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Designing a Maintainable and Sustainable Coast Guard Icebreaker for Arctic and Antarctic Operations

Abstract

The U.S. Coast Guard is at the start of the process of acquiring a new class of heavy icebreaker. This class will replace the aging Polar Class ice breaker and supplement the medium icebreaker USCGC HEALY, WAGB 20. The Coast Guard must be able to control acquisition and lifecycle cost in acquiring this new class of ship as well as provide for a sustainable ship with minimal environmental impact. The focus of this paper is on the ability to maintain an independent steaming vessel in the remote arctic regions of the globe and how the design of the vessel will dictate much of the logistics support of the operations. It is assumed that the new class will be a direct replacement with the same capabilities of the current Polar Class with similar anticipated mission requirements namely; escorting merchant shipping traffic through ice fields, search and rescue, and scientific research operations. With the White House's release of its arctic strategy and the increased shipping traffic in arctic waters because of the open seaways, a long-term presence is required to meet the demands of the current international trends. The first objective of the Presidents arctic strategy to ensure the freedom of the seas and air for United States national interests and ensure that international treaties are enforced, the objective states the need to "intelligently evolve our Arctic infrastructure and capabilities, including ice-capable platforms as needed". Responsible stewardship within the region requires United States entities, government and commercial, operating in the area to prevent environmental damage to the area. The third point in the President's plan is to work with the international community in the preservation and exploration of the arctic region. In the national Arctic Policy the need for securing safe passage of United States ships and interests in the Arctic Region is required [10]. A second national level policy has been introduced called, the National Fleet Policy signed by the Chief of Naval Operations (CNO) and the Commandant of the Coast Guard, outlining plans to build a fleet that compliments each other and does not duplicate capabilities. The national fleet policy is in concert with continuing with the interoperability of the Navy and Coast Guard as well as continuing the standing practice of not duplicating capabilities where possible, especially with icebreakers. The duplication of capabilities would mean the Coast Guard would maintain the lead in icebreaking operations and spearhead the polar operations [4]. The two national policies place the Coast Guard as the lead maritime component of the United States Arctic strategy to ensure the rights of the United States on the international state. The design considerations of a new icebreaker to implement this policy and the need to integrate early in the design process to positively affect the total lifecycle cost of the new class must be taken into consideration as equal to the operational requirements of the vessel, not as an afterthought.

Key Terms:

International Maritime Organization (IMO), Marine Pollution (MARPOL), Engineer Officer of the Watch (EOW)

Sustainability Considerations

The Coast Guard is the example of marine environmental protection in the region and the ship design must reflect that. The disposal of trash, oil, and waste are requirements of every ship at sea. In the delicate region of the arctic, disposal of these items becomes an issue, as regulations and ethical issues dictate the need to retain these items for long periods of time, or dispose of such items. International treaties developed by the International Maritime Organization (IMO) include the treaty on Marine Pollution (MARPOL) of which Annex V prohibits the discharge of solid waste other than food refuse less than 25mm in diameter into the Antarctic Region [6]. The trend of international environmental regulations is toward more stringent and greater regulations therefore the design of the vessel in this manner will be important. The extended deployment and lack of facilities and infrastructure in the polar regions of the globe offer few places to process these items. The Coast Guard must plan for each accordingly.

Solid waste onboard ships are always an issue no matter where the ship is operating. With sizeable crews, the Coast Guard icebreakers will produce significant amounts of trash, which will have to be disposed of. The best option is to sort trash into three categories that can be burned, recycled, and non-burnable waste. Plastic will inevitably be brought onboard even with an active program to reduce the amount of plastic the actual amount can only be reduced and not eliminated. A controlled dedicated space will be needed to store plastic until it can be disposed of on a shore recycling facility. The same is true for other recyclables such as metals, which will also need dedicated storage as well. The use of incinerators is currently authorized in these areas and provides a way of disposing of burnable garbage, such as paper and cardboard [6]. Non-burnable garbage and refuse will have to be stored onboard for period of time this can include batteries, paint, and other chemical waste products that will have to follow a specific storage plan.

The ability to dispose of waste is imperative to maintain sanitary conditions such as food and human waste will need to be processed and disposed of at sea in the ice. The Antarctic region is classified as a special region under the International Maritime Organization, and has more stringent requirements that have gone into effect in 2013. The IMO requirement is to have commuted or processed food waste. There are many ways to accomplish this, mostly by mechanical means such as grinding, macerating, or pulping. The Coast Guard will have to select one of these methods, similar to those used onboard U.S. Navy vessels [9]. This mandatory requirement based on the revised IMO treaty in that the Polar Class makes deployments of two to four months in the Polar Regions and to retain the food waste on board would be extremely unsanitary for the crew. This is a departure from the current Coast Guard fleet that was constructed prior to many international environmental regulations.

The ability to sustain the required amounts of fuel and lubricants, as well as the waste from the fuel and lubricants will be an issue. The proper disposal of oily waste products is required by both United States and International law. The requirements for oily waste discharges in normal operating environments such as the Pacific or Atlantic Oceans is 15 ppm, while in the Antarctic, the requirement is 0 ppm [2]. This means that no oily water separator can be used to reduce the volume of the collected fluid. Essentially the oil-water mixture must be stored onboard for the length of time the ship is operating in Antarctic waters or below 60 degrees south latitude. The dirty oil tank and the processing tank should be of a size sufficient to retain onboard enough dirty oil from all generator prime movers, reduction gear, and

propulsion equipment assuming that each will need to have an oil change within a 90 day deployment. There are no waste oil facilities on Antarctica or on the northern slope of Alaska or Canada to offload the waste. Vessel emissions are another issue since the used lube oil or waste oil cannot be burned and still be in compliance with federal emissions standards.

Reliability of Controls

Shipboard controls have evolved extensively since the United States built the last heavy icebreakers in the late 1970's. Today's control systems have reduced crew-manning requirements and made equipment more responsive, however they require updates and system stability that may not be available in polar regions. Most computers have an operating system that needs constant updating, similar to a personal computer. These updates patch errors in the code and correct errors in the system. Therefore as the operating system ages, so does the control program, controlling the ship's propulsion and auxiliary systems. However operating systems have a much shorter lifecycle than a ship or control system and will have to be replaced more frequently.

Upgrades and patches to the computer systems will be technically feasible while underway, however extremely expensive as two possible options are available, download over an internet connection, or send a disc with updates via mail and have it transported to the ship. The first while seemingly the easiest, connect the computer to the internet or Coast Guard Intranet and conduct the update that way. Updating in this manner leads to two problems. First, the ship uses a satellite link for all internet access. Downloads of large programs or files is extremely slow and given the fact that there are not a vast number of communications satellites in the area, the connectivity will be spotty at best. The second problem is a matter of network security and physical security of the ship by having a part of the control system of a ship linked to an outside network, opens the ships propulsion and electrical power generation to cyber-attack. Recent reports indicate vulnerabilities of network control systems aboard the U.S. Navy's Littoral Combat Ship [1]. The second option of having a physical disc sent is the most secure but the slowest and may require extraordinary lengths to send critical patches to the ship.

A control and monitoring system built on redundancy should be installed. The complete elimination of a computer control or monitoring system is not necessarily advised, as computers can perform excellent monitoring functions and fill the roles of complex tasks in the control of gas turbines, clutches, and some speed control, that save both time and money. There needs to be a balance between the advanced modern technology and some of the tried and true methods. Having a control room with a large control board to start, stop, and/or control the speed of equipment with remotes for the vast majority of the installed equipment. Electrical remotes do not require systems grooves or refresh from multiple commands such as computers slow over time, and the control itself is simpler for the operator to use. The redundancy of the electrical remote verse the computer to start will enable the manual or local electrical start at the motor controller more easily. This provides each piece of electrical equipment with at least two ways of starting and stopping. The computer interface should be via display with no actual control allowing for the Engineer Officer of the Watch (EOW) to monitor the ships systems. The monitoring system would allow plotting graphically, printing, and saving all monitored parameters, this is a less critical function than having complete computer control system, critical pressures and temperatures are required to have local backup sensors so the loss of a monitoring system could be overcome by addition of a watch stander to

fill this function. The redundancy on the monitoring system would be human with a person making a round of all monitored parameters in the event of a monitoring system failure.

The objective of minimizing the amount of wasted time from having multiple watch stations under the EOW, propulsion, generators, boilers, and auxiliaries watches, could be reduced to just an EOW and assistant even without a computer control system. Limiting of the computer interfaces to perform only monitoring allows the EOW to perform a control task with assistance from the Throttleman. This is a cost reduction of three full time equivalent positions that can be rolled back into personnel to perform maintenance and repairs. So equivalent advantages of having a computer control system and electric remote control system; however a well laid out control console for the EOW and Throttleman could make the entire system safer and more efficient. The second advantage of an electrical control system, as far as starting and stopping equipment, is that the failure rate of motor switches is significantly less. Switches and motor controls require far less preventative maintenance, nearly to the point of less than one hour per quarter.

Redundancy of Equipment to Reduce Onboard Spares

Onboard spares are assets that cannot be used by other units in the inventory system when the ship is underway. These spares provide insurance against equipment failure and prevent the loss of operational hours or days. However when sizing pumps, motors, valves and the like, as close to identical size equipment should be sought. The goal is that for two independent systems, there are potential spares for another system. For example a seawater circulating system could potentially use the same pump and motor combination as the bilge system, so if the bilge pump were to fail, the components could be transferred rapidly to the bilge system. However, due to the seawater circulating system having two pumps, the system would remain functional but slightly degraded due to the lack of redundancy. If systems are sized so that multiple pieces of equipment are identical onboard in the construction the sparing model could be streamlined so that less spares are carried for the same amount of equipment. This would mean higher operational availability at lower cost by using interchangeable parts. This has to be built into the original design of the vessel and would be nearly impossible to retrofit a ship with this logistics capability.

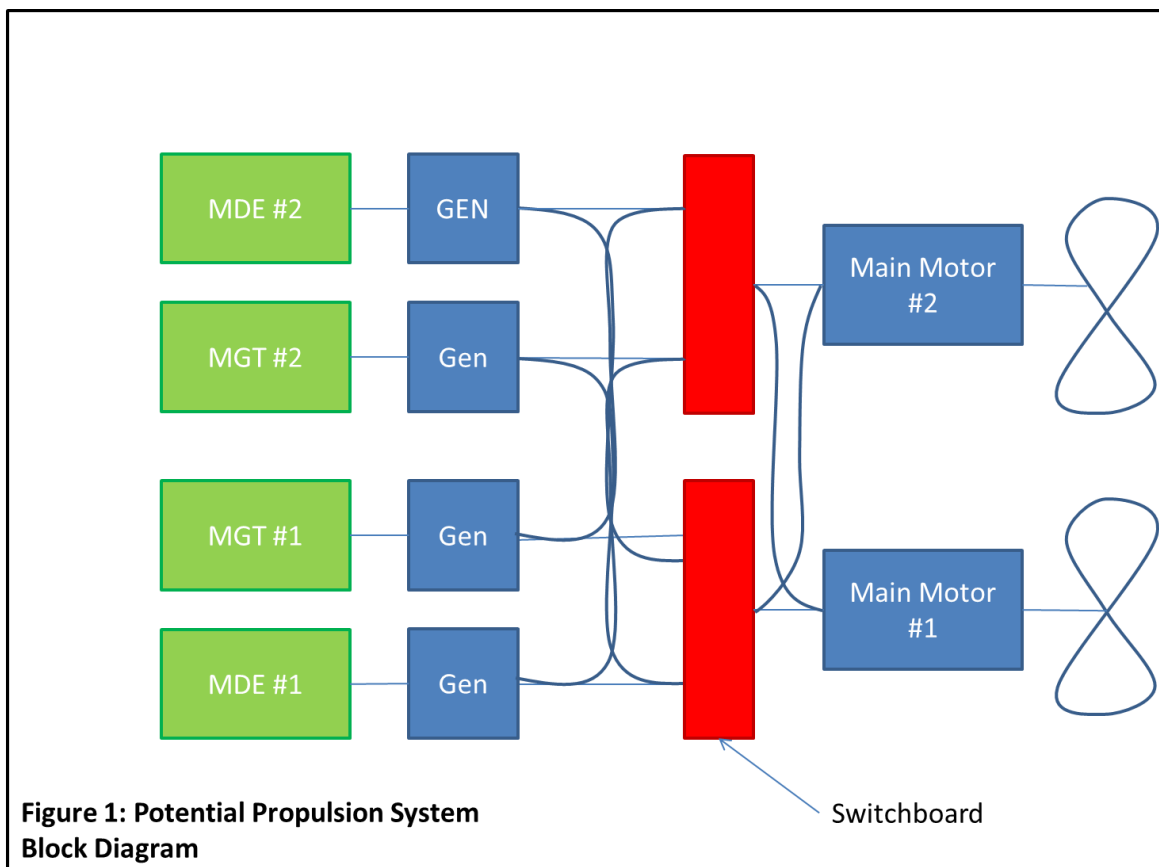
Shore based spares could be reduced as well if multiple systems use the same equipment. This would allow for fewer spare parts, less warehouse space, and less manpower in managing the spare parts. The long-term effect would be a storeroom of spares that would be utilized, verses a storeroom full of spares that are essentially permanent ballast for the ship. The overall effect of interchangeable parts would be amplified by having multiple ships of the same class and further reduce the overall lifecycle cost of each asset. The Coast Guard's Cold War era fleet had seven Wind-Class heavy icebreakers [3], which offers the potential for the support organization to reduce operating cost by having multiples of the same equipment verses a one of one, such as the USCGC Healy WAGB-20. As the majority of major systems funding is not in the acquisition of the actual system but in the sustainment, it also offers the greatest potential savings after a well-executed acquisition.

The need to maintain an above ninety percent operational availability while the ship is underway away is critically important to the mission and safety of the crew. There is a definite need for the ship to have several redundancies; however, being able to use interchangeable parts reduces the cost of redundant

engineering systems. The savings when applied over the entire ship, and then the entire class, could mean a significant reduction in annual operating and maintenance cost with increased asset availability.

Propulsion Redundancy

It is expected that the propulsion system of heavy icebreakers will be a diesel-gas turbine-electric propulsion plant. The electric drive has several advantages, such as not having reduction gears attached to the shafting that could be over torqued or damaged due to ice. This also offers an easier way of cross connecting prime movers and motors. This system offers great flexibility for both long economical steaming and still provides the horsepower required to break the multiyear ice continuously. The possibility of using nuclear power is available, as the Russians have installed on many of their heavy icebreakers. However this is not a realistic option for the Coast Guard for several reasons. The first is the capital investment for a nuclear ship is very high. The Coast Guard has never operated or maintained a nuclear powered ship; the only possibility of the Coast Guard operating a nuclear powered ship would be at the assistance of the U.S. Navy for training, maintenance, and repair of the nuclear systems. The benefits of nearly unlimited power do not outweigh the financial capital and operational costs [7].



The advantages of a diesel/gas turbine electric propulsion system allows for efficient transit speed while using diesel power and the power surge needed for ice operations from the gas turbines. The electrical drive versus a mechanical drive prevents damage to reduction gear due to over torque or shock from hitting small icebergs.

Installed Equipment for Logistics

Installing specific equipment to maintain a logistically easy route of bringing on supplies and removing trash or equipment for repair should be considered. Often on military ships there are ample people to complete tasks such as on loading dry and cold stores or removing garbage from the ship. There is also a problem of having to remove large pieces of equipment without either using a shore-based crane, which in remote regions may or may not be available, or manually moving the equipment down the gangway. By having a stores crane, stores can be sorted on deck and easily moved via pallet jack or other means to the appropriate storeroom. Current state is to call all hands to the pier and line up in a bucket brigade to move the items. Trash could again be moved quickly to shore, by having the trash collection room exit near this area, and bins of trash and recyclables can be easily removed and put ashore even when several tons are involved.

Facilitating large equipment removal for components out of engineering spaces needs to be easier than traditional naval construction. There are several options, first is having vertical access from the main deck to the upper level of the engine room with a crane lift that is capable of removing or placing large heavy equipment [5]. This access could be similar to those found on commercial vessels with a 6'x6' water tight hatch with an installed crane above. Lifting points for chain falls and hand trucks will suffice to move such equipment within the engine room. By having this large permanent opening, savings of personnel time will be accrued from not having to cut structure to remove equipment as is the case on some newer constructed classes of vessels using modular construction methods.

The U.S. Navy and Coast Guard often use a brow for embarking and disembarking crew members, passengers, and visitors. While useful in areas with large portions of the naval fleet where facilities are available, they are not practical in areas with little to no support facilities. Accommodation ladders allow for two to three people on the ship to setup and store the ladder, verses a brow that may require a crane or be picked up and manhandled onboard.

Conclusions

Building a ship is a complex undertaking that requires many years of planning, design, and construction; however these make up the shortest phase of the ship's lifecycle. New environmental and operational requirements complicate the maintenance and logistics of the ship. Planning for the future in the design of a ship is difficult as the environmental regulations continue to increase, the mission demands will change, and the need to stay cost efficient remains. Means to reduce total lifecycle cost is at the beginning of the ship's lifecycle, and plans for the ever increasing environmental regulations, as well as the need to control the lifecycle cost, will be necessary for the Coast Guard to provide successful mission execution in both of the Polar Regions. Icebreakers play a key role in the maritime safety and security plan for the arctic and without a significant improvement of this asset type, the Coast Guard will be hampered in its ability to execute this mission set [11]. The need to design a ship that will last for forty to fifty years is required, as the ship class will be exposed to the most extreme conditions and must return safely to port. The Coast Guard icebreaker will be the instrument of diplomacy for the United States in the Arctic and Antarctic regions providing escort to vessels, responding to environmental problems, and protecting our interests in the region for much of the remainder of this century.

The views expressed herein are those of the author and are not to be construed as official or reflecting the views of the Commandant of the U. S. Coast Guard or Department of Homeland Security.

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