. Subsequent sections detail the overall design approach, including requirements, key assumptions, design philosophy, and technical and cost analyses.

### II. Study Objectives

a. Projects in Naval Ship Conversion Design, MIT Course 2.704 builds on pre-requisite naval ship design subjects (2.701-2.703) in the MIT 2N Program. Major requirements and objectives include:

(a) Application of naval architecture and ship design knowledge/skills to complete a conversion/modified-repeat ship concept design project;

(b) Ability to plan and execute work as part of a design team; and

(c) Demonstration of effective communications, in both written reports and oral presentations.

These objectives must be considered in specifying requirements and planning the project.

b. This study aims to convert existing T-ESD ships into heavy lift capable vessels. The project will focus on specifications necessary for accommodating the at sea docking and transport of an Arleigh-Burke class destroyer. The conversion will involve adapting the ship's ballasting systems and ship structure for this purpose. Notably, logistics associated with repairs at sea will be excluded from the analysis. The study will conduct structural and stability analyses, addressing any identified deficiencies through appropriate modifications.

## III. Overview

a. Motivation

In response to the imperative to bolster the U.S. Navy's battle-damage repair capabilities, this project assesses the feasibility of converting an existing T-ESD into a heavy lift-capable ship. The recovery, transportation, and redeployment of damaged naval vessels stand as critical competencies during armed conflicts between global powers. The swift repairs of the USS Yorktown before the Battle of Midway in World War II underscore the strategic necessity of promptly restoring damaged warships, emphasizing the significance of each vessel in times of war. Furthermore, recognizing the cumulative strategic impact, the ability to repair ships provides enduring benefits over the long term.

b. General Concept of Operations

The Heavy Lift Vessel (HLV) is conceived as an integral asset within the U.S. Navy, specifically designed to recover and transport damaged naval assets at sea. Tailored to lift a Flight III Arleigh-Burke class destroyer, the HLV prioritizes the safe lifting and transportation of these vessels. The operational workflow entails meeting a damaged warship at sea, facilitating docking, preparing it for transport, and subsequently relocating it to a secure area for repairs. This strategic approach ensures the HLV's adaptability, swiftly removing damaged vessels from harm's way, and facilitating efficient repair and reintegration into operational service across a diverse range of global regions.

It's essential to note that while the HLV is expected to operate in areas where it may be exposed to potential threats, it will not be equipped with advanced defensive weapons. The provision of defensive capabilities will be coordinated with other warships, acknowledging that the associated risk is deemed acceptable within the broader naval operational context.

c. Sponsor Requirements

The mission statement for this project is to transport a damaged Flight III Arleigh-Burke class destroyer by recovering it at sea using a converted T-ESD with heavy lift capability.

From this mission statement, the following sponsor requirements were obtained:

| | **Threshold** | **Objective** |
|---|---|---|
| **Lifting Capacity** | 9,000 tons | 10,000 tons |
| **Sea State (Transporting)** | 3 | 5 |
| **Range** | 8,000 nm | 10,000 nm |
| **Classification Authority** | ABS | - - - |

d. Derived Requirements

From the sponsor requirements, the following derived requirements were obtained:

| | Threshold | Objective |
|---|---|---|
| **Max Line Load Safety Factor** | 1.5 | 2 |
| **Max Structural Stress Safety Factor** | 1.5 | 2 |
| **Reserve Buoyancy** | 5% | 15% |

Additional derived requirements include:

(a) Incorporate into the design necessary operational equipment and monitoring devices to support at sea operations.

(b) Provide necessary support services to the hosted vessel, such as fire prevention and electricity.

(c) Provide accommodation, sanitation, and messing spaces for additional crew and passengers.

## IV. Assumptions

a. Major Study Assumptions

The following major assumptions are made for this project:

(a) T-ESD as Starting Point. The study assumes that the T-ESD vessel will serve as the starting point for the conversion project. The design will retain the existing hull form and propulsion system layout, with modifications limited to what is necessary for the mission of lifting and safely transporting a damaged Arleigh-Burke class destroyer.

(b) Limited Changes to Accomodate Mission. It is assumed that changes to the vessel's design will be minimal, focusing only on modifications necessary to fulfill the mission (i.e. additional ballasting capability). The number of crew and passengers that can be accommodated will be a consequence of this mission-centric approach.

(c) Commercial Standards for Classification: The study assumes that the heavy lift vessel will be modified to conform to commercial standards, specifically those of the American Bureau of Shipping (ABS). Deviations from commercial standards to U.S. Naval standards will be considered in mission-specific areas such as services provided to the hosted vessel.

(d) Exclusion of Secondary Missions. No secondary missions are assumed for the heavy lift vessel. The vessel will be tailored exclusively for the mission of lifting and transporting damaged Arleigh-Burke class destroyers.

(e) No Cargo Handling Systems. The study assumes that the heavy lift vessel does not require specialty cargo handling systems.

(f) Simplified Structural Analysis. The study assumes that structural analysis for the heavy lift vessel will rely on simplified beam theory. The loading models applied during the analysis will be simplified for ease of computation and pragmatic feasibility, ensuring that the analytical approach remains straightforward and efficient.

These assumptions provide a foundational framework for the study, guiding the overall design process and operational considerations for the conversion of the T-ESD vessel into a heavy lift vessel.

b. Margins

The following margins are considered throughout this project:

(a) Design Margins for New Systems. Design margins of 20% will be applied to new system electrical loads and air conditioning loads associated with systems in the changed regions of the baseline ship. This ensures a margin of safety for the electrical and air conditioning systems affected by modifications.

(b) Ship Weight. A service life allowance of 5% will be applied to the ship's weight to accommodate potential changes and additions during its operational life.

(c) Ship Vertical Center of Gravity. An allowance of 0.5 feet will be provided for potential variations in the ship's vertical center of gravity over its service life.

(d) Ship Service Electric Load. A service life allowance of 20% will be applied to the ship's service electric load to account for potential changes in electrical demands over time.

These margin considerations aim to provide a safety buffer and flexibility for the heavy lift vessel, accounting for potential variations and ensuring the vessel's robustness over its operational life.

No speed or powering margins will be applied since the hull form and propulsion systems are not being modified from the baseline T-ESD design. It is acknowledged that the removal of cargo and cargo handling loads may result in a significantly shallower draft.

## V. Approach

### a. Project Proposal and Study Guide

The Project Proposal and this Study Guide documents the agreement between all stakeholders on the study objectives and major inputs and assumptions for the design effort, including the sponsor requirements. This Study Guide includes and conveys the team's initial thoughts on the design approach that are intended to be employed and the proposed outline for the final report.

### b. Design Philosophy and Objectives

The primary design philosophy for this project is to prioritize robustness and durability in the conversion of the T-ESD vessel into a heavy lift vessel. Given the predetermined baseline, the primary objective is to retain the existing hull form and propulsion system layout, making modifications only as necessary for the mission of lifting and safely transporting a damaged Arleigh-Burke class destroyer. Simplicity and affordability will be considered as secondary objectives, ensuring that the design remains practical and cost-effective.

### c. Evaluation and Decision Framework

The decision-making framework will be shaped by the design philosophy, emphasizing robustness, durability, simplicity, and affordability. Given the predetermined baseline, decisions will be made based on the results of structural and stability analyses. The evaluation criteria will focus on the safety and performance of the heavy lift vessel.

### d. Concept Exploration and Selection

Concept exploration will be focused on refining the predetermined baseline design. While the exploration may not involve a broad tradespace analysis, adjustments will be made based on structural and stability analyses. The selection process will prioritize concepts that align with the design philosophy and meet safety and performance criteria. Alternative concepts will be explored if necessary to resolve technical or programmatic concerns.

### e. Concept Definition and Feasibility/Performance Analyses

The concept definition phase will center on finalizing the design based on the selected concept, taking into account suitable shipboard arrangements. Feasibility and performance analyses will concentrate on verifying the chosen design's structural integrity, stability, and overall performance. Engineering software, including POSSE and RHINO with ORCA plug-ins, will be employed for detailed design work when appropriate. Analytical tools, such as comparative naval architecture, will be utilized to draw reasoned conclusions during feasibility and performance analyses.

f. Final Report/Project Brief

As part of the final report and project brief, the following expectations and project agreements are outlined to ensure the comprehensive and standardized delivery of study outcomes:

(a) Final Report Format. A final report will be submitted that is consistent with the following structure:

(i) Executive Summary

(ii) Project Overview

(iii) Design Approach and Decision Framework

(iv) Concept Exploration and Selection

(v) Concept Definition and Feasibility/Performance Analyses

(vi) Conclusions and Recommendations

(vii) Appendices and References

(b) Minimum Drawings and Diagrams. The final report will include drawings and diagrams encompassing internal and external arrangement scaled drawings, primary electrical distribution schematics, a floodable length curve, damage stability and flooding diagrams, and structural drawings, including midship section scantlings and a longitudinal shear & bending moment diagrams. Additional diagrams will cover major/critical system block diagrams, and seakeeping operating envelope polar plots.

(c) Final Briefing and Project "Posterboard". The final briefing will be presented in PowerPoint format, aligning with the specified format and content requirements. A project "posterboard" will be developed and submitted for display and/or inclusion in the MIT Ship Design and Technology Symposium CD-ROM.

(d) Report Submission. The final report, in Adobe Acrobat format, will be submitted, encompassing all relevant appendices and meeting the specified format guidelines. All "raw" spreadsheets and computational program files will be provided electronically in their original application format. For example, *.xls for Excel files or *.3dm for Rhino models.

These expectations and agreements aim to ensure a standardized and comprehensive approach to the final report and project brief, meeting the specified criteria and facilitating effective communication of the study outcomes in various formats.

g. Project Sponsor and Briefings

The team shall conduct at least two sponsor briefings – the first to brief the concept exploration set-up/plan and the second following identification of the "preferred" concept configuration. The timing shall allow for the sponsor to have some decision-making impact on the project. The team shall consult both the sponsor and the instructors to determine how/where the briefings will be conducted; the instructors may participate if scheduling permits. The team shall prepare a summary report (i.e., minutes) of each sponsor briefing and present it to the instructors at the next scheduled weekly review.

h. Presentations and Publication

The team will brief their progress at a 2N peer review and shall present their projects at the local ASNE/SNAME section "student paper night" in April or at the *MIT Ship Design and Technology Symposium* in May. A publication-ready summary of this conversion project will be submitted.

## VI. Key Milestones and Scheduled Events

a. Key milestones and scheduled events for this project are summarized in the table below.

| Date | Milestone/Event | Additional Info |
|---|---|---|
| 12/20/23 | Study Guide Submission | Email to Instructors |
| 12/21/23 - 1/7/24 | IAP Kickoff Meeting Preparation | Meet with PRB to review Proposal in 5-317. Teams schedule time. |
| 1/8/24 | IAP Kick-Off Meeting | 0900-1000 Room 5-314 |
| 1/15/24 | Technical and Operational Feasibility Analysis Complete | Draft report Ch.'s 1-2 Due |
| 1/20/24 | Economic Feasibility Analysis Complete | Draft report Ch.'s 3-4 Due |
| 1/22/24 | Mid Project Progress Review | Brief to sponsors |
| 1/24/24 | Risk Analysis Complete | Draft report Ch.'s 5-6 Due |
| 1/26/24 | Final Paper Draft Due | Email to sponsors |
| 1/29/24 | Electronic Poster Creation Draft Due | Email to sponsors |
| 2/2/24 | Project Deliverables Finalized | Electronically by COB |
| 2/5/24 | Project Deliverables Finalized | Submit to instructors/sponsors |
| TBD (Mar) | 2N Peer Review | Room 5-314 |

| | | |
|---|---|---|
| TBD (Mar) | Final Project Brief to Sponsor | Teams arrange travel/telcon |
| TBD (Apr) | -Present Project at ASNE/SNAME student paper night<br>-Naval Construction and Engineering Design Symposium | Time/Location TBD |

## VII. Study Participation

a. The team members for this project are LT Matthew Ahlers, LCDR Matthew Dickerman and LCDR Wade Meyers. The project sponsor is NAVSEA 05D (Dr. Norbert Doerry). Representatives from the following organizations may be contacted for support as needed:

(a) Military Sealift Command

(b) SUPSALV

(c) NAVSEA 05D, 05C, 05H

## VIII. References


a. Lamb, T. (2003). *Ship Design And Construction.* Society of Naval Architects and Marine Engineers.

b. *T-ESD Ship Drawings.*

c. American Bureau of Shipping (ABS). (2023). *Guide for Application of Higher-Strength Hull Structural Thick Steel Plates in Container Carriers, March 2023.* ABS.

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## APPENDIX B: REFERENCES AND SOFTWARE

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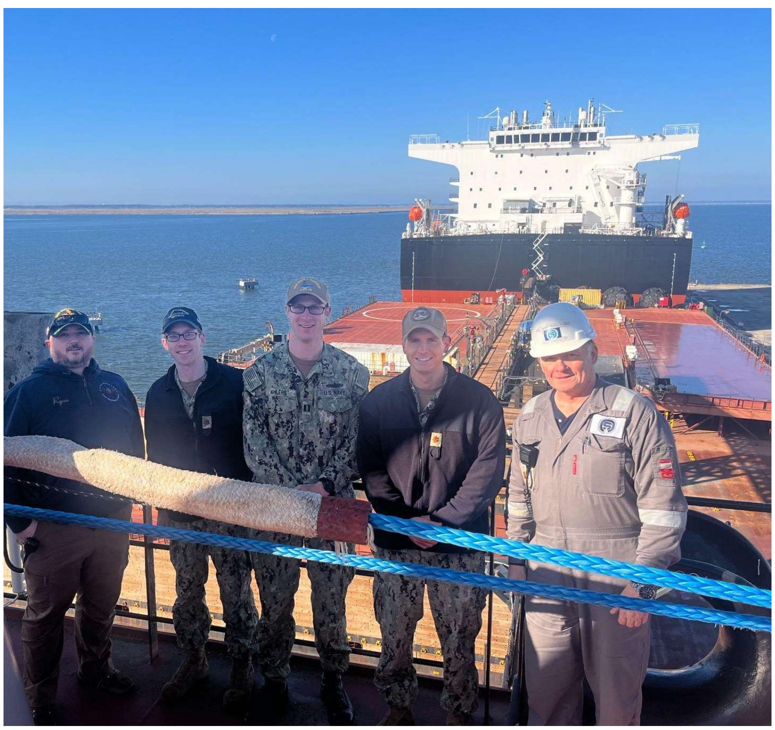

*Above: MIT second year students LCDR Matt Dickerman, LT Matt Ahlers and LCDR Wade Meyers (left to right) in between Master, Captain Ryan Arnold (left) and Chief Engineer, Joe Gelhaus (right) onboard a USNS Montford Point (T-ESD 1).*
*[Photo by Lawrence "Mo" Moriarity]*