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THESIS

YARD TORPEDO TEST CRAFT DESIGN UPDATE CONFIGURED FOR MISSION SETS INCLUDING HEAVY WEIGHT TORPEDO AND UNMANNED UNDERWATER VEHICLE TESTING

by

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June 2023

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13. ABSTRACT (maximum 200 words)

The U.S. Navy's Yard Torpedo Test Craft (YTT) was commissioned in 1986 to serve as a range craft designed for heavy weight torpedo testing based out of Naval Undersea Warfare Center (NUWC) Keyport. Since the inception of the YTT, missions and tests have changed to align with new technology and goals of the Navy. The focus has shifted to add large unmanned underwater vehicles (UUV) to the primary mission areas. As the mission changed, the YTT was retrofitted to accommodate different testing missions. As the Navy moves into a Distributed Maritime Operation mindset and shifts its focus to unmanned technology, the need to further update this dated test craft to align with new missions is clear. This thesis explores the documentation of both the old and new missions of the craft to highlight where there is a need for update and modification. An analysis into the most feasible alternative to replacing or rebuilding this craft is conducted to justify the follow-on work of the YTT that is suggested throughout the remainder of the thesis. The thesis proposes the implementation of new systems on the existent hull. With this new equipment, the YTT will be capable of multiple-UUV supporting missions through a multi-mission configurable combat systems suite without compromising its already capable torpedo testing mission and extending its operating area. The final product of this thesis is a plan for the new equipage on board as well as an installation and maintenance plan.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADCAP	advanced capability
ADS	Aegis Display System
AOR	area of operation
C2	command and control
CIC	Combat Information Center
CNO	Chief of Naval Operations
COTS	commercial-off-the-shelf
DIW	dead in the water
DMO	Distributed Maritime Operations
DOD	Department of Defense
DP	dynamic positioning
GPM	gallons per minute
GPS	Geographical Positioning System
GPU	graphics processing unit
HM&E	Hull, Machinery, and Electrical
HWT	Heavy Weight Torpedo
KPP	Key Performance Parameters
LCS	Littoral Combat Ship
LUUV	large unmanned underwater vehicle
LWT	Light Weight Torpedo
MDUUV	medium unmanned underwater vehicle
METL	Mission Essential Task List
MFD	multi-function display
MILSPEC	military specification
MRG	main reduction gear
NMETL	Navy Mission Essential Task List
NUWC	Naval Undersea Warfare Center

OPAREA	operating area
OSHA	Occupational Safety and Health Administration
OTS	over the side
RADAR	radio detection and ranging
RHIB	rigid hull inflatable boat
RO	reverse osmosis
ROV	remote operated vehicle
RSV	remote survey vehicle
SHP	shaft horsepower
SIB	Ship's Information Book
SLEP	Shelf Lift Extension Program
SONAR	sound navigation ranging
T&E	test and evaluation
UPS	uninterrupted power supply
UUV	unmanned underwater vehicle
UWDC	Undersea Warfighting Development Center
XLUUV	extra large unmanned underwater vehicle
YTT	Yard Torpedo Test Craft

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I. INTRODUCTION

A. MOTIVATION

As unmanned systems continue to become a more important component of U.S. Naval strategy, and the U.S. Submarine Force looks to increase its ability to use Heavy Weight Torpedoes (HWTs). Currently, the U.S. Navy uses two Yard Torpedo Test crafts (YTTs) to test these torpedoes in inshore waters near Keyport, Washington [1]. As the battlespace continues to evolve and technology develops beyond what is available on these test craft, it is clear that a new mission and an updated vessel need to be developed to meet the needs of the Navy and aid in reaffirming the U.S. military as a dominant sea power [1].

The YTTs of Keyport, Washington, are a Cold War era platform that is still used today. These hulls are already 10 years beyond the intended design life but are still actively used by the U.S. Navy, as well as international contractors. These two range craft were built use torpedo launchers that were taken off of submarines over 75 years ago. These hulls and their associated equipage are old and reaching the end of their life spans. A retrofit and upgrade will keep these craft, and their capabilities, usable for the next 15–20 years before a more modern and capable solution can be built to cover the needs of the U.S. test ranges.

An appropriate range craft in today's Navy would be able to accomplish the YTT's HWT testing mission as before but also be able to conduct offshore testing and support for the new unmanned technology to keep the U.S. Navy as an active competitor in the military technology race of the 21st century. While there is still a need for torpedo tubes on range vessels, the focus is shifting towards vessels that can support the range activity associated with unmanned systems and seabed warfare. Until a new class of range craft can be built, the YTTs must be retrofitted to accomplish both their current and evolving mission sets simultaneously.

B. THESIS ORGANIZATION

This thesis shall introduce the mission and purpose of the YTT as well as the range at Keyport, Washington, on which they are currently in service. After discussing the mission and how the currently installed equipment is used to support this, this thesis will discuss the updated plan for YTT or similar range craft as well as notable shortcomings in the current design of the ship. Taking the new updated mission in mind, this thesis will then analyze potential solutions to equipment and design and determine if it is more feasible for the Department of Defense (DOD) to update these range craft or if the investment should be made to design and build a new class of range craft. From that point and weighing all data a recommendation will be generated on the future of these range craft and their support of the U.S. Navy's mission in the future.

The majority of the ship-specific information comes from the Ship's Information Book (SIB) as well as the original mission and purpose statements to Naval Sea Systems Command at the advent of the craft in 1986 and upon the mission update in 2019. Additional data was collected from studies into the utilization of range craft within the structure of the U.S. Navy and DOD. Past this, commercial technology and marine industrial sources were used to find applicable components that would meet the new mission of the craft and compare and updated version of the YTT to a new construction project.

The thesis begins with analyzing the currently existing YTT and the background of the class. The new mission and operating area (OPAREA) are then introduced to shed light on the modifications that will be needed. A comprehensive analysis took the new mission and applied it to a redesign of the craft as well as other options for purchasing and building a replacement ship. This allowed for the justification of the remainder of the thesis with explaining the redesign and proving that the new threshold performance parameters and mission would be met. With that in mind, cost was estimated for both the project and life cycle.

C. CONTRIBUTION

This thesis shall contribute by offering detailed alternatives and modifications to the current YTT hull. This will provide a new variety of mission sets and capabilities for the Navy without the cost of a new ship class and the time needed to design, procure, and build new hulls. A comprehensive analysis of the current ship and resource allocation will be provided to show the best way forward for heavy weight torpedo and unmanned underwater vehicle (UUV) Testing Range Craft.

Additionally, this work will outline the way forward to creating a viable testing platform for large (LUUV) UUVs. Safe testing and operation of UUVs as well as an advancement in unmanned systems technology is a goal for the U.S. Navy as it strives to increase capabilities. Through the outfitting of the YTT to be able to operate with larger UUVs, there is hope that this thesis will serve as a template for how to design other ships to also operate in concert with the increasing focus on UUVs.

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II. BACKGROUND

A. ORIGINAL YTT MISSION STATEMENT

The YTT, at inception was given a board scope of mission sets in the underwater environment. Primarily the YTT was intended to conduct HWT testing and as such was designed with organic torpedo tubes and cranes capable of recovering those HWTs at the completion of testing. From the YTT Mission Essential Task List (METL) the current mission of the YTT is:

> Enable Keyport to perform in water test and evaluation (T&E). Careful analysis of the above mission allows Keyport to arrive at a set of capability-based requirements. These requirements are then expressed in terms of the essential tasks to be performed, the conditions under which these tasks will be performed, and the standards to which these tasks must be performed. [1]

While the YTT class is still capable of meeting the intent of this mission statement, this thesis will explore updating the mission statement to meet the current tasking and needs of both the United States and Canadian entities that operate the craft. The updated mission statement will generate a new list of requirements, tasks, and by doing so will require either a modification or redesign of the existing hull form. An exploration into a new mission statement and a new design of the craft will be explored in the follow-on chapters.

B. ORIGINAL YTT MISSION ESSENTIAL TASK LIST

The Mission Essential Tasks of the YTT guided how it was constructed in 1980 and has been updated to reflect the current needs of both the United States and Canadian services using the YTT. The list is presented in Table 1 and will not be amended but instead added to with the new mission areas of the YTT. Throughout the course to this thesis, the following list will be referred to as the minimum capability Navy Mission Essential Task List (NMETL) for the vessel and be used to ensure that the final vessel recommendations will create a more competent and complete craft and not compromise the initial purpose and capabilities of the vessel. The METLS the craft was designed to are shown in Table 1, below and expanded on with the entire list in the Appendix.

Table 1. YTT Original Mission Essential Task List. Adapted from [2].

Task	Explanation
1.0 Maneuver	1.1 Movement 1.2 Navigate—safely transit taking into account navigational hazards and the rules of the road. 1.3 Conduct Meteorological and Oceanographic Measurement and Analysis—measure environmental conditions which may affect or impair operations
2.0 Operations	2.1 Torpedo Operations—launch, recovery, loading and unloading of torpedoes 2.2 Employ Remote Vehicles—To operate vehicles such as robots, drones, unmanned underwater vehicles (UUVs), unmanned aerial vehicles (UAVs), unmanned underwater vehicles (UUVs), and other devices from a local control station. This task includes deployment, launch, control, and recovery operations. 2.3 Perform Underwater Object Recovery 2.4 Conduct Small Boat Operations—launch, recovery, loading and 2.5 Conduct Range Maintenance 2.6 Conduct Diving Operations 2.7 Provide Damage Control 2.8 Prevent Environmental Pollution 2.9 Rescue and Recovery of Personnel
3.0 Command and Control	3.1 Provide Information Technology Services 3.2 Acquire, Process, Communicate Information, and Maintain Status

Task	Explanation
4.0 Logistics	4.1 Fuel/Lube Oil 4.2 Potable Water 4.3 Provide Messing 4.4 Provide Berthing 4.5 Provide Sanitation 4.6 Pyrotechnics Storage 4.7 Repair/Maintain Equipment—To preserve, repair, and ensure continued operation and effectiveness of YTT's equipment 4.8 Perform Emergency Towing 4.9 Load/Offload, Transport, and Store Material 4.10 Provide Materials Handling Equipment 4.11 Provide First Aid, Hearing Conservation, Eye Sight Conservation and other OSHA program

C. SHIP'S HYDROSTATIC INFORMATION

1. Ship's Characteristics Table

The current table of hydrostatics for the vessel clearly illustrates the original purpose of HWT testing. It was built to accommodate torpedo tubes safely and launch and recover only torpedoes. Since then, the UUV mission has been added and the offshore capability has become desirable. For the new mission, a longer range and more stability is needed but the size does not necessarily need to be increased to fulfill the updated NMETLS and Key Performance Parameters (KPP). Table 2 shows the characteristics of the original crafts that are currently in operation at Naval Undersea Warfare Center (NUWC) Keyport.

Table 2. Principal Characteristics of the YTT. Source: [3].

Table 1–1. Leading Characteristics

Length	186 feet 6 inches
Beam	40 feet
Design Water Line	10 feet 6 inches
Displacement (full load)	1,186.51 Long Tons
Horsepower	1,250 shaft horsepower
Speed	11 Knots
Endurance	1,000 Nautical Miles
Crew Accommodations	40 People
Weapons Systems	MK 32 Surface Torpedo Tubes MK 59 Subsurface Torpedo Tubes

At this time, the YTT operates inside the intercoastal waters of the Pacific Northwest, but it is of a size and displacement that it would be capable to operate outside the harbor and complete a safe transit to San Diego if needed. The 1,000 nm range is shown with the map overlay in Figure 1. This includes multiple ranges currently used by the Navy off the coast of San Diego, CA, and Hawaii. In order to support an increased mission set, the goal of the newly updated YTT is to potentially travel as far as the Hawaii test ranges. These ranges are approximately 4000 nm from San Diego [4].

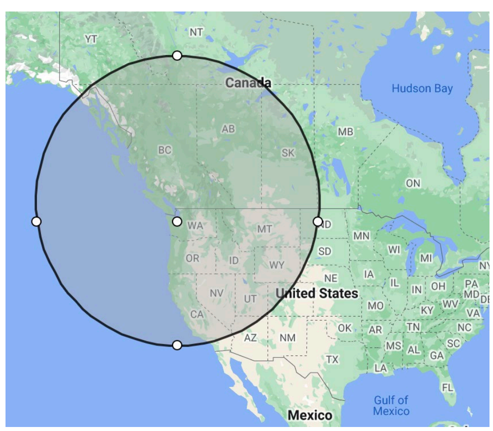


Figure 1. A 1000 nm Range Circle Overlay from Homeport in Keyport, WA. Adapted from [4].

2. Installed Engineering Equipment

The lists of technology currently installed in the YTT was largely gathered from the SIB, which lists the equipage on the ship, much of which has not been updated since the commissioning. The list of installed technology that will be focused on for updates and improvements is listed in Table 3, which is organized by the intended purpose of each piece of machinery.

D. MISSION ESSENTIAL EQUIPMENT

The current YTTs, as discussed have been retrofitted multiple times with technology that has made it possible to complete the current mission set. While the ship is able to meet the main objectives, it is not designed to operate with this equipment on board. This section will elucidate where machinery has been added to meet mission requirements, but the modification has caused other challenges to the craft and is considered a temporary patch not a permanent solution.

1. Crane Systems

The crane systems on board include the aft knuckle boom crane and a deck mounted heavy lift crane. These cranes are both made by Appleton and their specifications are shown in the tables included in Chapter VIII. As heavy weight torpedoes and UUV systems grow in both size and weight, a larger more capable crane was added to the aft deck of YTT-10. The specifications of this crane, made by Wisconsin's Appleton Marine, shown in the follow-on comparison of cranes using information from the SIB [3]. The most capable YTT currently in service can lift a point load weighing 10886 kg (12 tons) at a maximum [5].

Table 3. Installed Engineering Equipment for the YTT. Adapted from [5].

Main Propulsion Engine (1)	Cummins Model KTA-50MV-16 Turbo Diesel, 1,250hp at 1,800 rpm
Ship's service Generators/ Engines (3)	420kw, 450 Vac, 3 phase, Cummins VTA28GS/GC V-12, 900bhp at 1,800 rpm CPL 0977
Emergency Generators/Engines (1)	125kw, 450 Vac, 3 phase, Cummins NT855, 355hp at 1,800 rpm, CPL 0945
Main Propulsion Shafting (1)	48 feet 1.56 inches. Tail Shaft 35 feet, 6–13/16 inches long, diameter 8 ¼ inches; line shaft 12 feet 6 ¾ inches long, diameter 7 ½ inches
Propeller	90 feet x 76 feet, 4 blades, NiBrAl, BAR 0.550, ISO Class 1
Steering Propulsion Engines (2)	L-Drive, HRP, 400 hp, 1500 rpm, Model 3011 WM
Reduction Gear	Reintjes, Model WAV870, 7.053 to 1 ratio
Bow Thruster	Omnithruster, Model HT-600TD, 600 hp
Fuel Oil Capacity	34,182 gallons
Lube Oil Capacity	1,216 gallons
Potable Water Capacity	15,016 gallons
Black Water Capacity	8,210 gallons
Gray Water Capacity	12,444 gallons
Ship's Service UPS	Ferrups 18 KVA
High Pressure Air System	Two 2,200 psi at 21.7 cfm, 4-stage compressors, Ingersol-Rand Model 15T4CSC; one storage air flask (10 cubic feet at 2,200 psi); two moisture separators and two impulse air flasks (10 cubic feet at 700 psi). High-pressure air (2,200 psi) is also reduced to 400 psi for operating the torpedo tube air valves [5].
Low Pressure Air System	One 150-psi single stage compressor Bauer, Model RC50 E344DRVSSN4 supplies 150 psi at 120 scfm. 700-psi air from the high pressure air system is also reduced to 150 psi and provides for alternate (emergency) supply of low-pressure air [5].
Fire Main System	Two, 200 gpm centrifugal pumps supply 100 psi seawater to nine fire stations, and overhead sprinkling system in the Torpedo Hold, and flushing water for the Gray Water Tanks and Sewage Tank.
Fire Fighting Systems	Halon 1301 System- Engine Room: 475 lb bottle, two nozzles; Paint Locker: 40 lb bottle, one nozzle AFFF System—50 gallon bladder tank, and mixing proportioner unit located in the Workshop (1-46-2-E); serves the Engine Room hose reel and nozzles, and the 01 Level hose reel. Miscellaneous Systems- Gaylord Galley Fire Extinguishing System, Portable fire extinguishers, and Portable Pumps Honda Dewatering [5].
Surveillance System	Provides pilothouse personnel with a real-time look at the aft working deck, and with selected video from the Recovery Operations Center. The system consists of four video cameras and six monitors. Two cameras provide for working deck surveillance. Four monitors for these camera outputs are located in the pilothouse. The cameras for recovery operations are located on the Remotely Operated Vehicle (ROV) and the Acoustic Tracker. The monitors for these cameras are located in the Recovery Operations Center and the pilothouse.

The image shown in the above figure depicts the YTT in operation from the starboard quarter. From this angle, both operating cranes can be seen demonstrating the redundant capabilities as well as the possibility for interference that would marginalize the capability of the larger, heavy lift crane.

Figure 2. YTT Underway Showing Both Aft Deck Cranes. Source: [1].

The necessity to use multiple cranes at once does not arise in normal or planned operating conditions. On top of this, with the planned minimally manned vessels, there will not be enough manpower to operate these redundant cranes. Instead, one larger and more capable crane would increase the heavy lift capability of the YTT, reduce manning requirements, and create open deck space for other mission essential equipment.

The knuckleboom crane in this image is smaller of the two cranes currently installed on the Aft Deck of YTT-10. This crane is currently being used for both Torpedo Recovery missions and UUV missions as well as miscellaneous loading and unloading of the ship. A larger crane is installed one deck higher for missions requiring heavy lift capabilities.

Figure 3. Aft Knuckleboom Crane on YTT-10

2. Tri-Moor System

The Tri-Moor system is based on the 1990s kedging technology used for torpedo recovery. Three kedge wires are attached from the YTT down to the recovery vehicle and over to the mooring buoys [6]. The wires are then moved from the three mooring buoys to maintain or manipulate station to retrieve the torpedo or test equipment. From a 1998 report published by NUWC Keyport, the effectiveness of this system was alluded to by stating, "Typically systems using this method of maneuvering do not have much search capability and must be positioned nearly directly above the object to be recovered" [6]. The advancement of crane and remote operating vehicle (ROV) technology as well as highly capable dynamic positioning systems have rendered the tri-moor system obsolete. Even though modern technology accomplishes the same goal with a higher success rate and in a more efficient manner, the YTT still has a tri-moor system rigged on board and taking up valuable space both on deck and inside the Combat Information Center.

3. Integrated Sensors

Integrated sensors on the YTT aid in their contracted activities and testing from their ability to have radar, weapons control system. The YTT has no integrated sonar system but does feature the ability to connect to external sensors such as ROVs, UUVs, and Sonobuoys.

This thesis will not look into any replacements to the YTT that have built in SONAR equipment. Additionally, there is no need to add any hull mounted SONAR sensors to the current design. Although the YTT does primarily operate in sub surface testing environments, the testing teams that come on board the craft have their own testing and data collection mechanisms that would not be aided by an organic sonar suite. Underwater data collection that is needed for both UUV and HWT testing activities is possible to be collected entirely through external equipment such as sonobuoys.

4. Combat Systems Suite

The current combat systems suite is home to the original equipment from when the YTT was commissioned. This equipment is old and much of it is no longer useful. The primary use of the consoles in the combat information center is to control the rarely used Tri-Moor system. The majority of testing done on board the YTT ends up using the mess decks as a combat information center with contractor provided laptops instead of the installed consoles. The current, mostly unusable consoles are shown in Figure 4.

Figure 4. Currently Installed Combat Systems Consoles on YTT-11. Source: [5].

The consoles, as visually portrayed in Figure 4, are antiquated. Their analog inputs are rendered useless by the cutting-edge technology that is being tested on the craft. The inability to use the provided equipment causes other spaces, generally used for crew meal and meeting spaces, to be needed for contractor work areas. A modernization of this space, which is explored in the follow-on chapters of this space, will not only create a better suited testing platform, but also return useful available space to the YTT and her crew.

5. Torpedo Testing Equipment

The YTT is invaluable to the fleet as it can currently test the widest variety of torpedoes off a single platform outside of using a submarine itself. Although the YTT clearly is in need of upgrades and reconfiguration, removing the class from fleet operation would remove the capabilities for both HWT and light weigh torpedo (LWT) shots, tests, and recovery performed with the equipment listed in Table 4 . The table is broken up to show which equipment is used for each type of Torpedo. The munitions listed as HWT are launched from the ships organic Heavy Weight Torpedo Tubes in the bow of the vessel.

Table 4. Organic Torpedo Testing Equipment. Adapted from [5].

Torpedo Classification	**Equipage**	**Launchable Munition**
Heavy Weight Torpedo	• Uninterruptible Power Supply • Presetters (TCP, FCSIM) • System Interface/Switching • MK22 mod 3 and MK 75 Weapon Simulators • Launch Control/ Wire Guidance • Torpedo Data Monitoring/Recording • Air-over-Water Ejection System • Power Conditioning and Distribution • Torpedo Tubes MK 59/Interlocks/Sensors • Launch Attitude Measurement System (LAMS)	MK 48 MK 58 ADCAP MK 37
Light Weight Torpedo	• MK331 Mod 4 Torpedo Setting Panel • MK 432 Mod 6 Presetter Test Set • Signal Conditioner • Torpedo Preset Data Monitor/Recorder • Power Conditioning and Distribution • Surface Vessel Torpedo Tube MK32 Mod 5 (3 tube cluster)	MK 46 MK 50 MK 54

The LWT testing is done with primarily topside equipment mounted on the deck of the YTT. The system uses the Surface Vessel Torpedo Tube that can also be found on the Arleigh Burke Class Destroyer to launch test shots of smaller munitions. Figure 5 below shows a test shot from the topside mounted launcher of a YTT.

Figure 5. Lightweight Torpedo Launch from YTT-11. Source: [5].

E. OPERATING AREA

The operating area that the YTT currently performs much of their operations in is shown in the figure below. They operate with both the U.S. and Canada so the location in the waterways outside of Seattle is beneficial to international travel. Prior studies on the operations of the YTT produced the following analysis of the operating area:

> Naval Undersea Warfare Center (NUWC) Keyport supports Department of Defense and Canadian Ministry of Defense customers in test and evaluation (T&E) of naval undersea systems. These events occur on one of six in-water ranges. The two principal ranges are in Nanoose, Canada, and Keyport, Washington. T&E collects data on system performance to inform decision makers of system progress toward meeting key performance parameters. [7].

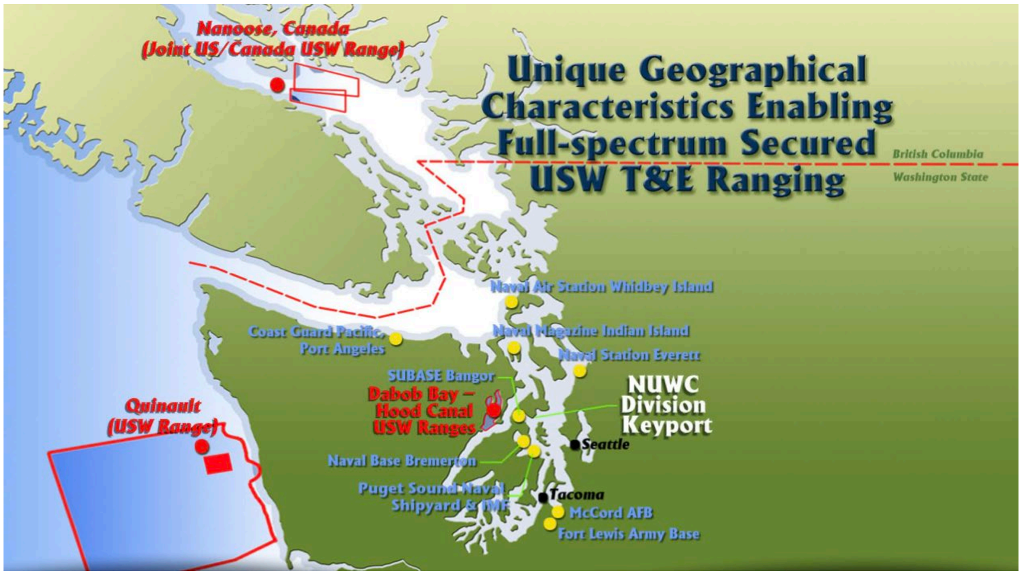


Figure 6. USW Range Areas in Keyport AOR. Source: [1].

While the goal of the craft is to contribute to the Distributed Maritime Operation (DMO) concept with offshore testing and potentially operating with a battle group, the reality is that the YTT rarely even operates to the max extent of its currently projected 1000 nm Range. While the Quinault range is well within the operating range of the vessel itself, most missions take place in the Dabob Bay if deep water is not needed, and the Jarvis Deep Range is deeper testing is a necessity.

Generally, the operating depths range from 600 ft to 2400 ft. At any of these operating areas, the YTT uses a Dynamic Positioning (DP) system to conduct stationary operations while using a three line tri-moor system as a backup to the computerized DP system. While the redundancy of a tri-moor to the DP adds an additional safety factor, the necessity of this system given the sheltered operating area will be explored further as it pertains to a modernized and efficient testing platform.

1. Current Mission Sets in OPAREA

The current missions that the YTT has been tasked with in the operating area were spread between remote service vehicle (RSV), UUV, and Torpedo Missions. The YTT was used mostly by U.S. forces, Canadian Forces, and contractors. Although this seems like a multi-purpose ship with multiple users, the craft is still underutilized. A study done on the use of range craft shows that the YTT's specifically are being underutilized in RSV and UUV testing. The utilization of these test crafts would be increased by having a more capable and user-friendly platform. The results of the study are depicted graphically in Figure 7, below, with the underutilized craft, to include the YTTs highlights.

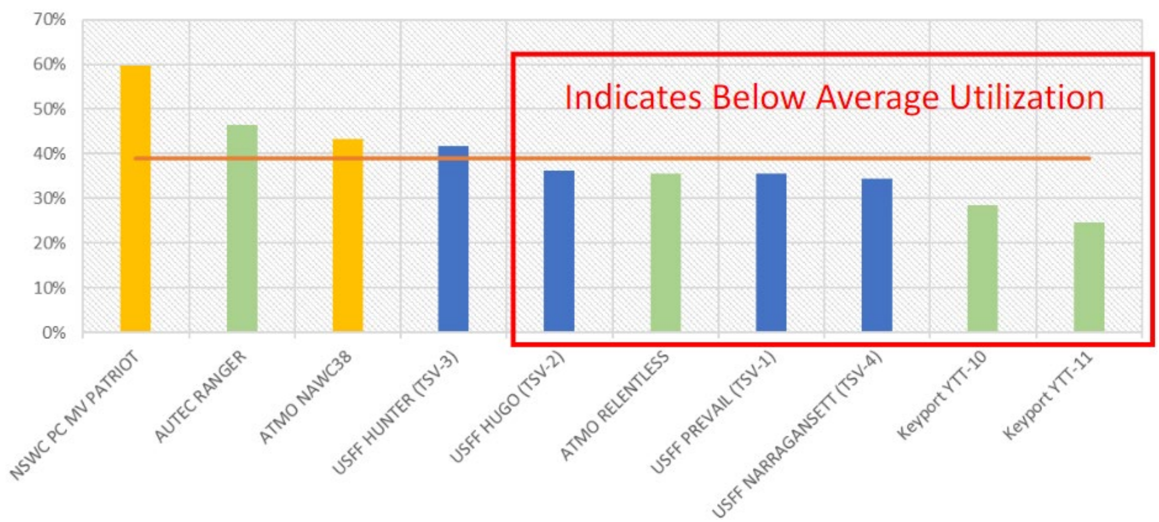


Figure 7. RSV and UUV Test Craft Utilization. Source: [8].

F. CURRENT MANNING

As the craft currently operates, it is significantly understaffed. As addressed above, it would be possible to run this vessel with a minimal manning construct if the YTT was designed and automated to run and monitor its equipment on its own. Technology maturation since this vessels commissioning would allow the modernization for such a minimally manned platform. The craft which was initially allocated 40 sailors in 1986 and was then revised to have 28 Sailors in its complement, is generally operated by 8 civilian mariners and the contractors who are on board for scheduled testing missions [9]. From a previous study into the optimal manning of the YTT craft is has been asserted that:

> Range craft minimum manning levels are driven by the requirements to: i) Steer and navigate the boat, to include startup, monitor, and shutdown running equipment. ii) Conduct operations on deck such as line handling and launch and retrieval of equipment. iii) Damage control effects such as firefighting, where the four deckhands and two engineers on the YTT

> provide for two three-man fire teams. The YTT is configured with a galley and berthing and can support around the clock operations. In this case, the YTT manning increases to 11 personnel to allow for rotation of watchstanders. [6]

While the YTT is conducting current operations with 11 personnel, the personnel are stretched thin. With little to no automated system controlling ballasting or monitoring systems, all engineering plant monitoring, navigation systems, testing operations, and ballasting have to be manually observed and all valves and switches actuated by hand by an operator in the space. There is an installed Bailey Controls and Monitoring system that has been described of limited and antiquated and is not serving the intended purpose on the vessel. This slows down operations and adds tasking to the sailors that is no longer necessary given the progression of automated and computer aided engineering software. A better calculation and allocation of manpower as well as the addition of automated and assisted technology will be provided below to outline a more sustainable operational profile for future offshore and longer missions that are assigned to the YTTs and their crew.

III. SHORTCOMINGS OF THE CURRENT YTT

The YTT class was built in 1986 for the specific mission of testing heavy weight and Surface Vessel launched torpedoes. Soon after their introduction as a range craft, their mission was amended to include testing of UUVs and remote operated vehicles [9]. At the same time as the mission of the YTT changed, the goal of the Navy changes. Now the YTT show's its age through capability gaps. Through discussion with operators and analysis of the current hull's capabilities and the discrepancies between those and the mission, a clear list of shortcomings was developed. This chapter will shed light on the YTT's need for modification through specific regions of analysis.

A. DESIRE FOR UPDATE

The crew of the YTT class vessels, the staff at Undersea Warfighting Development Center (UWDC) Keyport, and the Navy at large unanimously agree on the need to modernize or replace the YTT as they currently exist in order to make mission readiness a reality now and in the future. The desire is to be able to modernize the craft for safer and easier minimally manned operations but, more importantly, to widen the variety of missions that the YTT can complete.

B. ACKNOWLEDGED SHORTCOMING

Acknowledged shortcomings of the craft were generated through three primary methods. Research was conducted while visiting the YTT-10 hull in Alameda Shipyard and identifying areas of concern. The research was added to through discussions with her crew and contractors who could pinpoint areas in which updates were needed or they felt improvements could be made. Additionally, the equipment on board the ship and its nominal capabilities were compared to the mission requirements and tasking to show where inconsistencies and inadequacies would arise.

The current YTT-10 and YTT-11, although modifications have been made, are not designed for optimal performance of their current missions. As they currently stand, the YTTs hold equipment designed for the original heavy weight torpedo testing missions as well as evolving UUV missions. The constant addition of technology has used up space that should have been allocated for personnel and left the interiors cluttered and unusable. Examples of this include but are not limited to: Gyro in staterooms, workshop with redundant tools, extra equipment in torpedo strike down area. In order to better serve the mission, an overhaul of the technology to use minimal space with added practicality would be recommended. Suggested technology implementation is listed below and will be elaborated on in subsequent sections.

1. Automated remote controlled ballasting system
2. Dynamic Positioning for digger use instead of tri-moor
    a. More deck space
    b. Less power and resource dedication
3. Single Larger A-frame crane
    a. More deck use
4. Engine Room Remote Monitoring
5. Multipurpose Consoles with Updateable/ Configurable System
6. Stand Alone GPS and Comms Suites
7. New Workshop Equipment/ Overhaul
8. Updated Generators for Added Power Output
9. Drivetrain modifications

    More redundancy and horsepower for offshore operations

Combat Systems Suite configurable Consoles:

    a. Why this is better than modular
    b. Why this is better than building a new ship class

1. Space Constraints

The ship was initially designed only for the torpedo testing mission and to be run with a crew of up to 28. The addition of equipment specific to new UUV missions has limited crew space to berths for 11 with little to no space available for other activities. On top of this, equipment has been added with each new mission but not removed. The space that best exemplifies this issue is the workshop [3]. The workshop is home to equipment that was installed before the commissioning of the vessel and is now useless. The equipment has been added to with tools needed for individual missions and contracting agencies that have used the vessel. A prime example of this equipment would be large and outdated lathe that remains in the space. The arrangement of the main deck illustrating the workshop and potential available space on that level is shown in Figure 8 below.

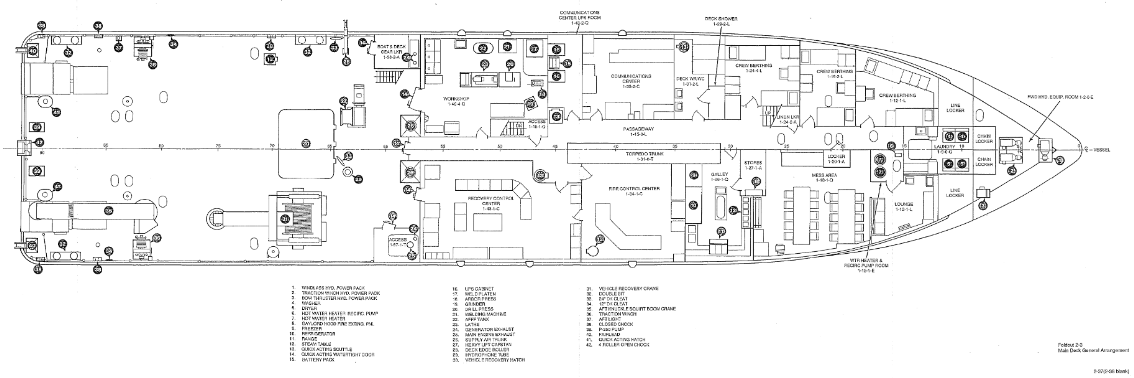


Figure 8. Main Deck Arrangement Plan of the YTT. Source: [3]

Deck space is a large concern on the aft end of the vessel as that is where any testing equipment or UUV is stored in transit or while not in the water actively completing a test mission. With numerous cranes and the line spools for the tri-moor system, the aft deck is crowded with little to no excess space for stowage.

2. Increased Need for Testing of UUV

UUVs and other unmanned and minimally manned craft are the future of Navy Surface Assets. As these platforms are designed, there is a clear need for a testing platform that can launch, monitor, and recover larger UUVs. Since the YTT was built, the size of UUVs has increased. The systems that now need to be tested are larger and more complex. The Navy is looking to bring the Orca XLUUV program online in the near future [10]. This project was introduced in March 2016 and is delayed by testing and production. The Orca shown in Figure 9 below, with the dimensions outlined in Table 4 would be just one of the MDUUV, LUUV, and XLUUVs that would be desirable to test and recover from an updated YTT or similar Platform. As currently outfitted, the YTT could tow but not recover the Orca or a similar UUV. To meet the missions of the rapidly modernizing Navy, the need is evident for a craft updated to work with the newest updates to the unmanned fleet.

The figure above shows the design from Boeing in conjunction with Huntington Ingalls (HII) for a XLUUV. All five of these vehicles were scheduled to be delivered to the fleet by the end of 2022 but have been held up by supply chain backups and are now awaiting testing and delivery [10].

Figure 9. Echo Voyager, Boeing's XLUUV. Source: [11]

Table 5. Characteristics of the Echo XLUUV. Adapted from [11].

Echo XLUUV Characteristics		
Length	15.54 m	50.9843 ft
Width	2.6 m	8.53018 ft
Weight	50 T	
Range	6500 nm	
Speed	2.5 kts (min)	8 kts (max)

The torpedo shaped design of the Echo, as seen above, as well as the dimensions are specifically designed to allow the system to be launched and recovered from a submarine's torpedo tube [11]. The YTT, as it is outfitted with HWT Tubes, would not be able to test this capability before fleet integration as the installed torpedo tubes are smaller than required by the Echo. Similar designed UUVs that are meant for torpedo launch could be a better fit for testing on the YTT. However, with modifications, the YTT could be able to recover or tow an Echo as well as monitor its operations during testing. This design is one of many, and one of the largest UUVs looking to be brought into the U. S. Navy's underwater fleet but clearly exemplifies a need for updates to be able to test the technology that will drive the Navy into the future [10].

3. Combat Systems Suite Shortfall

The currents combat systems suite was designed for the initial critical mission of HWT Testing. As the mission set has expanded to different torpedoes and multiple sizes and typed of UUVs, the singular combat systems suite has been rendered useless for the majority of missions with which the YTT is tasked. Do to this, the physical space designated as CIC is suboptimal for the wide variety of missions and technology needed to support both U.S. and Foreign weapons testing. As a result equipment is installed or stored in different spaces, such as the mess decks, to facilitate testing and monitoring.

The current CIC contains the necessary equipment for operation of the tri-moor system, the digger system, and HWT launching. With updates to this, the tri-moor system can be removed from the space to allow room for a more functional Dynamic Positioning system and a customizable platform and display for any testing for which the YTT is contracted to perform.

The optimal combat systems layout for any ship tasked with the wide variety of mission sets is a customizable platform. Due to the number of different entities, both U.S. and Canadian, using the craft- a CIC on this vessel should be designed such that any contractor was able to bring their own hard dive or computing program into and be able to seamlessly customize the combat systems suite to meet the needs of their project. At the most basic level the space for is purely C2, data collection, and display for any program that is brought on board. As it currently stands, there is no room for this function in the designed space and the ship's mess hall has filled that roll.

The main purpose of this craft, as designed, was to test HWTs. The evolving mission set for both the U.S. Navy and International Contractors includes primarily UUV operations. Upgrading the combat systems suite to be able to facilitate more UUV testing and adapt to new equipment will make a more useful testing platform without compromising the HWT test capability that makes the YTT invaluable.

C. CREW AND MANNING NEEDS

The YTT was designed for a full complement of sailors but, since its commissioning has continued to see smaller crews operating the vessel. The vessel was designed for more than 20 operators, not including the contracting and testing entities onboard the vessel for missions. As it currently operates, a crew or, at best, 15 are running day to day operations. The vessel was designed with operating roles for those 20+ sailors and, as such, the borderline skeleton crew is does not fit the ideal operational profile. The craft however, sitting at only 186 feet long, would be able to operate in a minimally manned status if the equipment and technology was configured to aid the human operators in support of controlling the YTT's operation.

D. NOT OUTFITTED FOR MINIMAL MANNING

As the current hull design sits, it is not optimal for the minimal crews that are currently running the day-to-day operations. The systems on board were built to have multiple operators in communication with each other at any given time. A key to optimizations of a minimal manned system is automating systems and removing unnecessary redundancy of manned systems. Manpower is wasted by backing up the Dynamic Positioning system with the Tri-Moor System. Additionally, not having an automated ballasting system or a computerized monitoring system for the engineering plant requires a manned space. Automating processes such as this allows for a minimally manned ship with more space for contractor and their equipment and less need for large galley spaces and excess in the potable water tanks. To have a truly minimally manned and still capable system, the YTT needs to embrace automated processes and computer monitoring instead of allocated human resources to those tasks. This thesis will provide potential solutions to these issues within the YTT by providing affordable system alternatives to facilitate computer aided remote control of the ship's critical systems when and where applicable.

IV. A NEW SET OF OBJECTIVES AND REQUIREMENTS

As the mission of the Navy and the goals of the Chief of Naval Operations (CNO) adapt to the advancing battlespace, so must the range crafts that support the deployable ships. Talking into account the baseline of the YTT craft and the restrictions of the homeport, the focus has been out on developing a new mission statement from which all updates or reconstruction to the craft can be built upon. From this new mission statement, a new list of METLs, new KPPS, and requirements can be generated in order to lay out a format and target for the new or updated craft that will be used by NUWC Keyport in the future.

A. THE NEW MISSION

The YTT mission has been updated and expanded to cover more goals of the Navy in their R&D realm.

> a. Serve as a platform for the research, development, test and evaluation (RDT&E), developmental test (DT), operational test OT), production acceptance testing, post-overhaul. proofing, and engineering evaluation of advanced and in-service undersea warfare weapons, vehicles, and systems at the Naval Undersea Warfare Center (NUWC) Keyport. Programs supported vary over time, but include MK 48 ADCAP torpedo, MK 54 torpedo, Next Generation lightweight torpedo, MK 30 target, SLACE, Orca XLUUV, Snakehead LDUUV, Razorback MDUUV, anti-torpedo torpedo (ATT) and other weapons and systems developed by Office of Naval Research ONR), Office of Naval Intelligence (ONI), Defense Applied Research Projects Agency (DARPA), and Strategic Capabilities Office (SCO). Programs supported will remain flexible within the stability and structural capability of craft and that of individual systems and equipment with applicable safety factors and following regulatory documents [2].
>
> b. Provide direct support for fleet operational training and undersea warfare combat system testing on existing test ranges and open ocean including launch and recovery of vehicles and equipment, including Snakehead LDUUV sized vehicles with nominal weights of up to 24,000 lbs during launch and up to 36,000 lbs during recovery as a result of entrained water [2].

c. Provide a platform for launching and supporting vehicles capable of deep water bottom recovery. This includes the ability to make 3 and 4-point moors in 2,400 feet of water and to dynamically hold position [2].

d. Provide a platform for installing and maintaining underwater tracking range systems in depths of up to 1400 feet of water and weights of up to 16,000 lbs while dynamically holding position [2].

e. Provide a platform for loading of stores and equipment from the pier to the YTT's topside while moored outboard another vessel of similar beam. [2].

B. UPDATED MISSION ESSENTIAL TASK LIST

The Mission Essential Task List for the YTT will include all the former NMETLs as outlined in Chapter II but will contain a more robust set of NMETLS to account for offshore operations, testing with a battle group, and a more robust UUV testing program that operates with a highly capable combat systems suite.

C. NEW ENVIRONMENT

As the current operations indicate- YTT-10 and YTT-11 rarely operate outside of the Dabob and Nanoose operating areas. While those areas are sufficient for the tests of small UUVs and HWT that the craft was previously tasked with, it would greatly benefit the new mission to be able to meet with a battle group in order to test both heavy weight torpedoes and UUV's with the fleet that will be utilizing them. The YTT, with modification will be capable of operating in new OPAREAs.

The Naval Sea Systems command that serves as the Validation of Top Level Requirements For Torpedo Test Crafts, YTT-10 and YTT-11. This instruction stated the OPAREA would be:

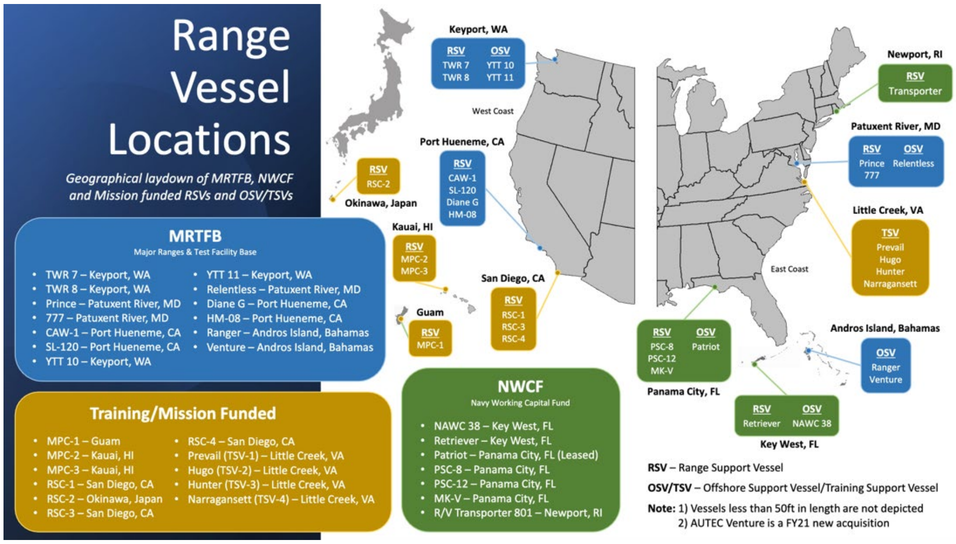
> The YTT shall operate as required on both inland waters and open ocean ranges in the Pacific Northwest, and be capable of transiting to San Diego, California. No operations in ice without icebreaker support are required. [12] .

1. The Updated OPAREA

The updated OPAREA was determined by the threshold KPP of the improved YTT craft. This threshold was the ability to operate in all of the Puget Sound area with a goal of a transit to San Diego. By operating in these areas, the YTT will be able to conduct test HWT shots, operate UUV's, and conduct sonobuoy testing in concert with and in support of U.S. Fleet Operations. The ability to get further offshore allows the in-situ interaction with the surface and subsurface fleet that directly supports the CNO's Distributed Maritime Operation Goals. The YTT would be able to operate frequently in the active Quinalt USW range shown in Figure 6 above and many of the ranges of the west coast shown in Figure 10, below**.** While this would provide more missions for the YTT it would also provide more realistic testing data demonstrating the ability of a strike group to operate with UUVs and HWTs. The distance that the YTT would have to travel to get to the Quinalt USV range is approximately 200 miles which is noticeably further than the 130 miles to the Nanoose range. This range distance and then the additional time on station required for testing creates the need for a more efficient propulsion method as well as a better potable water system to sustain longer term underway operations.

2. Range Location and Operation

Weapons and technology testing ranges used by the U.S. Navy are located all over the surrounding waters of this country, usually near fleet concentration areas. Figure 10 shows the vessels located at each of these ranges. The YTTs are located in Keyport, Washington. The two crafts there are isolated to only operate in the testing locations of the Pacific Northwest by the current ship configurations. The desire has been expressed for the YTTs to be able to extend their range to operate in more of these Pacific testing ranges.



The graphic above shows the current ranges in use by U.S. Navy range craft. The YTT is only operated currently out of Keyport, Washington. Proposed updates would allow use of the YTT at other U.S. bases with a key focus on the ability to travel to offshore locations such as Hawaii and Guam.

Figure 10. Current U.S. Navy Operated Testing Ranges. Source:[[8] .

3. Supporting Distributed Maritime Operations

The CNO's 2022 Navigation Plan "introduces six force design imperatives to maintain combat credibility in increasingly contested seas: expand distance, leverage deception, harden defense, increase distribution, ensure delivery, and generate decision advantage. These force design imperatives enable distributed maritime operations, the Navy's foundational operating concept" [13]." In order to align the YTT with the goals of the Navy and the vision for range craft within that goal, the YTT needs to be able to operate in more versatile environments and with more platforms.

D. UPDATED KEY PERFORMANCE PARAMETERS

With the new goals and operating area taken into account a set of updated Key Performance Parameters can be generated in order to guide the modification to the YTT and ensure the best possible product is designed. In Table 6, the KPP is outlined with its corresponding threshold to be considered "met" as well as the goal, which, if met would signify the YTT is operating at maximum potential to best meet mission requirements.

Table 6. Update Key Performance Parameters for YTT Mission. Adapted from [12].

Design Driving KPP	Description	Threshold	Goal
1. Torpedo Testing Platform	Test capabilities of heavy weight and surface launched torpedoes	Maintain Current Capability	Complete mission capable for all HWT and SVTT test shots and recovery.
2. Configurable Combat Systems	Able to display and interphase with any contractor equipment	Display ability for any installed hard drive or Operating System	Totally modular combat systems suite able to operate any program
3. Heavy Lift Capability	Ability to place and remove submersibles over the side	30 ton UUV	50 ton XLUUV
4. UUV/ ROV System	Control, Operate, and Recover ROV/UUVs	Ability to monitor and operate up to a MUUV	Large scale UUV: 40 tons
5. Offshore Operation	Operate in large ranges and/or with Navy Fleet	Puget Sound	San Diego
6. Minimally Manned	Maintain full mission readiness with minimal manning	10 Persons	8 persons with fully automated systems
7. Dynamic Station Holding	Conduct all stationary mission sets using DP	80% of operation	No use of Tri Moor system

E. MISSION RE-PRIORITIZATION

The updated key mission of the YTT have been modified to show the increasing focus of the Navy and it is testing contractors on the use of the YTT for UUV operations. Figure 11 below shows the mission as well as the priority of that mission. It is clear that, due to the HWT tubes, HWT test shots are still the primary focus but a close second is the ability to conduct UUV operations. With the proposed new dual primary mission set of the YTT it is clear the alterations or a rebuilt YTT needs to be introduced to the fleet in order to meet the new METLs of this class.

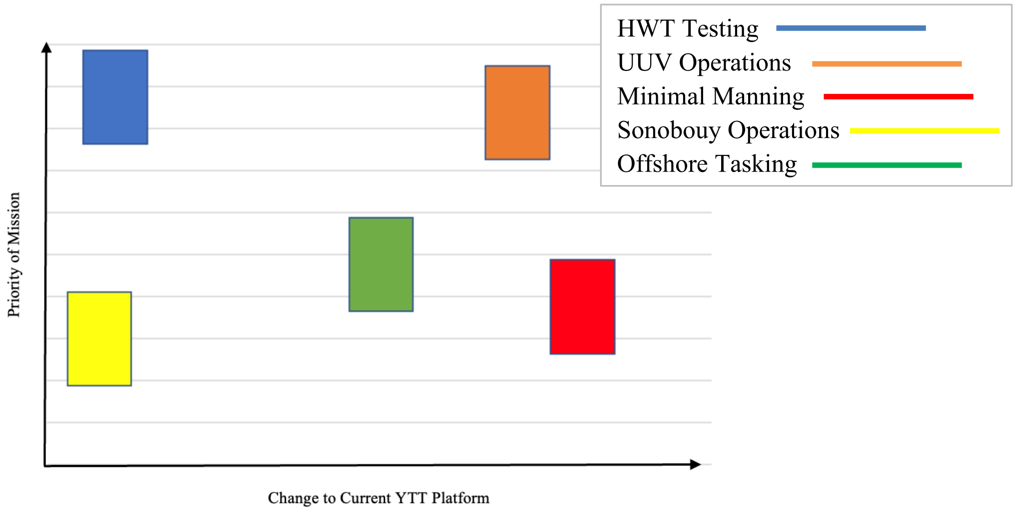


Figure 11. Mission Reprioritization Chart. Adapted from [8].

Much of the mission reprioritization comes from the Navy's increased focus on UUVs. As outlined in Figure 12 below, the Navy is looking to bring on many UUVs online through a variety of sizes [14]. YTT is a primary platform for testing these and making it possible. The mission is no longer to test HWTs and then operate UUVs when not tasked. The mission is now to be a multi-capable Torpedo and UUV testing platform.

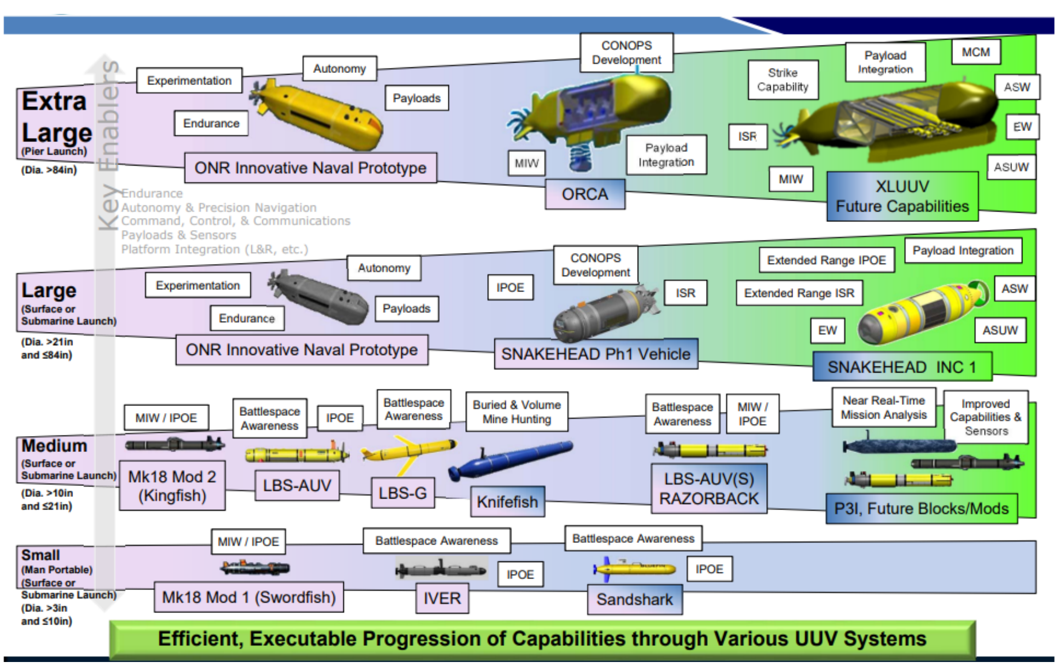


Figure 12. U.S. Navy's UUV Systems Classified by Size. Source: [14].

F. NEW MANNING REQUIREMENTS

With the updated mission and KPPs, a reasonable expectation would be to bring the entity requiring testing onboard to facilitate their operations while the YTT's integral crew focuses solely on the underway operations of the craft and its systems. For this reason, minimal manning of the craft would allow for the most efficient operations as well as allow the most space for testing entities and contractors to operate onboard. In order to effectively operate the vessel and have adequate berthing for each passenger, the following manning, as outlined in Table 7 below is recommended.

Table 7. Manning Requirements for Minimally Manned Operations

	Normal Operation	Extended Operations
Master	1	1
Mate	1	2
Engineers	2	3
Seamen	4	4
Contractors*	6	6
Total	15	17

*As required for testing and mission completion

The updated manning requirements move from the more than 20 crew members that the YTT was built to operate within 1980 to the realistic number of operators capable of accomplishing current missions. The removal of required crew members also allows for spaces previously allocated as berthing to be redesignated for mission essential equipment. The ability to reduce manning size is consistent with the current trend of the U.S. Navy and the commercial shipping industry to use computer assisted equipment in the place of added hands to run ships just as effectively with less human operators.

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V. ANALYSIS OF ALTERNATIVE COURSES OF ACTION

The previous chapters outlined all the necessary equipment that would need to be added to or replaced onboard the YTT in order to create an offshore vessel that is capable of the new mission. It is acknowledged that there are also other viable routes for the DOD to take to accomplish this mission without converting the YTT crafts that are currently in service. Potential other pathways to mission accomplishment will be explored within this chapter with a specific focus on the cost, complexity, and time until able to be placed on station. The alternatives to be analyzed include the options shown in Table 8 with the feasibility chart for each alternative shown in Table 9.

Table 8. Alternative Courses of Action for the YTT

Number	Option
1	Buying an already existing commercial hull design and converting it into a military range craft.
2	Modifying other current DOD owned hulls to meet the new mission requirements
3	Designing a new range craft from the list of requirements to build and commission a new class of ship as a replacement to the YTT
4	Modify the Current YTT Hull

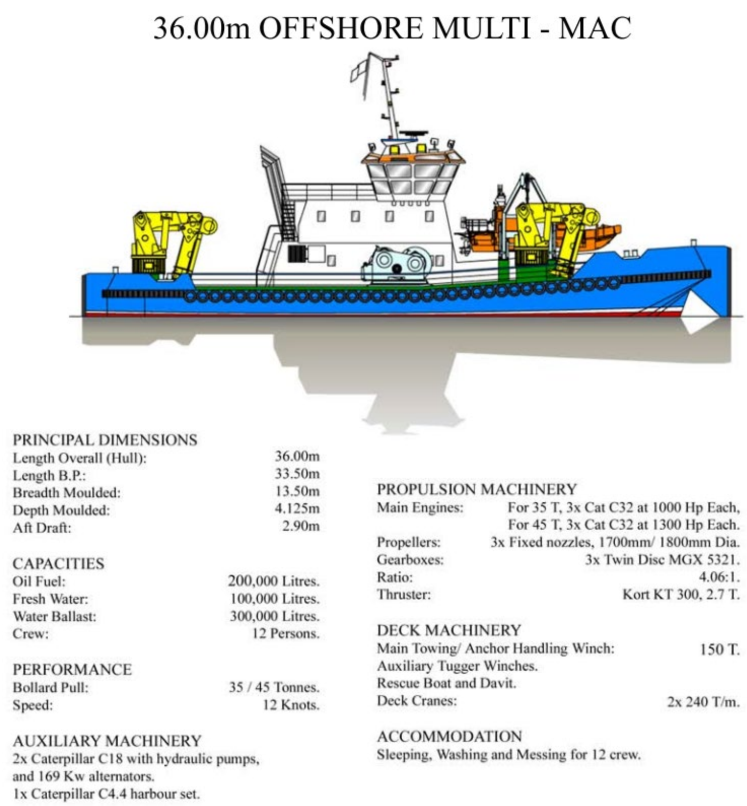
A. BUYING EXISTENT HULL DESIGN

Commercially available ship designs are a potentially viable option for purchase to accomplish a significant portion of the KPP's for the YTT. The purchase of a completed design would allow for significant cost reduction in the initial iterations of the design loop and allow for minor modifications before the construction is contracted to a DOD existent shipyard. A completed concept design available for purchase is shown in Figure 13.

Table 9. Analysis of Feasibility Chart for YTT Update Alternatives

	KPP's Met	Cost Effective	Time to completion	Complexity
New Design and Build	Green	Red	Red	Red
Retrofit Existing Hull	Yellow	Yellow	Yellow	Green
Buy Design &Build	Yellow	Red	Red	Yellow
Utilize Navajo Class	Yellow	Yellow	Yellow	Yellow

Table 9 uses a stoplight color scheme to clearly show the overall analysis of the options for mission completion. The options will be discussed in depth throughout this chapter. Boxes of this table in red indicate that the goal is not met, yellow indicate a partial solution, and green signify the best fit. From this, before the full elaboration, it is clear that a retrofit would be the most nearly complete solution.



The ship shown in the above figure would be available to be purchased entirely then slightly modified before building in order to meet mission requirements and KPPs as closely as possible.

Figure 13. Macduff Ship Design Offshore Multipurpose Vessel Specifications. Source: [15].

1. Cost

The cost for ship building projects does not start at the laying of the keel. The price tag is generated from all the iterations of architectural drawings and plans as well as the stability analysis of a full ship design. Through the purchase of a fully planned ship, the cost of labor for design would be removed from the equation to present a cheaper option than building a ship fully customized for the Navy's YTT mission. The Macduff ship design vessel as shown above would cut out the design cost of the Navy. This estimate is based on the average price of a yearlong design project valued at $108,000 [16].While that is a small fee compared to the overall budget of the Department of Defense.

2. Complexity

The purchase of an already completed design would take the complexity of the Naval Design Spiral out of the equation. Using a design similar to the Macduff design pictured in Figure 13 would allow the Navy to deliver all the plans, drawings, and materials to a contracted ship builder [15]. The complexity would then come from outfitting the designed hull with the equipment needed for KPP accomplishment. In any of the alternative options, this same outfitting hurdle would exist. The purchased design has existing open space for the configurable combat systems suite as well as the deck and crane space to accomplish the heavy lifting mission that is necessary to operate large and extra-large UUVs. Unlike in a remodel, there would be no complexity to updating the HM&E systems or propulsion as the design would come with plans to accommodate for the systems required to achieve KPP goals and thresholds.

3. Mission Accomplishment

While this or a similar design would accomplish the Heavy Lifting KPP, a significant loss would be felt due to lack of torpedo tubes. The original mission and a continued KPP of the YTT is to be able to conduct HWT test shots and recovery. While recovery of any heavy object will be possible with the significantly more capable aft Heavy Lift Knuckle boom crane. This full loss of a mission area will render the craft useless to the HWT mission set and therefore it can be stated that, although heavy lift is possible in this new craft, the full extent of mission accomplishment will not be possible.

4. Time to Completion

The DOD acquisitions process and shipbuilding contracting that would have to take place to make the construction of a new hull, even without the entire design process being completed in house, would be long. If the capabilities for HWT testing and UUV operations are needed within a five-year time frame, this is not a viable option for the Navy to choose going forward.

B. MODIFYING DOD OWNED HULL

Numerous other ships have been designed and built to accomplish missions that overlap with those of the YTT. These crafts are ocean going vessels that are capable of providing heavy lift capabilities and combat systems support to the fleet. A viable option to be used as a solution to the YTT update would be to replace the YTT with one of the already DOD owned craft that is most compatible with the new mission of the YTT.

Numerous other ships have been designed and built to accomplish missions that overlap with those of the YTT. These crafts are ocean going vessels that are capable of thr transit goals needed for the YTT however fall short in specific areas of the mission set. While the hulls may not be perfectly suited for the mission, they are already in production by U.S. Shipbuilding entities. The National Oceanographic and Atmospheric Association (NOAA) operates many similar size ocean research vessels that could be viable. For the purpose of this specific mission and comparison, the Navajo class is the most nearly similar in construction, size, and purpose to the YTT and is explored below as a viable alternative option for the goals of this project.

1. Navajo Class

The Navajo Class (T-ATS) provides similar capabilities to the YTT and could be used as a replacement with minor adjustments. There are no T-ATS in service currently in the U.S. fleet. Despite none being in service, three have been built with a two more purchased and scheduled for construction [17]. These crafts are designed to be a multi mission capable common hull platform. As a multi mission platform, they provide the ability to "Support modular payloads with hotel services and appropriate interfaces." Additionally, they support one of the main objectives of the YTT update in that these ships "can embark any type of containerized, standalone system" [18]. This modular capability is very similar to the desire for a configurable combat systems suite in the YTT. The YTT is shown in Figure 14 below with its deck space and crane that would be capable of supporting much of the RSV and UUV tasking.

Figure 14. The Navajo Class Ship Underway. Source: [18]

The Navajo Class as shown above, has ample crane and deck space for the YTT's UUV Tasking. An important physical characteristic to note in the figure above is the bulbous bow that would prevent organic HWT tubes to be installed underneath the vessel.

Table 10. Principal Characteristics of the Navajo Class. Adapted from [18].

Navajo Class Characteristics		
LOA	80.1 m	262.8 ft
LBP	70.2 m	230.3 ft
Beam	18 m	59.1 ft
Depth	7.5m	24.6 ft
Draft	5.4 m	17.7 ft
Displacement	5110 LT	
Speed	15.1 knots	
Range	8170 nm	

On top of this they have the Wartsila - DP2 Dynamic position, 6000 sq ft of deck space and a multi-use crane capable of lifting up to 40T [17]. The dynamic positioning system is a modern approach to station keeping that is used in the launch and recovery process of both UUV and Torpedo test shots. The current YTT does have a dynamic positioning system, which is outdated and less capable then the Wartsila, and uses the Tri-moor system as a physical station keeping backup. While the Navajo class would not be capable of shooting a HWT from an internal torpedo tube or lifting the Echo, modifications would be possible to facilitate testing these technologies.

2. Cost

In 2018 the DOD awarded a contract to purchase and build eight hulls in the T-ATS class to be completed by fiscal year 2027. The estimated cost of these hulls is $129.9 million for two hulls based on the firm-fixed price contract awarded to Gulf Island Shipyards LLC in Houma, Louisiana [17]**.** As this hull is capable of meeting the stationing requirements, configurability, goals, and has the increased range to allow fleet deployment and in situ weapons testing, an additional 3 hulls could be added to the build package to replace YTT-10 through YTT-12. The major modification however that would need to take place is the installment of systems to meet the Torpedo testing and launching mission. This involves and heavy weight torpedo tube being installed within the ship as well as a deck mounted SVTT. The addition of these systems can be expected to add complexity, cost, and a considerable time to solving the problem of the YTT and its need for advancement.

3. Complexity

The added complexity of building more of the Navajo Class is not extreme. The hull is already being produced for the Navy thus adding another contracted hull will not be extremely difficult. However, the complexity will come from modifying the Navajo to meet the Missions of the YTT. Torpedo testing requires Low Pressure and High Pressure air systems as well as the instillation of torpedoes tubes and a larger ballasting system. Inserting such large systems into an already completed and complex design will be an arduous task, although not as difficult as starting the design process from scratch.

4. Mission Accomplishment

The Navajo, as built, can accomplish all but one of the threshold KPPs for the YTT redesign. The loss of the HWT tubes that the YTT has would severely compromise all HWT missions that the craft was initially designed to accomplish. However, with the shifting focus to UUVs, the Navajo would still meet most criteria and could use mounted torpedo tubes to launch smaller torpedoes for testing. The only UUV support that would be better served by the installed HWT tubes is the Echo XLUUV.

5. Time to Completion

The Navy currently is building two more hulls in the Navajo class to bring the total number of hulls to 14 by 2026 [19]. As such, the use of one of these craft to accomplish the YTT mission would just require the purchase and building of more hulls. While that does sound like a simple task, this would require an expansion of the current shipbuilding contract and the associated budget allocations. As the current contract for Navajo construction is behind schedule, these additional craft would not be ready for fleet integration in a near future and most assuredly would not meet a 2025 timeline to match XLUUV testing goals. The contract for the current hulls is already delayed, which does not provide reassurance that additional purchases would be on schedule.

C. NEW SHIP CLASS DESIGN

It should come as no shock that the best alternative to meet all mission objectives would be to start a new ship design updated to fit the new mission of the YTT. Through designing an entirely new class of ship, all necessary capabilities can be accounted for in the initial design and concept development. Though this ship would be the best suited for the missions, it includes the most hurdles and obstacles to completion which make it a far less desirable choice.

1. Cost

The cost of designing and building a new ship class would be the most costly option. Although this is not a large warship, the cost will still be astronomical in comparison to the other alternative. The baseline for a cost estimation of a new build started from the $64.95 Million estimate for a single Navajo class ship [18]. This estimate was based on production cost for an already complete design. One would have to add on the additional cost of the contractors involved in the design phase, the research and development process and then the more costly equipage such as the torpedo tubes. Traditionally a warship's design and research and development phase totals in the area of $100 million. Through these two quantities alone it is clear that the option to start from ground zero on an entirely new ship design would be the most cost ineffective way forward.

2. Complexity

Designing from scratch is a complex task. Not only do you have to make sure all the missions are completed, but you must pick materials, test and evaluate them and then meet a budget. All of this must be complete before contracting and building the vessel a full design and construction would take the longest and most complex series of iterative processes.

3. Mission Accomplishment

Building a new class of ship will be costly and time consuming but it would provide the most complete accomplishment of the mission at hand. This is the case because the ship would be custom tailored to meet the mission. It would be optimally designed to have installed torpedo tubes and a ballasting system optimized for both HWT missions and torpedo tube stored and launched UUVs such as the Echo XLUUV. On top of this, the ship would be designed with the correct power and stability to operate a knuckle boom crane with a 50-ton lift capacity. These two designed capabilities alone would make the new ship class construction the best platform or effective accomplishment of the new mission.

4. Time to Completion

The time is takes to complete design and build a new ship class within the U.S. Shipbuilding industry and the acquisition system of the DOD would lead to this being the longest lead time. With the goal of the XLUUV testing to be completed by 2025 it can be assured that a new ship class construction would not be completed in time to match the necessary timeline.

D. MODIFICATION OF CURRENT CLASS

The currently existing YTT hulls are DOD owned and structurally sound. They can be re-outfitted to best fit the new mission. While space and practicality of this option is a concern, the complete overhaul of the current hull does not present the same challenges and lead time as buying or building an entirely new ship class.

1. Cost

The cost of this choice is significantly cheaper than the other options as there is no need for the purchase and construction of an entire ship. The cost involved in this option would come from the costs of labor and the primarily commercial off the shelf (COTS) equipment that would be installed in place of the old equipment. Additionally, if the refurbishing of the current hulls is done within an already budgeted availability window, there will be no need for additional finding requests for the shipyard and the majority of the money will be spent on the outfitting and installation costs. While the cost of shipyard work, labor, drydocking, and new technology is not cheap, it will still be able to operate under a smaller budget than designing, buying, and building an entirely new hull to accomplish the updated mission set.

2. Complexity

The complexity of retrofitting the existing hull is actually the simplest of the options to complete the new mission. No massive overhauls need to take place and no major construction that will compromise the integrity of the hull structure. After executing the known drydocking procedure of this vessel, new COTS purchased systems will be able to be transported and installed through the ship using previous overhaul methods and access points. Although this is a larger scale project than previous maintenance overhauls, the precedence for completing yard work on this vessel, as well as necessary protocols, have been established.

3. Mission Accomplishment

The YTT's as they currently stand, are not perfectly designed for the newest mission set. Given a full re-outfitting of the hull they still may not be optimal, but they will be the nearest to perfect way forward. The biggest asset to mission accomplishment that the using the current hull brings is the already installed torpedo tube sized and outfitted to be able to shoot Heavy Weight Torpedoes. A commercially available hull or already existent design such as the Navajo class does not have a torpedo tube. The HWT mission will be easiest to uphold using the YTTs. The YTTs will be able to perform better on UUV missions with a larger crane and, given a stronger drive train, could pursue more offshore mission sets and testing. While the size, age, and current outfitting of the YTT will prevent the ability to test the largest and most complex UUVs and restrict the YTT from trans-pacific travel, the YTT when reoutfitted will be able to easily meet the threshold for completion of the newly outlined KPPs.

4. Time to Completion

Shipyard work and hull overhaul is a timely process. If all materials for a refit are secured before the hull enters a dry-docking availability, it will still take the better part of two years to reach completion of a project of this size. However, this is significantly less time than it takes to build a ship from the keel up. As outlined above, that process takes an average of two years based on the previous availability timelines of the vessel.

VI. ENGINE POWER AND ENGINEERING PLANT MODIFICATION

The YTTs that are currently in service have been undergoing or are currently undergoing overhauls in order to modernize the hulls and provide engine power that allows them to successfully complete their mission. A more robust modernization and overhaul would need to be conducted in order to create the electrical, horsepower, and system redundancy to make offshore operation a safe and realistic premise. On top of this engine room overhaul, multiple new additions of combat systems and surveillance equipment would need to be installed so that a new and robust mission is a reality. This chapter will explore new equipment better suited to meet the new mission requirements that would be feasible to install in the YTT hulls. For each updated to the engineering plant, the benefit to the mission will be explicitly stated to justify this specific approach and solution.

A. PRIME MOVER

The current prime mover set up is designed to support stationary and dynamically positioned operations in coastal areas. The limited horsepower does not allow for high-speed transit or the requisite power that an offshore operation would entail. To meet the requirements of the new mission and be able to travel further- a more powerful, redundant, and user-friendly engine room would be advised. The bow thruster- a Omnithruster, Model HT-600TD will still suffice for maneuverability and dynamic positioning concerns but the actual prime mover should be upgraded to provide better range, power, and fuel efficiency for YTT-10 and YTT-11 [3]. A schematic design of the diesel engine that is currently in use is shown in Figure 15.

T9YTT–AJ–SIB–010/YTT–CLASS SIB

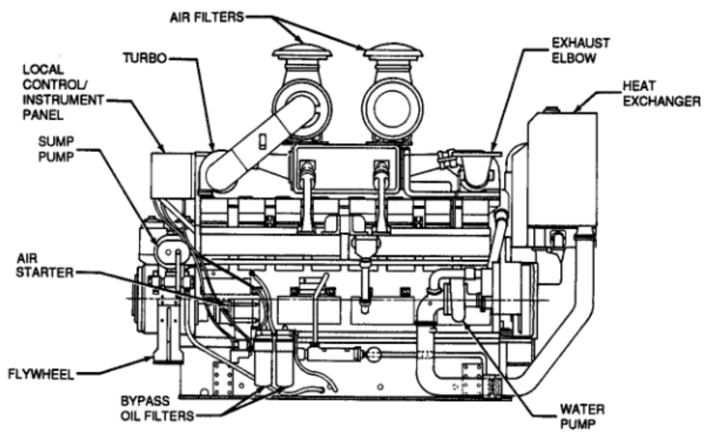


Figure 3–1. Propulsion Diesel Engine

Table 3–1. Propulsion Diesel Engine

Manufacturer	Cummins
Type	Model KTA50M V–16
Rating	1250 shp at 1800 rpm
No. of Cylinders	16
Bore	6 1/4 inches
Stroke	6 1/4 inches
Total Displacement	3067 cu. inches
Compression Ratio	15 to 1

Figure 15. YTT's Currently installed Diesel Engine and Rating. Source: [3].

The main reduction gear (MRG) that is being used in concert with the engine of Figure 15 is shown in a photograph in Figure 16. In this figure the engine is sitting in the workshop waiting to be installed into the YTT during a planned maintenance overhaul. The shipyard facility and YTT crew already have the means and knowledge to remove and install main engines which will allow the proposed reinstall of two engines to be completed in a timely manner.

Figure 16. Main Reduction Gear of YTT-11 in workshop for Overhaul and Reinstallation

1. Drive Train

The current drive train of the YTT as discussed above is shown in the schematic of Figure 17. The layout has a single point of failure with one diesel engine feeding the MRG, Shaft, line shaft bearing, and propellor. In order to promote extended offshore operations and increase safety in those conditions, the drive train should be updated to resemble Figure 18. The difference between these two layouts is the single engine in the current plan feeding a single input main reduction gear which should be replaced by two engines feeding a dual input MRG, the specifics of which will be provided in the discussion on redundancy.

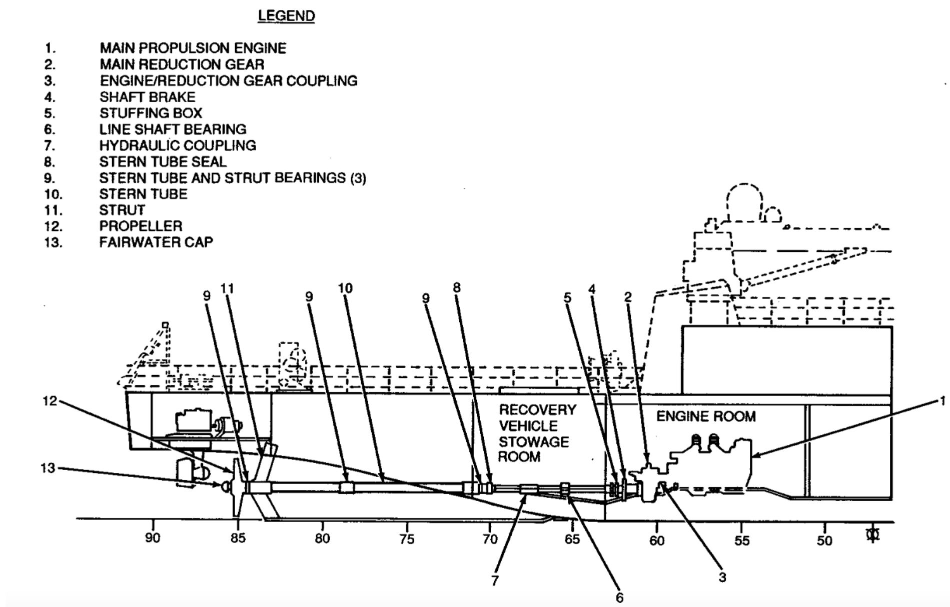


Figure 17. Current YTT Drive Train Schematic. Source: [3].

Redundancy, which will be discussed in a follow-on section as it related to extended range and underway sustainable operations, will require the installation of a new MRG. This MRG, although similar in size both physically and in gear ratio, will need to be dual input to account for the two diesel engines instead of a singular diesel engine as the prime mover. The drive train will now resemble what is shown in a simplified rendering the Figure 17.

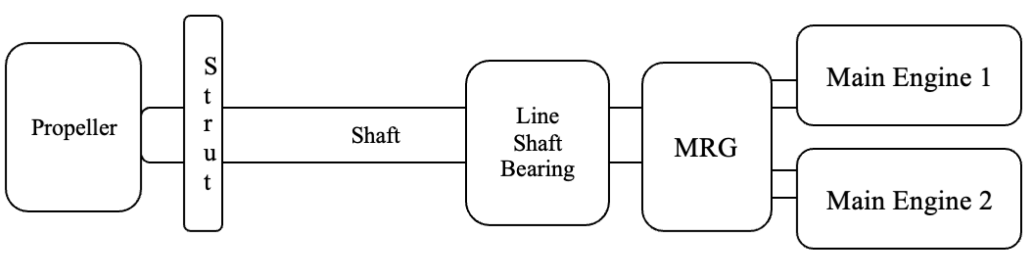


Figure 18. Simplified Schematic of Proposed Drive Train

2. Fuel Usage and Efficiency

Fuel capacity is a fixed quantity given the choice to refit the current hull rather than start a new design. Due to this limitation, the fuel capacity of the YTT will be the same as previously outline in the ship's SIB at 129,393 liters (34,182 gallons) [3]. The limit to the amount on fuel storage forces the focus to be on fuel efficiency. The efficiency of this allows for a max range limitation and as the ship has no underway refueling capability, fuel is a limiting factor in the extended range goals of the new missions. The chosen alternative of a redesign option will use more efficient and powerful prime movers with the same fuel take. The efficiency difference calculated in Table 12 will allow for the longer range between the port visits required to refuel or allow for a longer time on station to complete required range testing missions.

From previous reports on the generalized use of the YTT the current speed and engine usage is shown on a typical 12-day deployment. Operations were primarily conducted at 0–3 knots while conducting testing operations or keeping station. The majority of the remaining operating hours were conducted at 11 knots which can be assumed as the YTT transit speed.

Table 11. 12-Day Deployment Typical Operating Speeds. Adapted from [1].

Typical 12-Day Deployment				
Speed (kts)	0	3	6	11
% of Time	41	26	9	24

Using these speeds as an input for fuel consumption, the values for actual Gallons per Hour per engine were tabulated and are shown in Table 12. Twelve knots was used in this table to represent the transit speed as that was the closest possible given value for fuel consumption of the engine that fit the provided data for the operational profile.

Table 12. Total Fuel Consumption by Main Engines. Adapted from [20].

Main Engine Fuel Consumption				
	Operating Speed (kts)	Operating RPM for 12 Knots	Consuption Rate (L/Hr)	Fuel Consuption Rate (Gal/Hr)
Main Engine 1	3	1800	72.4	19.1
Main Engine 1	12	1800	90.7	24
Main Engine 2	3	1800	72.4	19.1
Main Engine 2	12	1800	90.7	24
Total Consumption per hour	3		144.8	38.2
Total Consumption per hour	12		181.4	48

Significant fuel usage by the generators simultaneously to the main engines has to be factored in to account for total consumption of the craft. These totals for generator usage are shown in Table 13 and the values used to aid in the new maximum range predictions.

Table 13. Total Fuel Consumption by Generators. Adapted from [21].

Generator Fuel Consumption		
	Fuel Consumption Rate	
Generator 1	40	40
Generator 2	40	40
Generator 3	Standby Generator	40
Total Consumption per hour	80	120

For all fuel consumption, range, and time calculations the maximum allowed low point in the 34,182 gallon tank [3] was 20% or 6836.4 gallons. This determination of a low level was made with U.S. Navy safety guidelines in mind as well as the understanding of the need for a surplus in case of emergencies or deviations as it is impractical and not in sound practice to drive a ship to the point of a completely empty fuel system.

3. Updated Max Range

Max range was based on the total fuel carried on board, minus the expected amount consumer per day by each generator to determine the time (in hours) that the ship could continue to operate. Using this time and given speed, the range which the YTT will be able to travel in the new configuration is determined. Assumptions made for Max range calculations were conservatively made using the fuel consumption rates shown above for operating both main engines at a speed of advance of 12 knots. It is assumed that during this entire time the vessel is in transit and operating only two of the three generators on board. The results for maximum time operating underway and range are shown in Table 14.

Table 14. Predicted New Range and Operating Time for Updated YTT

New Ranges and Time on Stations		
Total Available Fuel	34182	Gallons
(Calculated assuming all three generators are running)	3 kts	12 kts
Total Combined Fuel Use (GPH)	158.2	168
Time Operating until Fuel Tank at 20% (hours)	172.85	162.77
Time Operating until Fuel Tank at 20% (days)	7.20	6.78
Range (nm)	518.5	1953.26

In order to determine KPP accomplishment of the threshold and goal, San Diego, which is withing 1000 Nautical Miles of Keyport, is well within the new maximum range. The maximum range ,while operating only 2 generators, is 2563 nm although this would allow no room for error or extenuating circumstances does also include the 2,388 nm it would take to reach Kaneohe Bay, Hawaii [22].

Table 14 also accommodates for max range given that all three generators are online. It is possible to extend the maximum range of the vessel by operating with minimal generators and only one engine if needed. As stated in the fuel analysis of the above section, all of these values were calculated to account for maintaining at least 20% of the fuel supply in reserve.

4. Updated Max Speed

Speed is not a primary concern or objective of the YTT. As the YTT conducts testing mainly under station keeping conditions. However, the input of two main engines rated to the same rotations per minute (RPM) and horsepower (HP) but carrying a slightly larger load will allow for very little change in the max speed of the vessel. If needed the YTT will still be able to transit at 25 knots if needed but it is acknowledged that traveling for extended periods of time at such a speed will reduce the range of the vessel.

5. Redundancy for Sustained Operation Offshore

The YTT's original design for the engine room does not contain the redundancy needed for safe sustained offshore operations. With only one z drive connected to a singular Diesel Engine, the YTT runs the risk of becoming dead in the water (DIW) with any casualty to that one engine. The current Cummins diesel that provides 1250 shaft horsepower (SHP) within a size of 3067 in^3 as shown in Figure 16 should be replaced with two diesel engines that fit in the same space and are combined to provide more total horsepower than the previous engine [3]. These engines should be connected to an updated dual input Main Reduction Gear (MRG) before operating with the same propeller shafting and Z-Drive configuration [3].

A single QSK 60 Cummins Diesel Provides 2000–2700 SHP and is only 3672 in^3 which will fit in the same engine room space as the original engine and provide double the horsepower with a better fuel consumption rate than the current prime mover [20]. Although that increases the power of the YTT, it does not provide any more redundancy than the current system. Slightly smaller engines can operate at the same RPM and a combined greater horsepower to increase both the power and the safety of the system.

Having the redundant QSK19 IMOIII will be able to provide 800 SHP per engine while running at 1800 RPM [20]. The combined 1600 SHP of these engines will offer more power than currently available as well as provide the redundancy between the engines in case of engine or equipment failure. At 1150 in^3 per engine block, these will fit in the same allotted engine room space [20]. The major modification to the plant that will have to occur, given this redundant plan, is upgrading the currently installed MRG to a dual input MRG. Wartsila- the same manufacturer as used for the dynamic positioning system offers a dual input, single output MRG that will allow for the redundant engines to feed the singular propeller shaft [23]. The proposed new MRG, shown in Figure 19, will be able to combine both of these 800 SHP engines and output the same RPM as previously attained in the old design in order to ensure that the YTT will operate at the same speeds.

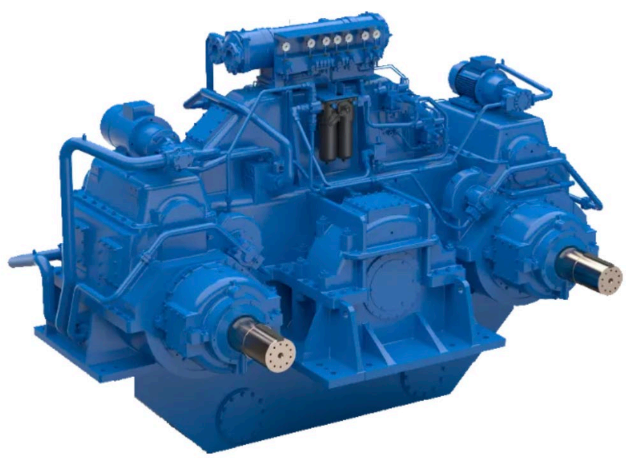


Figure 19. Wartsila Dual Input Single Output MRG. Source: [23].

6. Engine Room and Remote Monitoring

Remote monitoring of unmanned engineering spaces is crucial to an efficient and safe minimal manning structure. By using a an ethernet local area network (LAN) connected to the controlling and monitoring systems of the major components of the engineering plant, it is possible to monitor and control any part of the ship's power plant from the bridge or a central controlling station.

Modernizing the ship's layout and installing an ability to monitor engine rooms and the installed firefighting systems will provide assurance to the crew that safe operating conditions are being met while freeing up watch stations to be able to have fewer crew stationed throughout the ship and more focused on the tasked testing. This monitoring technology has been used by Northrup Grumman with the Engineering Control System Units that are installed in DDG 1000 and the Littoral Combat Ship (LCS) [24].

B. AUTOMATED BALLASTING SYSTEM

The YTT hull is focused on the ability to store and launch HWT's out of integrated torpedo tubes below the waterline. This capability wouldn't be possible without the ballasting system allowing for the required trim to launch a torpedo. Following that mission, ballasting also helps to compensate for and maintain stability while lifting large loads with the crane. As the YTT is currently built, the ballasting system is run manually meaning that multiple operators must enter the engineering space to adjust valves and monitor fill levels in a long procedure to ensure safety. On a ship with a goal of minimal manning and efficient operation, an automated ballasting system would speed up procedure as well as take less dedicated personnel to use a system that is crucial to success of multiple key mission areas.

C. DYNAMIC POSITIONING

The YTT's currently have a dynamic positioning system installed via the Kongsberg SDP-10 DP 0 [6]. Despite having this installed capability, it does not maintain position with enough of a certainty and stability for other operations to be conducted without a physical mooring procedure as it is outdated. The redundancy of a tri-moor system and a DP system takes up more space and power on board then is needed and takes away power and space from mission specific equipment. The proposed solution to this problem is the complete removal of the tri-moor system and the installation of a new, COTS, dynamic positioning system. Removing the tri-moor system will return deck space to the ship as well as move a significant amount of carried weight. The capability will be replaced by the modern station keeping system.

The best fit dynamic positioning system for this ship and its mission set is a much newer product from Kongsberg marine. While this commercial provider does offer full COTS products, they also will create a custom system to work with the installed propulsion equipment of the vessel. For the purposes of the mission set of the YTT is the K-POS DP-21 [25] . This system integrates with the ships equipment and is controlled and monitored from a bridge based console. It meets industrial regulations for accuracy and offers its own redundancy, failure detection, and fault isolation. The control console for this dynamic positioning system is shown in Figure 20.

Figure 20. K-POS DP-21 Control Console. Source: [26].

D. POTABLE WATER SYSTEM

In order to operate offshore or with an extended range for sustained periods of time it would be prudent to shift from the current system of carrying potable water on board and refilling in port to having an integrated system to make potable water. This transition would allow for smaller tank size then currently advertised as the capability would now be installed to be able to constantly refill the tanks. The new, smaller tanks, as well as the required equipment for reverse osmosis would fit within the space taken by the old potable water tanks. The same brominator that is currently installed would also be able to be used for the ship made water system removing the need to install a new system. Of note, this brominator has not been used in recent years and if it is deemed inoperable can be replaced by bromination systems manufactured by the same company as the reverse osmosis system proposed in Figure 21.

Amount of water used per day per person is provided by Keyport for their construction and measurement purposes as 30 gallons per person per day [1]. Medical research provided by the Mayo Clinic sites that each person should use 74 gallons per day if living full time above the craft. Additionally, the ship used approximated 450 gallons per day for normal operations [27]. The breakdown of current water usage is shown in Tables 15 and 16 which feature water consumption from the Water Footprint Calculator that has been extrapolated to show what would be consumed by the YTT and her crew [28].

Table 15. Tabulated Human Water Consumption per Day.

Human Daily Water Usage (Gallons)		
	Per Person	Full Crew (15)
Shower	25	375
Food	10	150
Toilet	33	495
Misc	5	75
Drink	1	15
Total	74	1110

Adapted from [28], [27].

Table 16. Tabulated Ship Daily Water Usage

Ship System Water Usage (Gallons)	
	Daily Usage
Cooling	100
Fire Systems	100
Electrical System	150
Aux	100
Total	450

From the total water usage calculation by both human and the ship itself, the total water used per day on the ship is 1560 gallons. The Potable water tank currently used on board the ship contains 7532 gallons of water [3]. As the ship currently stands, the ship can support normal operations with regards to potable water consumption for 4.82 Days. The ability to constantly refill the potable water tank would remove potable water accessibility as a range and operation limiting factor. The system shown in Figure 21 would fit in the already available engineering space and be fed from already existent pumps and piping. If more volumetric space was needed for an installation of this potable water system, it would be prudent to move to a 4000 gallon potable water tank. This tank would be able to sustain shipboard operations for 3 days without rationing.

Figure 21. Reverse Osmosis Potable Water System and Characteristics.
Source: [29]

This commercially available system can be fed from sea water taken out of the fire main system. This sea water is then treated and forced through the semi permeable membrane of the RO system to be stored as distilled or drinking water in the storage tanks. The size of the system needed is chosen based on the ability to fill a 4000 gallon tank nearly twice in a single day if needed. This provides a significant margin of available water to the ship at any given time and thus effectively removes potable water from the range limiting factors. Table 17 shows which model of Pure Aqua RO systems to choose based on gallons per day of water production.

Table 17. Water Production Capabilities of Chosen RO System. Source: [29].

Model No.	Permeate		Membranes		Motor HP at 1000 ppm		Approx. Weight	Dimensions
	GPD	M^3/Day	Size	Qty	60 HZ	50 HZ	LBS.	L"xW"xH"
SW-0.38K-125	380	1.4	2.5" x 40"	1	2	2	220	51X21X30
SW-0.70K-225	700	2.7	2.5" x 40"	2	2	3	230	51X21X30
SW-1.0K-325	1,000	3.8	2.5" x 40"	3	3	3	250	51X21X30
SW-1.3K-425	1,300	5	2.5" x 40"	4	3	3	290	51X21X30
SW-1.1K-104	1,100	4	4" x 40"	1	5	5	395	61X34X50
SW-2.1K-204	2,100	8	4" x 40"	2	7.5	7.5	500	61X34X50
SW-3.0K-304	3,000	11	4" x 40"	3	7.5	7.5	360	61X34X50
SW-3.8K-404	3,800	14	4" x 40"	4	7.5	7.5	500	61X34X50
SW-4.7K-504	4,700	18	4" x 40"	5	10	10	750	61X34X50
SW-5.6K-604	5,600	21	4" x 40"	6	10	10	850	61X34X50

VII. ELECTRICAL POWER

The key to a productive testing platform and an offshore capable vessel is to provide enough power to sustain hotel systems offshore and operate a wide variety of testing systems. The YTT class, with their original power generation systems were capable of achieving their initial mission sets and goals. As technology and weaponry matures and the ship began tasked with more UUV missions, it is clear that more power needed to be readily available. In this chapter, the current power available on board will be analyzed and an updated power system will be recommended. With this update, and the updated mission essential equipment a new estimate will be given for the total power generated, used, and available for future configurable combat systems equipment.

A. TOTAL GENERATED POWER

1. Currently Installed System

The generators that are currently installed on board the YTT, the Cummins VTA28GS/GC V-12 are classified in Table 18. These provide 480 KW of power [21], as listed and, with three on board, are sufficient to power the old mission of the ship. With the addition of the RO system and the new, larger crane, it would be prudent to install more efficient and powerful generators in the same space to provide a larger electrical power margin for any future updates or additional machinery brought onboard.

Table 18. Characteristic and Ratings of Shipboard Diesel Generators. Source: [3].

Generators (3)		
	Manufacturer	Cummins Engine Corp.
	Model	VTA 28GS/GCV–12
	Capacity	480 KW
	Voltage	450 Vac
	Current	900 A
	Frequency	60 Hz
	Phase	3
	Frame Size	5
	Temperature Rise (at rated load)	80 °C
	Insulation Class	F
	Resistance at 25 °C	
	Main Stator (line to neutral)	0.185 ohms
	Main Rotor	3.50 ohms
	Exciter Stator	47 ohms
	Exciter Rotor (line to line)	0.17 ohms

On YTT-10 the generator shown in Figure 22 was installed in the last maintenance overhaul period of the vessel. YTT-10 and YTT-11 have different generators installed due to non-identical maintenance activity. The provided information on the Cummins engine from the SIB was used for comparisons and calculations.

Figure 22. Cummings Generator For Installation on YTT-10

B. POWER NEEDED FOR SHIPS SYSTEM

1. Power Margin Requirements

The YTT was instructed to be designed with a power margin of 20% available for use by any testing equipment or future systems of to be brought on board [9]. The addition of three more powerful and more efficient generators will allow for this power margin to be maintained as each will output 600 KW for a total of 1800 KW of available power compared to the previous 1200 KW [21]. This 400 KW increase will be primarily available for testing usage as the installed equipment will not be drawing that full capacity after ship modifications.

2. Combat Systems Power Margin

The installed components of the configurable power system do not, independently, require massive amounts of power as they are mostly of a repeater or display function. The ship however needs to provide power to any testing entities hard drives and/or computers.

The vast majority of the power is to be used for the HWT test shots, which is not a continuous load. Power also will be delivered via tether to any operated RSVs or used to charge UUVs. The cranes, when in operation, will require power for control as well as for hydraulic pumps but this is a non-continuous operation state for the ship's generator services.

C. PROPOSED NEW SHIPS SERVICE GENERATORS

In order to choose the best generator to serve as a replacement for the current three in operation, a head-to-head comparison of efficiency and power output was conducted for generators of a similar size. The Cummins generator currently installed was used as the threshold that must be outperformed for that generator to be considered for installation. The initial comparative data for potential generators is shown in Table 19.

Table 19. Tabulated Values for Power Generation Comparison

Generator Ratings Comparison								
Manufacturer	Model	Frame Size	GPH	Capacity (KW)	Voltage (VAC)	Current (A)	Frequency	Phase
Cummins (Installed)	VTA28GS/GC V-	5	45.7	480	450	900	60	3
Cummins (Updated)	VTA28G5	5	40.7	600	450	900	60	3
Kohler	500EOZCS	5	69.6	500	480	752	60	3
CAT	C32	5	55	730	450	913	60	3

Adapted from [20], [30], [31].

The installed Cummins Diesel Generator does perform well in comparison to the CAT and Kohler marine diesel generators. While this is a solidly performing generator, it is important to note that an older engine will not run as well and as efficiently as originally specified, and their newer generator has the ability to produce 120 more KW of power while operating at a slightly more efficient fuel consumption rate [20]. This comparison in terms of KW produced and the fuel consumption rates is shown graphically in Figure 23 and 24.

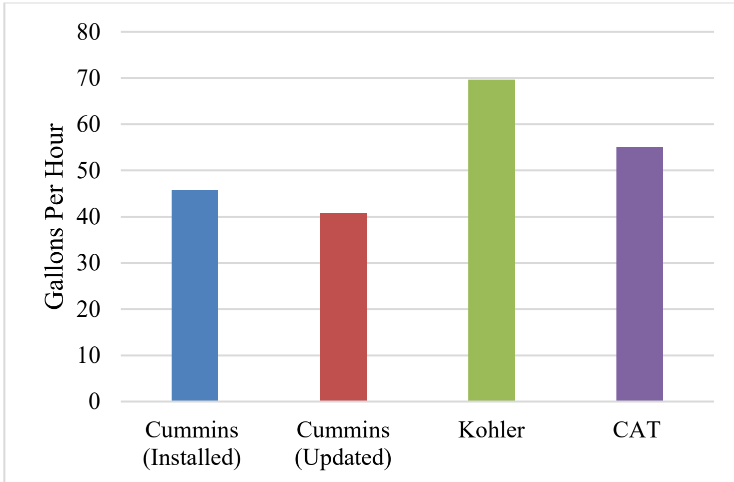


Figure 23. Comparison of Fuel Consumption Rates of Generators

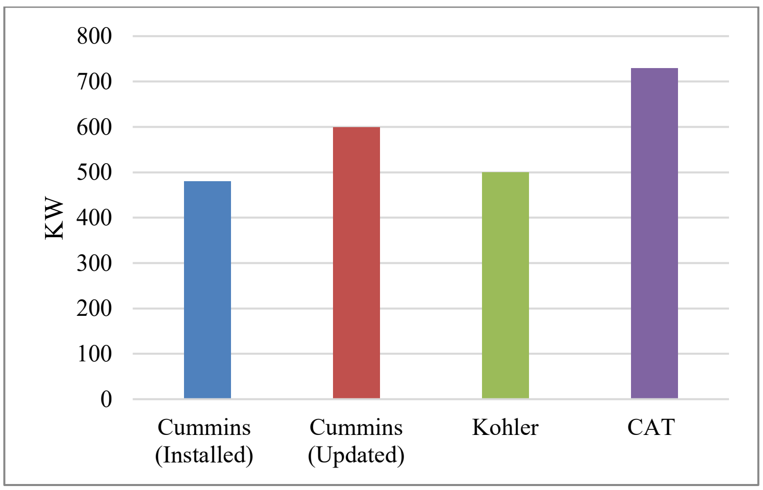


Figure 24. Comparison of Generator Power Capacity

The compared power output and fuel consumption of these generators show that the best choice of generator to use in the rebuild of the YTT is the updated Cummins VTA/G5. Three of these generators will be able to provide a total maximum power of 1800 KW (600 per Generator) [21]. While operating at this maximum power output, each generator will be using 40 Gallons per Hour of fuel (120 GPH with all three generators online) [21]. In normal steaming operations when transiting between test points, only two generators need to be online. This means that in almost half of the operating conditions of the vessel only uses 80 GPH of fuel. Not only is the amount of power increased by installing this newer and more reliable generator engine, but the reduction in fuel use aids in the effort to increase the maximum transit range of the vessel and/or allow for more time on station during extended offshore testing operations.

VIII. HEAVY LIFT CAPABILITY

As a range test craft, the ability to remove testing or expended equipment is crucial to the success of the missions. To this end, a crane must be able to lift the largest tested UUV or Torpedo from the water upon completion of tasking. Additionally, the crane should be flexible enough to help move equipment on deck. All of these objectives must be met without compromising the stability of the vessel or the available deck space. This Chapter will explore the lifting needs of the YTT based on mission sets and operating area and propose the best equipment to meet the mission requirements.

A. HEAVY LIFT MISSION

The primary mission, when not launching torpedoes is centered around the ability of the YTT to conduct heavy lift. This heavy lifting capability is used for torpedo recovery as well as to launch test and recover UUVs. Due to the need to lift increasingly heavy objects- and the increasing size of these UUVs, the installed will soon not be able to complete the tasks at hand. The optimization of the lifting capability would be completed by exchanging the current dual crane set up for a single larger aft crane. This is based on the need to open space for working and test equipment storage on the aft deck and the goal of being able to work with a 40+ ton XLUUV such as the Echo. Heavy lift is the primary limiting factor to large scale RSV and UUV testing and therefore a major priority in the mission reprioritization of this vessel. Dual crane operations are not needed or frequently used and therefore a single larger crane will create a more capable heavy lift platform without compromising deck space or overloading the hull and structural stability of the craft.

B. CURRENT CRANE CAPACITY

The current combined crane capacity on the YTT is such that it will limit the proposed operations of their updated mission. The combined two cranes (Heavy Lift and Aft Knuckleboom) provide 11 and 12 tons of lift capability respectfully. While this works for small UUV and ROVs as well as various over the side test equipment, it cannot accommodate larger scale UUVs that the Navy and Canadian Navy are looking to be working with.

C. PROPOSED NEW EQUIPMENT

In a search for marine applicable cranes that would both fit in the space of the aft deck of the YTT and be able to complete the mission, there were multiple potential options as shown in Table 20. From the outlined updated KPP's of Figure 6 in Chapter IV the threshold goal of this reconstruction was the ability to operate 30 ton UUVs with the target objective of full scale operations with the Echo UUV. Table 20 shows a comparison in size and capabilities of multiple commercially available marine knuckle boom cranes to include those currently installed on the YTT. The crane that was chosen as the replacement can lift 30 tons at the maximum extended boom radius with a higher rating at smaller lift radii. This crane, the Palfinger Marine DKF220, would be able to lift most, if not all, testable UUVs to include the Orca (Echo XLUUV). The lifting capability for the Echo will be limited if the XLUUV is carrying a full complement of weapons increasing its weight above the maximum capacity of the crane.

Table 20. Comparative Capability of Installed and Recommended Heavy Lift Cranes

	Crane	Manufacturer	Model	Max Lift (lb)	Max Lift (Tons)	Max Boom Length (ft)	Min Boom Length (ft)	Pedestal Size (mm)
Currently Installed	Heavy Lift Deck Crane	Appleton Marine	EB70-35-70	22000	11	75	30	1500
	Aft Knuckle Boom	Alaska Marine Crane	MCK-1240	24000	12	35	10	1700
	Total Current Lift Capability			46000	23			
Proposed Single Knuckle	Knuckle boom	Palfinger Marine	DKF220	60000	30	90.22	22	1800
	Knuckle boom	Allied Systems	K40-55	38000	19	38	10	1500

Adapted from [3], [32], [33], [34].

1. New Crane Space Requirement

To lift such a large UUV, obviously a larger knuckle boom crane than previously installed would be needed. Having said this, creating the space and weigh availability to be able to install a larger crane would require removal of now obsolete and antiquated systems.

The improvement of the dynamic positioning system to replace the tri-moor technique would open space on the aft deck to be used for crane operations instead of for capstans and line reels. To further the reallocation of space, both cranes on the aft portion of the YTT shall be removed in favor of the single larger crane. The majority of the controls, mechanics, and hydraulics needed to operate the chosen new crane are located within the pedestal of the crane.

2. New Crane Power Requirement

The power for the chosen crane will be supplied from the existing power wiring that powered the two aft cranes. Additionally, the pedestal having only 300 mm more of a diameter will be able to be placed into the same spot and cabled with limited impact to existing electrical wiring. This installation plan should be able to provide the requisite power to the crane. 200 More KW per generator are being produced by the updated generators proposed for the installation leaving an extra 400–600 W of available power depending on external system operation.

3. Updated Lift Capability

The proposed new crane will give provide a lifting capacity of 30 tons while fully extended and up to 40 tons at smaller radii. This capability is nearly double the combined lifting power of the currently installed heavy lifting cranes. With a 40 ton capacity, the YTT is capable of lifting all torpedoes and of lifting any UUV falling in the LUUV category. An unloaded Echo XLUUV would also be within the margins of a liftable weight however, would be too large with a full payload. The new crane, shown in Figure 25 would meet at least the threshold KPP goal set forth and would be able to operate in some configurations with the Echo allowing for a mostly achieved goal.

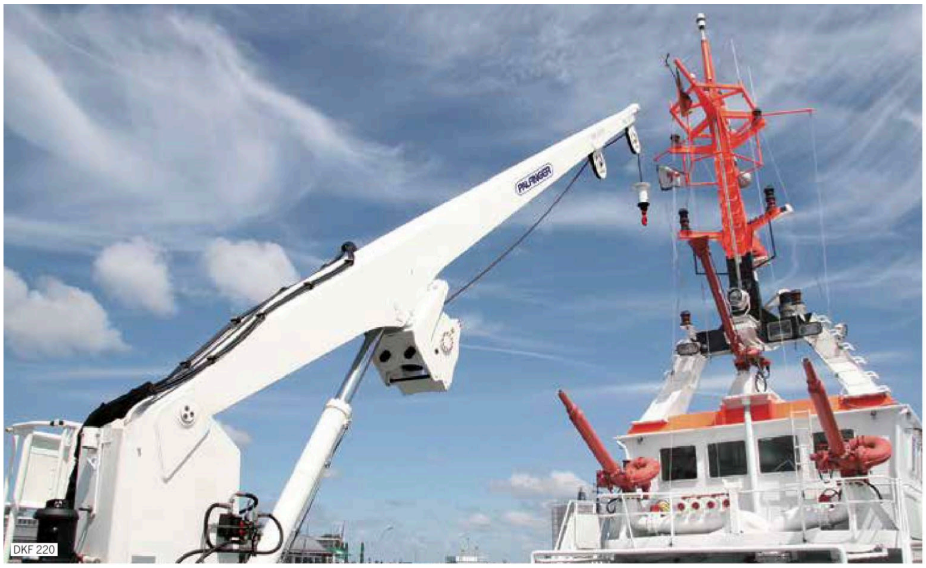


Figure 25. Proposed New Palfinger Marine DKF 220 Crane. Source: [32].

IX. CONFIGURABLE COMBAT SYSTEMS SUITE

Technology used on ships and in weapons is constantly maturing. It is not feasible that a ship built specifically for testing the weapons of today will be capable of testing systems that are developed in the future. With that notion in mind, the desire for the YTT is that the combat systems is configurable. The ship will provide the displays, the power, and various other needed hotel systems to test the technology. The testing entity will be able to bring in their own system and connect it to the YTT's power source to seamlessly create a testing platform. This chapter will explore the technology needed to make a configurable combat system suite to meet this desired KPP and establish the effect of such an adaptable system on current and future mission readiness.

A. ADAPTABLE COMBAT SYSTEMS SUITE

A primary goal for the YTT is to be able facilitate the testing of any portable equipment. To be able to make this goal into a reality- the combat systems suite must be able to display various types of information. By designing a suite with universal consoles, users will be able to bring in their own system, hardware, and drives and plug them into the console. This is similar to the newer combat systems suite of DDGs or LCS where any console can be a control station for any equipment on board.

B. CONFIGURABLE CAPABILITIES

A type of configurable combat systems suite has been designed before and implemented by the U.S. Navy. The modular design of the LCS Combat Systems and the baseline 9 Aegis Display System (ADS) both aim to allow any screen and console in their Combat Information Center (CIC) to display the program from any hardware rack [35]. In order to make the YTT's CIC configurable to technology that is not hardwired to the hull, the CIC would need to follow the same principles as the other two platforms but with a more open architecture.

1. Rapid Update and Reconfiguration Capabilities

The basis for this platform will take many key principles from the combat systems library (CSL) and ADS systems that Lockheed Martin has had proven success within their Aegis Platforms [36]. It will also use racks from commercially available suppliers to create a system that can be customized for whatever purpose and technology that contracting agencies need. The racks will be configurable as they contain their own intel processing but can be run off of different SSD card or blade plugged into them containing testing software [37]. Through these hookups, and similar to the ADS system, any console, to include a large screen display, will be able to show and operate the necessary software and test program/ data.

C. PROPOSED EQUIPMENT

The new generator systems should be able to provide more power for day-to-day operations as well as for the larger load from the new crane and computer servers installed in the combat systems suites. The proposed screens listed shown in Figure 26, are merely display systems and only draw a relatively small amount power at 2.5 Amps at 28 VDC [38]**.** Up to six of these touchscreens can be installed in the new console without drawing a compromising amount of power from the electrical plant. The biggest draw will be from the racks acting as docking stations from which the equipment will be powered which, as they are replacing current racks, will use the same power allocation as projected for the previous Combat Systems suite and installed technology.

1. New System Components

The mercury configurable rugged racks would provide the perfect base to connect software into the ships sensors and power programs that use ship power and capabilities with independent programs and can display the collected data onto screens inside the ship. These racks feature modular blades within the rack that can be swapped to configure the system to the intended purpose [37]. Additionally, the SSD reader capabilities allow smaller programs to bring their own SSD based systems and input those into the racks and still use the ships sensors and the GPU capabilities of the modular combat systems suite.

The pyramid from Mercury outlining the configurable architecture of their systems is shown in Figure 26.

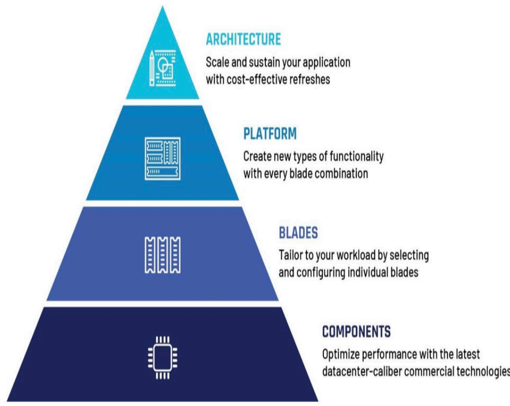


Figure 26. Visual Representation of Configurable Combat System. Source: [37].

The Mercury company also makes the screens used to display the data from their configurable racks. These screens can be used in the already installed consoles within the YTT to locally control the systems that the contractors have brought on board and installed in the available rack and/or blade space- dependent on the scale of the project and size of the software and equipage that has been brought on board for testing. Table 21 provides the specific data for the screens that could be purchased in tandem with the Mercury Modular rack blades. Figure 27 shows what this display on the console would look like once installed. The touch screen option would allow this to be a user-friendly platform with less human learning involved before operating technology onboard.

Figure 27. Proposed 17 in Multi-Function Display Screen from Mercury. Source: [38].

A key takeaway from the table below that shows the specific characteristics and power of the multi-function display is the HD video and DVI outputs. These will allow for COTS cabling to be rigged easily to large screens such as mounted televisions or standard projected screens for full room viewing of data. The use of the rack, blades, MFD, HD/DVI outputs, and large scale simple display will allow for a fully functional combat systems suite that can be updated rapidly and customized to operate, record, and display any systems and their affiliated data that the YTTs are contracted to test. [38]

Table 21. Specific Characteristics of Proposed Multi-function Displays. Source: [38].

I/O	
Power	28 VDC
Composite Video	6 inputs/2 outputs
HD Video	4 inputs/2 outputs
VGA	2 inputs
DVI	2 inputs/1 output
Signals	NTSC, PAL, DVI, SMPTE 292M, VGA
Characteristics	
Power Draw	2.5 A at 28 VDC (70 w); 4.8 A at 28 VDC (134.4 w) with heater
Aspect Ratio	16:9
Resolution	1920 x 1080 pixels
Horizontal Viewing Angle	180°
Vertical Viewing Angle	180°
Contrast Ratio	5000:1
NVIS	Class B (optional)
Operating Temperature	-45°C to +71°C (with heater)

2. Effects on Mission Readiness

Mission readiness, based on the updated mission statement of the YTT, would be the ability to get underway within 24 hours and operate any system for testing with minimal alteration to the ship. The configurable combat system comprised of this rack and blade structured open architecture and connected to multi-function touchscreen displays would increase mission readiness. The open architecture and the constantly updated software will allow the ship to test any intel-based system with no modification. The only logistical questions left lingering would be the ability of the crane to lift any test equipment. The new crane should provide the lift capability for nearly all testing equipment contracted to the Vessel. This system will provide a 100% Mission ready platform for any and all testing missions at any given point in the ships schedule.

3. Power Needed and Margin Increase

The YTT is already designed with a 20% margin in power and hospitality systems in order to support the testing of equipment on board [5]. With that being said, the removal of an extra, unused crane has added potentially available power. The updated screens and rack system should add no considerable power draw when compared to the previously existing console system. Though the new continuously operating Potable Water System does draw significant power, there will still be ample Amperage waiting to power any systems needed by contracting services through either DC plug in receptacles for personal computer systems or larger power sources for testing specific equipment. The remainder of the testing supplies in the form of blades or hard drives will be powered by the already installed racks that are budgeted into the electrical plant of the ship. All this being said, electrical power available is not a limiting factor of the YTT and any and all tests should have the power to both charge and run simultaneously at any given point in the operation cycle.

X. RECOMMENDED COURSE OF ACTION

The U.S. Navy currently has multiple YTT's in operation that are both manned and seaworthy. While as these ships are currently outfitted, they do not provide the optimal platform for the updated mission proposal, they can be overhauled to do so and to have room to continue to modernize. The major question is if it is beneficial to completely modernize the existing hull form into an offshore multi mission test platform or would it be faster to design a hull that is new and built specific to this mission. After weighing the cost of both options, and acknowledging that neither is inexpensive, but using the current hull with updated COTS systems will be the most cost effective, immediately available, and economically sustainable solution.

A. UPDATE VS. REPLACE

The cost to build a new ship would be astronomical and the lead time required would leave the United States without a valuable asset. Updating the existent hull will be the best solution as it is using a currently available platform and cost-effective means of installing COTS equipment to improve and enhance current capabilities. On top of this, with the current shipbuilding efforts of the U.S. Navy focused on building a larger fleet of warships, the delay in the build of a test craft would leave NUWC Keyport without a serviceable vessel for an appreciable amount of time. The stronger option is to update this platform using a means that is proven to be more inexpensive- using COTS technology. This strategy will allow the YTT to be a viable platform for the next decade of needed HWT and UUV testing until a replacement craft can be designed and budgeted. The majority of manpower in ship construction generally comes from the structure of the ship as shown in in Figure 28. By removing that cost associated with the manpower expenditure and updating and existing structure, the overall price of the project will be driven down.

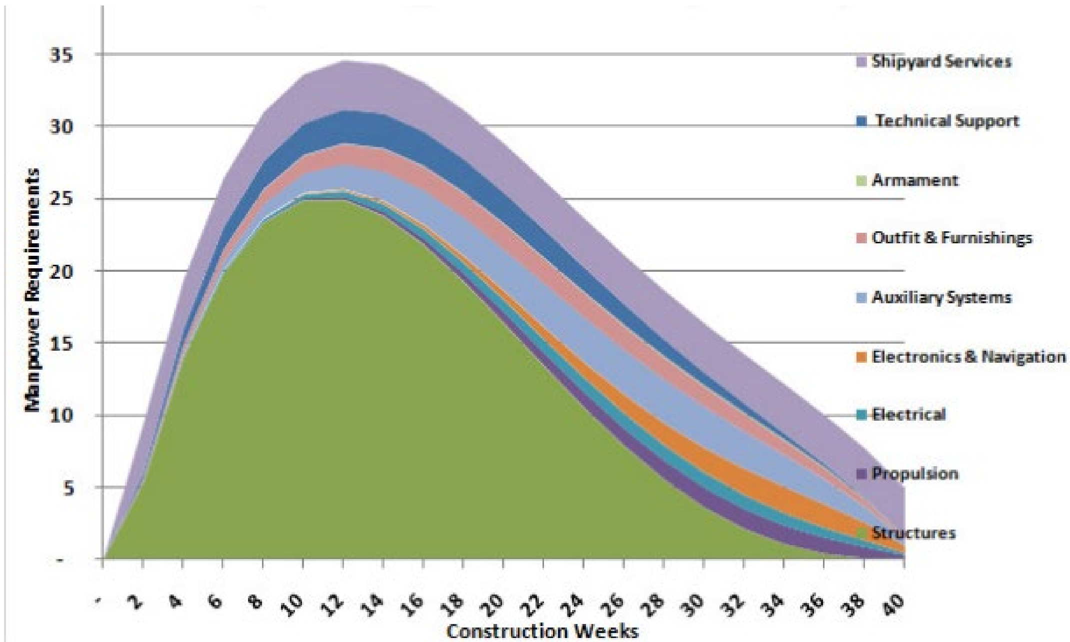


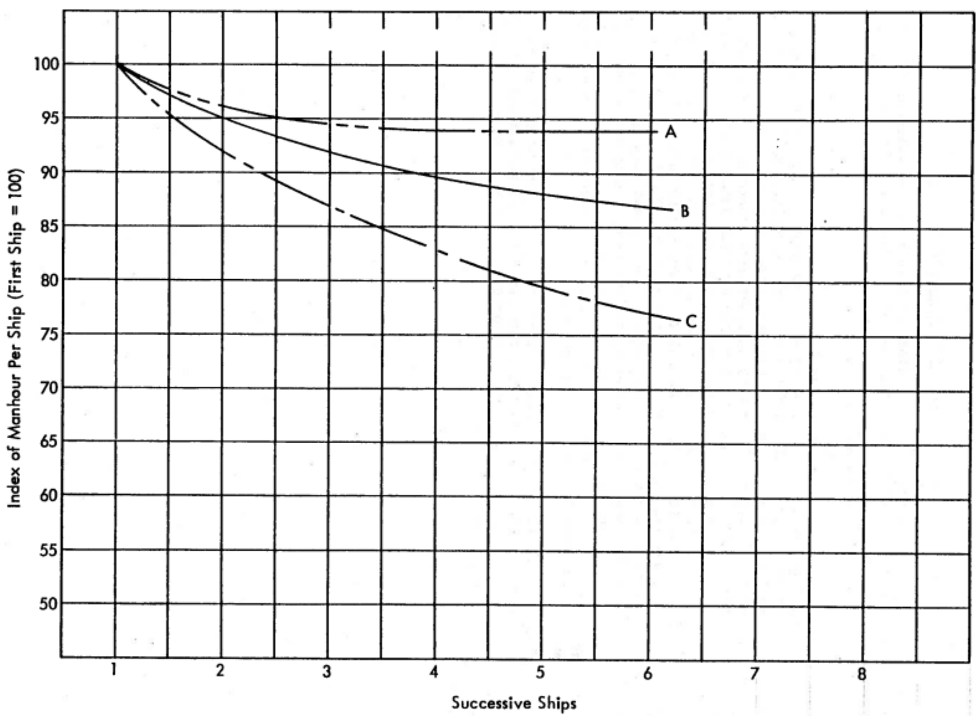
Figure 28. Sample Lead Ship Construction Manpower Estimate. Source: [39]

B. COST ANALYSIS

1. New Design and Construction Cost Analysis

The cost of all the recommended new technology as outlined above will be significantly cheaper than the past ship building and repair costs. This is primarily due to the use of all COTS products. As a COTS platform the maintenance, repair, and replacement of parts will come from commercially available sources and will be readily available for purchase in multiple locations compared to 1 of 1 government designed systems that quickly become obsolete and nearly impossible to perform repairs on.

A major reduction of cost and build time in new ship construction comes from producing multiple of the same hulls in a row. This cost and time reduction comes from human learning curve in building and the ability to buy parts in larger quantities. When multiple ships are built sequentially by the same manufacturing team, a reduction in building time and cost occurs. As humans learn the process the naturally become more efficient and effective which drives down labor and production costs. As only two YTTs would be constructed at this time, the true cost reduction due to human learning would not be seen. Additionally, parts would only be bought and designed for two vice more than 10 crafts. The advantage of bulk buying as it pertains to cost reduction would not be seen in this small construction model. Due to the impractical cost of building two ships instead of a new class design and larger production, it is more financially viable, at this time, to retrofit and temporarily make the YTT viable than to start the construction of a new vessel without the lead time to properly optimize the design. Figure 29 depicts the manhour reductions to further prove the effect of the learning curve on shipbuilding.



For the purposes of this graph, curve A represents the learning curve of a highly automated foreign shipyard, curve B represents the typical U.S. Shipyard with a skilled labor force, and curve C correlates to the majority of U.S. Shipyards.

Figure 29. Reduction of Manhours Due to Learning Curve on Successive Ships. Source: [40].

The last new design of a small ship for the Navy, for comparison, was the Mark VI patrol craft. "The U.S. Navy has twelve MK VI Patrol Boats that were built from 2015–2017, costing $15 million each, and all are completed and are in service with the U.S. Navy" [41].The MK VI are no longer in production due to the high price to build and maintain the unique craft. Although there are fewer YTTs than MK VI, and the MK VI is considerably smaller. The astronomical price of this hull, especially for a relatively small amount constructed, shows that building even fewer YTTs will also have an unapproachable cost compared to the rough estimate of the retrofitted parts discussed in the next sections.

2. Retrofit and Installation Cost Analysis

It should come as no surprise that the cost of an overhaul of the majority of the ships systems is an expensive undertaking. Taking the route to by COTS products rather than customized, one of one, MILSPEC technology should help to limit the cost. The Navy, in this method, can buy technology at wholesale prices and use industry experts to install and maintain the equipment. Additionally, a broken part that is supplied by a commercial manufacturer can be fixed or replaced then a customized system as the inventory is already in existence. The costs therefore will be broken down into just labor of old equipment renewal, the labor of installation, and the purchase of the equipment. The cost of initial design and testing is removed by using already existing commercially tested and developed technology.

A cost breakdown will include the following categories:

1. Labor
2. Shipyard Work (Drydocking, etc.)
3. Propulsion Equipment
4. Electrical
5. Water Systems and Piping
6. Crane Outfitting

All of these put together will run up a total that will be over the six figure mark. A cost breakdown of known prices for the generators and engines is shown in Table 22. Large expenses such as labor, the dynamic positioning system, a crane, and the CIC electronics are not added making this not a complete parametric cost analysis but an indication of the comparative cost to a new construction project such as the Mark VI. The majority of the cost will be a product of manhours. By purchasing available already build products, manhours are limited to those associated with installation and not construction. Additionally, the ship, as it is already an existent hull, will require fewer overall construction manhours.

Table 22. Engineering Equipment Cost Estimate

	Quantity	Cost (USD)	Total (USD)
Cummins Diesel Engine	2	35000	70000
Cummins Generator	3	60000	180000
		Total:	250000

Adapted from sources [20], [21].

While that may seem daunting to add the collective price of newly purchased technology and labor, it is significantly more reasonable than the multi-million dollar price tag that generally comes with the design and purchase of a new class of ship as shown with the cost for the design and build of only 15 of the Mark VI Patrol craft. By using COTS components instead of individually designed parts specific to the crafts, parts can be sourced in less time and for a lower cost. These parts are also generally easier to install, maintain, and subsequently replace [42].

Combining a Service Life Extension Program (SLEP) with continual preventive maintenance, and regularly scheduling overhauls, the service life of these craft can be extended out as much as 15 years more as demonstrated by many U.S. Navy service craft and ships that have conducted SLEPs. The extended life as well as the new equipage that is better fit to the modern YTT mission will keep the NUWC YTT fleet as a useful test range asset.

C. PROJECTED NEW LIFESPAN AND FUTURE SLEP

The new lifespan of the ship is limited by the endurance of the older steel hull and not by the technology. The installation of newer COTS technology will allow for relatively rapid maintenance and overhaul of any potential breakdowns or outdated components. The YTT hull, built in 1986 [9], is already approaching 40 years old and is past its planned life cycle. Future SLEP plans should aim to keep the technology working but acknowledge that the aging hull realistically only has around 20 years left as an active vessel.

The ability to remove and update parts as well as continuously reconfigure the Combat Systems Suite without physical modification to the space will naturally increase the lifespan and lower the scope of work in follow on maintenance availabilities. The projected new lifespan will only be limited by hull age but, with minimal additional major overhauls, be able to be extended by 15–20 years. This extension allows time for the research and development needed for the design and build of a class of range craft to be used in numerous range applications. From a previous study into the benefit of SLEP in the YTT class it was determined that, "For one YTT craft, a $12M SLEP provides up to 15 years of service life or $.8M/yr. New construction at $50M provides 25 years of service life or $2M/yr. Performing a SLEP and deferring vessel replacement will result in a Return on Investment (ROI) of 10 years. A SLEP also defers the high cost of vessel replacement" [43].

D. PROJECTED TIMELINE TO FLEET INTRODUCTION

The YTT class is already built and in service which removes the major lead time of a ground up production process. Any commercial shipyard with an available dry dock of suitable size would be able to accommodate the project as an overhaul. Based on the length of previous overhauls and the time needed to acquire all the requisite equipage, the turnaround time on each retrofitted YTT will be approximately 24 months.

XI. CONCLUSIONS AND FUTURE WORK

A. THESIS CONCLUSIONS

The YTT as stands should remain a fleet asset if given the upgrades to become a sustainably minimally manned platform with a wider variety of UUV and HWT missions. Heavy Weight Torpedo's are valuable assets to the U.S. Submarine Force and will always need a testing platform. As the U.S. and global technology move towards unmanned systems, it is clear the testing platforms need to be able to account for both assets.

The YTT craft is valuable for its initial intended mission area as a HWT testing platform. As one of very few surface vessel test platforms with organic torpedo tubes, it is crucial to keep the YTT in service. However, as an increasing focus shifts towards UUV integration with the fleet it is prudent to create a ship that can accommodate these new missions without sacrificing the torpedo capabilities that the YTT was intended to provide. In order to add value to the YTT when it is not conducting HWT test shots, the updated and open architecture combat systems suite will allow for American Contractors, DOD, and Foreign Entities. A minimally manned adaptable platform, as this thesis outlines, will provide the greatest platform capabilities with the most potential for return on investment. While operating with few dedicated personnel and the ability to travel to multiple ports with multiple available mission sets, the YTT provides a very capable in situ asset to the surface and subsurface fleets.

The YTT hulls that are currently in operation shall be most effective to the current and future operations of the U.S. Navy if they are updated with primarily COTS equipment. Not only will this be the most cost-effective way to improve the capabilities of the platform but it will allow the fastest return of the craft to a fleet supporting role in comparison to building an entirely new hull. Additionally, by updated the YTT with the suggested plan of this thesis, the YTT will be able to support its former HWT mission and be an invaluable addition to the UUV testing needs of modern technology. The technology and reconstruction plan that has been shown through this thesis will allow NUWC Keyport testing operations to continue until a new, modern, and permanent, solution can be found to replace the aging YTT and other range testing vessels.

B. FUTURE WORK

Future work conducted on the YTT can include an analysis into both this Range Craft, and global range craft. Range craft should in the future be designed with the advancement of technology in mind. They should take into account that updates to technology in both physical and software assets will require different configurations of both monitoring equipment and deck equipment. The goal for future work should be to define a crew, a mission, and an AOR for range craft in order to specifically optimize the construction of these vessels and the crew that are employed to serve aboard them.

Additional future work could include a financial analysis of the reconstruction of this craft and the additional life cycle maintenance and SLEP costs. The YTT, once a redesign and build is complete will require an updated maintenance program and budget proposal. On top of this a complete analysis of the return on investment should be performed to see how much the use and effectiveness of the craft increased and the benefit that brings to UUV capabilities going forward. However, the proposed work in this thesis is a temporary solution to a long-term problem. The U.S. Navy needs more capable range craft that can travel offshore and conduct a wide variety of missions. Adding 20 years of life to the current YTT as this thesis suggests, will not alleviate the issue but will allow for more time to develop a plan to build a replacement ship. A full replacement to the YTT that could be used in other ranges around the country would be an application of future work and resources that bring an appreciable increase in capability to this country's testing ranges.

APPENDIX

NMETLS listed in this appendix are adapted from NUWC Keyport's Analysis of their own craft and provided in the YTT's Mission Essential Task List [22]

M1. Maneuver—move the YTT to a position to carry out its mission

1.1 Movement

1.1.1 Mobilize—load personnel, equipment, and supplies

1.1.2 Sail Ship from Port, Anchorage, or Moorage

M1—Water depth at the pier (feet)

1.1.3 Transit

M1—Distance traveled (nautical miles)

1.1.4 Maintain station

M1—Time underway (days)

1.1.5 Return Ship to Port, Anchorage, or Moorage

M1—Water depth at the pier (feet)

1.1.6 Demobilize—offload personnel, equipment, and supplies

1.2 Navigate—safely transit taking into account navigational hazards and the rules of the road.

1.3 Conduct Meteorological and Oceanographic Measurement and Analysis—measure environmental conditions which may affect or impair operations

2. Operations

2.1 Torpedo Operations—launch, recovery, loading and unloading of torpedoes

M1—type (submarine, surface, air, foreign)

M2—weight (pounds)

M3—length (feet)

M4—diameter (inches)

M5—quantity (number)

M6—propulsion type

2.2 Employ Remote Vehicles—To operate vehicles such as robots, drones, unmanned underwater vehicles (UUVs), unmanned aerial vehicles (UAVs), unmanned underwater vehicles (UUVs), and other devices from a local control station. This task includes deployment, launch, control, and recovery operations.

M1—weight (pounds)

2.3 Perform Underwater Object Recovery

M1—weight (pounds)
M2—recovery methodology
M3—control (data quantity)
M4—power (watts)
M5—station keeping (inches)

2.4 Conduct Small Boat Operations—launch, recovery, loading and unloading of small boats

M1—type of craft (RHIB, life boat, etc.)
M2—weight (pounds)
M3—clearance (feet)

2.5 Conduct Range Maintenance

M1—depth (feet)
M2—weight (pounds)
M3—clearance (feet)
M4—station keeping (inches)

2.6 Conduct Diving Operations

M1—type of operations

2.7 Provide Damage Control

2.8 Prevent Environmental Pollution

2.9 Rescue and Recovery of Personnel

3. Command and Control

3.1 Provide Information Technology Services

3.2 Acquire, Process, Communicate Information, and Maintain Status

3.2.1 Provide Internal Communication
3.2.2 Provide External Communication
3.2.3 Manage Means of Communication

4. Logistics—to provide for sustained operations while away from home port

4.1 Fuel/Lube Oil

4.2 Potable Water

4.3 Provide Messing

4.4 Provide Berthing

4.5 Provide Sanitation

4.6 Pyrotechnics Storage

4.7 Repair/Maintain Equipment—To preserve, repair, and ensure continued operation and effectiveness of YTT's equipment

4.7.1 Perform preventative maintenance

4.7.2 Diagnose and Repair—To monitor equipment and material performance through the use of on-board sensors, diagnostic equipment, and visual inspections in order to identify impending and/or actual malfunctions. This task includes trend analysis and efforts taken to restore an item to serviceable condition through correction of a specific failure or unserviceable condition.

4.7.3 Provide Repair Parts

4.8 Perform Emergency Towing

4.9 Load/Offload, Transport, and Store Material

4.10 Provide Materials Handling Equipment

4.11 Provide First Aid, Hearing Conservation, Eye Sight Conservation and other OSHA program

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