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Carderock Division
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Center for Innovation in Ship Design
Technical Report

Auxiliary Salvage Tow and Rescue: T-STAR

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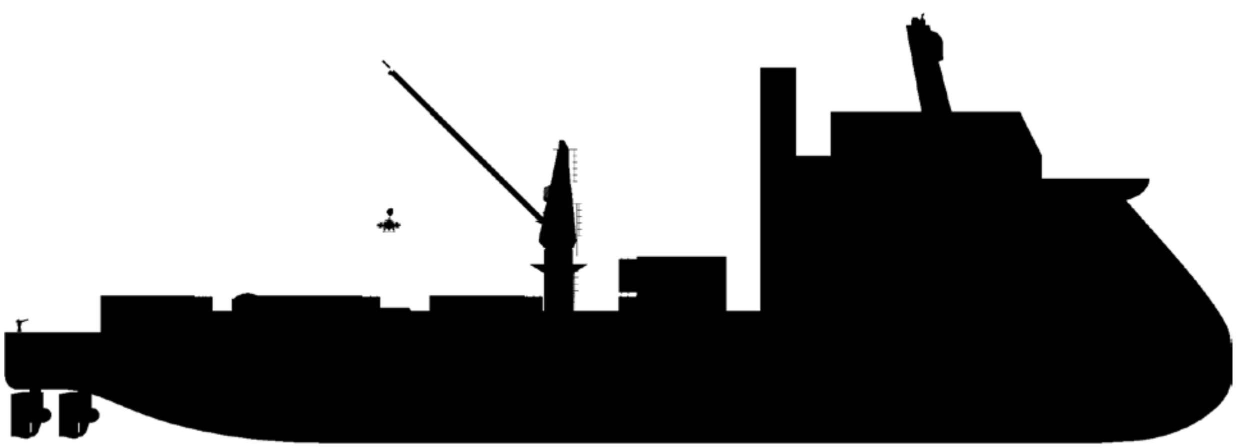

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14. ABSTRACT
Currently the United States Navy (USN) and Military Sealift Command (MSC) have four ships of the T-ARS class (Rescue & Salvage): Safe guard (T-ARS 50), Grasp (T-ARS 51), Salvor (T-ARS 52), and Grapple (T-ARS 53). These agencies also operate four ships of the T-ATF class (Fleet Ocean Tug): Catawba (T-ATF 168), Navajo (T-ATF 169), Sioux (T-ATF 171), and Apache (T-ATF 172). These ships were commissioned during the 1980's and will begin to reach the end of their forty-year life expectancy in 2019. The Navy, and more specifically the Center for Innovation in Ship Design (CISD) at the Naval Surface Warfare Center Carderock Division (NSWCCD), is exploring the design space for a single platform to fulfill the mission capabilities of both the T-ARS and T-ATF. A major component of this project is utilization of modularity. This will include modularity in construction; hull, mechanical, and electrical (HM&E) systems; mission specific systems; and crew accomadations. The goal of modularity is to allow a single platform to be equipped quickly with the tools, machinery, and equipment necessary to perform an array of missions more efficiently than multiple mission tailored ship classes. The missions of the combined platform include but are not limited to, towing, dive support, salvage, submarine rescue, oil spill clean up, and humanitarian aid.

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Symbols and Acronyms

Δ	Displacement
A_{wp}	Waterplane Area
ABS	American Bureau of Shipping
ABT	Automatic Bus Transfer
AFFF	Aqueous Film Forming Foams
AMR	Auxiliary Machine Room
AP	Aft Perpendicular
B	Beam
BM_T	Transverse Metacentric Height
BM_L	Longitudinal Metacentric Height
BOA	Beam Overall
C_b	Block Coefficient
C_x	Section Coefficient
C_p	Prismatic Coefficient
C_{wp}	Waterplane Area Coefficient
CHT	Collection, Holding, and Transfer
CISD	Center for Innovation in Ship Design
C.O.	Commanding Officer
COTS	Commercial Off-the Shelf
D	Main Deck Depth
DoN	Department of the Navy
DP	Dynamic Positioning
DSR	Double State Room
DSV	Deep Submergence Vehicle
DWL	Design Waterline
ECR	Engine Control Room
FP	Forward Perpendicular
GFE	Government Furnished Equipment
gpd	Gallons per Day
gpm	Gallons per Minute
HM&E	Hull, Mechanical & Electrical
HPAC	High Pressure Air Compressor
HVAC	Heating, Ventilation, and Air Conditioning
lbs	Pounds
LCB	Longitudinal Center of Buoyancy
LCF	Longitudinal Center of Floatation
LOA	Length Overall
LT	Long Tons
LWL	Length on the Waterline
kts	Knots
MDFP	Motor Driven Fire Pumps

MDG	Main Diesel Generator
MDSU	Mobile Diving and Salvage Unit
mm	Millimeter
MMR	Main Machine Room
MSC	Military Sealift Command
NAVSEA	Naval Sea Systems Command
NSWCCD	Naval Surface Warfare Center Carderock Division
RHIB	Rigid Hull Inflatable Boat
ROV	Remote Operated Vehicle
rpm	Revolutions per Minute
SAT-FADS	Saturation Fly Away Diving System
SCFM	Standard Cubic Feet per Minute
SITS	Ship Interface Templates
SRDRS	Submarine Rescue and Diver Recompression System
SS#	Sea State
SSR	Single State Room
SWBS	Ship Work Breakdown Structure
T	Draft
T-AGS	MSC manned Ocean Survey Ship
T-ARS	MSC manned Salvage Rescue Ship
T-ATF	MSC manned Fleet Tug
USN	United States Navy
VCB	Vertical Center of Buoyancy
VOO	Vessel of Opportunity

1 Abstract

Currently the United States Navy (USN) and Military Sealift Command (MSC) have four ships of the T-ARS class (Rescue & Salvage): SAFEGUARD (T-ARS 50), GRASP (T-ARS 51), SALVOR (T-ARS 52), and GRAPPLE (T-ARS 53). These agencies also operate four ships of the T-ATF class (Fleet Ocean Tug): CATAWBA (T-ATF 168), NAVAJO (T-ATF 169), SIOUX (T-ATF 171), and APACHE (T-ATF 172). These ships were commissioned during the 1980's and will begin to reach the end of their forty-year service life expectancy in 2019. Thus, a vessel replacement program needs to commence in the near future.

The Navy, and more specifically the Center for Innovation in Ship Design (CISD) at the Naval Surface Warfare Center Carderock Division (NSWCCD), is exploring the design space for a single platform to fulfill the mission capabilities of both the T-ARS and T-ATF. A major component of this project is utilization of modularity. This will include modularity in construction; hull, mechanical, and electrical (HM&E) systems; mission specific systems; and crew accomadations. The goal of modularity is to allow a single platform to be equipped quickly with the tools, machinery, and equipment necessary to perform an array of missions more efficiently than multiple mission tailored ship classes. The missions of the combined platform include but are not limited to, towing, dive support, salvage, submarine rescue, oil spill clean up, and humanitarian aid.

2 Introduction

2.1 Background

Within the next decade, the already small fleet of rescue salvage vessels (T-ARS) and ocean fleet tugs (T-ATF) is scheduled to be decommissioned. The USN is currently investigating the benefits of replacing both platforms with one common hull with the capability of completing all missions.

2.1.1 T-ARS

Military Sealift Command currently operates four T-ARS 50 class ships. The oldest is the USNS SAFEGUARD (T-ARS 50), which was commissioned in 1985. SAFEGUARD is shown in Figure 1. The newest ship, USNS GRAPPLE (T-ARS 53), was commissioned in 1986.

Figure 1 USNS SAFEGUARD (T-ARS 50)

Table 1: T-ARS 50 Class Characteristics

General Characteristics	
Length	255 feet
Beam	51 feet
Draft	17 feet
Displacement	3,200 LT
Speed	14 knots
Launched	11 December 1983

The primary missions of the T-ARS are:

- Lifting submerged objects up to 150 tons
- Off-ship fire fighting
- Rescue and open ocean towing with wire rope or synthetic fiber line
- Air diving operations to a depth of 190 feet with recompression facility
- Emergency underwater repair
- Refloating stranded ships and other craft
- Dewatering of sinking/sunken ships
- Underwater salvage operations, independent of off-ship logistic support, on short notice

The T-ARS secondary missions consist of:

- Limited patrol, surveillance, and reconnaissance functions
- Search and rescue
- Collect hydrographic and oceanographic data
- Limited self-defense against low-flying air penetration; small high speed combatants; magnetic mines; and biological and chemical warfare agents.

2.1.2 T-ATF

The T-ATF fleet currently consists of four ships and is slightly older than the T-ARS fleet. The newest is the USNS APACHE (T-ATF 172), which was launched in 1981. Apache is shown in Figure 2.

Figure 2: USNS Apache T-ATF 172

Table 2: USNS APACHE (T-ATF 172) Characteristics

General Characteristics	
Length	240 feet
Beam	42 feet
Draft	15 feet
Displacement	2,260 LT
Speed	14.5 knots
Launched	28 March 1981

As a unit of the Mobile Logistic Support Force, the mission of the T-ATF is to salvage and tow ships in the Fleet which are battle damaged or non-operational. T-ATF tasks are:

- Towing at-sea operations
- Salvage, diving and emergency towing at-sea operations; performing repair if augmented with material, equipment, and personnel.
- Support ship for portable, self-sustaining, deep diving equipment
- Fire fighting assistance to other ships
- Simultaneous defensive functions while maintaining readiness condition I
- Open ocean oil spill pollution abatement operations.
- Support ship for submarine rescue and intervention at sea operations.

2.2 Mission Breakdown

The T-ATF mission breakdown displayed in Figure 3 illustrates that 42% of the T-ATF mission profile is dedicated to towing, salvage and submarine support while the remainder is primarily maintenance and special projects (Roberson). This shows that towing, salvage and support operations are primary T-ATF missions, but adequate flexibility needs to be incorporated for other missions. Figure 3 also shows that any reduction in maintenance periods would greatly increase the operational availability of the T-ATF.

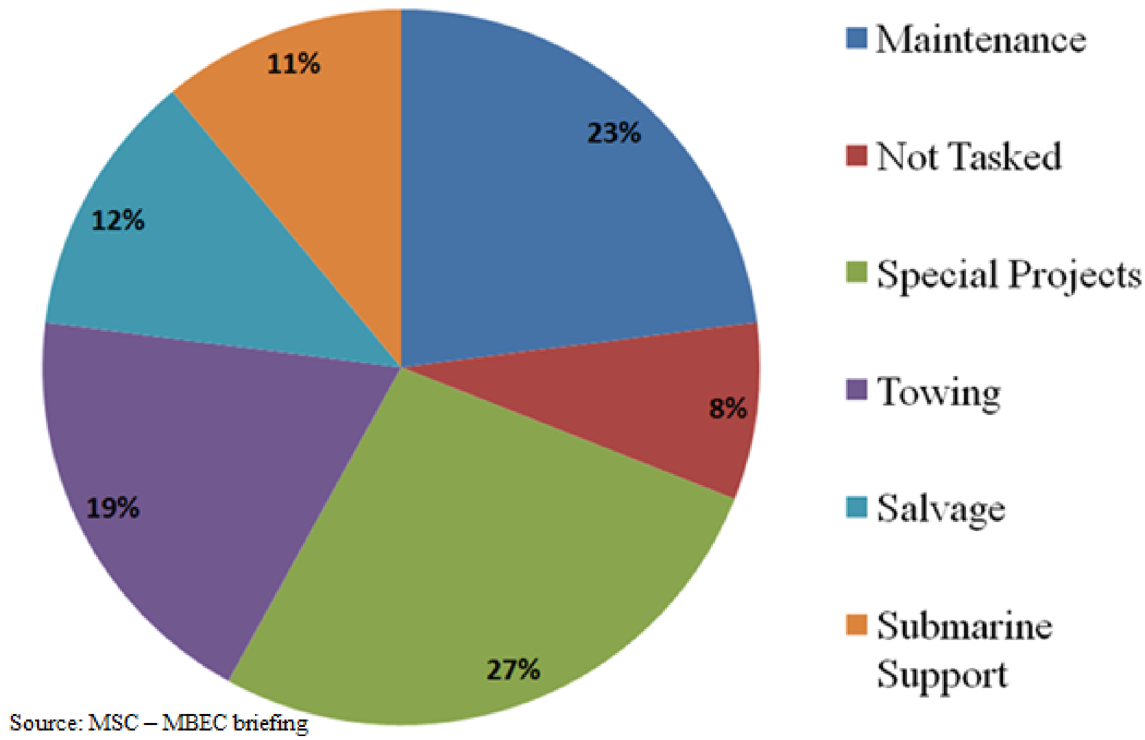


Figure 3: T-ATF Mission Breakdown

The mission breakdown for the T-ARS was unavailable, but the major difference between the T-ATF and T-ARS is the inclusion of diving and salvage equipment. To incorporate the primary missions of the T-ATF and T-ARS into a single mission profile, each individual mission was prioritized from high to low. Towing, salvage and diving have high probabilities of occurrence and are of high importance, so they became primary missions for the replacement platform. Submarine support is different than submarine rescue and occurs frequently. It requires equipment common to both platforms; therefore, being inherent in design, it was not specifically incorporated in the mission profile. However, submarine rescue was labeled as a primary mission because although it rarely occurs, it is a high-risk operation that must be accomplished when needed. The secondary missions of the replacement platform were determined from the remaining missions of both the T-ATF and the T-ARS. The resulting mission profile is shown in Table 3.

Table 3: Replacement Platform Mission Profile

Primary	Secondary
Salvage	Patrol
Towing	Fire Fighting
Diving	Oil Spill Recovery
Submarine Rescue	Humanitarian Aid

2.3 Requirements

Predetermined design requirement ranges were specified in the early stages of the replacement platform design process (Laing, 2011). The upper values of the ranges and objective requirements were the levels that the replacement platform would meet in a best case scenario. These are indicated in the top half of Table 4. The lower values of the ranges were threshold requirements, the bottom line levels that the replacement platform must meet to fulfill the missions of T-ATF and T-ARS. These requirements are located in the bottom half of Table 4.

Table 4: Concept Design Requirements

Threshold	Threshold	Objective
Draft	18 feet	15 feet
Speed	15 knots	20 knots
Bollard Pull	134 LT	165 LT
Range	8,000 nm, 8 kts	12,000 nm, 12 kts
Operating Level	SS4	SS5
Crane Lift Capacity	36 LT	54 LT
Dynamic Positioning	DP1	DP2

3 T-STAR Summary

3.1 Design Process

The tasking issued by NSWCCD CISD was to provide an affordable adaptable auxiliary mono-hull concept vessel that would replace the T-ATF and the T-ARS. The new Auxiliary Salvage Tow and Rescue (T-STAR) ship concept must meet the requirements of Section 2.3 and have the capability to perform the missions stated in Section 2.2. Three areas were researched during the design process including previous efforts, mission capabilities, and various hull designs. Figure 4 represents a process chart showing the development of the T-STAR design.

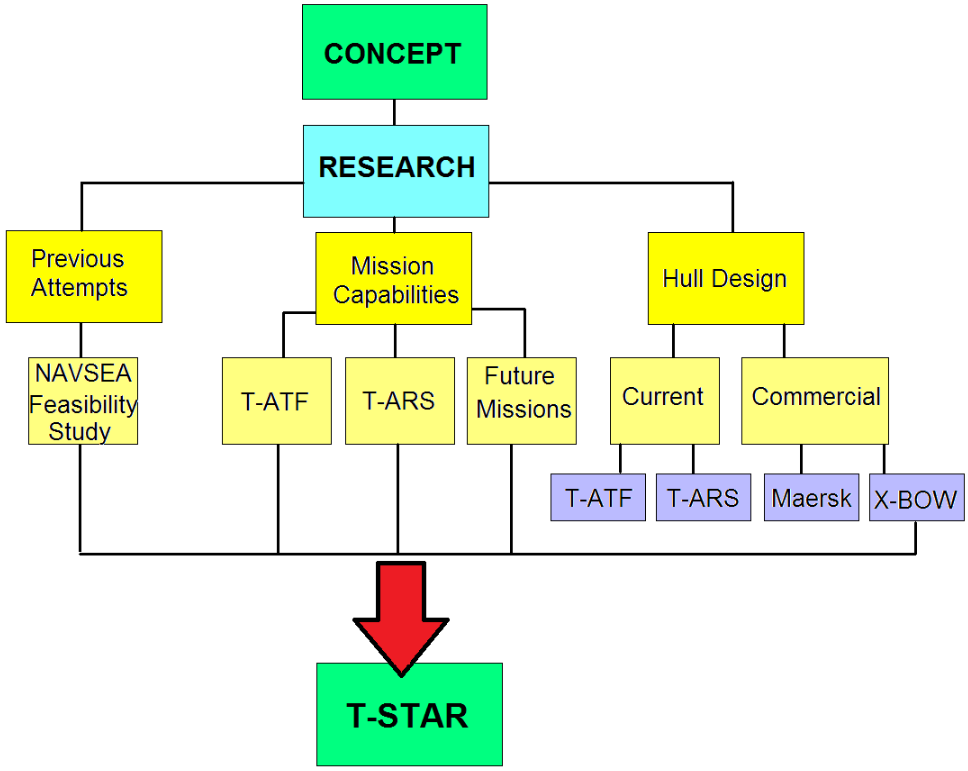


Figure 4: Process Chart

3.1.1 Previous Efforts

The T-STAR design process began by researching previous attempts, specifically the NAVSEA Feasibility Study of a Multipurpose Ship Report No. 6114-75-2 (Naval Ship Engineering Center, 1974). The objective of this report was to determine the characteristics of a multipurpose ship that would replace the mission capabilities of four USN vessels, two of which were the T-ATF and the T-ARS. This design was intended to incorporate permanent and portable equipment. From this study, the group was able to gather information on T-ATF and T-ARS mission equipment, weights, and deck layouts which led to determining T-STAR mission equipment specifics.

3.1.2 Mission Capabilities

Through researching the mission profiles of the T-ATF and T-ARS, a prioritized combination of these mission capabilities was needed to design a multipurpose ship. The primary, high priority missions from each ship were identified and combined to create the mission profile for the T-STAR amongst various possible future missions. The primary missions of the T-STAR were chosen based on the probability of occurrences and risk factors. Salvage, towing, diving and submarine rescue were all high priorities and became primary missions. Refer to Section 2.1 for the missions of the T-ATF and T-ARS and Section 2.2 for T-STAR missions.

3.1.3 Hullform Selection

The T-STAR hull's primary purpose is to support the mission modules. Once the requirements of the modules were determined, the hull design process began. If possible, the T-STAR should be built to commercial standards and with a standard commercial design. This should greatly reduce the cost. Various hull forms were considered, starting with the current hull forms of the T-ATF and T-ARS, to provide a baseline. Figure 5 shows the various hull forms considered.

Due to limited mission module capacity and open deck space, these designs were not feasible. Commercial designs from Maersk and Ulstein AS were then considered. The Maersk tug and the UlsteinX-Bow share similar characteristics; however, the Ulstein design claims better seakeeping and fuel consumption through the use of a wave piercing bow (Ulstein, 20 May, 2011). The An X-Bow influenced hull was selected for the T-STAR in order to include the wave piercing bow.

T-ARS 52 | Maersk Tug | X-Bow

Figure 5: Considered Hull Forms

3.2 Mission Modules

Based on the primary missions from the mission breakdown, two mission modules were created for the T-STAR. They are the Tow/Salvage module and the Dive/Rescue module. Some equipment is required for-both missions and can be difficult to remove. This type of equipment, such as the towing winch and crane, is considered to be installed equipment native to the platform. It is not necessarily permanent, and can/must be removed for some special missions. This feature allows the T-STAR to support mission modules including, but not limited to, those explored in this report.

3.3 Hull

The major drivers for the hull design were the bollard pull, draft requirements and dynamic positioning requirements. The X-bow hull is largely conventional below the waterline, so a rough 3-D model was created (AS, 2006). This hull was then extensively modified to meet the propulsion requirements. Compact steerable thrusters are a commercial system that is able to meet the bollard pull and dynamic positioning requirements in a minimal amount of space. This system was selected for the T-STAR and drove the overall beam and draft at the stern. The T-STAR was designed to include significant ballast and fuel tankage to account for varying mission module weights and the required range of the vessel. A moon pool was also included in the design for the benefit of dive and salvage operations. It can also be used to deploy ROVs. The T-STAR is a very stable design which is necessary because of the inclusion of a deck crane and heavy lift capability. Some damaged stability calculations were also conducted. Seakeeping requirements were determined from the T-ARS, but further analysis is required (Ship Design and Integration Directorate, March, 1981). No specific structural design was conducted, but the T-STAR's current innerbottom and collision bulkhead meet ABS guidelines (Steel Vessel Rules, 2011). Ice class was considered, but was not a major design consideration for the T-STAR because the hull could be reinforced with minimal redesign; therefore did not drive the design.

3.4 Machinery

For improved efficiency in the multi-mission role, the T-STAR features an integrated power system. The ship features three Wartsila 16V26 generator sets, for redundancy purposes, but is capable of operating on two per US Navy standards. The generators are coupled to four compact thrusters via AC/AC synchronous electric motors in a z-drive configuration.

3.5 Manning

Another important design consideration was the personnel required to complete the mission activities. Currently the T-ATF has a crew of 16 with the capability to take on a transient crew of 18 enlisted personnel and two officers (T-ATF 166 Class Operations Handbook, September 1981). The T-ARS has accommodations for a total crew of 30 with the capability to house 48 additional personnel (T-ARS 50 Class Operations Handbook, 30 December, 2002). The T-STAR will have a crew of 16 with accommodations for an additional 46 mission related personnel.

3.6 Arrangements

A basic set of arrangements was generated for the T-STAR. One main feature of the arrangements is that all accommodations lie within the superstructure to facilitate modular construction and refurbishment. A second main feature of the arrangements is that the machinery spaces are located entirely below the Main Deck. This facilitates access, maintenance and removal/insertion routes. The third feature, and a design driver for the T-STAR as a whole, is the expansive aft deck area. This space is designated for the mission modules and is approximately 9,200 square feet. It is reconfigurable as desired being open and fitted with securing tiedowns in the deck.

3.7 Principal Characteristics

The resulting T-STAR design represents a balance between the threshold and objective requirements, with principal characteristics as shown in Table 5 and 3-D rendering in Figure 6.

Table 5: T-STAR Principal Characteristics

Hull		
Length Overall	274.5	[ft]
Waterline Length	274.5	[ft]
Beam	52	[ft]
Draft	15	[ft]
Depth to Main Deck	25	[ft]
Displacement	3,907	[LT]
Block Coefficient	0.64	
Machinery		
Integrated Diesel Electric		
3 Main Diesel Generators	20,075	[hp]
4 Wartsila LCT 275 Compact Thrusters	13,947	[hp]
Operations		
Sustained Speed	15-18	knots
Range	8,000 @ 8	nm knots
Crew	16	
Accommodations	62	
Bollard Pull	165	[LT]
Crane Capacity	54	[LT]
Moon Pool	320	[ft^2]
Mission Module Payload Capability	460	[LT]

Figure 6: T-STAR 3-D Rendering

4 Modularity

Modularity is a subset of the overall vessel flexibility in which the ship systems act as independent units that can be interchanged without conflict. This is a fundamental part of the T-STAR project. Modularity was integrated into the T-STAR design in four different ways: through construction, ship systems (HM&E), accommodations, and mission modules (Doerry, 2011).

Utilization of modularity through construction includes having a parallel mid-body which is a transverse section in the ship's midships region that extends without change for a fraction of the ship's length.(U.S. Navy Salvage Engineer's Handbook Volume 1). This feature allows construction and/or modification, such as lengthening or shortening the hull, to facilitate the process and reduce cost. Similarly, modularity was incorporated in ship systems. Redundant systems were installed with identical components utilizing COTS and GFE to decrease the storage requirements of spare parts, to facilitate maintenance, and to allow for expedient removal and installation when required.

The accommodations were designed to be a standard size and, as much as possible, accessible for construction. Most can be installed, removed, renovated or reconfigured in a fashion similar to that used by the cruise ship industry (Lamb, 2003).

5 Mission Modules

Mission equipment modularity is incorporated through the use of mission modules. In this report, the term mission module will be referred to as an example of a possible mission layout for the T-STAR based on the mission profile. A mission module is an independent building block with distinct interfaces. It is a collection of equipment that is connected to the ship in a way that allows independent development of the module, so long as the interfaces are compatible and it is within the weight requirements. Mission modules allow for ease of assembly and repair, as well as flexibility in arrangements and for use. Mission modules utilize existing commercial and/or government equipment wherever possible. Some of this equipment is containerized.

Based on the generated mission profile, a list of common equipment to be shipyard installed for the T-STAR, as well as equipment for two mission module was created. The two modules that were considered are a Tow/Salvage mission module and a Dive/Rescue module as shown in Table 6. Take note that each mission module includes equipment required to perform that mission in addition to the installed equipment. The mission module weights drove the payload capacity of the T-STAR to 460 LT. For detailed equipment specifications, refer to Section 12.

Table 6: T-STAR Mission Equipment

Mission Equipment	Installed Equipment [LT]	Tow/Salvage Module [LT]	Dive/Rescue Module [LT]
Common	75.89	75.89	75.89
Towing	32.14	32.14	32.14
Salvage/Dive	82.99	82.99	82.99
Fire fighting	4.20	4.20	4.20
4 Point Mooring	-	-	179.06
Diving	-	-	46.56
Rescue	-	-	36.68
Beach Gear	-	55.85	-
Salvage	-	22.40	-
Additional Salvage/Dive	-	69.29	-
Oil Spill	-	13.10	-
TOTAL	195.22	355.86	457.52

The Tow/Salvage and Dive/Rescue mission modules are two likely mission module possibilities for the T-STAR; however, the modules are not limited to just these two. The T-STAR ship concept is designed as an open platform with approximately 9,200 square feet of available deck space for equipment necessary for missions as long as they remain within the 460 LT weight limit. This is much larger than the approximately 2,500 square feet of deck space on the T-ARS.

Other options that were explored include the Saturation Fly Away Dive System (SAT-FADS) and the Submarine Rescue and Diver Recompression System (SRDRS). These systems are briefly explained in Section 5.4.

5.1 Installed Equipment

The following tables show more details of the installed and mission specific equipment including descriptions, quantities and weights. Table 7 displays the installed equipment for the T-STAR; Table 8 shows the mission specific equipment required for the Tow/Salvage module. Table 9 shows the mission specific equipment for the Dive/Rescue module. These equipment lists are based on the NAVSEA Feasibility Study of a Multipurpose Ship (Naval Ship Engineering Center, 1974). Figure 7 shows the layout of the equipment listed in Table 7.

Table 7: T-STAR Installed Equipment

T-STAR Installed Equipment	Qty	Weight [LT]
35' NSW RHIB	1	7.6
Lifeboat Davits	2	4.5
Lifeboat Winch	2	4.0
Anchor Chain 2.25"x165 Fathoms	2	44.6
Ships Anchors	2	3.6
Bow Hawse Pipe and Bull Nose	1	1.6
Anchors, Mooring Chains, Lockers and Pipes	4	5.4
31' 3" Skimmer Boat	1	3.1
Stern Bulwark/Rollers	1	4.5
Electric Towing Winch (Stern)	1	23.2
54 LT Crane	1	45.5
Bow Sheaves	2	8.9
Beach Gear Pad-eyes	4	1.4
Beach Gear Sets	2	17.8
Divers Davits and Platforms	2	0.9
Diving Air Compressor	1	1.3
Diving Air Bottles	12	1.0
AFFF	17	3.6
Fire Monitors	4	0.4
TOTAL		**181.9**

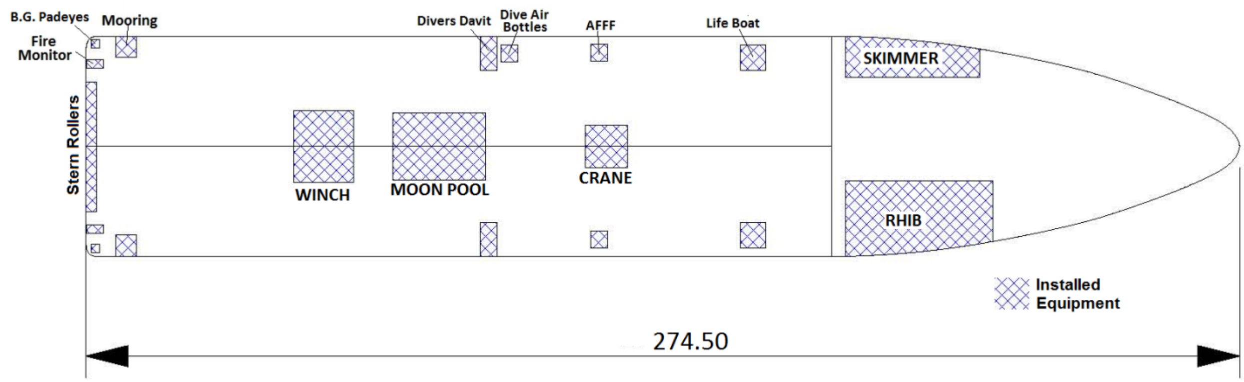


Figure 7: T-STAR Main Deck Layout

The most significant equipment installed on the T-STAR includes a 54 LT crane capable of a 50 foot outreach and a double drum winch with stern rollers for heavy towing/lifting purposes. Telescopic and knuckle boom cranes were considered for the T-STAR; however, a knuckle boom crane was selected because it allows the jib boom to fold in toward the main boom when not in use. Weight and dimension estimations for the crane installed were based on the commercial knuckle boom crane KB750 produced by Appleton Marine Inc.

No specific winch was selected but a similar commercial winch to the one required for the T-STAR would be the Markey TDSD-32 double drum winch. However, this model is diesel-driven whereas the winch required for the T-STAR would be electric-driven. For crane and winch specifications, refer to Section 12.

Although installed, this equipment is not permanent and can be removed if needed. This is because the other mission module options available such as the SAT-FADS and SRDRS require large open deck space to operate. In these cases, the winch would be removed. The only permanent main deck feature on the T-STAR is a 20’ x 16’ moon pool placed about 84’ from the stern as shown in Figure 7. This dimension is the minimum requirement for ROV deployment. The moon pool is an integral feature chosen to support the various diving and salvage missions of the T-STAR. Refer to Section 12. for specifications of the crane, winch and other installed equipment.

5.2 Tow/Salvage Mission Module

The Tow/Salvage mission module was designed to perform missions including, but not limited to, towing, salvage, salvage diving operations, and oil spill abatement operations. Equipment required for this module involves beach gear, various salvage equipment, and oil spill recovery gear. Table 8 lists the equipment necessary for these missions.

Table 8: T-STAR Tow/Salvage Mission Module Equipment

Mission	T-STAR Tow/Salvage Equipment	Qty	Weight [LT]
Beach Gear	Chain 2 Shots 2.5" Die Lock	4	19.7
	10,000 lb Stato Anchors and Racks	2	11.2
	Retrieval Pendant 600' 1"	4	1.8
	Wire; 2.5” x 1,800’	2	15.0
	Buoys, Crown (Foam)	4	0.1
	Carpenter Stopper	4	0.9
Salvage Diving	No 1. Deep Diving Outfits & Compressors	4	6.7
	Helium Oxygen Diving Outfits	3	7.7
	Scuba Gear	10	0.5
	Mixed Gas Bottle Pallets	1	5.4
	Mixed Gas Control Van (TEU)	1	3.6
	Recompression Chamber	1	2.7
	Oxygen and Acetylene Bottles	1	0.6
	Portable HP Air Plant 10'x18'x10'	1	40.2
	200 Amp Welder	2	0.4
	Power Pack Unit	1	8.4
Salvage Equipment	400 Amp Welder	1	0.7
	30 KVA A.C. Generator	1	2.3
	125 cfm Compressor	1	0.8
	10" Pump	3	1.6
	6" Salvage Pump	2	1.3
	10" Salvage Pump	2	2.6
	3" Salvage Pump	6	2.4
	6" Submersible Pump	1	0.7
Oil Spill Recovery	Oil Containment Boom		13.1
	Model USS-42HB, 42” x 55’	36	
	Model USS-42SB, 42” x 25’	4	
	Pallet, Storage, USS-42/USS-42HB Boom	3	
	Equipment Basket, USS-42/USS-42HB Boom	1	
	Air Compressor	1	
	19 cfm @ 125 psi, Diesel	1	
	Containment Pool, Machinery, 5’x 5’ x 12”	1	
	Pump, Diaphragm, 1” Pneumatic	1	
	Carpenter Stopper, 5/8”	2	
	Bridle, Wire Rope, 5/8” Carpenter Stopper	2	
	Round Sling, Polyester, 14’ 6” SL0011	4	
	Round Sling, Polyester, 16', w/1” Shackle	4	
TOTAL			**150.2**

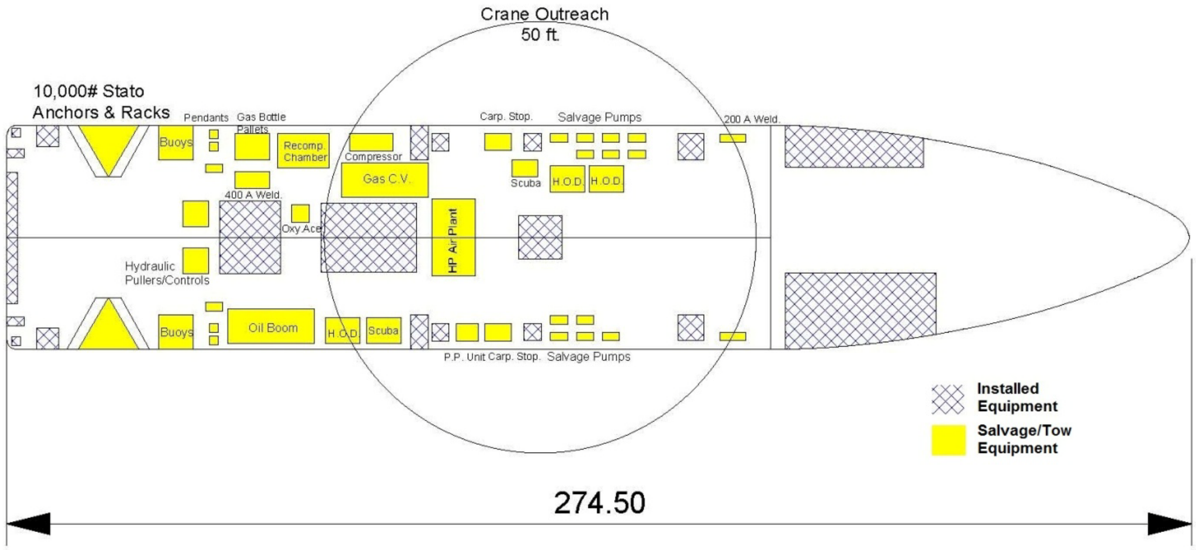


Figure 8: T-STAR Tow/Salvage Main Deck Layout

Figure 8 shows the Main Deck layout of the Tow/Salvage Mission Module. The hatched areas represent the permanent equipment and the highlighted areas are Tow/Salvage related equipment. The equipment arrangements shown were determined by weight distribution between port and starboard side in conjunction with the layout given by the NAVSEC Drawing No. 806-6114-75-2-04 from the NAVSEA Feasibility Study (Naval Ship Engineering Center, 1974). These Tow/Salvage deck arrangements were determined concurrently with the trim and stability analysis. Refer to Section 12 for details on the Main Deck arrangements including weight distribution and center of gravity calculations.

5.3 Dive/Rescue Mission Module

The Dive/Rescue module was designed to perform missions including, but not limited to, dive and rescue operations including the ability to perform a four point moor. A four-point moor is required for dive operations for the T-ARS. It was therefore included in the Dive/Rescue module even though it may not be necessary because of the T-STAR's dynamic positioning capability. For Dive/Rescue, the ship would be equipped with anchors and buoys necessary for a four-point moor. Anchors and buoys would be deployed from the Aft Deck of the ship. Table 9 lists the equipment necessary for a four-point moor as well as for the dive/rescue missions.

Table 9: T-STAR Dive/Rescue Mission Module Equipment

Mission	T-STAR Dive/Rescue Equipment	Qty	Weight [LT]
Diving	Mk1 Mod1 Carriage	1	33.8
	Winch Boom	1	0.7
	Dive Suit Water Hose Reel	1	0.7
	Dive Suit Water Heater	1	2.2
	Compressor and Accumulator	1	2.1
	Gas and Oxygen Supply	1	36.8
	Life Support Package	1	0.7
	Life Support Bundle and Bin	1	1.1
4-Point Moor	6,000-lb Anchor	4	10.7
	Chain 1.5"	4	89.3
	Buoy	4	26.8
	Buoy Racks	2	44.6
	Lines 11" x 1200' Cir Nylon	4	7.6
Rescue	FADS-III	1	2.9
	Recompression Chamber	1	2.7
TOTAL			**262.3**

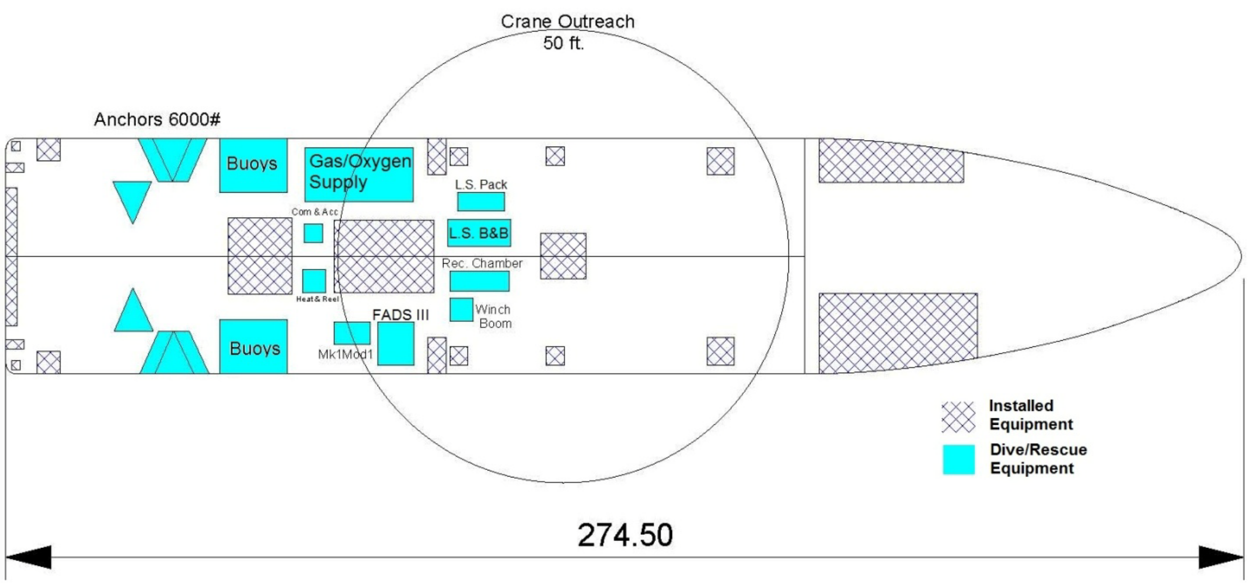


Figure 9: T-STAR Dive/Rescue Main Deck Layout

Figure 9 shows the Main Deck layout of the Dive/Rescue Mission Module. The hatched areas represent permanent equipment and the highlighted areas are Dive/Rescue related equipment, which was purposely arranged around the moon pool for convenience. The equipment arrangements shown were determined by weight distribution between port and starboard sides in conjunction with the layout given by the NAVSEC Drawing No. 806-6114-75-2-05 from the NAVSEA Feasibility Study(Naval Ship Engineering Center, 1974). Like the Tow/Salvage deck arrangements, the Dive/Rescue deck arrangements in Figure 9 were designed concurrently with trim and stability analysis. Section 12 contains more detailed information for Dive/Rescue.

5.4 Other Mission Module Options

5.4.1 Saturation Fly Away Dive System

The Saturation Fly Away Dive System (SAT-FADS), shown in Figure 10, is a six-person saturation diving system the US Navy intends to use to conduct combat salvage and recovery. It operates to at least 600 feet, supports rescue capabilities, and responds to missions that support national security requirements including object recovery (U.S. Navy Supervisor of Salvage and Diving, 20 Nov. 2007). SAT-FADS requires 80' x 42' deck space for set-up and weighs 77.2 LT. It is highly mobile and able to be transported to anywhere in the world (Saturation Diving Project Description, May 2007). Refer to section 12 for detailed layout.

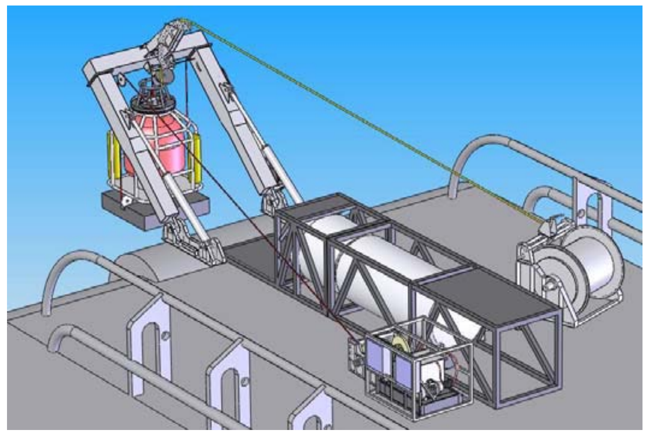


Figure 10: SAT-FADS

5.4.2 Submarine Rescue and Diver Recompression System

Submarine Rescue and Diver Recompression System (SRDRS) is referred to as the US Navy's 21st century submarine rescue system. The SRDRS has quick response time and does not require a mother submarine or additional surface support ships. SRDRS will provide a new capability of pressurized transportation of crew from a stricken submarine directly to the decompression system. SRDRS weighs 145.1 LT and requires 92' x 30' of open deck space where the entire system is laid on the deck via SITS (Ship Interface Templates) (Muzia, 2011). These are sent first and welded to the deck so that when the components reach the ship they can be installed directly at their preset locations. It provides a rapid global response and improved capability at a fraction of the cost of currently available systems (Submarine Rescue Diving and Recompression System SRDRS). The SRDRS layout is shown in Figure 11.

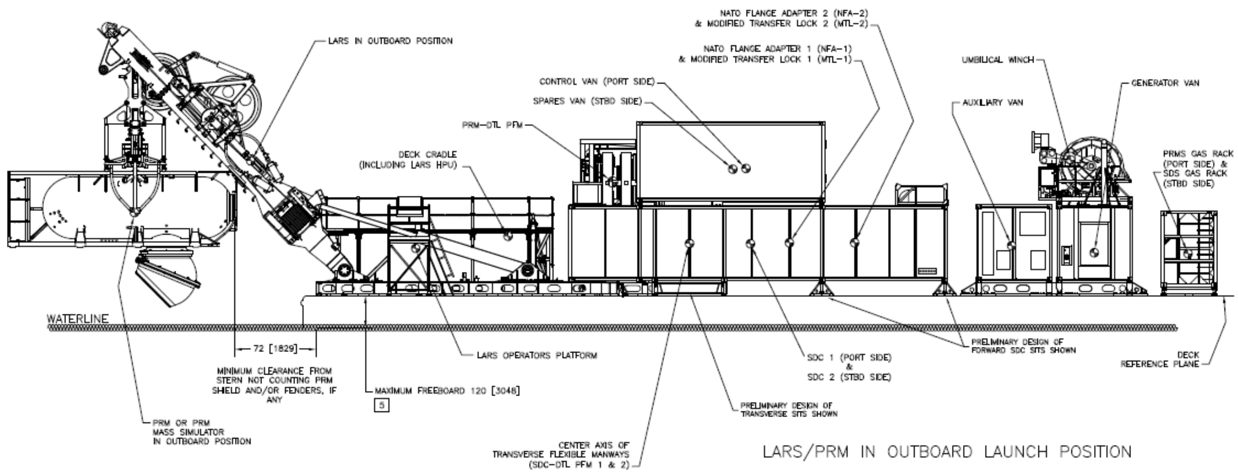


Figure 11: SRDRS

6 Hull

6.1 Development

The primary purposes for the T-STAR hull are to support the mission modules provide shallow water capability and high bollard pull towing capability. Supporting mission modules requires a large open deck, a dynamically and statically stable hullform, and, optimally, a moon pool. Commercial platforms were preferred for this design because of perceived lower development and acquisition costs. However, the existing T-ATF and T-ARS hulls were considered as a starting point. The T-ATF hull was not capable of supporting the mission module weights or dimensions, nor was it capable of supporting the machinery required to meet the bollard pull requirements. The T-ARS hull is larger and better able to accommodate the mission module weight, but has insufficient open deck area.

The T-STAR hull was developed from the concept of the X-Bow design from Ulstein (Ulstein, 20 May, 2011). The principal reason this concept was selected over similar commercial offerings was a claimed seakeeping benefit, specifically in head seas due to the wave piercing bow. Salvage, tow and dive operations involve the deployment of people and equipment over the side (or through the moon pool), requiring small relative motions. If an X-Bow design reduces these motions, it may increase operational availability over similar seakeeping limited ships. The X-Bow design also claims to reduce the power necessary to operate in higher sea states which may contribute to capability for open ocean towing and improved transit range and speed. Since the X-Bow is largely conventional below the waterline it was felt that the risk associated with the concept was minimal. The primary design impact was limited to the superstructure and forward deck arrangements. The operational impacts will primarily be from the large vertical distance from the forward open deck to the waterline. To mitigate this on the T-STAR, nearly all mission related equipment was located on the Aft Deck. At the time the T-STAR hull was developed, lines drawings or detailed models for an X-Bow or any other similar vessel were not available. Some three-dimensional views and basic bow dimensions were available from a patent application (AS, 2006). These figures served as the primary source for the T-STAR design. After the hull was developed, body plans for the T-ATF feasibility study and the T-ARS were found (Naval Ship Engineering Center, 1974). As the design continues, it may be advisable to consider these drawings for T-STAR hull refinement. A table of comparable ships is shown in Table 10.

Table 10: Comparable Ship Dimensions

Ship	L_{wl} [ft]	B [ft]	T [ft]	Δ [LT]	C_b
T-ATF	204	42	15	2,260	0.62
T-ARS	240	50	17	2,840	0.49
T-ATF Study	245	49	15	2,420	0.47
Bourbon Orca X-Bow	283	61	23	N/A	N/A
T-STAR	275	52	15	4,034	0.66

The development of the T-STAR hull followed a path consistent with the design drivers; bollard pull, draft, and mission module weight/required area. A rough hull was developed mimicking the X-Bow sketches with a 15 ft draft and the addition of parallel midbody. Next, the propulsion arrangements satisfying the bollard pull requirements were used to shape the stern Hull-propulsor integration was found to drive the beam of the ship. Finally, the parallel midbody was adjusted in length until a weight/buoyancy balance was achieved. The result differs from the parent hullforms in a few critical areas. The first is the inclusion of a 50 ft wall-sided parallel midbody with a mid-section coefficient of 0.94. The midbody was designed in this fashion for producibility and modularity, allowing for lengthening of the vessel if desired (Doerry, 2011). The T-STAR length to beam and depth ratios are 5.27 and 10.98 respectively. These are not inconsistent with other draft limited vessels and indicate that length could be increased significantly before longitudinal structural strength concerns intervene. Though a parallel midbody, in principle, does not negatively impact hydrodynamic performance, the comparatively high section coefficient and resulting block coefficient do, as will be discussed later (Lamb, 2003). The volume of the midbody also results in an LCB farther aft than desirable considering that the entire superstructure weight of the T-STAR is located forward. T-STAR is designed to maintain ballast-free trim at full load but requires significant tankage aft to maintain draft and trim in partially loaded or burned out conditions.

The second critical area of the T-STAR hull design is the stern geometry. Four propulsion thrusters are required and their dimensions, in combination with the 15 ft draft requirement, dictated a significant rise of the keel. The stern's draft and flat bottom are more extreme than found on comparable ships including the X-bow. These attributes individually would not present a problem, but together they lead to concerns of propeller cavitation, air entrapment and stern slamming. Ordinarily the thrusters would be allowed to protrude below the keel with a protective skeg, but this would violate the 15 ft draft requirement. It should be noted that the 15ft requirement was a goal, with a threshold of 18ft. The 15 ft draft was not be relaxed as it is critical to access waters in which other shallow-draft ships, such as an FFG, may be grounded. The propulsion arrangement drove the beam of T-STAR to 52ft. This allows the compact thrusters to lie completely beneath the hull, a feature deemed necessary considering the amount of people and equipment to be handled over the side at the stern of the vessel. Hydrostatic characteristics are shown in Table 11. These characteristics do not reflect the lost buoyancy of the moon pool. The T-STAR lines are shown in Figure 12.

Table 11: T-STAR Hydrostatics without Moon Pool

Length, Waterline	275	[ft]
Beam	52	[ft]
Draft	15	[ft]
Depth	25	[ft]
Displacement	4,034	[LT]
Wetted Surface Area	17,125	[ft^2]
A_{wp}	12,563	[ft^2]
Max Sectional Area	737	[ft^2]
LCB (from midships)	-3.73	[ft]
VCB or KB (from baseline)	8.42	[ft]
LCF (from midships)	-15.05	[ft]
BM_T	18	[ft]
BM_L	504	[ft]
C_b	0.66	
C_x	0.94	
C_p	0.70	
C_{wp}	0.88	

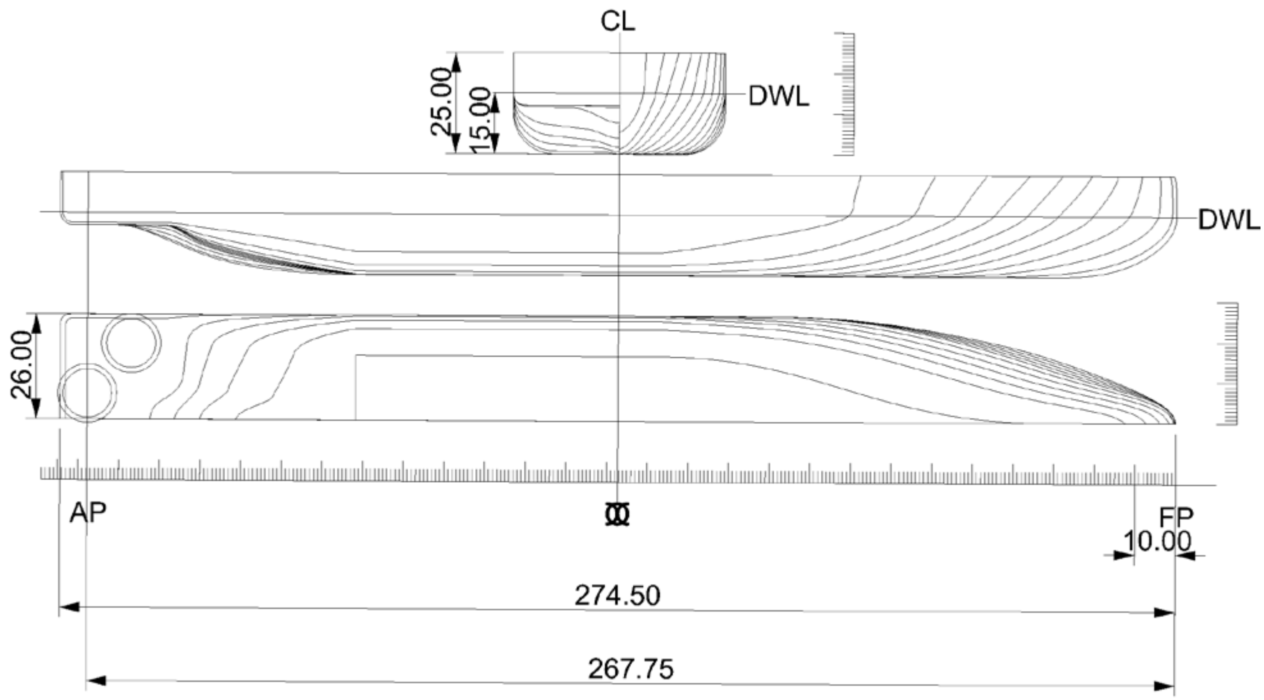


Figure 12: T-STAR Lines Drawing (circles on stern indicate thruster placement)

6.2 Resistance and Propulsion

6.2.1 Resistance

Two methods were used to estimate the T-STAR's resistance properties. The first was a regression model developed by Holtrop and Mennen based on model test data from a wide range of vessels and is most applicable to conventional single screw ships (Parsons, September 2007). The T-STAR is not conventional or single screw. However, the Holtrop and Mennen model was the best suited of the *available* regression methods and was very fast to implement. Regression models specifically for tugs were also investigated, but the T-STAR did not lie within the boundary conditions of the model. The second method used was the Integrated Hydrodynamics Design Environment's (IHDE) Total Ship Drag (TSD) Computational Fluid Dynamics (CFD) code. IHDE was developed by NSWC Carderock Division as a Leading Edge Architecture Prototyping System (LEAPS) compliant tool for CFD analysis. The results of these two estimation methods are shown in Table 12. A design margin of 8% has been included in accordance with NAVSEA guidelines (Parsons, September 2007). It was assumed that bow thruster and moon pool openings would be closed with doors. The appendage drag associated with the thrusters themselves was also neglected, an assumption which needs closer examination.

As is evident from both Table 12 and the delivered power curves from Figure 13, there is a significant difference between the two resistance estimations above 10 knots. The IHDE curve has a more conventional shape, and is the more conservative estimation. However, no validation was available for either method with anything comparable to the T-STAR hull. Model testing or a validated resistance model would be required before more reliable resistance estimate could be made. The widely varying resistance estimates were not considered to be crucial to the design for the following reasons:

- It can be argued that speed is not a major design driver for a tow and salvage ship. Critical missions are conducted at zero speed or towing speeds. In either case, the resistance of the T-STAR hull itself is a negligible factor compared with other power requirements.
- The resistance models are largely in agreement at the threshold transit speed of 8 knots.
- The resistance models bracket the threshold service speed of 15 knots.

Table 12: Resistance Estimate Data

Holtrop and Mennen				IHDE	
V [kts]	EHP	V[kts]	EHP	V [kts]	EHP
1	1	13	1,442	8.0	244
2	5	14	1,962	10.4	728
3	17	15	2,655	12.7	2,285
4	39	16	3,750	15.0	7,164
5	75	17	5,267	17.4	8,861
6	126	18	6,763	19.8	12,927
7	195	19	8,036	22.1	26,946
8	286	20	9,462	24.5	40,901
9	404	21	11,587		
10	559	22	14,960		
11	766	23	21,523		
12	1,048	24	29,376		

6.2.2 Propulsion

The T-STAR propulsion system was primarily designed to meet the bollard pull and draft requirements. Open screw propellers, Kort nozzles, Voith Schneider propellers and water-jets were conceptually considered. Open propellers were eliminated based on size and cavitation using Wageningen B-Series polynomial regression analysis (Isin, 1987). Kort nozzles were investigated as a way to increase the power while reducing size compared to open propellers but the estimated size reductions were insufficient (Parsons, September 2007). Like open propellers, Kort nozzles do not provide station-keeping/dynamic position capability. Voith Schneider propellers were eliminated because of perceived inflow issues, high expense and maintenance. Water-jets were initially eliminated because of their perceived inefficiency at low speed which is where the T-STAR operates, but should be re-investigated if the design progresses. Thrust vectoring may allow them to be part of a dynamic positioning system.

Four Wartsila LCT 275 compact steerable thrusters with controllable pitch propellers were selected for the T-STAR. They achieve the required bollard pull capacity, meet dynamic positioning requirements and are commercially available standard designs. The propellers are designed for bollard pull and controllable pitch enables them to operate at better efficiencies throughout the speed range versus fixed pitch alternatives. Each thruster outputs 3,487 hp for a maximum delivered power of 13,947 hp. This was the basis for the T-STAR maximum speed, while the trial speed and sustained speed were constrained by power generation capacity.

T-STAR uses three Wartsila 16V26 generator sets for electrical power, but only two are assumed to be on line in the calculation of trial and sustained speeds. This data is shown in Table 13. Hull efficiency was estimated using Holtrop and Mennen wake fraction and thrust deduction coefficients, and the open water propeller efficiency was assumed to be 60%. Electrical losses for propulsion were assumed to be 10% using (Marine Diesel Power Plant Performance Practices, 1989). This information was used to generate the trial and sustained speed plots shown in Figure 13. As stated earlier, these curves represent the *best available* estimates and have not been validated. Both curves are presented to show that there is a discrepancy that requires further design analysis.

Table 13: Available Propulsion Power

	Generators Online			
	3	**2**	**2**	**1**
Loading	100%	100%	80%	100%
Total Power Output [hp]	20,075	13,383	10,707	6,692
Ship Service Power [hp]	1,073	1,073	1,073	1,073
Propulsion Power [hp]	19,002	12,311	9,634	5,619
Thruster Limit [hp]	13,947	13,947	13,947	13,947
Speed Condition	Maximum	Trial	Sustained	Efficiency

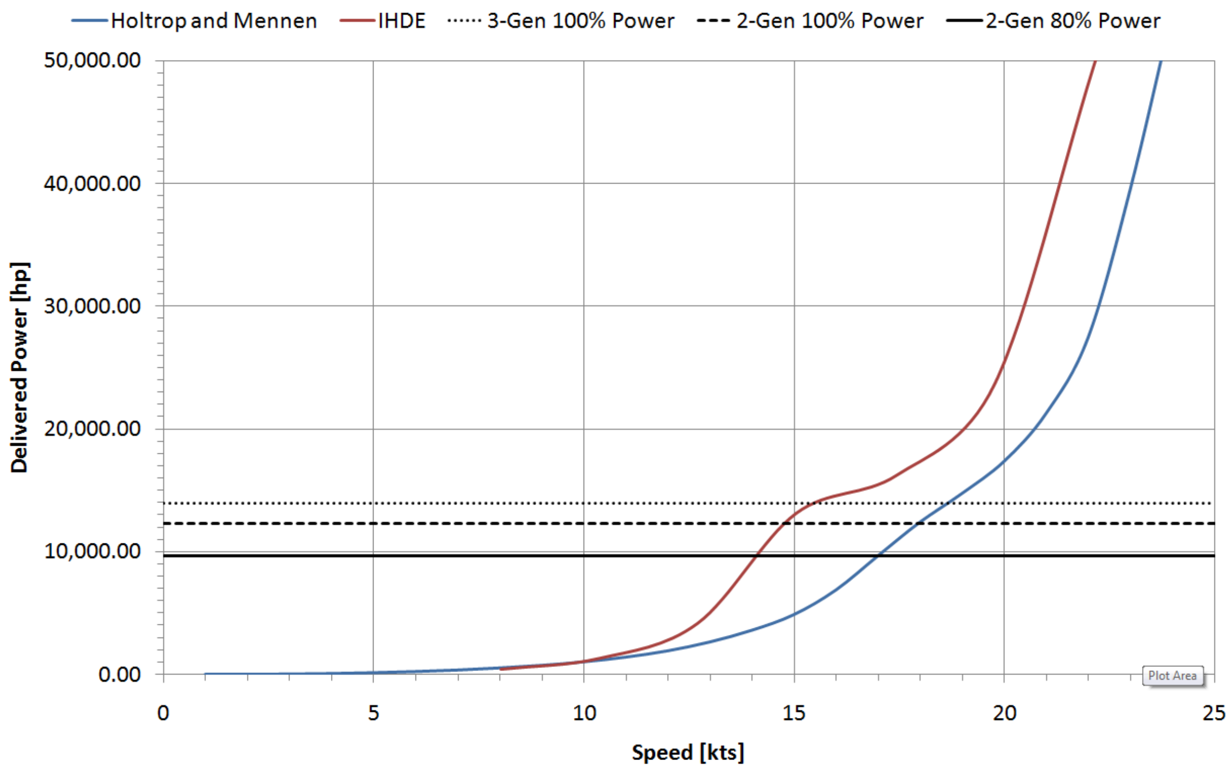


Figure 13: T-STAR Speed/Power Estimates

6.3 Weights

Table 14 summarizes T-STAR lightship weights (exclusive of mission systems) well as the scale factor for the estimates. Weights for installed mission equipment and mission modules were not included in the lightship weight summary so that they could be easily distinguished. Installed mission system weights, module weights for the Tow-Salvage and Dive-Rescue missions, and variable loads are shown in Table 15.

T-STAR Ship Work Breakdown Structure (SWBS) 2-digit weights were primarily scaled from T-ATF, T-AGM 25, T-AGS 66, and the Feasibility Study of a Multipurpose Ship (Naval Ship Engineering Center, 1974). Only 1-digit SWBS weights were available for the T-ATF and Multipurpose Ship study, but 3-digit weights were available for the other two vessels. Vendor equipment weights, such as the mission modules, main engines and thrusters, were used when available. The lightship design margin was 9.25%, recognizing medium design uncertainty and medium consequences in accordance with NAVSEA policy (NAVSEA INSTRUCTION 9096.6B, 16 August 2001). The service life allowance for auxiliary ships is 5%, set by the same document. For the T-STAR design, both these margins were grouped into one 15% lightship margin. This is not common practice, as the service life allowance is not normally considered part of the lightship weight. Normally, a ship is designed to tolerate a slight increase in draft as weight is added over the life of the ship. However, T-STAR is designed to not exceed a 15 ft draft throughout its life, so weight was included in the design condition to account for the service life allowance.

Weights for installed mission equipment and mission modules were not included in the lightship weight summary so that they could be easily distinguished. Table 14 shows the 2-digit SWBS breakdown for lightship weights (exclusive of mission equipment weights) as well as the scale factor used to determine it from similar ships. It is recognized that better scale factors may exist, but were not available during the T-STAR design. Single-digit SWBS hull structural weight was estimated as the sum of the 2-Digit SWBS estimates, as a displacement-scaled 1-Digit SWBS estimate using the four basis ships, and using the Watson and Gilfillan model (Parsons, September 2007). The Watson and Gilfillan model was selected as the most appropriate for this design. The results of the Watson and Gilfillan estimate as well as 1-digit and 2-digit structural weight scaling are shown in Table 14.

Table 14: T-STAR SWBS Weights

SWBS		Scale Factor/Source	Result
110	SHELL + SUPPORTS	Displacement	446
120	HULL STRUCTURAL BULKHDS	Displacement	381
130	HULL DECKS	Displacement	220
140	HULL PLATFORMS/FLATS	Displacement	181
150	DECK HOUSE STRUCTURE	Displacement	229
160	SPECIAL STRUCTURES	Total Accommodations	67
170	MASTS+KINGPOSTS+SERV PLATFORM	Displacement	8
180	FOUNDATIONS	Displacement	99
190	SPECIAL PURPOSE SYSTEMS	Installed Power	102
100 Total	HULL STRUCTURES	Displacement	1,733
100	HULL STRUCTURES	Displacement	1,284
100	**HULL STRUCTURES**	**Watson and Gilfillan**	**1,478**
230	PROPULSION UNITS	Vendor Data	138
240	TRANSMISSION+PROPULSOR SYSTEMS	Installed Power	86
250	SUPPORT SYSTEMS	Installed Power	64
260	PROPUL SUP SYS- FUEL, LUBE OIL	Installed Power	8
290	SPECIAL PURPOSE SYSTEMS	Installed Power	41
200 Total	**PROPULSION PLANT**		**337**
311	SHIP SERVICE POWER GENERATION	Vendor Data	210
312	EMERGENCY GENERATORS	Installed Power	4
320	POWER DISTRIBUTION SYS	Displacement	45
330	LIGHTING SYSTEM	Displacement	10
340	POWER GENERATION SUPPORT SYS	Installed Power	24
350	GROUNDING AND BONDING	Installed Power	0
390	SPECIAL PURPOSE SYS	Installed Power	19
300 Total	**ELECTRIC PLANT, GENERAL**		**312**
400 Total	**COMMAND & CONTROL**	**Educated Guess**	**5**

510		Total	65
511	COMPARTMENT HEATING SYSTEM	Accommodations	2
512	VENTILATION SYSTEM	Accommodations	22
513	MACHINERY SPACE VENT SYSTEM	Installed Power	14
514	AIR CONDITIONING SYSTEM	Accommodations	27
516	REFRIGERATION SYSTEM	Accommodations	4
517	AUX BOILERS+OTHER HEAT SOURCES	Accommodations	0
500 Total	**AUXILIARY SYSTEMS, GENERAL**		**134**
610	SHIP FITTINGS	Displacement	8
620	HULL COMPARTMENTATION	Displacement	99
630	PRESERVATIVES+COVERINGS	Displacement	140
640	LIVING SPACES	Accommodations	44
650	SERVICE SPACES	Accommodations	9
660	WORKING SPACES	Accommodations	33
670	STOWAGE SPACES	Accommodations	27
90	SPECIAL PURPOSE SYSTEMS	Displacement	2
00 Total	**OUTFIT+FURNISHING,GENERAL**		**362**
700 Total	**ARMAMENT**	**Displacement**	**2**
Lightship Total			**2,630**
Lightship Margin (15%)			**394**
Lightship w/Margin			**3,024**

6.4 Hydrostatics

A first principles approach was taken to calculate the hydrostatic characteristics of T-STAR, which were then verified with Paramarine (Zubaly, 1996). The moon pool was included in these calculations as an open water column within the ship rather than a fixed weight. This approach accounted for the loss of waterplane area and displacement as well as small shifts in the LCF and LCB. The hydrostatic properties including the effects of the moon pool are shown in Table 16.

6.4.1 Intact Stability

The full load departure weight and stability data is shown in Table 15. A GZ curve is shown in Figure 14 from the tow-salvage fully loaded condition. This curve was calculated using Paramarine. The stability spreadsheets used to generate Table 15 can be found in Section 12, with an example arrival condition as well.

T-STAR's GM_T is about 18% of the beam, 9-10 ft, depending on loading condition. The righting arm is about 5.2 ft with an angle of vanishing stability greater than 80 degrees. This very stable platform may be necessary for crane or heavy lift operations. In a fully loaded condition, T-STAR exhibited a 4 degree list when the maximum transverse moment was applied to the crane. Stability is not compromised in other loading conditions with the use of ballast. However, the large GM_T may decrease the roll period to uncomfortable levels at sea, making the vessel too stiff. Seakeeping analysis is discussed in Section 6.5.

Table 15: T-STAR Full Load Departure Conditions

Full Load Departure Conditions			
	Tow-Salvage	Dive-Rescue	Installed Only
Installed Equipment (LT)	195	195	195
Mission Modules (LT)	148	262	0
Fuel (LT)	397	397	397
Ballast (LT)	114	0	262
Total Deadweight (LT)	923	923	923
Lightship Weight (LT)	2,973	2,973	2,973
Full Load (LT)	3,895	3,895	3,895
KG (ft)	18	18	17
GM_T (ft)	9.6	9.0	10.4
GM_L (ft)	484	483	484
Trim (ft)	0	0	0

Table 16: T-STAR Hydrostatics with Moon Pool

T-STAR Hydrostatics w/ Moon Pool		
Length, Waterline	274.5	[ft]
Beam	52	[ft]
Draft	15	[ft]
Depth	25	[ft]
Displacement	3,897	[LT]
Wetted Surface Area	17,125	[ft^2]
Waterplane Area	12,243	[ft^2]
Maximum Sectional Area	737	[ft^2]
LCB (from midships)	-1.94	[ft]
VCB or KB (from baseline)	8.45	[ft]
LCF (from midships)	-14.02	[ft]
BM_T	18.75	[ft]
BM_L	491	[ft]
C_b	0.64	
C_x	0.94	
C_p	0.67	
C_{wp}	0.86	

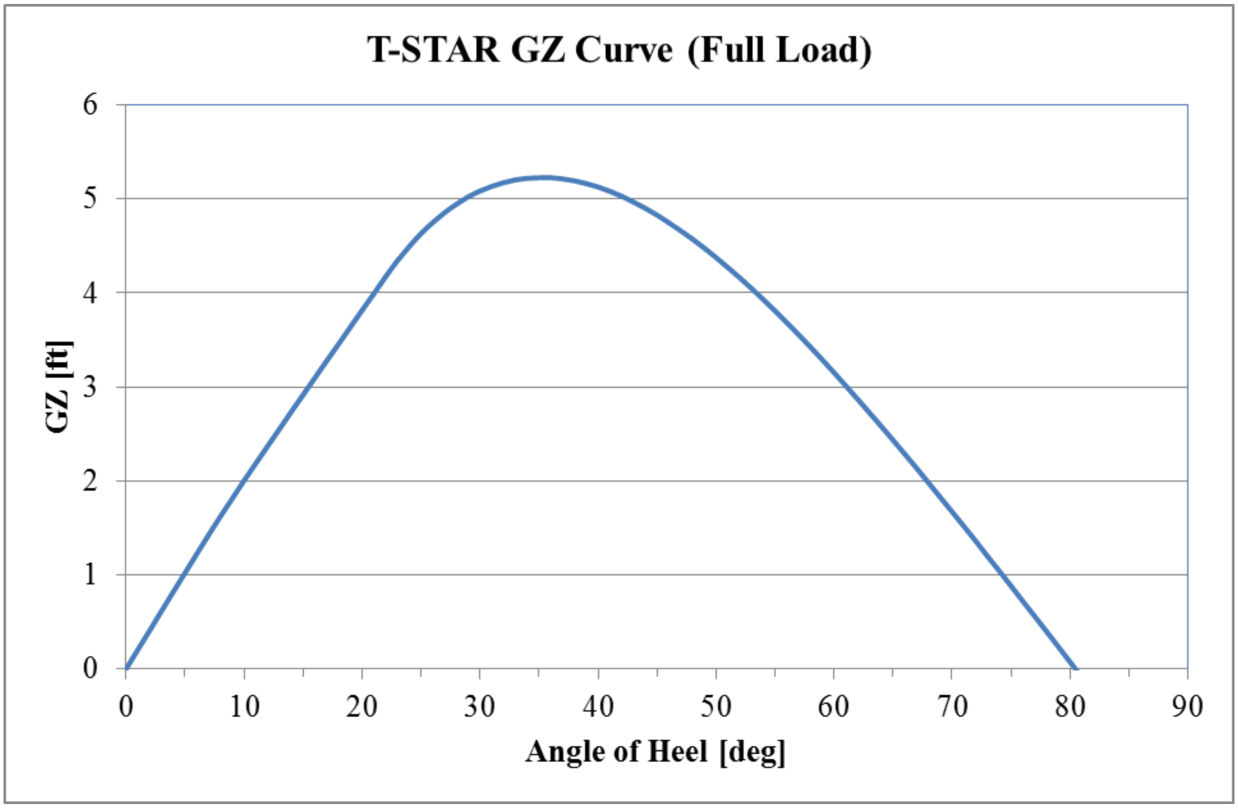


Figure 14: T-STAR GZ Curve

6.4.2 Damaged Stability

T-STAR damaged stability was evaluated using POSSE, a variant of the commercially available HECSALV program. A complete analysis was not conducted, but initial results suggest that the T-STAR is a one compartment ship in the current arrangement. It is possible to cause deck edge immersion when particular bow compartments are flooded. However, the largest compartments in the hull are the machinery rooms (dictated by engine size) and both can be flooded without immersing the deck edge. They have a relatively central location, thus there is reduced trim when flooded. As mentioned in Section 6.4.1, T-STAR has a high degree of intact transverse stability, so longitudinal watertight bulkheads would be the first step in improving damaged stability characteristics. The correct set of stability criteria, commercial or naval, for T-STAR should be determined before bulkhead placement is adjusted.

6.4.3 Tankage

The tank plan was developed from a 3-D model of the T-STAR. As the design continues, the tanks can be divided to match loading conditions to avoid the free surface effects from partially filled tanks. It was verified that tankage volumes and centers would satisfy the necessity for constant draft. The required fuel tankage was calculated based on specific fuel consumption and required power (including at sea ship's service) for a range of 12,000 nm at 12 knots. The required power estimations vary slightly, so the T-STAR's total fuel tankage includes a margin. Any excess tankage allows fuel to be shifted to adjust trim. Tankage locations and volumes are shown in Table 17. Fuel tankage accounts for 5% expansion, 2% structure and 2% unfilled space. Ballast tankage is the same, except no room was allowed for expansion (Parsons, September 2007).

Table 17: T-STAR Tankage

T-STAR Tankage				
Tank	Volume [ft^3]	LCG [ft]	VCG [ft]	Liquid Capacity [LT]
Inner Bottom Centerline Fuel	19,699	-123.59	2.61	432.4
Stern Fuel	6,318	-221.00	10.10	138.7
Inner Bottom Ballast	14,261	-147.11	2.85	391.3
Wing Ballast	7,750	-136.22	10.07	212.6
Forward Wing Ballast	1,629	-46.55	10.37	44.7
Stern Ballast	6,594	-219.62	10.66	180.9

6.5 Seakeeping

Seakeeping analysis was conducted using the linear seakeeping code Proteus which is a module of Paramarine. The requirements for T-STAR were taken from T-ARS (Ship Design and Integration Directorate, March, 1981) and are shown in Table 18. Figure 15 and Figure 16 show predicted motions at the transom in sea state 5 in the transit condition.

The results of this analysis show that T-STAR meets acceleration limits in all conditions, but significantly violates roll and pitch limits in higher sea states. However, the validity of the linear seakeeping model for this application is in question, particularly for the higher seas where large motions are predicted. The shapes of the output curves are correct, but the magnitude of the results may not be accurate. Non-linear seakeeping analysis or model tests should be used in the future for T-STAR and similar hullforms.

As mentioned previously, T-STAR's large GM_T was a concern for roll periods and accelerations. The Proteus acceleration results do not reflect this concern, but further analysis may indeed show that T-STAR rights itself too quickly for safe or comfortable operations. It should be noted that no bilge keels or other roll damping methods were incorporated into the Proteus analysis. Bilge keels are standard features on ships such as T-STAR, and their inclusion would lessen the roll motion and lengthen the roll period. However, bilge keels will add to appendage drag requiring re-evaluation of resistance and powering characteristics.

Table 18: T-ARS and T-STAR Seakeeping Requirements

T-ARS Seakeeping Limiting Requirements					
Operation Type	SS	Roll [deg]	Pitch [deg]	Lateral Acc. g	Vertical Acc. g
Transit	5	10	3	0.2	0.4
Salvage	5	5	3	0.22	0.2
Continuous Operation	6	10	3	0.2	0.4
Towing	6	10	3	0.2	0.4
Limited Operation	7	10	3	0.5	0.4
Survivability	8	30	8	0.5	1

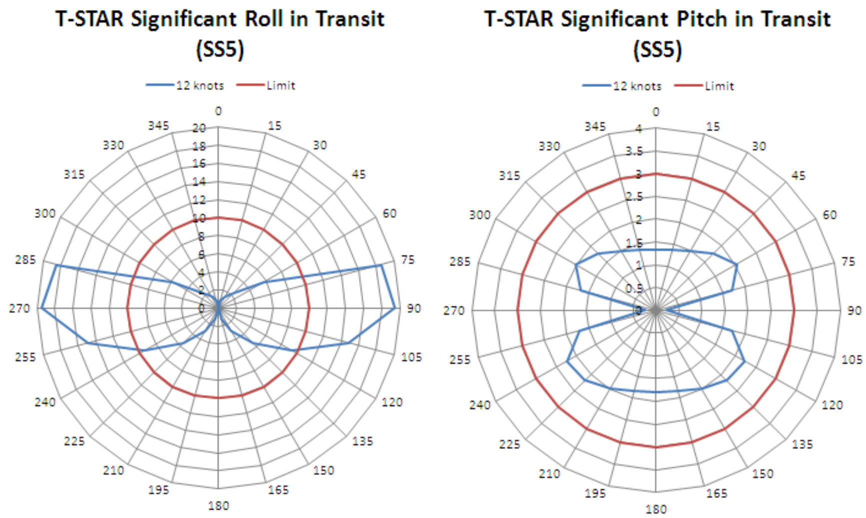


Figure 15: T-STAR Significant Motions

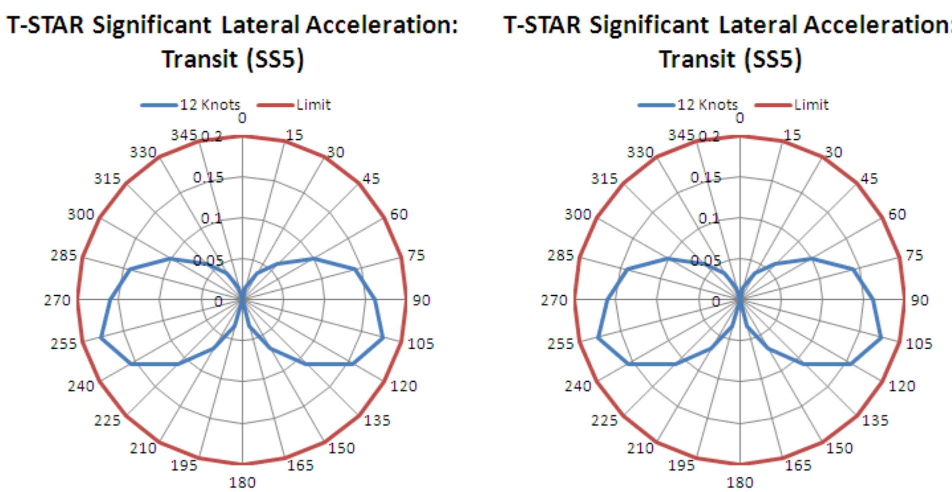


Figure 16: T-STAR Significant Accelerations

6.6 Structure

6.6.1 General Considerations

No structural analysis was conducted for T-STAR. If the vessel is built to ABS standards, it would fall under the steel vessels under 90 meters guidelines. However, it would be advisable to build the vessel to the normal steel vessel rules as expansion of the parallel midbody could easily increase the length to more than 90 meters. T-STAR structure will likely be a combination of longitudinal and transverse framing systems. The bow and stern sections with their curvature would be largely transverse while the parallel midbody would be framed longitudinally (Zubaly, 1996). T-STAR's structural design will be unique due to the large deck loads from the crane, winch and other equipment. The moon pool will also require special structural accommodation. The moon pool is located as far astern as possible for operational reasons, but this has the added benefit of reduced structural bending loads. T-STAR was designed with an innerbottom height of 5 ft, which was in excess of the ABS steel vessel rules, to allow for lengthening of the ship (Steel Vessel Rules, 2011). This innerbottom height also provides a large space for fuel and ballast tanks, and makes the vessel easier to construct. The collision bulkhead was placed in accordance with ABS steel vessel rules (Steel Vessel Rules, 2011).

6.6.2 Ice Class

The current T-ATF is constructed to an ABS C0 ice classification, the second lowest ice rating available. ABS recommended a 10-15% increase of structural weight to accommodate C0 or D0 classification. Since the estimated structural weight of T-STAR lies within the scaling range for similar ships including the ABS C0 classed T-ATFs, no extra weight was added. Another major ice class issue is ice strengthening of the propulsion system. T-STAR's compact thrusters are not ice class rated, likely due to the nozzle. Other thruster designs, like those on the USCG ice breaker Mackinaw, are ice class rated. Further requirement clarification is required to determine just how much ice strengthening T-STAR requires.

7 Machinery

A diesel-electric integrated power system with AC generators and AC synchronous propulsion motors is employed on T-STAR. These systems usually have a higher acquisition cost but can reduce life-cycle costs on vessels such as T-STAR by increasing efficiency and reducing maintenance (Marine Diesel Power Plant Performance Practices, 1989). T-STAR's operational profile has widely ranging power requirements for propulsion, auxiliary and mission related equipment. By combining these systems to operate off of one power system, they can be optimized for fuel efficiency over the entire operational range. This is apparent in the propulsion system, where direct drive diesels would have to be sized for trial speed, but would be less efficient at lower speeds. The majority of the T-STAR's operating profile is at these lower speeds. The final major advantage of the integrated power system is its modularity. When changing, adding or removing mission equipment, it is much easier to add remove or change electrical connections than mechanical or fuel connections. This is especially true if the power system and equipment interface is of a standard design.

7.1 Propulsion

7.1.1 Thrusters

The propulsion plant of T-STAR consists of four Wartsila LCT 275 compact thrusters driven by four electric motors through Z-drives. LCT 275 is a steerable thruster, with a controllable pitch propeller in a nozzle. While all of the thrusters are identical, only the outer two are rotatable. Due to space restrictions, the inner two thrusters are fixed in place. Table 19 shows thruster data for T-STAR. The cumulative maximum thruster power is 13,947 hp, generating about 83 LT of bollard pull per thruster pair according to vendor data. The U.S. Navy Salvor's handbook estimates the bollard pull to be 100 LT per pair based on the installed shaft power (U.S. Navy Salvor's Handbook, 1 January, 2004). This indicates that T-STAR would have little difficulty meeting the bollard pull requirement with all four thrusters online. It is important to note that the main driver for the high propulsion requirement is not speed, but bollard pull. The T-STAR's thruster arrangement is demonstrated in Figure 17. This thruster arrangement allows the outer two thrusters to rotate 360 degrees, and provides both lateral and longitudinal separation from the inner two thrusters. The concentric circles on the waterline view from the lines drawing in Figure 12 also show thruster locations.

One important feature of the LCT 275 is that it is a commercially available and cost effective system. Four thrusters were required to meet the bollard pull requirement, but an added benefit is that the T-STAR can perform all missions except maximum towing with only two thrusters online. This brings a level of redundancy to the system required for dynamic positioning requirements and increases the operational availability of the system. Another benefit of the LCT 275 is that the thrusters can be replaced without the use of a dry dock. This operation is not simple, but it does mean that the T-STAR is equipped to perform self-repair in an emergency situation.

Table 19: LCT 275 Thruster Specifications

Compact Thruster Data	
Input Power	3,485 [hp]
Input Speed	1,000 [rpm]
Reduction Ratio	4.084
Propeller Speed	245 [rpm]
Propeller Diameter	8.50 [ft]
Bollard Pull per Pair	83 [LT]

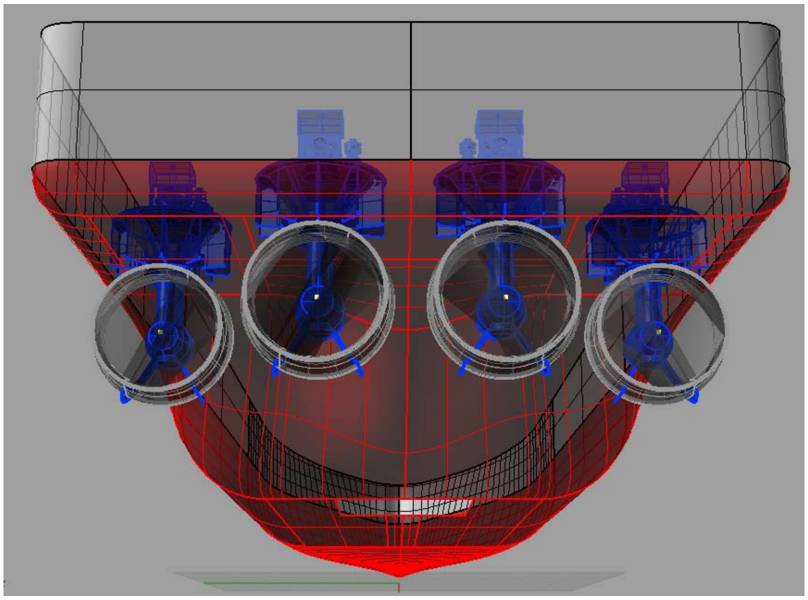


Figure 17: Thruster Arrangement

7.1.2 Electrical Propulsion Motors

No specific electrical motor was selected for T-STAR, but the motors will be 60Hz AC synchronous motors which are well suited for controllable pitch applications and do not require power conversion from AC to DC. A motor similar to that required by T-STAR is the GE 5TS851275A3 which was used as a basis for weight and dimension estimation for T-STAR's electrical motors. This motor has a power factor of 0.9 which is in agreement with the estimation made for T-STAR's propulsion system. If the electrical motors used on T-STAR are of similar dimension to the GEs, they would have to be in a z-drive configuration for vertical clearance reasons. An L-drive configuration is preferable to reduce gearing complexity and may be achievable if a more compact motor design is selected.

7.1.3 Generator Sets

The power plant is a 60 Hz diesel electric plant consisting of three Wartsila 16V26 diesel generator sets. Diesel generator specifications are given in
Table 20. Multiple generator options are feasible for the T-STAR. The current selection was made because one generator is capable of powering two thrusters to nearly full power. As a result all operations with the exception of maximum towing can be completed with two generators online. Generators with a slightly higher output capable of powering two thrusters at full power with a slight margin were also considered, but they weighed significantly more. The smaller generators selected are slightly less fuel efficient. Wartsila generators were selected over other brands because the thrusters are also from Wartsila. Purchasing the major components from one vendor may result in a better integrated package and reduced costs. It might be possible to select a generator combination with multiple sizes, but identical generators allow for interchangeable parts.

Table 20: Diesel Generator Specifications

12V26 Gen Set	
Engine Rated Power	6,973 [hp]
Generator Rated Power	6,692 [hp]
Weight	59 [LT]
Cylinder Output	436 [hp/cyl]
Engine Speed (rpm)	900
Generator Efficiency	.95-.96
SFOC	187 g/ kWh

7.1.4 Bow Thrusters-Dynamic Positioning

Dynamic Positioning 2 requirements mean that T-STAR must maintain position with the loss of one propulsion thruster and one bow thruster. Therefore two bow thrusters are required. Retractable steerable bow thrusters were investigated but are heavier, larger and more complex than similar tunnel thrusters. Two tunnel thrusters have been included in the T-STAR design on the assumption that their lateral thrust combined with the directional thrust of the steerable stern thrusters is sufficient for dynamic positioning. A rough power estimate of 2,700 hp per thruster was made based on T-ATF feasibility study, but no maneuvering analysis was conducted for T-STAR (Naval Ship Engineering Center, 1974).

7.1.5 Electrical Power Distribution

The electrical system is evenly distributed with redundancy built in for safety purposes as shown in Figure 18. The electrical system is split into Port and Starboard busses with each bus supplied by a diesel generator set while leaving the third set to be connected to either or both busses. All vital loads are carried on the vital bus which receives power from either the port or starboard side, and uses the other as a back up through a power-seeking automatic bus transfer (ABT) switch. If all power sources fail there is also an emergency diesel generator located in the pilot house that can power the loads on the vital bus.

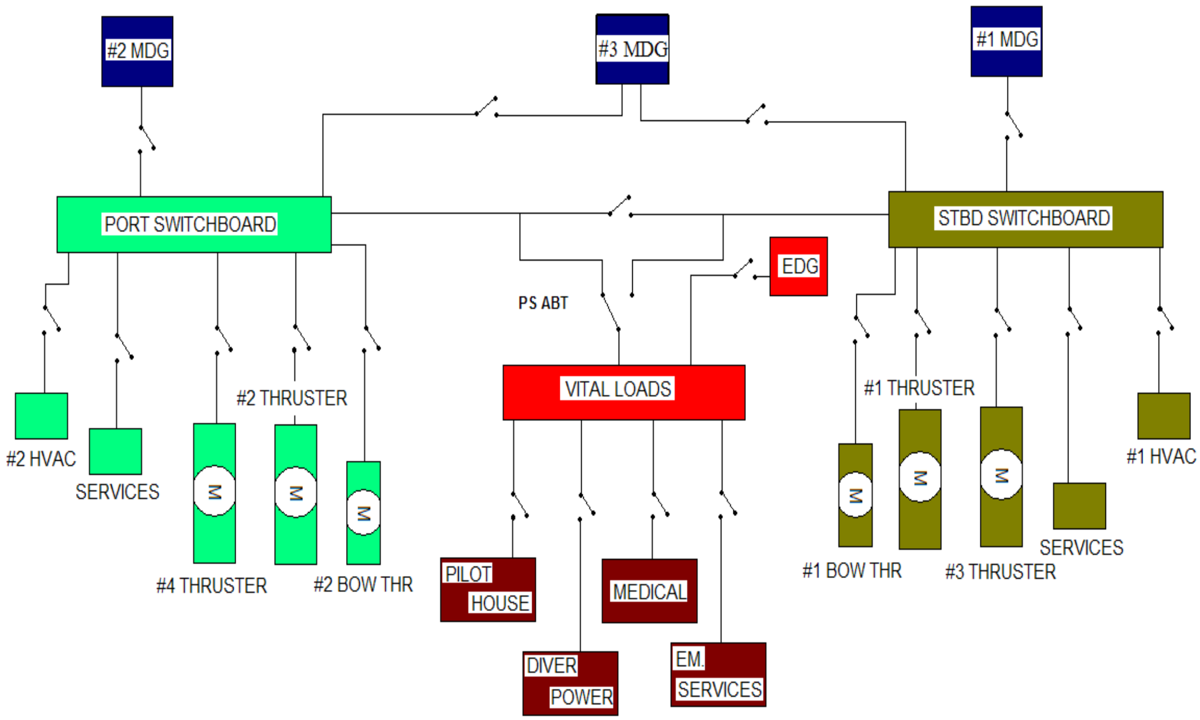


Figure 18: Electrical Distribution Schematic

7.1.6 Electrical Requirements

The electrical power requirements of the T-STAR were calculated using extrapolation from the T-AGS 66 and T-ARS electrical load estimates. The resulting data is shown in Table 21.

Table 21: Electrical Power Requirements, T-STAR

All units [kW]	100% PWR	1. Shore	2. Anchor	3. Sum Cruise	4. Win Cruise	5. Sum Tow	6. Win Tow
Machinery Room	416.7	1.1	0.9	1.8	1.8	1.8	1.8
Mooring	666.6	66.7	599.9	0.0	0.0	0.0	0.0
General Electronics/ Comm.	18.0	3.3	5.7	6.6	6.6	6.6	6.6
Hotel	1,205.6	268.6	251.3	244.5	276.4	246.3	278.5
HVAC	379.5	157.2	156.2	195.7	103.4	182.5	99.1
Misc Organic	35.0	35.0	35.0	35.0	35.0	35.0	35.0
Minimum	**2,721.4**	**531.8**	**1,049.1**	**483.7**	**423.3**	**472.2**	**421.0**
Salvage/ Tow(1)	400.0	200.0	320.0	0.0	0.0	360.0	360.0
Rescue/ Dive(2)	600.0	180.0	480.0	0.0	0.0	0.0	0.0
SATFADS(3)	700.0	0.0	630.0	140.0	140.0	0.0	0.0
SRDRS(4)	700.0	0.0	630.0	140.0	140.0	0.0	0.0
Total (1):	**3,121**	**732**	**1,369**	**484**	**423**	**832**	**781**
Total (2):	**3,321**	**712**	**1,529**	**484**	**423**	**472**	**421**
Total (3):	**3,421**	**532**	**1,679**	**624**	**563**	**472**	**421**
Total (4):	**3,421**	**532**	**1,679**	**624**	**563**	**472**	**421**

7.2 Auxiliary Equipment

7.2.1 Collection, Holding, and Transfer (CHT) Pumps

Two CHT pumps are located in a segregated bilge area in the AMR lower level and are used to pump sewage and waste water either to tanks or overboard to treatment facilities. Table 22 lists the CHT pump specifications.

Table 22: CHT Pump Data

CHT Pump Characteristics	
Discharge Size	4 [in]
Motor Output	40 [hp]
Speed	1,760 [rpm]
Material	CuNI & Monel
Weight	1,553 [lbs]

7.2.2 High Pressure Air Compressors (HPACs)

The compressed air needs of T-STAR are supplied by two Bauer K-42D four-stage 5,000 psi service air compressors located in AMR upper level. The compressors are designed and approved to not only supply miscellaneous ship loads, but also diving air if needed. Specifications of the Bauer HPACs are given in Table 23.

Table 23: HPAC Data

HPAC	
# of Stages	4
Charging Rate	42 [scfm]
Motor Output	44 [hp]
Weight	3,200 [lbs]

7.2.3 Potable Water Pumps

There are two VF 4060 F2 Buffalo Pump potable water pumps located in the lower level of the MMR that supply potable water throughout the ship. Table 24 shows the characteristics of the Buffalo water pump chosen for T-STAR.

Table 24: Potable Water Pump Data

Potable Water Pump	
Discharge	2 [in]
Motor Output	15 [hp]
Speed	1,150 [rpm]
Weight	265 [lbs]
Capacity	300 [gpm]

7.2.4 Reverse Osmosis (RO) Watermaker

Fresh water is created by two reverse osmosis units supplied by Aqua-Chem. The process extracts fresh water from seawater through the use of semi-permeable membranes. These units are the standard USN reverse osmosis water-makers in use throughout the fleet. They are sized to meet MSC requirements (COMSC INSTRUCTION, 6 June, 1991). Table 25 gives the RO specifications for a single unit.

Table 25: Reverse Osmosis Specifications

Reverse Osmosis Characteristics	
Design op. temp	34-95 [degrees F]
Recovery Rate	19 [%]
Pressure vessels	9
Membranes	9
High Pressure Pump	30 [hp]
Weight	2,750 [lbs]
Capacity	6,800 [gpd]

7.2.5 Fire Pumps

There are four motor driven fire pumps (MDFP) in the T-STAR design. Two are located in the MMR lower level, and two are located in the AMR lower level. These pumps can be used not only for shipboard firefighting, but can also supply a firemain for off-ship firefighting efforts. The MDFP specifications are listed in Table 26.

Table 26: Fire Pump Specifications

Fire Pump	
Discharge Size	6 [in]
Flow Rate	1,000 [gpm]
Motor Output	60 [hp]

8 General Arrangements

The T-STAR's general arrangements were driven by the largest individual spaces on the ship, the machinery rooms. For efficient producibility and maintenance, these spaces were placed below the open deck and within the parallel midbody. The moon pool was also located below the open deck which further drove the arrangements. The location of these spaces has a major impact on trim and stability, so they were arranged in conjunction with the heavy mission module deck arrangements. All accommodations were placed in the superstructure to enable modular cabin construction. Permanent spaces, such as the engine control room and galley, were located below. The inboard profile is shown in Figure 19 and the size of the machinery rooms relative to other spaces is very clear. The T-STAR features 10 ft deck heights to facilitate distributed systems installation in the overhead. The waterline of the vessel is at the Level 2 deck, 15 ft above the baseline. Volumes of various spaces and regions of the ship are shown in Table 27.

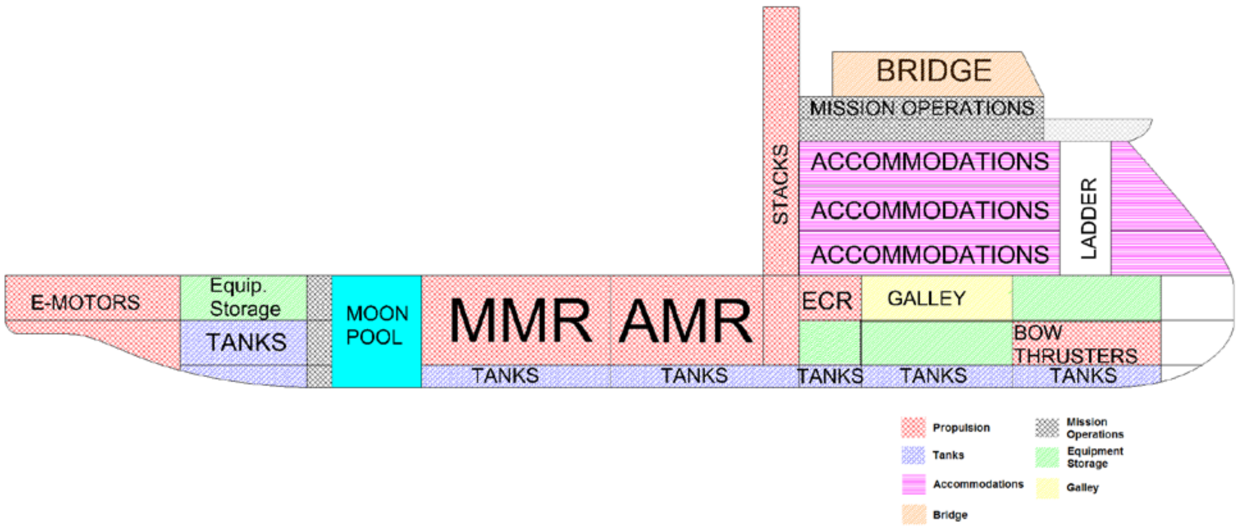


Figure 19: T-STAR Inboard Profile

Table 27: T-STAR Volume Summary

T-STAR Volumes			
	Volume [ft^3]	**LCG [ft]**	**VCG [ft]**
Hull Above Waterline	123,796	-150.02	20.02
Hull Below Waterline	136,402	-139.20	8.45
Total Hull	260,198	-144.35	14.45
Superstructure	108,880	-60.31	39.93
Total Ship	**369,078**	**-119.55**	**21.62**
Main Machinery Room	52,175	-160.85	12.85
Auxiliary Machinery Room	53,050	-118.90	12.92
Total Machinery	**105,226**	**-139.70**	**7.82**

8.1 Accommodations

The T-STAR accommodation block contains double state rooms, single state rooms, offices, crew facilities, and passageways with a width of 5 ft. Wide passageways facilitate equipment and personnel movement as well as providing space for distributed systems. Single staterooms have private toilet/showers while double staterooms have shared facilities. Minimum areas of the single and double staterooms throughout the vessel are 13’ x 10’ and 14’ x 10’ respectively. These areas meet MSC guidelines for berthing which require double staterooms to have a total area of 140 ft^2, and single staterooms to have a total area of 130 ft^2. The Chief Engineer and

Master staterooms are 200 ft^2 in area. The offices for both positions together have a total area of 270 ft^2. This requirement also comes from the MSC standards for berthing.

T-STAR was designed to accommodate 62 personnel while in transit; therefore, there are a total of 29 double state rooms and 4 single staterooms. This accounts for 49,800 ft^3 of the deckhouse which has a total volume of approximately 108,880 ft^3. The leisure spaces located throughout the deckhouse have a minimum area of 215 ft^2 for every 15 people onboard to meet MSC standards. This implies that at least 860 ft^2 of area needs to be dedicated to leisure throughout the vessel. Additionally, standard medical spaces are augmented by a mental health room. This is necessary because of the types of operations T-STAR may be engaged in and doubles as emergency medical space.

The crew mess of the vessel has a volume of 11,468 ft^3. This is a result of the Watson, Gilfillan and Lamb model for general arrangements of a standard crew (Parsons, September 2007). The galley of an MSC vessel must have an area of 7 ft^2 per person served. This size galley would allow up to 50 men to be served at a time. The total volume of the dry, chill, and freeze storage along with the ship's general and ship stores total 2,942 ft^3. Also, the total weight of these items sums to 40,500 lbs. These dimensions and weights stem directly from the COMSC INSTRUCTION 9330.6D for accommodation standards of MSC ships. The crew mess and stowage are located on Platform 1 adjacent to the MMR. This placement allows the accommodation block within the superstructure to be constructed and outfitted with individual stateroom modules, similar to the cruise ship industry (Lamb, 2003). It also means that the accommodation block can be renovated or modified easily in the future. Next to the crew mess is a designated space for laundry. Laundry equipment includes a US Navy Shipboard Washer-Extractor model NX60NSWE and an EDRO DynaDryer M-Series for US Navy Surface Ships.

Figure 20, Figure 21 and Figure 22 below show the general arrangements of the superstructure of T-STAR for the 02 Level, 01 Level, and Main Deck respectively. All modular cabins are modular, so the arrangement can easily modified with minimum interference issues. Equipment int the RHIB and the skimmer boat spaces are not modular and are permanently fixed. A volume breakdown of the superstructure general arrangements can be found in the Section 12.

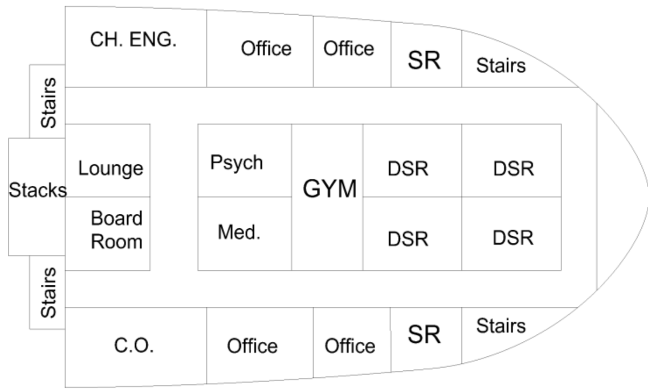


Figure 20: 02 Level

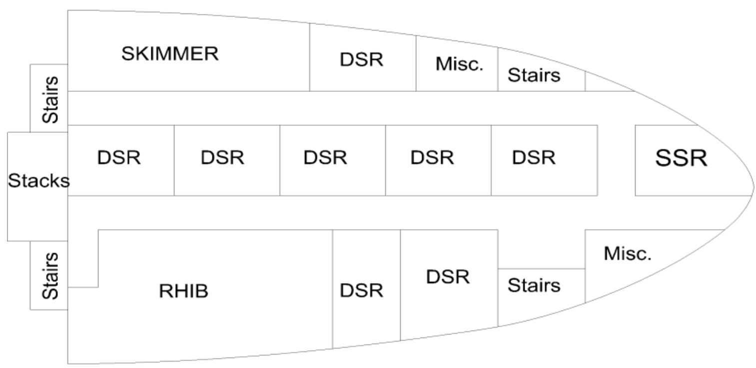


Figure 21: 01 Level

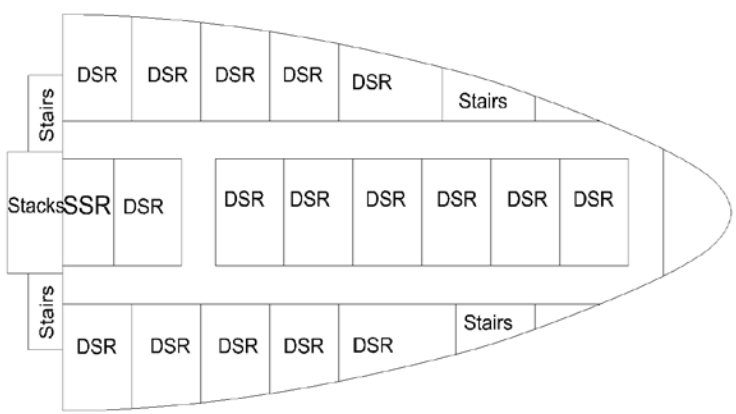


Figure 22: Main Deck

8.2 Machinery

Equipment in the Main and Auxiliary Machinery Rooms is arranged on two levels, one upper (1st Platform) and one lower (2nd Platform), located on the centerline of the ship amidships. The Engineering Control Room is located forward of the AMR.

The MMR upper level contains the upper half of the two main generator sets. The MMR lower level holds the lower half of two of the main generator sets and support equipment, including the fuel oil purifier and fuel oil transfer pump. It also contains auxiliary equipment such as potable water pumps. The AMR upper level contains the upper half of the third main generator set and the two reverse osmosis machines as well as the high pressure air compressors (HPACs). The AMR lower level contains the lower half of the third main generator set and the two reverse osmosis machines. It also contains a fuel oil purifier, fuel oil transfer pump for the third main generator set and the CHT pumps. The machinery room layouts are displayed in Figure 23 and Figure 24.

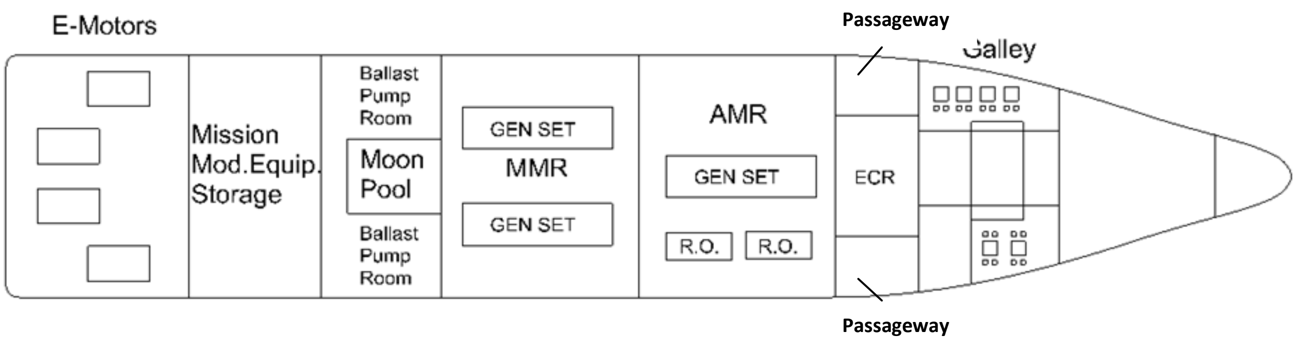


Figure 23: 1st Platform

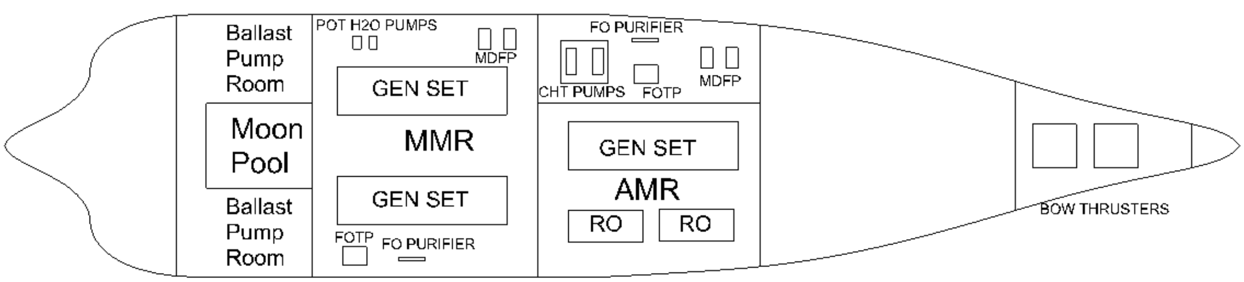


Figure 24: 2nd Platform

8.3 Mission Spaces

Most mission spaces are located on the main deck aft of the deckhouse. In addition, there is a Mission Module Equipment stowage space on the 1st Platform aft and unallocated space on the

2nd Platform forward, as shown in Figure 19, that could be used for mission specific functions such as mission module equipment and workshop space. Access to these spaces, especially with large equipment, could be problematic. There is some deckhouse volume located beneath the Bridge, as seen in Figure 19, that serves as the Mission Module Operations Center.

8.4 Distributed Systems

The most voluminous distributed system on T-STAR is the diesel generator intake and exhaust. All three generators will be oriented so that main exhausts face each other. This will allow the exhaust and intake trunks to be run in line minimizing loss in usable space. Two parallel longitudinal passageways extend from the Electrical Motor Rooms to the forward AMR bulkhead on 1st Platform. These passageways will also be the main distributed routing trunks. The bulkhead that separates the AMR and Electrical Motor Room (EMR) is in the same plane as the aft end of the superstructure both for routing and structural considerations. This has bulkhead a single passageway that extends forward with systems branching to port and starboard sides. There are four ladders/stairwells on T-STAR. The aft two are adjacent to the stacks and continue down to the AMR as shown in Figure 22. These stairwells will serve as the main vertical routing trunks as well. All decks on T-STAR have 10 ft deck heights, allowing extra room for distributed systems in the overhead.

9 Operations

The current T-ATFs are stationed at Norfolk, San Diego, San Francisco and Pearl Harbor. Of the four T-ARSs in service, two are stationed at Norfolk, one at Sasebo and one at Pearl Harbor. If T-STARs were stationed at Norfolk, San Diego, Bahrain and Pearl Harbor, global coverage is assured with the 12,000 nautical mile range. The primary mission modules would also need to be located at those ports or be easily transported to. Certain other mission modules like SAT-FADS can be flown where needed as needed. Multiples of these modules are not needed as they are easily transportable and rarely used.

10 Further Study

The T-STAR hull is uniquely shaped at the stern to provide the necessary clearance for the main propulsion thrusters. The size of these thrusters is dictated by the bollard pull requirement. Initially, Initial powering estimates relied on parametric tools and standard series. IHDE analysis became available later in the design process, past the point where the hull could be modified. The most significant outcome of this analysis was the resistance curve discussed previously and the surface wave pattern seen in Figure 25.

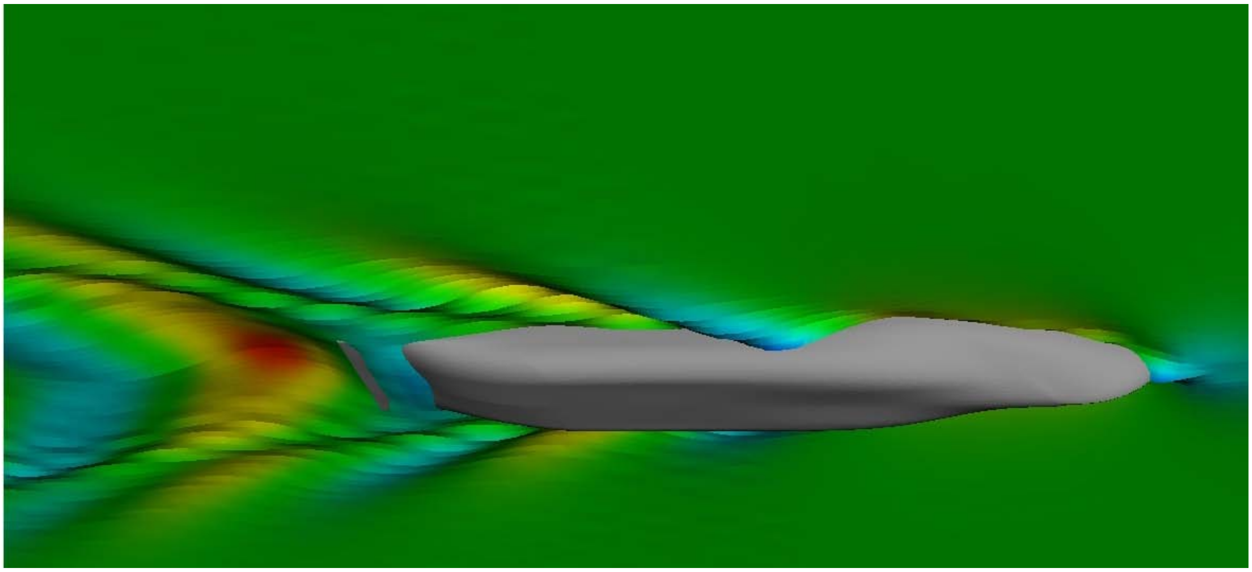


Figure 25: IHDE Surface Wave Pattern

What this figure shows is a large air pocket beneath the stern of T-STAR at around 15 knots. This air pocket corresponds to the location of the T-STAR's thrusters. Whether or not this condition exists in the real world, it points out the risk factors involved with a very high bollard pull requirement in combination with a shallow draft. The concept design of the T-STAR has led to several recommendations to mitigate the risks, all of which require further study.

Reevaluation of the draft and/or bollard pull requirements is recommended. If either is relaxed, a near exact commercial X-bow anchor handling tug would be suitable for this mission.

Some reshaping of the T-STAR hull may be required to alleviate potential seakeeping and trim sensitivity problems. This involves shifting volume forward and lengthening the hull, creating a more slender ship. These changes may also reduce the wave patterns, decrease drag and alleviate the air entrapment problem.

Alternative propulsion methods should be investigated. The most obvious choice would be to reinvestigate water jets. However, some recent tow tank studies have suggested that fixed shaft propellers in series with pods or thrusters can increase propulsive efficiency and reduce drag. This may allow the propellers to be decreased in size thereby deepening the draft at the stern and eliminating the air entrapment.

It is also possible to operate the ship trimmed by the stern, ballasting to a level draft only when conducting shallow water operations.

Other areas that require further study are: damage stability analysis and bulkhead placement, more detailed arrangements, identification of appropriate classification standards, structural design, and cost estimate.

11 Conclusions

It is important to note that the primary purpose of this project was to demonstrate that the missions of T-ARS and T-ATF could be combined in one design. The use of mission modules and the design of T-STAR have proven this concept feasible. The specific details and/or problems of the hull form are a result of the requirement for a much higher bollard pull than either T-ATF or T-ARS currently has. While the T-STAR design is feasible, particular attention needs to be focused on the hull and propulsion system interaction.

Cost was not a quantifiable design parameter for T-STAR, but the ship is designed to be affordable. To achieve this, only equipment that was commercially available or in government stock was used. The hullform was designed to meet commercial standards and is based on a commercial design. Construction should be simplified due to the machinery and accommodation arrangements as well as the parallel midbody. The biggest cost savings is assumed to come from the mission modules, where only one class of ship can be used for missions normally requiring two. However, there is no effective way to measure the construction or life-cycle costs of T-STAR. T-STAR is assumed to be more affordable than two new ship classes if mission modules are used efficiently. This requires that mission modules and ships are designed in such a way that they can be exchanged quickly so that response time is comparable to that of a mission tailored ship. This implies that only one T-STAR hull would be required where both a T-ATF and T-ARS hulls are currently required.

12 Appendices

12.1 Mission Modules

12.1.1 Main Deck Installed Equipment

	T-STAR INSTALLED EQUIPMENT PORTSIDE	Quantity	Weight [KIPS]	Weight [LT]	LCG [ft]
Common	Ships Anchor	1	4.00	1.79	-49.21
	Anchor Chain 2.25" x 165 Fathoms	1	50.00	22.32	-49.21
	Mooring	2	6.00	2.68	-49.21
	Mooring			0.00	-272.01
	Skimmer	1	7.00	3.13	-81.46
	Lifeboat Davits	1	5.00	2.23	-116.04
	Lifeboat Winch	1	4.50	2.01	-116.04
	Bow Hawse Pipe	1	3.50	1.56	-49.21
Salvage/Dive	Bow Sheaves	1	10.00	4.46	-49.21
	Beach Gear Padeyes	2	0.40	0.18	-272.21
	Beach Gear Partial Sets	1	19.95	8.91	-196.85
	Diver Davit	1	1.00	0.45	-178.84
	Diving Air Bottles	6	1.10	0.49	-174.02
	Hydraulic Pullers	1	5.00	2.23	-30.00
	Hydraulic Controls	1	3.00	1.34	-35.00
	Dive Air Compressor	1	3.00	1.34	-154.49
Towing	Stern Bulwark	1	10.00	4.46	-49.21
Fire Fighting	Fire Monitor	2	0.50	0.22	-265.32
	AFFF	9	4.40	1.96	-154.69
	Total Port		**138.35**	**61.76**	**-84.71**
	T-STAR INSTALLED EQUIPMENT STARBOARD	Quantity	Weight [KIPS]	Weight [LT]	LCG [ft]
Common	Ships Anchor	1	4.00	1.79	-49.21
	Anchor Chain 2.25" x 165 Fathoms	1	50.00	22.32	-49.21
	Mooring	2	6.00	2.68	-49.21
	Mooring			0.00	-272.01
	RHIB	1	17.00	7.59	-79.95
	Lifeboat Davits	1	5.00	2.23	-116.04
	Lifeboat Winch	1	4.50	2.01	-116.04
	Bow Hawse Pipe	1	3.50	1.56	-49.21

Salvage/Dive	Bow Sheaves	1	10.00	4.46	-49.21
	Beach Gear Padeyes	2	0.40	0.18	-272.21
	Beach Gear Partial Sets	1	19.95	8.91	-196.85
	Diver Davit	1	1.00	0.45	-178.84
	Diving Air Bottles	6	1.10	0.49	-174.02
	Hydraulic Pullers	1	5.00	2.23	-30.00
	Hydraulic Controls	1	3.00	1.34	-35.00
Towing	Stern Bulwark	1	10.00	4.46	-49.21
Fire Fighting	Fire Monitor	2	0.50	0.22	-265.32
	AFFF	8	4.00	1.79	-154.69
	Total Starboard		**144.95**	**64.71**	**-82.67**
	T-STAR CENTERLINE	Quantity	Weight [KIPS]	Weight [LT]	LCG [ft]
Salvage	54 LT Crane	1	102.00	45.54	-150.92
Towing	Winch	1	52.00	23.21	-218.04
	Total CL		**154.00**	**68.75**	**-173.58**

Installed Total Weight [KIPS]	**437.3**
Installed Total Weight [LT]	**195.22**
Installed LCG [ft]	**-115.33**

12.1.2 Main Deck Tow/Salvage Equipment

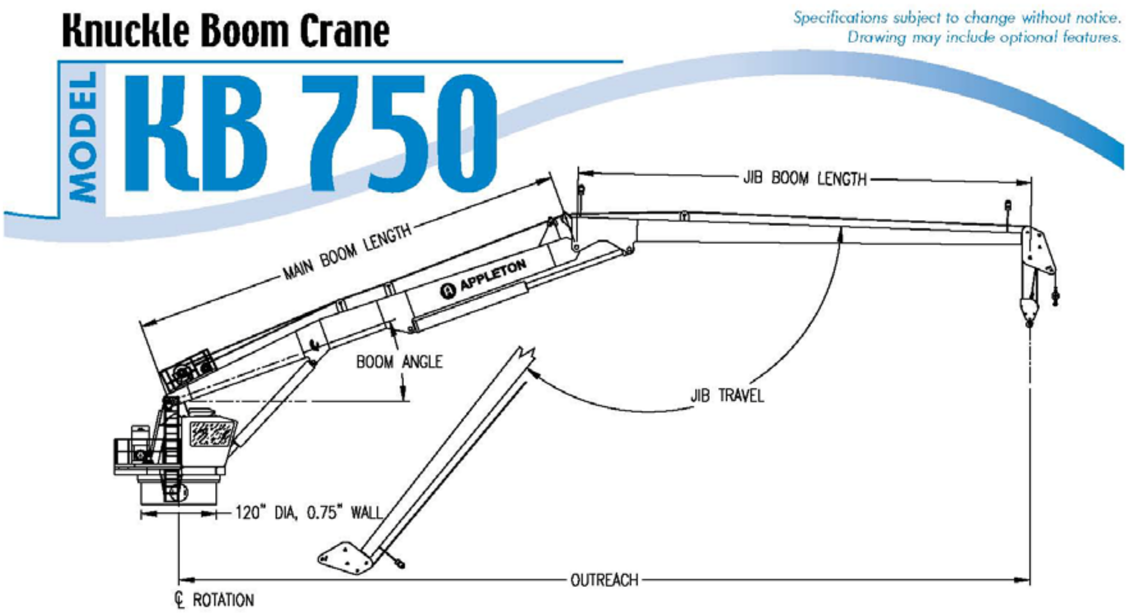
	T-STAR TOW/SALVAGE PORTSIDE	Quantity	Weight[KIPS]	Weight [LT]	LCG [ft]
Beach Gear	Chain 2 Shots 2.5" Die Lok	1	12.50	5.58	-250.89
	10,000# Stato Anchors and Racks	2	22.10	9.87	-250.89
	Retrieval Pendant 600' 1"	2	2.00	0.89	-226.48
	Wire; 1,800' 2.5"	1	16.85	7.52	-218.04
	Buoys, Crown (Foam)	2	0.10	0.04	-235.27
	Carpenter Stopper	2	1.00	0.45	-160.63
	Hydraulic Pullers	1	5.00	2.23	-230.64
	Hydraulic Controls	1	3.00	1.34	-230.64
Salvage Diving	Helium Oxygen Diving Outfits	2	11.46	5.12	-144.52
	Scuba Gear	5	0.53	0.23	-135.56
	200 Amp Welder	1	0.38	0.17	-106.33
	Mixed Gas Bottle Pallets	1	12.00	5.36	-217.55
	Mixed Gas Control Van (TEU)	1	8.00	3.57	-186.88
	Recompression Chamber	1	6.05	2.70	-205.77
	Oxygen and Acetylene Bottles	1	1.28	0.57	-206.46
Salvage Equipment	6" Salvage Pump	1	1.42	0.63	-136.52
	10" Salvage Pump	1	2.97	1.32	-136.52
	3" Salvage Pump	3	2.64	1.18	-136.52
	10" Pump	2	2.43	1.08	-136.52
	6" Submersible Pump	1	1.64	0.73	-226.44
	400 Amp Welder	1	1.50	0.67	-217.52
	Total Port		**114.83**	**51.26**	**-210.80**
	T-STAR TOW/SALVAGE STARBOARD	Quantity	Weight [KIPS]	Weight [LT]	LCG [ft]
Beach Gear	Chain 2 Shots 2.5" Die Lok	1	12.50	5.58	-250.89
	10,000 # Stato Anchors and Racks	2	22.10	9.87	-250.89
	Retrieval Pendant 600' 1"	2	2.00	0.89	-226.48
	Wire; 1,800' 2.5"	1	16.85	7.52	-218.04
	Buoys, Crown (Foam)	2	0.10	0.04	-235.27
	Carpenter Stopper	2	1.00	0.45	-160.63
	Hydraulic Pullers	1	5.00	2.23	-230.64
	Hydraulic Controls	1	3.00	1.34	-230.64
Salvage	Helium Oxygen Diving Outfits	1	5.73	2.56	-183.56

Diving	Scuba Gear	5	0.53	0.23	-187.14
	200 Amp Welder	1	0.38	0.17	-106.33
	Power Pack Unit	1	18.90	8.44	-167.78
Salvage Equipment	6" Salvage Pump	1	1.42	0.63	-144.52
	10" Salvage Pump	1	2.97	1.32	-144.52
	3" Salvage Pump	3	2.64	1.18	-144.52
	10" Pump	1	1.21	0.54	-144.52
Oil Recovery	Oil Containment Boom	1	29.34	13.10	-213.22
	Total Starboard		**125.66**	**56.10**	**-212.04**

12.1.3 Main Deck Dive/Rescue Equipment

	T-STAR DIVE/RESCUE PORTSIDE	Quantity	Weight[KIPS]	Weight [LT]	LCG [ft]
4 Point Moor	Anchor 6,000#	2	6.00	2.68	-246.39
	Anchor (Rack)		6.00	2.68	-237.60
	Chain	2	50.00	22.32	-246.39
	Chain (Rack)		50.00	22.32	-237.60
	Buoy	2	30.00	13.39	-219.49
	Buoy Rack	1	50.00	22.32	-219.49
	Lines	2	8.55	3.82	-49.21
Diving	Gas and Oxygen Supply	1	82.42	36.79	-196.16
	Life Support Pkg.	1	1.50	0.67	-169.16
	Compressor and Accumulator	1	4.63	2.07	-206.23
	Life Support Bundle and Bin	1	2.51	1.12	-169.49
	Total Port		**291.61**	**130.18**	**-215.65**
	T-STAR DIVE/RESCUE STARBOARD	Quantity	Weight[KIPS]	Weight [LT]	LCG [ft]
4 Point Moor	Anchor 6000#	2	6.00	2.68	-246.39
	Anchor in Rack		6.00	2.68	-237.60
	Chain	2	50.00	22.32	-246.39
	Chain in Rack		50.00	22.32	-237.60
	Buoy	2	30.00	13.39	-219.49
	Buoy Rack	1	50.00	22.32	-219.49
	Lines	2	8.55	3.82	-49.21
Diving	Recompression Chamber	1	6.05	2.70	-169.42
	Suit Water Hose Reel	1	0.68	0.30	-206.10
	Suit Water Heater	1	5.00	2.23	-206.10
	Winch Booms etc.	1	1.50	0.67	-173.43
Rescue	Mk1 Mod1 Carriage	1	75.75	33.82	-197.60
	FADS-III	1	6.42	2.87	-188.02
	Total Starboard		**295.95**	**132.12**	**-215.29**

12.2 Appleton Marine Crane Specifications



Standard Features

- Crane mounted sit-down ride around operator station
- Proportional hydraulic controls
- Simultaneous operation of two or more functions
- Boom angle indicator
- 360-degree continuous rotation
- Heat-treated stainless steel pivot pins
- Stainless steel or hard chrome-plated luffing and jib cylinder rods (diameter dependent)
- Stainless steel hydraulic tube assemblies
- AISI-316 stainless steel fasteners (3/4" dia. & smaller)
- Zinc-plated, corrosion-resistant, graded fasteners
- Acrylic epoxy marine coating system
- Glyptol internally-coated reservoirs
- Monel grease fittings
- Continuous welds
- Beveled pedestal (weld-down type)
- Factory assembled and tested

The "Maximum Crane Capacities" chart does not depict a load chart for a selected crane model. The listed capacities are maximum available capacities for the specific indicated boom lengths and outreaches/radii. For example: A Model KB 750-120 rated 51,000 lb at 80 ft radius cannot also be rated 28,300 lb at 120 ft radius and 134,300 lb at 25 ft radius due to the heavier or lighter booms required to achieve these particular capacities.

Maximum overturning moment for the Model KB 750 is 7,500,000 ft-lb (10,168 kN-m).

MAXIMUM CRANE CAPACITIES lb (kg)						
OUTREACH	BOOM LENGTH					
	80 ft (24.4 m)	90 ft (27.4 m)	100 ft (30.5 m)	110 ft (33.5 m)	120 ft (36.6 m)	130 ft (39.6 m)
20 ft	266,800	224,500	196,000			
(6.1 m)	(121,000)	(101,800)	(88,900)			
25 ft	230,000	206,100	182,200	158,200	134,300	110,400
(7.6 m)	(104,300)	(93,500)	(82,600)	(71,800)	(60,900)	(50,100)
30 ft	186,900	172,800	156,600	142,000	127,000	110,400
(9.1 m)	(84,800)	(78,400)	(71,000)	(64,400)	(57,600)	(50,100)
35 ft	160,200	151,200	140,400	131,000	121,400	110,400
(10.7 m)	(72,700)	(68,600)	(63,700)	(59,400)	(55,100)	(50,100)
40 ft	134,900	130,200	125,500	120,600	114,300	109,200
(12.2 m)	(61,200)	(59,100)	(56,900)	(54,700)	(51,800)	(49,500)
45 ft	117,800	116,200	113,300	111,600	109,800	108,000
(13.7 m)	(53,400)	(52,700)	(51,400)	(50,600)	(49,800)	(49,000)
50 ft	102,500	101,300	100,100	98,800	97,500	96,100
(15.2 m)	(46,500)	(45,900)	(45,400)	(44,800)	(44,200)	(43,600)
55 ft	89,400	88,300	87,200	86,000	84,800	83,500
(16.8 m)	(40,600)	(40,100)	(39,600)	(39,000)	(38,500)	(37,900)
60 ft	79,400	78,200	76,100	74,900	73,600	72,300
(18.3 m)	(36,000)	(35,500)	(34,500)	(34,000)	(33,400)	(32,800)
65 ft	71,200	69,300	68,200	67,100	65,900	64,700
(19.8 m)	(32,300)	(31,400)	(30,900)	(30,400)	(29,900)	(29,300)
70 ft	64,000	63,000	62,100	61,100	60,000	58,900
(21.3 m)	(29,000)	(28,600)	(28,200)	(27,700)	(27,200)	(26,700)
75 ft	59,300	57,900	56,500	55,800	55,000	54,300
(22.9 m)	(26,900)	(26,300)	(25,600)	(25,300)	(24,900)	(24,600)
80 ft	53,300	52,700	52,200	51,600	51,000	50,400
(24.4 m)	(24,200)	(23,900)	(23,700)	(23,400)	(23,100)	(22,900)
85 ft		48,800	48,400	48,000	47,500	47,000
(25.9 m)		(22,100)	(22,000)	(21,800)	(21,500)	(21,300)
90 ft		45,000	44,700	44,400	44,000	43,700
(27.4 m)		(20,400)	(20,300)	(20,100)	(20,000)	(19,800)
95 ft			41,100	40,600	40,100	39,600
(29.0 m)			(18,600)	(18,400)	(18,200)	(18,000)
100 ft			38,400	38,100	37,700	37,400
(30.5 m)			(17,400)	(17,300)	(17,100)	(17,000)
105 ft				35,500	35,200	34,900
(32.0 m)				(16,100)	(16,000)	(15,800)
110 ft				33,000	32,800	32,600
(33.5 m)				(15,000)	(14,900)	(14,800)
115 ft					30,700	30,300
(35.1 m)					(13,900)	(13,700)
120 ft					28,300	27,700
(36.6 m)					(12,800)	(12,600)
125 ft						25,500
(38.0 m)						(11,600)
130 ft						23,400
(39.6 m)						(10,600)

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12.3 Markey Winch Specifications

MARKEY

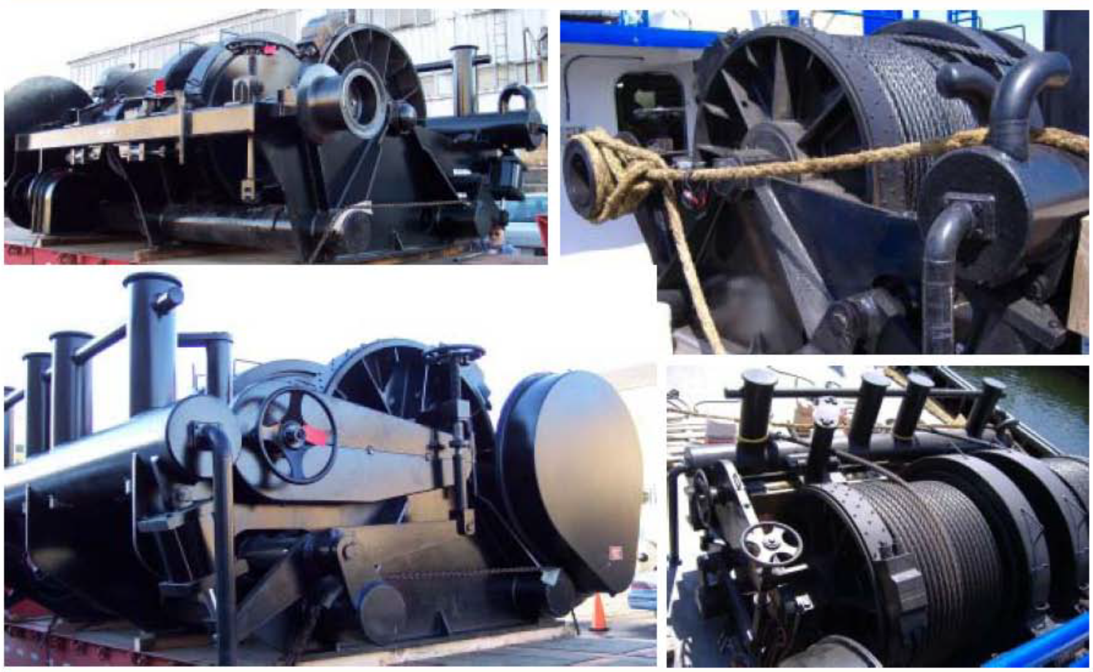
TDSD-32

Diesel Towing Winch

The TDSD-32 is a reliable diesel-driven double-drum towing winch with high line-pull and braking capacity, designed specifically for offshore towing or anchor-handling applications. Ruggedly built to provide decades of high performance with low maintenance requirements, the TDSD-32 is a proven industry workhorse.

WINCH SYSTEM SPECIFICATIONS

- **Max. Drum Capacity:** 2,450 feet of 2" wire-rope on each drum.
- **Rated Line-Pull:** 200,000 lbs rated pull (stall) at barrel layer, in first gear.
- **Diesel Power Unit:** Performance based on John Deere 6068TFM and Funk Series-2000 Transmission.
- **Winch Brakes:** Air-cylinder set and release, with manual handwheel provided for lock-down.
- **Winch Controls:** Pneumatic / Electric.
- **Winch Dimensions:** 82.0" H x 198.2" W x 154.0" D. **Approximate Weight:** 52,000 lbs.



Markey Machinery Company, Inc.
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JH Menge & Company, Inc - 5825 Plauche Street, New Orleans, LA 70123 (USA) Phone: 504-733-4871 Email: fclatour@jhmenge.com

12.4 Weight, Trim, and Stability Spreadsheets

Please note that the following spreadsheets are presented in SI units.

12.4.1 Installed Only Full Load Departure

	Analysis Condition:		**Installed Only Full Load Departure**			
DESIGN PARAMETERS						
	enter data in yellow					
LWL for displacement	83.67	m		Note: weights and centers in		
B for displacement	15.85	m		*italics* source from weight		
T for displacement	4.57	m		scaling or analysis. Other		
Cb for displacement	0.637			values are from designer		
Weight Margin	15.00	% W_{LS} at CG for LS		judgement or vendor data.		
(1 + s)	1.000	shell/appendage allow.				
KG Margin	0.50	m				
Free Surface Margin	3.00	per cent of KG				
BMT for analysis condition	5.72	m				
KB for analysis condition	2.58	m		estimates from prelim.		
BML for analysis condition	149.58	m		design equations		
LCB for analysis condition	42.43	m from FP		-0.711	%L,+fwd	
Water Weight Density	1.025	tonnes/m^3		(SW 1.025; FW 1.000)		
WEIGHT CATEGORY	SWBS Code	WT	VCG	product	LCG	product
		[t]	[m abv. BL]		[m from FP]	
Hull Structure		*1288.1*	*3.66*	4717.7	*42.40*	54612.9
Super Structures	W150	*189.5*	12.17	2306.4	18.38	3483.3
PROPULSION UNITS	W230	137.71	3.22	443.4	79.40	10934.2
TRANSMISSION+PROPULSOR SYSTEMS	W240	*86.06*	2.28	196.2	56.79	4887.3
SUPPORT SYSTEMS	W250	*63.52*	2.28	144.8	42.43	2695.2
PROPUL SUP SYS- FUEL, LUBE OIL	W260	*8.05*	2.28	18.4	56.79	457.1
SPECIAL PURPOSE SYSTEMS	W290	*40.74*	2.28	92.9	22.96	935.4
SHIP SERVICE POWER GENERATION	W311	210.00	3.08	646.8	44.65	9376.5
EMERGENCY GENERATORS	W312	*3.55*	12.18	43.2	23.05	81.8
POWER DISTRIBUTION SYS	W320	*45.08*	2.28	102.8	42.58	1919.5
LIGHTING SYSTEM	W330	*10.27*	6.59	67.7	36.44	374.2
POWER GENERATION SUPPORT SYS	W340	*24.34*	2.28	55.5	42.58	1036.4
SPECIAL PURPOSE SYS	W390	*18.54*	2.28	42.3	42.58	789.3
COMMAND AND CONTROL	W400	*5.00*	12.17	60.9	18.38	91.9
CLIMATE CONTROL	W510	*64.60*	6.59	425.7	36.44	2353.9
COMPARTMENT HEATING SYSTEM	W511	*2.16*	6.59	14.2	36.44	78.6
VENTILATION SYSTEM	W512	*21.93*	6.59	144.5	36.44	799.2
MACHINERY SPACE VENT SYSTEM	W513	*14.17*	4.00	56.7	42.58	603.4
AIR CONDITIONING SYSTEM	W514	*26.68*	7.21	192.4	36.19	965.7
REFRIGERATION SYSTEM	W516	*3.83*	4.14	15.8	36.24	138.6
SHIP FITTINGS	W610	*8.00*	6.59	52.7	36.44	291.5
HULL COMPARTMENTATION	W620	*98.75*	6.59	650.8	36.44	3598.6
PRESERVATIVES+COVERINGS	W630	*139.76*	6.59	921.0	36.44	5093.0
LIVING SPACES	W640	*44.33*	12.17	539.5	18.38	814.8
SERVICE SPACES	W650	*8.96*	4.14	37.1	22.88	204.9
WORKING SPACES	W660	*32.57*	4.14	134.8	22.88	745.1
STOWAGE SPACES	W670	*27.03*	4.14	111.9	22.88	618.4
SPECIAL PURPOSE SYSTEMS	W690	*1.71*	4.14	7.1	36.44	62.3
ARMAMENT	W700	*1.50*		0.0		0.0
Light Ship w/o Margin		2626.4				
Light Ship Margin		394.0				
Light Ship Weight		3020.4	4.66		41.14	
Installed Mission Equipment		198.4	9.00	1785.2	35.15	6972.2
Dive Rescue Port		0.0	9.00	0.0	65.72	0.0
Dive Rescue Starboard		0.0	9.00	0.0	65.62	0.0
Tow-Salvage Centerline		0.0	9.00	0.0	52.11	0.0
Tow-Salvage Port		0.0	9.00	0.0	64.16	0.0
Tow-Salvage Starboard		0.0	9.00	0.0	64.63	0.0
*Fuel Oil		*403.2*	1.00	403.2	44.80	18064.7
*Lube Oil		1.0	3.00	3.0	40.39	40.4
*Water		*31.0*	10.00	310.0	12.00	372.0
*Crew and Effects		*10.2*	12.20	124.4	20.95	213.7
*Provisions		*27.0*	12.20	329.4	20.95	565.7
*Temporary Ballast		266.5	3.00	799.6	65.70	17511.7
Total Deadweight		937.3	4.01		46.66	
Total Weight		3957.7	4.51	total VCG	42.45	total LCG
Displacement		3957.7	0.00	%; + weight exceeds displacement		
Difference		0.00				
GM AND TRIM RESULTS						
Design KG	5.14	m, including design and free surface margins				
GMT	3.16	m				
GML	147.65	m				
Trim	0.01	m; + by the stern				

12.4.2 Salvage/Tow Full Load Departure

	Analysis Condition:		Salvage/Tow Full Load Departure			
DESIGN PARAMETERS						
	enter data in yellow					
LWL for displacement	83.67	m		Note: weights and centers in		
B for displacement	15.85	m		*italics* source from weight		
T for displacement	4.57	m		scaling or analysis. Other		
Cb for displacement	0.637			values are from designer		
Weight Margin	15.00	% W_{LS} at CG for LS		judgement or vendor data.		
(1 + s)	1.000	shell/appendage allow.				
KG Margin	0.50	m				
Free Surface Margin	3.00	per cent of KG				
BMT for analysis condition	5.72	m				
KB for analysis condition	2.58	m		estimates from prelim.		
BML for analysis condition	149.58	m		design equations		
LCB for analysis condition	42.43	m from FP		-0.711	%L,+fwd	
Water Weight Density	1.025	tonnes/m^3		(SW 1.025; FW 1.000)		
WEIGHT CATEGORY	SWBS Code	WT	VCG	product	LCG	product
		[t]	[m abv. BL]		[m from FP]	
Hull Structure		*1288.1*	*3.66*	4717.7	*42.40*	54612.9
Super Structures	W150	*189.5*	12.17	2306.4	18.38	3483.3
PROPULSION UNITS	W230	137.71	3.22	443.4	79.40	10934.2
TRANSMISSION+PROPULSOR SYSTEMS	W240	*86.06*	2.28	196.2	56.79	4887.3
SUPPORT SYSTEMS	W250	*63.52*	2.28	144.8	42.43	2695.2
PROPUL SUP SYS- FUEL, LUBE OIL	W260	*8.05*	2.28	18.4	56.79	457.1
SPECIAL PURPOSE SYSTEMS	W290	*40.74*	2.28	92.9	22.96	935.4
SHIP SERVICE POWER GENERATION	W311	210.00	3.08	646.8	44.65	9376.5
EMERGENCY GENERATORS	W312	*3.55*	12.18	43.2	23.05	81.8
POWER DISTRIBUTION SYS	W320	*45.08*	2.28	102.8	42.58	1919.5
LIGHTING SYSTEM	W330	*10.27*	6.59	67.7	36.44	374.2
POWER GENERATION SUPPORT SYS	W340	*24.34*	2.28	55.5	42.58	1036.4
SPECIAL PURPOSE SYS	W390	*18.54*	2.28	42.3	42.58	789.3
COMMAND AND CONTROL	W400	*5.00*	12.17	60.9	18.38	91.9
CLIMATE CONTROL	W510	*64.60*	6.59	425.7	36.44	2353.9
COMPARTMENT HEATING SYSTEM	W511	*2.16*	6.59	14.2	36.44	78.6
VENTILATION SYSTEM	W512	*21.93*	6.59	144.5	36.44	799.2
MACHINERY SPACE VENT SYSTEM	W513	*14.17*	4.00	56.7	42.58	603.4
AIR CONDITIONING SYSTEM	W514	*26.68*	7.21	192.4	36.19	965.7
REFRIGERATION SYSTEM	W516	*3.83*	4.14	15.8	36.24	138.6
SHIP FITTINGS	W610	*8.00*	6.59	52.7	36.44	291.5
HULL COMPARTMENTATION	W620	*98.75*	6.59	650.8	36.44	3598.6
PRESERVATIVES+COVERINGS	W630	*139.76*	6.59	921.0	36.44	5093.0
LIVING SPACES	W640	*44.33*	12.17	539.5	18.38	814.8
SERVICE SPACES	W650	*8.96*	4.14	37.1	22.88	204.9
WORKING SPACES	W660	*32.57*	4.14	134.8	22.88	745.1
STOWAGE SPACES	W670	*27.03*	4.14	111.9	22.88	618.4
SPECIAL PURPOSE SYSTEMS	W690	*1.71*	4.14	7.1	36.44	62.3
ARMAMENT	W700	*1.50*		0.0		0.0
Light Ship w/o Margin		2626.4				
Light Ship Margin		394.0				
Light Ship Weight		3020.4	4.66		41.14	
Installed Mission Equipment		198.4	9.00	1785.2	35.15	6972.2
Dive Rescue Port		0.0	9.00	0.0	65.42	0.0
Dive Rescue Starboard		0.0	9.00	0.0	65.32	0.0
Tow-Salvage Centerline		40.8	9.00	367.4	52.11	2127.1
Tow-Salvage Port		52.9	9.00	475.8	64.16	3392.1
Tow-Salvage Starboard		57.0	9.00	512.9	64.63	3683.3
*Fuel Oil		*403.2*	1.00	403.2	46.00	18547.2
*Lube Oil		1.0	3.00	3.0	40.39	40.4
*Water		*31.0*	10.00	310.0	12.00	372.0
*Crew and Effects		*10.2*	12.20	124.4	20.95	213.7
*Provisions		*27.0*	12.20	329.4	20.95	565.7
*Temporary Ballast		115.9	3.00	347.7	67.00	7764.6
Total Deadweight		937.3	4.97		46.60	
Total Weight		3957.7	4.73	total VCG	42.43	total LCG
Displacement		3957.7	0.00	%; + weight exceeds displacement		
Difference		0.00				
GM AND TRIM RESULTS						
Design KG	5.38	m, including design and free surface margins				
GMT	2.92	m				
GML	147.43	m				
Trim	0.00	m; + by the stern				

12.4.3 Dive/Rescue Full Load Departure

	Analysis Condition:		Dive/Rescue Full Load Departure			
DESIGN PARAMETERS						
	enter data in yellow					
LWL for displacement	83.67	m		Note: weights and centers in		
B for displacement	15.85	m		*italics* source from weight		
T for displacement	4.57	m		scaling or analysis. Other		
Cb for displacement	0.637			values are from designer		
Weight Margin	15.00	% W_{LS} at CG for LS		judgement or vendor data.		
(1 + s)	1.000	shell/appendage allow.				
KG Margin	0.50	m				
Free Surface Margin	3.00	per cent of KG				
BMT for analysis condition	5.72	m				
KB for analysis condition	2.58	m		estimates from prelim.		
BML for analysis condition	149.58	m		design equations		
LCB for analysis condition	42.43	m from FP		-0.711	%L,+fwd	
Water Weight Density	1.025	tonnes/m^3		(SW 1.025; FW 1.000)		

WEIGHT CATEGORY	SWBS Code	WT [t]	VCG [m abv. BL]	product	LCG [m from FP]	product
Hull Structure		*1288.1*	*3.66*	4717.7	*42.40*	54612.9
Super Structures	W150	*189.5*	12.17	2306.4	18.38	3483.3
PROPULSION UNITS	W230	137.71	3.22	443.4	79.40	10934.2
TRANSMISSION+PROPULSOR SYSTEMS	W240	*86.06*	2.28	196.2	56.79	4887.3
SUPPORT SYSTEMS	W250	*63.52*	2.28	144.8	42.43	2695.2
PROPUL SUP SYS- FUEL, LUBE OIL	W260	*8.05*	2.28	18.4	56.79	457.1
SPECIAL PURPOSE SYSTEMS	W290	*40.74*	2.28	92.9	22.96	935.4
SHIP SERVICE POWER GENERATION	W311	210.00	3.08	646.8	44.65	9376.5
EMERGENCY GENERATORS	W312	*3.55*	12.18	43.2	23.05	81.8
POWER DISTRIBUTION SYS	W320	*45.08*	2.28	102.8	42.58	1919.5
LIGHTING SYSTEM	W330	*10.27*	6.59	67.7	36.44	374.2
POWER GENERATION SUPPORT SYS	W340	*24.34*	2.28	55.5	42.58	1036.4
SPECIAL PURPOSE SYS	W390	*18.54*	2.28	42.3	42.58	789.3
COMMAND AND CONTROL	W400	*5.00*	12.17	60.9	18.38	91.9
CLIMATE CONTROL	W510	*64.60*	6.59	425.7	36.44	2353.9
COMPARTMENT HEATING SYSTEM	W511	*2.16*	6.59	14.2	36.44	78.6
VENTILATION SYSTEM	W512	*21.93*	6.59	144.5	36.44	799.2
MACHINERY SPACE VENT SYSTEM	W513	*14.17*	4.00	56.7	42.58	603.4
AIR CONDITIONING SYSTEM	W514	*26.68*	7.21	192.4	36.19	965.7
REFRIGERATION SYSTEM	W516	*3.83*	4.14	15.8	36.24	138.6
SHIP FITTINGS	W610	*8.00*	6.59	52.7	36.44	291.5
HULL COMPARTMENTATION	W620	*98.75*	6.59	650.8	36.44	3598.6
PRESERVATIVES+COVERINGS	W630	*139.76*	6.59	921.0	36.44	5093.0
LIVING SPACES	W640	*44.33*	12.17	539.5	18.38	814.8
SERVICE SPACES	W650	*8.96*	4.14	37.1	22.88	204.9
WORKING SPACES	W660	*32.57*	4.14	134.8	22.88	745.1
STOWAGE SPACES	W670	*27.03*	4.14	111.9	22.88	618.4
SPECIAL PURPOSE SYSTEMS	W690	*1.71*	4.14	7.1	36.44	62.3
ARMAMENT	W700	*1.50*		0.0		0.0
Light Ship w/o Margin		2626.4				
Light Ship Margin		394.0				
Light Ship Weight		3020.4	4.66		41.14	
Installed Mission Equipment		198.4	9.00	1785.2	35.15	6972.2
Dive Rescue Port		132.3	9.00	1190.7	65.72	8694.8
Dive Rescue Starboard		134.2	9.00	1208.2	65.62	8808.8
Tow-Salvage Centerline		0.0	9.00	0.0	52.11	0.0
Tow-Salvage Port		0.0	9.00	0.0	64.16	0.0
Tow-Salvage Starboard		0.0	9.00	0.0	64.63	0.0
*Fuel Oil		*403.2*	1.00	403.2	44.60	17984.1
*Lube Oil		1.0	3.00	3.0	40.39	40.4
*Water		*31.0*	10.00	310.0	12.00	372.0
*Crew and Effects		*10.2*	12.20	124.4	20.95	213.7
*Provisions		*27.0*	12.20	329.4	20.95	565.7
*Temporary Ballast		0.0	3.00	0.0	67.00	0.0
Total Deadweight		937.3	5.71		46.57	
Total Weight		3957.7	4.91	total VCG	42.42	total LCG
Displacement		3957.7	0.00	%; + weight exceeds displacement		
Difference		0.00				
GM AND TRIM RESULTS						
Design KG	5.56	m, including design and free surface margins				
GMT	2.74	m				
GML	147.25	m				
Trim	0.00	m; + by the stern				

12.4.4 Installed Only Burned Out/Arrival

	Analysis Condition:		Installed Only Arrival			
DESIGN PARAMETERS						
	enter data in yellow					
LWL for displacement	83.67	m		Note: weights and centers		
B for displacement	15.85	m		in *italics* are linked to		
T for displacement	4.57	m		models on Input Data Sheet		
Cb for displacement	0.637			These may be overwritten if		
Weight Margin	15.00	% W_{LS} at CG for LS		not applicable		
(1 + s)	1.000	shell/appendage allow.				
KG Margin	0.50	m				
Free Surface Margin	3.00	per cent of KG				
BMT for analysis condition	5.72	m				
KB for analysis condition	2.58	m		estimates from prelim.		
BML for analysis condition	149.58	m		design equations		
LCB for analysis condition	42.43	m from FP		-0.711	%L,+fwd	
Water Weight Density	1.025	tonnes/m^3		(SW 1.025; FW 1.000)		
WEIGHT CATEGORY	SWBS Code	WT	VCG	product	LCG	product
		[t]	[m abv. BL]		[m from FP]	
Hull Structure		*1288.1*	*3.66*	4717.7	*42.40*	54612.9
Super Structures	W150	*189.5*	12.17	2306.4	18.38	3483.3
PROPULSION UNITS	W230	137.71	3.22	443.4	79.40	10934.2
TRANSMISSION+PROPULSOR SYSTEMS	W240	86.06	2.28	196.2	56.79	4887.3
SUPPORT SYSTEMS	W250	63.52	2.28	144.8	42.43	2695.2
PROPUL SUP SYS- FUEL, LUBE OIL	W260	8.05	2.28	18.4	56.79	457.1
SPECIAL PURPOSE SYSTEMS	W290	40.74	2.28	92.9	22.96	935.4
SHIP SERVICE POWER GENERATION	W311	210.00	3.08	646.8	44.65	9376.5
EMERGENCY GENERATORS	W312	3.55	12.18	43.2	23.05	81.8
POWER DISTRIBUTION SYS	W320	45.08	2.28	102.8	42.58	1919.5
LIGHTING SYSTEM	W330	10.27	6.59	67.7	36.44	374.2
POWER GENERATION SUPPORT SYS	W340	24.34	2.28	55.5	42.58	1036.4
SPECIAL PURPOSE SYS	W390	18.54	2.28	42.3	42.58	789.3
COMMAND AND CONTROL	W400	5.00	12.17	60.9	18.38	91.9
CLIMATE CONTROL	W510	64.60	6.59	425.7	36.44	2353.9
COMPARTMENT HEATING SYSTEM	W511	2.16	6.59	14.2	36.44	78.6
VENTILATION SYSTEM	W512	21.93	6.59	144.5	36.44	799.2
MACHINERY SPACE VENT SYSTEM	W513	14.17	4.00	56.7	42.58	603.4
AIR CONDITIONING SYSTEM	W514	26.68	7.21	192.4	36.19	965.7
REFRIGERATION SYSTEM	W516	3.83	4.14	15.8	36.24	138.6
SHIP FITTINGS	W610	8.00	6.59	52.7	36.44	291.5
HULL COMPARTMENTATION	W620	98.75	6.59	650.8	36.44	3598.6
PRESERVATIVES+COVERINGS	W630	139.76	6.59	921.0	36.44	5093.0
LIVING SPACES	W640	44.33	12.17	539.5	18.38	814.8
SERVICE SPACES	W650	8.96	4.14	37.1	22.88	204.9
WORKING SPACES	W660	32.57	4.14	134.8	22.88	745.1
STOWAGE SPACES	W670	27.03	4.14	111.9	22.88	618.4
SPECIAL PURPOSE SYSTEMS	W690	1.71	4.14	7.1	36.44	62.3
ARMAMENT	W700	1.50		0.0		0.0
Light Ship w/o Margin		2626.4				
Light Ship Margin		394.0				
Light Ship Weight		3020.4	4.66		41.14	
Installed Mission Equipment		198.4	9.00	1785.2	35.15	6972.2
Dive Rescue Port		0.0	9.00	0.0	65.72	0.0
Dive Rescue Starboard		0.0	9.00	0.0	65.62	0.0
Tow-Salvage Centerline		0.0	9.00	0.0	52.11	0.0
Tow-Salvage Port		0.0	9.00	0.0	64.16	0.0
Tow-Salvage Starboard		0.0	9.00	0.0	64.63	0.0
*Fuel Oil		*0.0*	1.00	0.0	44.80	0.0
*Lube Oil		1.0	3.00	3.0	40.39	40.4
*Water		*31.0*	10.00	310.0	12.00	372.0
*Crew and Effects		*10.2*	12.20	124.4	20.95	213.7
*Provisions		*0.0*	12.20	0.0	20.95	0.0
*Temporary Ballast		696.8	2.00	1393.5	51.80	36092.7
Total Deadweight		937.3	3.86		46.61	
Total Weight		3957.7	4.47	total VCG	42.43	total LCG
Displacement		3957.7	0.00	%; + weight exceeds displacement		
Difference		0.00				
GM AND TRIM RESULTS						
Design KG	5.11	m, including design and free surface margins				
GMT	3.19	m				
GML	147.69	m				
Trim	0.00	m; + by the stern				

12.5 General Arrangements Volume Requirements

Food and General Stores		
	Weight (lbs)	**Volume (Ft^3)**
Dry	9,600	517.5
Chill	9,000	621
Freeze	6,900	483
General Store	12,000	1,035
Ship Store	3,000	285
Total	40,500	2,941.5

Galley and Water Supply Requirements		
Potable Water	120	gal/person
Potable Water Margin	1,000	gal
Evaporator Cap.	60	gal/person/day
Galley	11,468.275	[ft^3]

Types of Rooms		
	Area [ft^2]	**Volume [ft^3]**
Single SR	130	1,300
Double SR	140	1,400
Master	200	2,000
Chief Eng.	200	2,000
Sanitary		
Bath	33	300
Toilets	33	180
Offices		
Master	270	2,700
Chief Eng.	270	2,700
Gen. Offices	165	1,650
Leisure Spaces		
Officer	15/person --> min 215	2,150
CPO	15/person --> min 215	2,150
Crew	15/person --> min 215	2,150
Recreational	375	3,750

Living Arrangements		
	Area [ft^2]	Volume [ft^3]
29 Double Staterooms	4,060	40,600
4 Single Staterooms	520	5,200
1 Masters Stateroom	200	2,000
1 Chief Eng. Stateroom	200	2,000
Total	4,980	49,800

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