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Using a systems engineering process to develop a parts harvesting procedure in support of decommissioning MCM-1 class ships

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MONTEREY, CALIFORNIA

THESIS

USING A SYSTEMS ENGINEERING PROCESS TO DEVELOP A PARTS HARVESTING PROCEDURE IN SUPPORT OF DECOMMISSIONING MCM-1 CLASS SHIPS

by

David E. Bowe

September 2015

Thesis Advisor:	Gary Langford
Second Reader:	Rick Williams

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This thesis uses systems engineering principles and an evolutionary process model to develop a parts harvesting procedure for the Mine Countermeasure (MCM-1) class ships. This procedure will facilitate harvesting required components from a decommissioning MCM-1 class ship that will be refurbished for reuse on the remaining in-service ships. These harvested components are critical to ensuring MCM-1 ships can conduct mine countermeasure operations by having required repair parts to keep the systems functioning as designed. Additionally, the harvested components will help the ship class meet expected service life. Parts harvesting is required to keep the ships operational due to various system(s)' single point failure design, installed equipment material low-permeability requirements, and limited overall part demand for the mine countermeasure unique systems. The parts harvesting process developed is executable, cost-effective and critical to ensuring the MCM-1 class ships are materially able to operate as designed. Various systems engineering tools are utilized in the parts harvesting procedure to assess the ship as an overall system, determine critical components, establish sparing requirements, and minimize cost for repair parts. The procedure includes identification of components to harvest, funding and execution of harvesting operations, warehousing, refurbishment of harvested components, disposal, and measuring procedure effectiveness.

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LIST OF ACRONYMS AND ABBREVIATIONS

3PP	third party planning
AC	air conditioning
Ao	operational availability
AOR	area of responsibility
APL	allowance parts list
ASW	anti-submarine warfare
BCA	business case analysis
BSP	battle space profiler
C3F	Commander Third Fleet
C4I	command, control, communications, computers, & intelligence
C5F	Commander Fifth Fleet
C7F	Commander Seventh Fleet
CASREP	casualty reports
CBSP	Commercial Broadband Satellite Provider
CEP	Class Execution Plan
CG	Cruisers
CHT	collection holding & transfer
cm	configuration management
CNO	Chief of Naval Operations
CNSL	Commander Naval Surface Forces Atlantic
CNSP	Commander Naval Surface Forces Pacific
COCOM	Combatant Commander
CEP	class execution plans
CPP	controllable pitch propeller
CS	combat systems
CW	chill water
DECOM	decommissioning
DFS	departure from specification
DLA	Defense Logistics Agency
EFD	equipment functional description
ERP	enterprise resource planning
ESL	expected service life
FFG	Frigates
FMS	foreign military sales
FTA	fault tree analysis
FY	fiscal year

GCCS	global command and control system
GE	government entity
GFE	government furnished equipment
GFI	government furnished information
HF	High Frequency
HM&E	hull mechanical & electrical
IA	industrial activity
ICAS	Integrated Control Assessment System
IED	improvised explosive devices
IPT	integrated product team
ISCS	Integrated Shipboard Control System
ISEA	in service engineering agent
ISIC	Immediate Superior in Command
JFMM	Joint Fleet Maintenance Manual
LCS	littoral combat ship
LO	lube oil
LoS	Line of Sight
MARAD	Maritime Administration
MCM	mine countermeasure
MCMRON	mine countermeasure squadrons
MD	Mini DAMA
MDA	mine danger area
MDE	mine danger environment
MEDAL	mine warfare and environmental decision aids library
MHC	Osprey-class Coastal Minehunters
MIW	mine warfare
MLDT	mean logistics downtime
MMGTG	magnetic minesweep gas turbine generator
MOE	measures of effectiveness
MPAC	medium pressure air compressor
MPDE	main propulsion diesel engine
MSMO	multi-ship-multi-option
MT	maintenance team
MTBF	mean time between failures
MTTR	mean time to repair
N95	Office of the Chief of Naval Operations
NAVSUP	Naval Supply Systems Command
NIPR	non-secure internet protocol
NMD	Navy maintenance database
NSA	Naval Supervisory Authority

NSTM	Naval Ships' Technical Manual
NSWC	Naval Surface Warfare Centers
OM&S	Operating Materials and Supplies
P/S	Port/Starboard
PARM	participating acquisition manager
PDF	portable format document
PE	port engineer
PESTOIN	Personnel, Equipment, Supply, Training, Ordnance, Infrastructure, and Networks
PINS	precise integrated navigation system
POC	point of contact
POM	program objective memorandum
PPBE	planning, programming, budgeting, and execution
PW	potable water
RBD	reliability block diagram
RDT&E	Research, Development, Test and Evaluation
RFI	ready for issue
RFP	request for proposal
RKC	Readiness Kill Chain
RMC	regional maintenance center
RMMV	Remote Multi-mission Vehicle
RMS	Remote Minehunting System
RO	reverse osmosis
Sat	Satellite
SBS	ship building specialist
SF	ships force
SIPR	secure internet protocol router
SME	subject matter experts
SMP	surface master plan
SPAWAR	Space and Naval Warfare Systems Command
SPF	single point of failure
SSPG	solid state pulse generator
SSV	Small Ship Variant
SW	seawater
SWE	Surface Warfare Enterprise
TWH	technical warrant holder
TXV	thermal expansion valve
TYCOM	Type Commander

U.S.	United States
UCHS	Umbilical Cable Handling System
UHF	Ultra High Frequency
UN	United Nations
USCG	United States Coast Guard
VHF	very high frequency
VSB	validation, screening, and brokering
WPER	work package execution review
WRFT	warship ready for tasking
WWI	World War I
WWII	World War II
XBT	expendable bathythermograph

EXECUTIVE SUMMARY

The naval mine is an inexpensive weapon that can be used to deny entry into a given body of water. As per the United States (U.S.) Navy program office report regarding mine warfare (MIW) in the 21st century, mines have caused more damage to U.S. naval ships than any other armament since the end of World War II (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 8). Further, Naval mines can deny commercial vessel traffic movement within a port or passage through a sea-lane that can result in catastrophic economic impacts. The United States must be able to deter and respond to this threat to ensure naval dominance in support of the nation's defense, keep sea-lanes open for the safe transit of commercial traffic, and to prevent economic upheaval. One of the primary means to deter and respond to MIW is the mine countermeasure (MCM-1) class ships. These 11 ships are strategically placed around the world to deter MIW and respond to mine countermeasure operations if required.

To sustain the material condition of the MCM-1 class ships, adequate repair parts are required to ensure the ships are operationally ready and that they can reach expected service life. Due to the MCM-1 class ships' age, various system(s)' single point failure design, installed equipment material low-permeability requirements, and extremely small population and demand of critical spare parts (as compared to the rest of the U.S. Surface Navy), it is extremely challenging to provide repair parts required for the ship class to achieve operational availability objectives. Further exacerbating this challenge is the fact that the replacement for the MCM-1 class ship is currently being developed and any increase in MCM-1 class ship sustainment costs for repair parts can result in delays to the replacement platform. Strategies proposed by the Diminishing Manufacturing Sources and Material Shortages guidebook to address this problem have included lifetime buys from an original equipment manufacturer or reverse engineering of obsolete components (Defense Standardization Program Office 2009). Neither of these two strategies is sustainable as both are extremely expensive and typically very time consuming. A realistic means to mitigate the repair part challenge is by harvesting components off

MCM-1 class ships as they decommission to restore the components for reuse on the remaining in-service ships. The problem is that no documented procedure outlining how to harvest parts effectively off decommissioning (DECOM) MCM-1 class ships exists today. Failure to address this issue will negatively impact the United States' ability to conduct mine countermeasure operations and is simply not acceptable based on the threat and potential impacts to the United States and its allies.

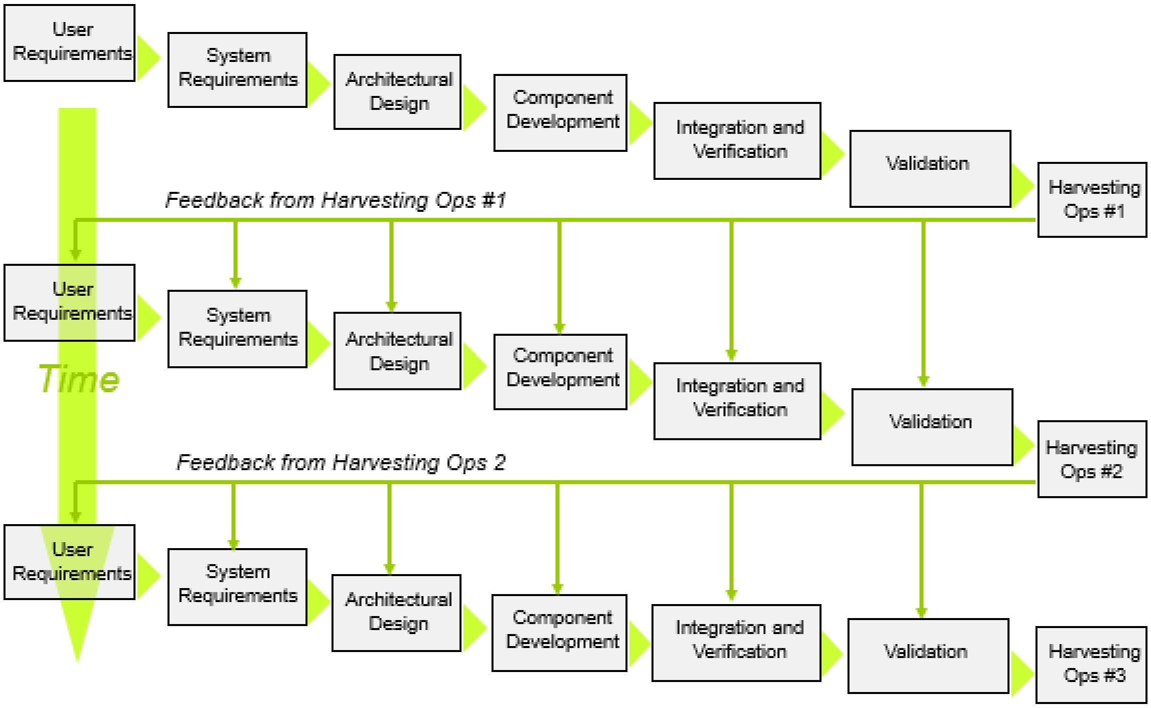
Systems engineering principles were utilized to analyze the problem and to develop a parts harvesting procedure that will meet stakeholder needs. This thesis recommends that the parts harvesting procedure be implemented to support the next MCM-1 class DECOM currently scheduled for fiscal year (FY) 19. It is noteworthy that the process includes budgeting for parts harvesting operations, which require planning efforts to commence in FY16. This essential process was developed to be both executable and cost-effective while striving to meet platform operational availability objectives at both the individual shipboard system, as well as the system of systems platform level. The procedure outlines the development of an integrated product team (IPT) that will perform 10 major functions as follows.

- Kickoff/Determine Harvesting Needs—Establishes IPT and provides engineering rigor and two models to support parts harvesting needs identification. The first model helps to determine sparing requirements for a given part and the second model minimizes cost to meet the sparing objective whether from procuring the part from a vendor or harvesting a component and refurbishing it for reuse.
- Plan Equipment Removal—Develop plan and/or work specifications to harvest equipment for ships force, government entities, and shipyard contractor. Also establishes a parts harvesting availability.
- Fund Parts Harvesting—Includes development and submission of budget request in support of harvesting operations, establishes contract vehicle to perform the availability, and funds the execution of the harvesting operation.
- Remove Equipment from DECOM Ship—Discusses removal of equipment from DECOM ship by appropriate entity (ships force, government, contractor).

- Store Equipment/Warehousing—Accounts for storing equipment once initially removed from DECOM ship in the ship repair facility, as well as warehousing long term.
- Ship Equipment—Describes need to coordinate and ship equipment following harvesting operation to the appropriate storage or repair facility. Accounts for scheduling shipments to warehouses open during regular business hours as well.
- Document in ERP—All harvested material must be documented in the Navy Enterprise Resource Program in accordance with applicable Operating Materials and Supplies (OM&S) procedures.
- Refurbish Harvested Equipment—Outlines assessing and refurbishing harvested equipment that can be utilized to support the in-service ships.
- Dispose of Unnecessary Components—Accounts for equipment harvested but found to be in an uneconomical repair condition and requires disposal.
- Wrap-up and Measures of Effectiveness—Closes out the parts harvesting operation and solicits feedback for process improvement. Describes measures of effectiveness metrics that should be tracked to determine harvesting operation level of success.

The methodology used to develop the parts harvesting procedure was an evolutionary systems engineering process model, as depicted in Figure 1. Using the evolutionary model facilitates process improvement based on feedback following each harvesting operation. Both technical and administrative changes will be required to keep the harvesting process procedure relevant over time.

Figure 1. Parts Harvesting Development Evolutionary Model



The analysis was conducted using systems engineering principles to facilitate process development and fulfilling the intent of each step in the evolutionary model depicted in Figure 1. User requirements were derived from the stakeholder analysis that outlined each of the parts harvesting operation stakeholder needs. The stakeholder needs facilitated the user requirements development. The system requirements arose from various system engineering principles and tools. The first was the parts harvesting operation functional decomposition. Understanding the functions that part harvesting operations required was fundamental to developing the system requirements. Each of the functions is a detailed section of the parts harvesting procedure that was developed, which was also fundamental to the procedure architecture design. One of the system requirements was to determine which components were critical on an MCM-1 class ships. This problem was solved by developing an MCM-1 class functional decomposition, mapping the ship functions to the physical form, building platform-level reliability block diagrams, and performing reliability and operational availability calculations to determine problematic systems and/or critical components. Problematic systems were then further analyzed using fault tree analysis to determine components negatively impacting operational availability, which could be great parts harvesting candidates. System sparing requirements were accomplished by developing a sparing model. The sparing model accounted for the probability of having a unique spare part at a given time, as well as the total number used in the fleet, the component failure rate, and operating time left in the system service life. Cost-effectiveness was addressed by building a linear program model that accounted for obtaining the sparing model requirement while minimizing cost as calculated based on the quantity of a part needed, the quantity of that part available for purchase or harvest, the expected repairable rate of harvested parts and cost of repair, the cost to harvest or purchase each, and the cost to store each.

Both the architecture and component development of the harvesting procedure was further facilitated by the functional decomposition. The functional decomposition was broken down until the individual process components were understood. Further, analyzing the system boundaries aided in the parts harvesting procedure constraints and assumptions identification, which further facilitated the architecture and component development.

The integration of the parts harvesting procedure was accomplished by analyzing the component interfaces, exhaustive research based on prior harvesting operations within the Surface Navy community, and understanding each functional process owners, dependencies, and behaviors. Verification was accomplished by analyzing the parts harvesting procedure to ensure all requirements would be fulfilled.

Conceptually, the parts harvesting procedure will be validated by meeting the stakeholder needs. However, validation will truly be realized by a review of the measures of effectiveness following the use of this process to conduct a parts harvesting operation. The measures of effectiveness (MOE) include usage over time, cost avoidance, and system operational availability. The most critical of these three MOEs is usage rate over time. If the harvested components are not used, then cost avoidance due to parts harvesting will not be possible, as costs would not be avoided. Additionally, system operational availability, and specifically, mean logistics down time, will not be influenced at all by parts harvesting operations if the reclaimed components are not used.

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I. INTRODUCTION

The purpose of this thesis is to analyze and recommend a cost-effective process to develop parts harvesting requirements for decommissioning MCM-1 class ships utilizing systems engineering principles. This process is critical to sustain the remaining in-service MCM-1 class ships.

A. RESEARCH QUESTIONS

MCM-1 class ships are nearing the end of their service life and require material from decommissioning assets to keep the remaining ships operational. However, the Navy currently lacks a documented procedure outlining the steps required to harvest parts off a decommissioning ship slated to be dismantled. Therefore, the following research questions are answered in this thesis.

- What is parts harvesting?
- Why is harvesting of material from MCM-1 class ships important?
- Does a cost effective means exist to determine what should be harvested off a decommissioning ship?
- What systems engineering applications or principles can be applied to effectively harvest parts from MCM-1 class ships to sustain the remaining in-service ships through expected service life?
- What are the constraints to an effective parts harvesting system/process?
- What are the measures of effectiveness?

B. BACKGROUND

To understand the importance of effectively harvesting parts from decommissioning MCM-1 class ships fully, it is first important to understand the history and mission of these ships. This background section covers mine warfare history, the mine warfare threat, and the importance of mine warfare. Further, this background information provides some of the building blocks to taking a systems engineering approach properly to developing an effective parts harvesting process.

1. Mine Warfare History

The naval mine dates back to the late 1500s with the Dutch floating explosives down the Scheldt River to destroy a bridge the Spanish Army had built to keep Amsterdam from access to the sea (Levie 1992). An Italian engineer, Frederico Gianbelli, who was working for the Dutch at the time, utilized boats filled with ammunition containing a triggering device to dispose of the Spaniards (Levie 1992). While this "floating petard" did not detonate under water, or depend on a vessel to be present, as is the case with most mines today, it can be considered the beginning of mine warfare (MIW) (Cowie 1949). The first successful mine was invented by David Bushnell during the American Revolution in 1776 (Cowie 1949). General George Washington commissioned Bushnell to develop a mine to counter the British Navy blockade of Philadelphia (Levie 1992). The mine was a wooden keg filled with gunpowder that could be floated down a river using floats and detonated upon contact (Levie 1992). Unfortunately, the mine did not damage the British frigate *Cerberus* as planned. However, the mine did detonate and sank a captured vessel the British were sailing alongside the *Cerberus* (Levie 1992).

Sea mines were also used often during the Civil War. In particular, the Confederate Navy utilized mines as the strategic sea-denial weapon of choice (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The Confederates also had a mine organization focused on research and development that even included a spy network to increase mine effectiveness (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). To counter the threat, the Union Navy developed mine countermeasures and tactics, albeit reluctantly at times (Melia 1991). The Union Navy's development of these countermeasures and tactics were almost all developed and improvised onboard each ship by the crew and captain (Melia 1991). Some of these countermeasure principles are still applicable today. By the end of the war, the Confederate mines had successfully sunk 48 Union ships and even 11 of their own (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009).

The first significant use of sea mines in deep or "blue" water occurred during the Russo-Japanese War of 1904–1905 (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The Russians mine warfare tactics were to lay mines in a defensive pattern (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The Japanese chose an offensive tactic and placed mines in deep water areas (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The mines utilized by both the Russians and Japanese resulted in the loss of three battleships, five cruisers, four destroyers, two torpedo boats, and one minelayer (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The Russians sank more ships through mine warfare than by any other means (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009).

Several mines were utilized during World Wars I and II (WWI; WWII). During WWI, "British and U.S. ships laid more than 73,000 mines" during the "North Sea Mine Barrage" (June–October 1918) (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 4). This campaign was successful in sinking 13 U-Boats and kept several in port until Armistice Day. During WWII, several different types of mines were also developed and used with ranging results throughout the encounter: advanced magnetic, acoustic, pressure influence, and electrical-potential/antenna-fired weapons (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009).

German U-boats were successful in laying over 300 mines in U.S. waters during WWII, ranging from Halifax, Nova Scotia, to the Mississippi Delta (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). This deployment of mines resulted in several port closures and even damaged 11 ships (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). However, WWII was probably the United States' most effective use of offensive mining. The U.S. Army (aircraft) and Navy were able to lay over "25,000 mines in Japanese shipping routes" and around the Japanese home island (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 4). This operation shutdown almost all commerce to the country and resulted in 760 Japanese ships being sunk (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The operation was appropriately named "Operation Starvation." Even after the war was over, and all fighting had ceased, a considerable amount of mine clearing was required in U.S. waters, predominantly carried out by the Japanese (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). In 1971, the U.S. Navy estimated that greater than "2,000 sensitive influence mines in the Pacific waters" remained (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 4).

The Korean conflict highlighted the U.S.' lack of ability to conduct mine countermeasure operations. The October 1950 assault on Wonson, Korea, was completely thwarted by 3,000 mines (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The United Nations had a 250-ship amphibious operation planned that could not take place due to the mines (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). The task force commander, Admiral Allen E. Smith stated:

> We have lost control of the seas to a nation without a navy, using pre-World War I weapons, laid by vessels that were utilized at the time of the birth of Christ. (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 4–5)

The Chief of Naval Operations, Admiral Forrest P. Sherman, also went on record stating:

> when you can't go where you want to, when you want to, you haven't got command of the sea. And command of the sea is a rock-bottom foundation for all our war plans. We've been plenty submarine-conscious and air-conscious. Now, we're going to start getting mine-conscious—beginning last week! (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 5)

Initial clearance operations were not successful and resulted in three countermeasure ships being sunk. By the end of the war in 1953, United Nations (UN) mine countermeasure forces experienced 20% of the Naval casualties (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009).

Vice Admiral C. Turner Joy, Commander, U.S. Naval Forces Far East, also stated the following regarding the importance of mine warfare:

> The main lesson of the Wonsan operation is that no so-called subsidiary branch of the naval service, such as mine warfare, should ever be neglected or relegated to a minor role in the future. Wonsan also taught us that we can be denied freedom of movement to an enemy objective through the intelligent use of mines by an alert foe. (Levie 1992, 142)

During the Vietnam War, the United States utilized both mining and mine countermeasures (Levie 1992). The Viet Cong used all available mines (both homemade and more sophisticated mines obtained from the Soviet Union) in the Saigon River (Levie 1992). Mining the Saigon River was the Viet Cong's plan to block transportation to Saigon, then the main port of entry for South Vietnam (Levie 1992). However, the Viet Cong's mining of the Saigon River was not very effective (Levie 1992). The United States used several mines during the Vietnam War. The Navy mined Haiphong harbor "with Destructor and magnetic-acoustic type mines" in an attempt "to bring the North Vietnamese to the Paris Peace Talks" (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 5). U.S. forces laid thousands of mines and succeeded in basically stopping all water-borne trade in North Vietnam (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009). This operation was so effective that a Danish naval mine expert stated the following:

> Although the deployment of mines brings weapons to bear on the adversary, it need not draw blood to be effective. The Vietnam operation proved this beyond doubt. The minefields off the Vietnamese ports were so effective that only some boats tried to pass them. And the North Vietnamese made no serious attempt to sweep or otherwise counter them, for they estimated the risk to be too high. (Levie 1992)

During the 1980s, Tanker War, the *USS Samuel B. Roberts* (FFG-58) was severely damaged by an Iranian mine it hit on April 14, 1987, as shown in Figure 1. The ship was trying to avoid three floating mines, and in the process, was struck by a submerged contact mine. While the mine was estimated to cost $1,500, the damage to the ship was approximately $96 million (Levie 1992; U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009).

Figure 1. *USS Samuel B. Roberts* Damage from Mine Hit

From U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate. 2009. *21st Century U.S. Navy Mine Warfare Ensuring Global Access and Commerce*. Washington, DC: Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate, 5.

In a letter to the Congress, President Reagan stated, “No doubt exists that Iran laid these mines for the specific purpose of damaging or sinking U.S. or other non-belligerent ships. We have warned Iran repeatedly against such hostile acts” (Levie 1992). During Operations Desert Shield/Storm (1990–1991), the Iraqis were laying sea mines in the Northern Arabian Gulf. The mines were a combination of WWII era and modern, multiple influence mines (Naval Surface Warfare Center Dahlgren Division Coastal Systems Station 1999). Two U.S. Navy ships experienced significant damage as a result. Both the *USS Princeton* (CG-59) and *USS Tripoli* (LPH-10) were struck by Iraqi mines in the Persian Gulf. The total damage to both ships was approximately $26 million in repairs plus collateral costs, such as the time and resources for the ship to travel back to the ship yard, cost to send a replacement ship to complete the mission, time lost on the mission, and injuries sustained by the crewmembers. By comparison, the total cost of the two mines that caused the damage was approximately $11,500. Shortly after the mine hits, U.S. Commanders were forced to change course and scrap plans for an amphibious assault designed to retake Kuwait City (Naval Surface Warfare Center Dahlgren Division Coastal Systems Station 1999; U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009).

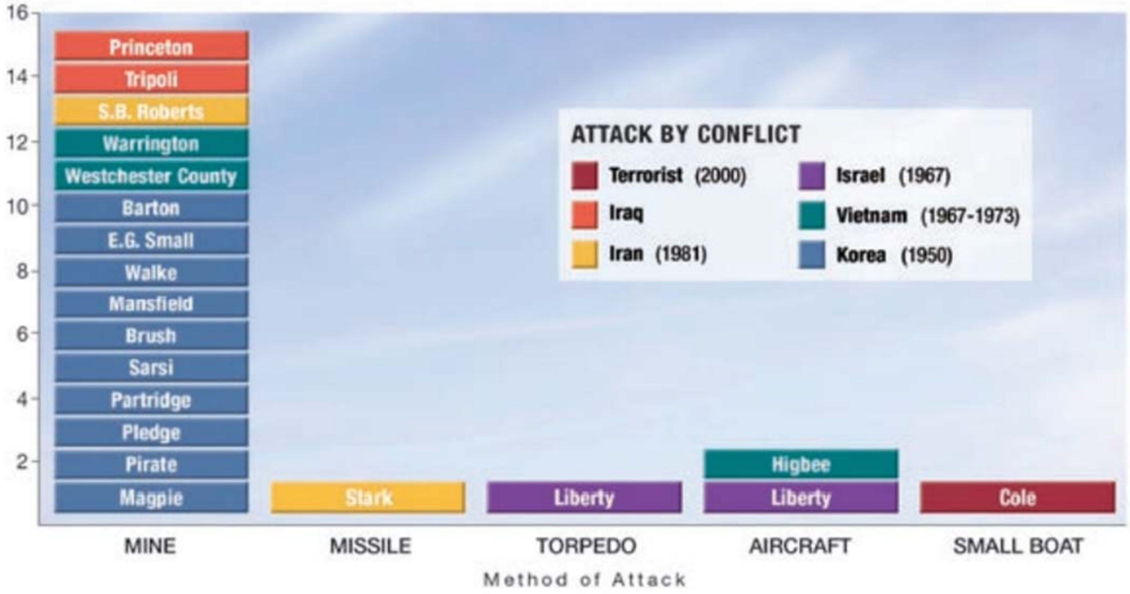
This synopsis of U.S. MIW history clearly shows not only the enemy intentions to conduct MIW, but that MIW can be quite effective when U.S. forces are not adequately prepared to deter the threat. MIW has prevented the U.S. dominance of waterways on various occasions and appears it will be one of the first weapons of choice in future encounters with the United States or its allies. The ongoing challenge with respect to the naval mines is whether the United States and its allies will be prepared to counter the MIW tactics used by enemy forces, be it another nation, peer competitor, or rogue state in the future.

2. Mine Warfare Threat

The naval mine is a relatively inexpensive weapon that can simply wait for its victim to cross its path. This weapon can cripple and even destroy a Navy vessel, if not properly countered or disabled. The naval mine can have significant psychological effects as well. Simply the threat of a mine in a given body of water can restrict vessel movements. This weapon is unique in that it does not have to detonate to be an effective deterrent, and to fulfill its reason for existence. The naval mine is an extremely effective weapon to neutralize the execution of various missions on a given body of water for both sides of a conflict (Rios 2005).

Even with the present technologically advanced U.S. Navy fleet, MIW technologies have remained a very viable threat. Despite various advances in reducing ship acoustic or magnetic signatures, the navy mine technology continues to adapt as well (Rios 2005). To that end, approximately 250,000 “sea mines of more than 300 types are in the inventories" of the various navies around the world (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 7). To make matters even more challenging, these figures do not include improvised explosive devices (IEDs) that can be made from 55-gallon drums or a household appliance. Since the end of WWII, mines have damaged or sunk three times more U.S. Navy ships than all other means combined, as outlined in Figure 2 (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009).

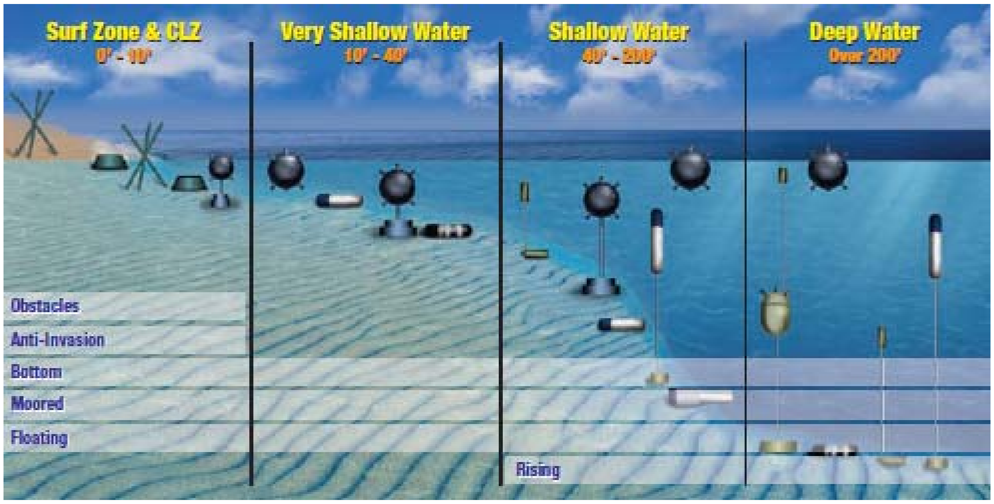
Figure 2. U.S. Navy Mine Casualties Since the End of WWII



From U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate. 2009. 21st Century U.S. Navy Mine Warfare Ensuring Global Access and Commerce. Washington, DC: Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate.

Mines or IEDs can operate within four water depth regions, as depicted in Figure 3: surf zone & CLZ (0–10″ of water), very shallow water (10″–40″ of water), shallow water (40″–200″ of water), and deep water (over 200″ of water).

Figure 3. Mine Warfare Regions



From U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate. 2009. *21st Century U.S. Navy Mine Warfare Ensuring Global Access and Commerce*. Washington, DC: Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate, 9.

While mines or IEDs can be made in several different configurations and operate in the above water depths, mines are comprised of four main types: bottom mines, moored and buoyant mines, limpet mines, and drifting mines.

a. Bottom Mines

Bottom or "ground" mines are negatively buoyant and rest on the ocean floor. They are held down by their own weight and may sink into bottom sediment at times, further complicating mine-hunting operations. These mines range in size from 36-inch cone shaped contraptions to weapons that are 12 feet long as seen in Figure 4. The bottom mines are most effective against surface ships in shallow waters. However, the bottom mines are also effective against submarines in deep water (Naval Surface Warfare Center Dahlgren Division Coastal Systems Station 1999; Truver 2012).

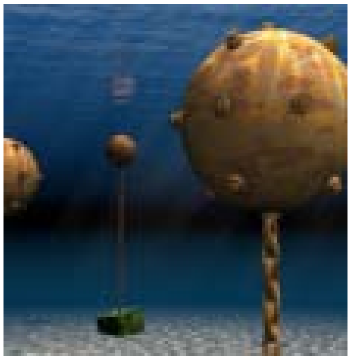
Figure 4. A Chen-Series Bottom Mine Aboard a Chinese Surface Warship

From Erickson, Andrew, Lyle Goldstein, and William Murray. 2007. "China's Undersea Sentries." *Undersea Warfare the Official Magazine of the U.S. Submarine Force*, 9(2) Winter.

b. Buoyant Moored Mines

Moored mines are in a positively buoyant casing, and maintain a constant vertical distance from the sea floor via a cable and anchor as per Figure 5. Since the casing for the mine must be filled with air to create the positive buoyancy, not as much room is available for explosives, as compared to a bottom mine. However, moored mines can be outfitted with influence sensors or rockets/torpedoes that increase their lethality (Naval Surface Warfare Center Dahlgren Division Coastal Systems Station 1999; Truver 2012).

Figure 5. An Illustration of a Buoyant Moored Mine Anchored to the Seafloor

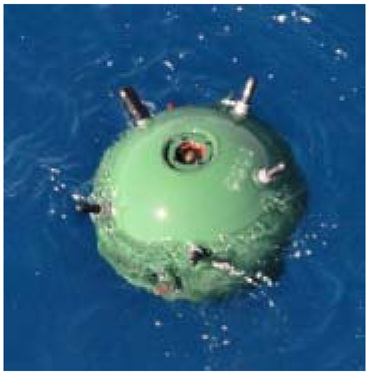


From Exelis Inc. 2013. *Sea Mine Fact Sheet*. McLean, VA: Exelis Inc.

c. *Drifting Mines*

Drifting or "floating" mines shown in Figure 6 are also positively buoyant and float at or near the water surface. If the drifting mine is not anchored, or has broken loose from its anchor, it literally just floats along with the current and is completely indiscriminate as to target that can cause any passing vessel's demise. The Hague Convention of 1907 outlawed the practice of using drifting mines; however, they are still used in conflicts today (Naval Surface Warfare Center Dahlgren Division Coastal Systems Station 1999; Truver 2012). The U.S. Navy has removed all drifting mines from its arsenal (Naval Surface Warfare Center Dahlgren Division Coastal Systems Station 1999; Truver 2012).

Figure 6. Drifting Mine



From Exelis Inc. 2013. *Sea Mine Fact Sheet*. McLean, VA: Exelis Inc.

d. Limpet Mines

Limpet mines are attached directly to the hull of a ship by divers and are set to explode after being put in place. An example is shown in Figure 7. This mine type may be outfitted with an anti-handling device that will detonate the weapon if removed from the hull of the ship.

Figure 7. Limpet Mine MK1

From Australian War Memorial. 2014. “Limpet Mine MK 1.” Australian War Memorial. Accessed August 13. http://www.awm.gov.au/collection/REL/19386.001.

The various mine types can be fired in three main ways. The firing initiation methods are “contact, sensing the signatures or “influences” of a ship or submarine,” and detonation on command (Truver 2012, 35).

Contact fired mines can be of the moored or drifting mine types. As the name suggestions, the mine is detonated when coming into contact with a target. Most of the contact mines have “a chemical horn that” acts as a battery once it is broken (Truver

2012, 35). This action triggers the detonation. Contact mines are the oldest style mines still in existence today.

Influence fired mines can be utilized on the bottom or moored mine types. These mines utilize sensors to trigger detonation. The sensors can range from magnetic, acoustic, seismic, underwater electrical potential, and pressure sensors. One of the sensors, or a combination of several sensors, can be utilized to sense a ship or submarine approaching and detonate on command. The detonation is typically accomplished via a microcomputer that interfaces with the sensors on the mine.

Command-detonated mines can be either bottom or moored mine types. These weapons are fired once the target enters the minefield. They are usually utilized for harbor or restricted sea-lanes (Truver 2012).

3. Mine Warfare Importance

Today, MIW is still very much a threat that the United States must address. To have successful efficient and secure transit of goods in today's global economy, waterways must remain open and free from criminal and terrorist networks with mine laying capabilities. The number one goal of the National Strategy for Global Supply Chain Security is to promote the efficient and secure movement of goods (Office of the President of the United States 2012).

As outlined in the MIW history section earlier, the United States has been unable to conduct amphibious operations due to mining by the enemy, and various ships were severely damaged during a few conflicts. Due to these challenges, it very important for the Navy to take "consistent, aggressive and focused action to ensure that it is prepared for all future mine events" (U.S. Navy, Program Executive Office Littoral and Mine Warfare Expeditionary Warfare Directorate 2009, 1).

To keep the waterways open, the United States must work with allies to identify any mine-laying activities as soon as possible. Using intelligence to prevent the enemy from ever laying mines is the best MIW strategy. However, it is not always feasible. For this reason, the MCM-1 Avenger class mine countermeasure ships were built and put in service as depicted in Figure 8.

Figure 8. *USS Avenger* (MCM-1) Neutralizing a Mine

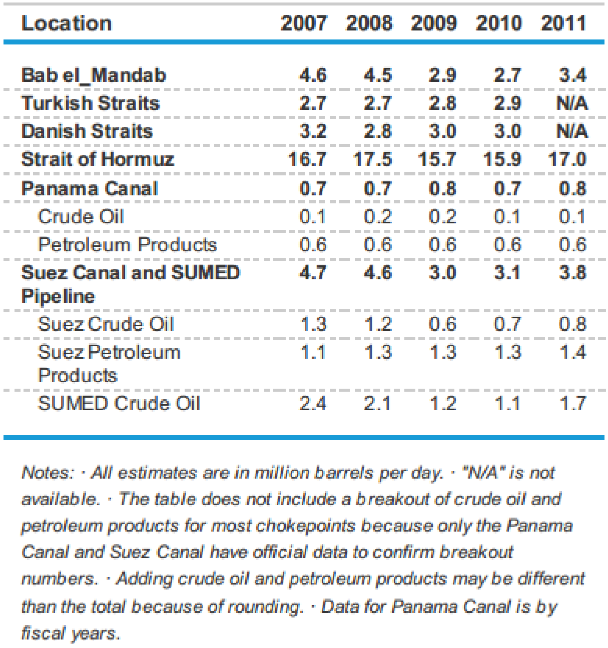
From Commander Naval Surface Force, U.S. Pacific Fleet. 2014a. "Mine Countermeasures Ships (MCM)." Accessed April 26. http://www.public.navy.mil/surfor/pages/MineCountermeasuresShips.aspx#.U1vH7-ZdX-I.

These ships are designed to hunt, detect, and neutralize mines. Enemies can develop mines for as little as $1,000 (Gough 2013, 1). Sea mines can be used to damage or sink ships that cost upward of several billion dollars. Mines also can be used to deter shipping from entering or leaving a specific body of water, usually as a military tactic. While mines can certainly cause significant material damage to vessels, deny traffic through a sea lane, or even result in the loss of lives, an economic effect also results (Chatham House The Royal Institute of International Affairs 2014, 3). The economic impact of laying mines in any of today's choke points (e.g., Strait of Hormuz, Strait of Malacca, Suez Canal, and Panama Canal) would be very significant. The seven straits highlighted in Figure 9 are major trade routes for global oil commerce, as defined by the U.S. Energy Information Administration. Figure 10 outlines the volume of petroleum products transiting the waterways each day. Not only would a reduction or complete stop of vessel traffic in a single strait cause oil and other goods prices to jump, the alternate routes would be significantly longer for commercial ships to travel.

Figure 9. Seven Straits that Serve as Major Trade Routes for Global Oil Distribution

From U.S. Energy Information Administration. 2012. *World Oil Transit Chokepoints.* Washington, DC: U.S. Energy Information Administration.

Figure 10. Volume of Crude Oil and Petroleum Products Transported through World Chokepoints, 2007–2011



Location	2007	2008	2009	2010	2011
Bab el_Mandab	**4.6**	**4.5**	**2.9**	**2.7**	**3.4**
Turkish Straits	**2.7**	**2.7**	**2.8**	**2.9**	**N/A**
Danish Straits	**3.2**	**2.8**	**3.0**	**3.0**	**N/A**
Strait of Hormuz	**16.7**	**17.5**	**15.7**	**15.9**	**17.0**
Panama Canal	**0.7**	**0.7**	**0.8**	**0.7**	**0.8**
Crude Oil	0.1	0.2	0.2	0.1	0.1
Petroleum Products	0.6	0.6	0.6	0.6	0.6
Suez Canal and SUMED Pipeline	**4.7**	**4.6**	**3.0**	**3.1**	**3.8**
Suez Crude Oil	1.3	1.2	0.6	0.7	0.8
Suez Petroleum Products	1.1	1.3	1.3	1.3	1.4
SUMED Crude Oil	2.4	2.1	1.2	1.1	1.7

Notes: · All estimates are in million barrels per day. · "N/A" is not available. · The table does not include a breakout of crude oil and petroleum products for most chokepoints because only the Panama Canal and Suez Canal have official data to confirm breakout numbers. · Adding crude oil and petroleum products may be different than the total because of rounding. · Data for Panama Canal is by fiscal years.

From U.S. Energy Information Administration. 2012. *World Oil Transit Chokepoints.* Washington, DC: U.S. Energy Information Administration.

For example, approximately $1.7 billion (assuming $100/barrel) of oil flows through the Strait of Hormuz per day. If just 10% of the normal vessel movement through the strait was disrupted due to mines, an almost instantaneous 75%+ rise in the price of oil would result (Office of Naval Intelligence 2010). Obviously, this situation would have negative global implications. The blockage of a chokepoint will not only drive up oil and energy costs, but significantly risk leaving commercial tankers open to piracy, terrorist attacks, and political unrest that can lead to war. All these factors can contribute to possible oil spills that have follow-on political, economic, and environmental impacts. To say the least, the United States' ability to conduct MIW operations, particularly mine countermeasures via the 11 remaining surface MCM ships, is essential for economic stability, keeping the sea-lanes open for commerce, and naval dominance during conflicts or peacetime projection of power.

C. BENEFITS OF STUDY

The benefit of applying systems engineering practices for harvesting material from MCM-1 class ships as they decommission is that the class can be sustained at a more reasonable cost while meeting operational requirements. Neither will be possible without a process in place to make efficient use of reclaimed material. Further, harvesting operations resource sponsors will clearly understand that a systematic approach was used to give them the confidence that the resources they apply will have a significant return on investment, both financially and operationally.

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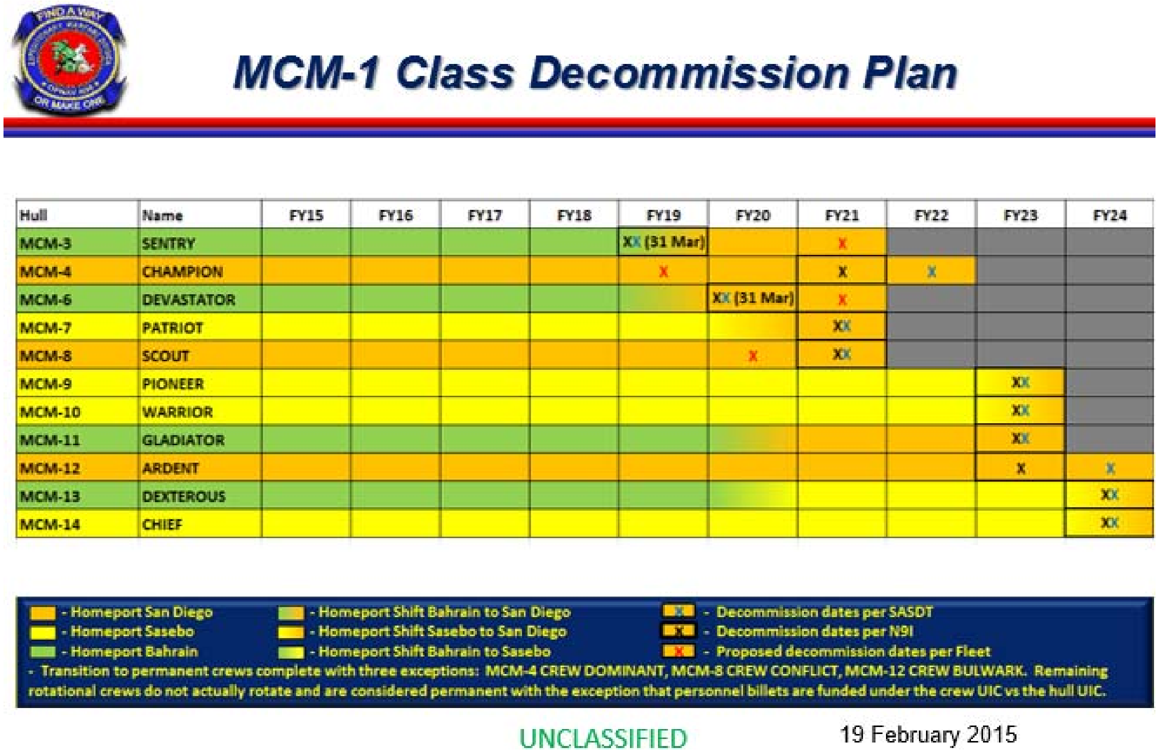
II. RESEARCH: MINE WARFARE CAPACITY—TODAY AND TOMORROW

The MCM-1 class ships are slated to be replaced eventually by the LCS MIW MP. This replacement is significant to understand, as resource sponsors in OPNAV N95 must pay for both in-service MCM-1 class ships' sustainment to fulfill today's mine countermeasure requirements, as well as funding the development and construction of tomorrow's platforms. While funding levels remain a continuous challenge, being able to sustain the MCM-1 class ships in the most economic manner possible is vital to both in-service and new construction spend plans. This concept is critical to remember throughout this thesis when analyzing the need for a cost-effective parts harvesting process for MCM-1 class ships.

A. MCM-1 CLASS SHIPS' EXPECTED SERVICE LIFE

Each year, the Department of the Navy provides Congress with an annual long-range plan for the new construction of Navy ships as per title 10, U.S.C., section 231 as amended requirements. As per a letter dated July 1, 2014, from the Deputy Secretary of Defense, Robert Work, to the Honorable Carl Levin, Chairman, Committee on Armed Services for the U.S. Senate, this plan "outlines the naval force structure requirements that are consistent with the strategic priorities and guidance contained in *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense*; the construction plan necessary to meet these requirements; and the fiscal resources necessary to implement the plan." The plan provides insight into how long the MCMs must be operational until decommissioning and a proposed schedule for the replacement platform, which is the littoral combat ship (LCS) containing the MIW mission module. Three of the MCM-1 class ships (Avenger, Defender, and Guardian) have already been decommissioned and scrapped. The remaining MCMs will need to be operational until decommissioning of each ship is complete, which is currently scheduled for 2024 as per Figure 11.

Figure 11. MCM-1 Class Decommission Plan



MCM-1 Class Decommission Plan

Hull	Name	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24
MCM-3	SENTRY					XX (31 Mar)		X			
MCM-4	CHAMPION					X		X	X		
MCM-6	DEVASTATOR						XX (31 Mar)	X			
MCM-7	PATRIOT							XX			
MCM-8	SCOUT						X	XX			
MCM-9	PIONEER									XX	
MCM-10	WARRIOR									XX	
MCM-11	GLADIATOR									XX	
MCM-12	ARDENT									X	X
MCM-13	DEXTEROUS										XX
MCM-14	CHIEF										XX

🟧 - Homeport San Diego
🟨 - Homeport Sasebo
🟩 - Homeport Bahrain
▨ - Homeport Shift Bahrain to San Diego
▨ - Homeport Shift Sasebo to San Diego
▨ - Homeport Shift Bahrain to Sasebo
X - Decommission dates per SASDT
X - Decommission dates per N9I
X - Proposed decommission dates per Fleet
- Transition to permanent crews complete with three exceptions: MCM-4 CREW DOMINANT, MCM-8 CREW CONFLICT, MCM-12 CREW BULWARK. Remaining rotational crews do not actually rotate and are considered permanent with the exception that personnel billets are funded under the crew UIC vs the hull UIC.

UNCLASSIFIED 19 February 2015

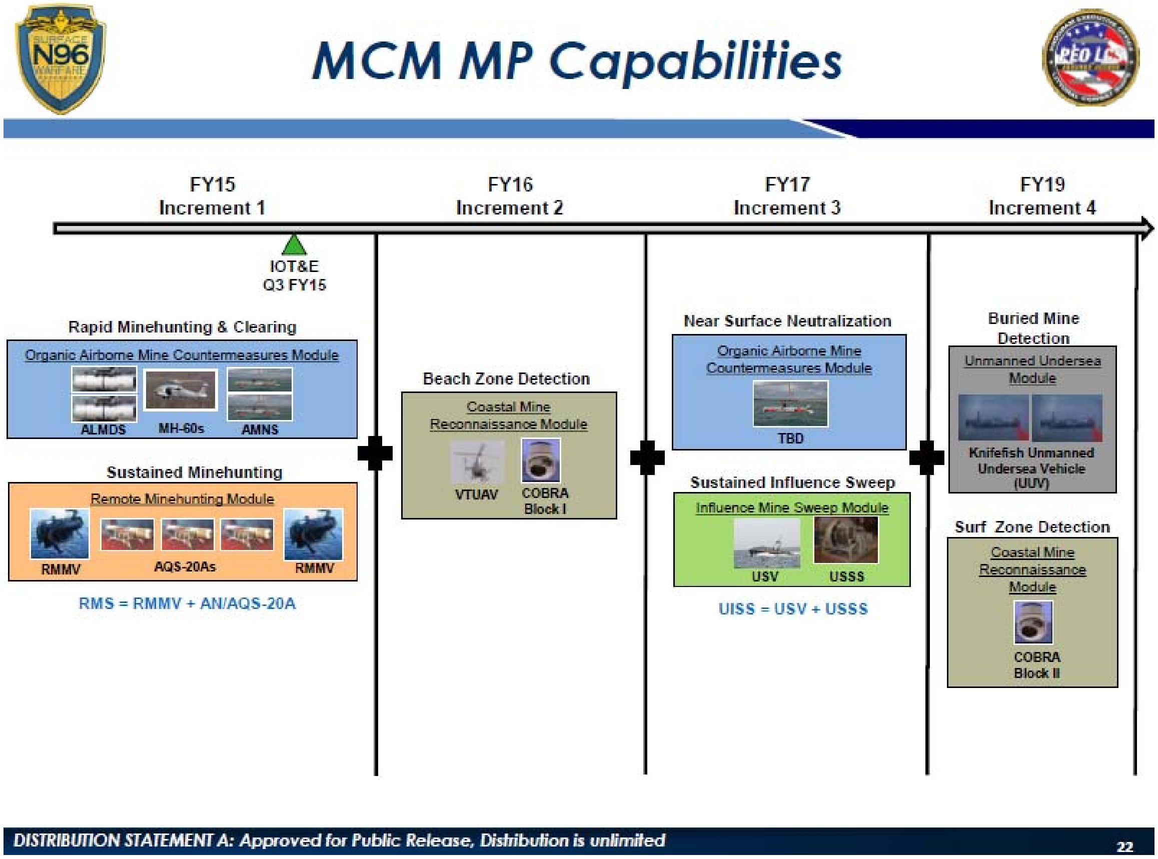
From Office of the Chief of Naval Operations (N95). 2015. *MCM-1 Class Decommission Plan*. Washington, DC: Office of the Chief of Naval Operations.

As of July 22, 2015, the next MCMs to be decommissioned will be the *USS Sentry* (MCM-3) in FY2019, followed by *USS Devastator* (MCM-6) in FY2020. However, fleet has proposed replacing the *USS Sentry* (MCM-3) with the *USS Champion* (MCM-4) in FY19 and the *USS Devastator* (MCM-6) with the *USS Scout* (MCM-8) in FY20. These decommissionings are awaiting leadership final adjudication. Regardless of the ship name, one MCM in FY19 and FY20 will be decommissioned and both ships are already slated to be dismantled following decommissioning (Office of the Chief of Naval Operations Deputy Chief of Naval Operations (Integration of Capabilities and Resources) (N8) 2015, 15).

B. READINESS KILL CHAIN/SURFACE MASTER PLAN/CLASS EXECUTION PLANS AND MINE WARFARE TRANSITION FROM MINE COUNTERMEASURE TO LITTORAL COMBAT SHIP MINE WARFARE MISSION PACKAGE

While the current plan is to decommission the last MCM in 2024, a bit of a wild card remains in that the LCS MIW mission package most likely needs to be fully operational on the LCS platform to replace the current capabilities of the MCM-1 class ships. A fully functional LCS platform, coupled with the MIW MP capabilities, is needed to enable the MCM-1 class ships to decommission as planned. The LCS MIW MP is utilizing an evolutionary development acquisition strategy as depicted in Figure 12.

Figure 12. MCM Mission Package Capabilities Plan



MCM MP Capabilities

FY15
Increment 1

FY16
Increment 2

FY17
Increment 3

FY19
Increment 4

IOT&E
Q3 FY15

Rapid Minehunting & Clearing
Organic Airborne Mine Countermeasures Module
ALMDS MH-60s AMNS

Sustained Minehunting
Remote Minehunting Module
RMMV AQS-20As RMMV

RMS = RMMV + AN/AQS-20A

Beach Zone Detection
Coastal Mine Reconnaissance Module
VTUAV COBRA Block I

Near Surface Neutralization
Organic Airborne Mine Countermeasures Module
TBD

Sustained Influence Sweep
Influence Mine Sweep Module
USV USSS

UISS = USV + USSS

Buried Mine Detection
Unmanned Undersea Module
Knifefish Unmanned Undersea Vehicle (UUV)

Surf Zone Detection
Coastal Mine Reconnaissance Module
COBRA Block II

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From Siel, Carl, Dave Welch, Tom Anderson, John Ailes, and Dan Brintzinghoffer. 2014. *LCS Update*. Washington, DC: U.S. Navy, 22.

In the event any of the LCS MIW MP increments' planning timelines are changed, it could potentially alter the MCM decommissioning dates. The next planned MCM decommissioning will be in FY2019; therefore, any MCM sustainment plans, including parts harvesting projects, will also have to take the LCS MIW MP status into account as well. The surface Navy is tracking this situation closely via the Surface Warfare Enterprise (SWE), which acts as a single voice for all non-nuclear surface ships.

In 2012, Commander, U.S. Pacific Fleet (CPF) and Commander, U.S. Fleet Forces (CUSFF) instituted the Personnel, Equipment, Supply, Training, Ordnance, Infrastructure, and Networks (PESTOIN) Pillar-based Readiness Kill Chain (RKC) approach to identify fleet readiness shortfalls and prioritize resources to address deficiencies. Also in 2012, the Surface Board endorsed the creation of class execution plans (CEP) and a surface master plan (SMP) to consolidate and integrate surface ship class and force planning. As a result of those decisions, an integrated assessment of wholeness by class and by pillar and an integrated recommended action list for SWE stakeholders now exist (Commander Naval Surface Force U.S. Pacific Fleet 2014b, 1).

The SWE charter also outlines the SWE objectives. Objective number two clearly deals with the MCM to LCS MIW MP transition. "Use the CEPs and the SMP to consolidate ship class and Force planning across the PESTOIN pillars to synchronize efforts, maintain the relevance and capability of the Force throughout its expected service life and facilitate a repeatable and transparent framework for implementing decisions" (Commander Naval Surface Force U.S. Pacific Fleet 2014b, 2).

The most current SMP outlines that "uncertainty in timing for the LCS mine countermeasures mission modules" exists (Surface Warfare Enterprise 2014, 58). The mission modules progress, or lack thereof, must be closely tracked utilizing the SMP and CEPs for both LCS and MCM class ships to ensure the appropriate harvesting operations can be planned accordingly. If the LCS MIW MP fielding plan starts slipping, this slippage could lead to a need for increasing MCM service life, which would affect any parts harvesting plans based on the currently planned 2024 MCM ESL.

C. CURRENT FUNDING ENVIRONMENT (CONSTRAINTS) AND IMPACTS TO MIW

While the previous section discusses LCS MIW MP fielding plan impacts due to technical challenges that could prevent meeting fielding plan goals, funding impacts can also impact current LCS MP fielding plans. In the event that funding constraints start to influence LCS MCM mission package delivery, funding constraints also could impact the MCM-1 class ships by forcing the Navy to extend some portion of the ships' expected service life. This risk is clearly feasible as depicted in an *Inside the Navy* article:

> Significant cuts to the Navy's Littoral Combat Ship's mission modules program, included in Congress" recent $1.1 trillion fiscal year 2015 omnibus spending bill, will increase life-cycle costs and result in further schedule delays to testing and fielding of the mission packages, according to information from a recent report to Congress.
>
> The appropriations bill significantly reduced procurement and research, development, test and evaluation (RDT&E) funding for the LCS mission modules. Appropriators zeroed out procurement funding for the LCS remote minehunting system (RMS), an integral component of the mine countermeasures (MCM) mission package, and anti-submarine warfare (ASW) mission modules.
>
> Further, the bill reduced RDT&E funds for the LCS mission packages from $196.9 million to $176.9 million due to "program execution," according to a report accompanying the appropriations bill.
>
> Reductions in mission funds "has an impact on the whole mission set that the Navy has to perform and the request from the combatant commands around the globe," Rep. Rob Wittman (R-VA), chairman of the House Armed Services readiness subcommittee, told Inside the Navy in a Dec. 17 interview.
>
> Appropriators likely decided to cut funds for the LCS mission modules in order to send a message to the Navy that they are frustrated with delays, cost increases and setbacks in the program, Wittman said. (Seligman 2014, 1–3)

The article further states:

> Cuts to LCS mission modules will also impact the Navy's ability to move forward with the RMS development. The program has in recent years faced criticism for both ballooning costs and repeated schedule delays.
>
> An operational assessment of the newest version of the Remote Multi-Mission Vehicle (RMMV) was delayed by six months earlier this year, resulting in a modest cost impact to the program, ITN reported in June.

> The assessment was initially slated to start in mid-January and run through the end of the February, but was pushed to July and August. The 6.0 configuration is an upgrade from the older 4.2 variant.
>
> Meanwhile, InsideDefense.com reported in August that the Navy deferred key actions on the RMS until the third quarter of FY-15, following the delay of a crucial Office of the Secretary of Defense review that was scheduled for May. That meeting, a Defense Acquisition Board milestone C review, is needed to validate four years of remedial engineering work and win back approval for low-rate production, which was rescinded in 2010 in a bid to halt ballooning cost growth.
>
> Last December, the Navy completed a reliability growth program called for by the Pentagon's acquisition executive in 2010 following a determination that "poor" management by the Navy of the RMS program was a major factor in cost growth of as much as 80 percent.
>
> Appropriators" decision to zero out the FY-15 funding line for the RMS program will likely impede the Navy's plans to award a low-rate initial production contract for a new-start RMMV program. The Navy in August issued a request for proposals for the project. (Seligman 2014, 1–3)

The article not only discusses RMS challenges, but also summarizes the sixth quarterly report to Congress for the LCS mission modules program that states that any reductions in FY15 funding would negatively impact the schedule and life cycle of the mission modules:

> reduced RDT&E funds for the LCS mission packages could delay the development, integration and testing of the unmanned influence sweep system–part of the MCM mission package–the surface-to-surface missile module–part of the SUW mission package–and/or the ASW mission package. Cuts could also delay opposite hull initial operational test and evaluation (IOT&E) mission packages, the report stated. (Seligman 2014, 1–3)

The aforementioned technical, funding and political challenges to the LCS MIW mission package only increase the uncertainty that the MCM-1 class will in fact be able to decommission as planned. This uncertainty further increases the importance of effectively and efficiently harvesting parts off MCM-1 class ships as they decommission to ensure appropriate spares are available to provide the Navy with the maximum flexibility to bridge the gap between legacy MCM-1 ship capabilities to the new LCS MIW MP.

III. PROBLEM DEFINITION

Systems engineering provides a framework and strategy to solve problems. To support this claim, step one is to define accurately and understand the problem that must be solved. This chapter defines the problem, provides amplifying analysis as to why the problem exists, and explains the importance of solving the problem.

A. STATEMENT OF PROBLEM

Currently, no documented procedure exists that outlines how to harvest parts effectively off decommissioning MCM-1 class ships, and therefore, realistic or cost-effective means are not available to provide required repair parts to sustain the MCM-1 class ships' mine-hunting capability. As discussed in the introduction, a degradation, not to mention elimination, of the mine-hunting capability can have disastrous effects on global trade and economies, the Navy's ability to perform its missions, and even loss of life. Decommissioning ships contain components critical to ensuring the remaining in-service ships have sufficient repair parts to meet today's mission and reach their expected service life. Often, these parts may be expensive to procure, difficult or impossible to find on the market, or have an extremely long lead time for procurement. It may make sense to harvest these parts instead. Conversely, parts on the decommissioning ships may be expensive to harvest and repair or store on the shelf when they could be procured when needed or have a very low likelihood and consequence of failure. In this case, it would not make sense to harvest them. A need exists to understand further what parts harvesting is, the associated steps, and a process for determining if it is best to harvest a given part, procure the part, or neither.

B. WHAT IS PARTS HARVESTING?

Parts harvesting or reclamation involves removing material from a decommissioning asset (in this case, the Mine Countermeasure Avenger class surface ship) for re-use on in-service platforms prior to dismantling or scrapping operations. Removal of the installed equipment can be utilized to sustain operational assets and facilitates required material readiness that enables the MCM-1 class ships capable of meeting all high-level functionality requirements. Depending on the scenario and risks, several instances of the harvesting of parts from a decommissioning asset can be a cost effective strategy to maintain in-service vessels to enable them to meet expected service life (ESL). Various considerations should be reviewed to determine whether a component should be harvested. Some include the number of in-service vessels that could utilize the harvested components, component mission criticality, number available in the Navy supply system, Navy supply system lead time of the component, and obsolescence.

The challenge is to weigh the costs of equipment removal, refurbishment, warehousing, and shipping (components of parts harvesting) against scrapping and disposal of the same equipment. These tradeoffs are discussed further in the process and addressed in models provided in Appendix B.

C. FUNCTIONAL DECOMPOSITION

One of the most fundamental tools in systems engineering is to understand the functional requirements when trying to solve a problem. To that end, Figure 13 is a functional decomposition for the parts harvesting process.

Figure 13. Parts Harvesting Functional Decomposition

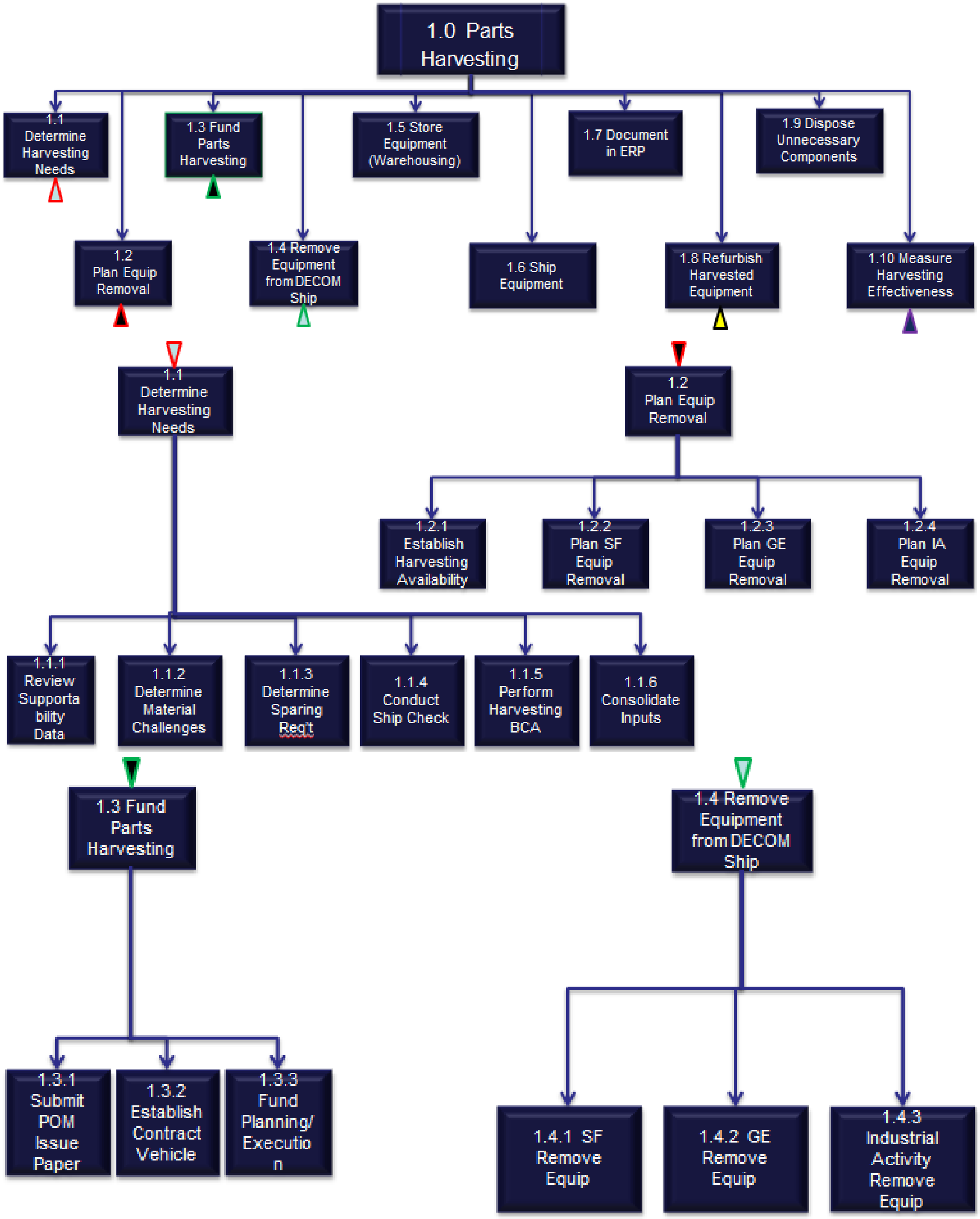
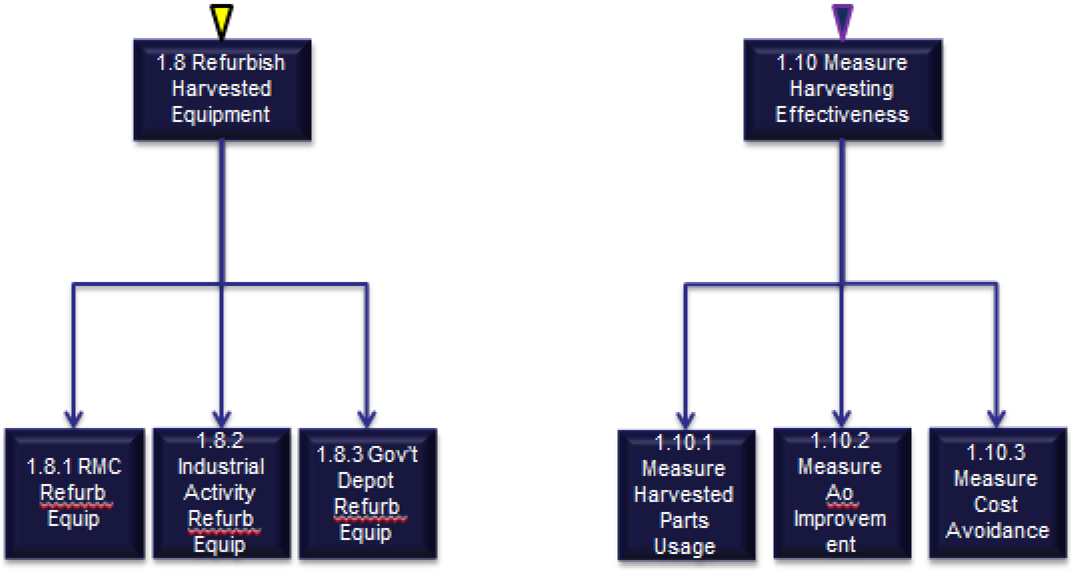


Figure 13 (cont'd). Parts Harvesting Functional Decomposition



The high-level functions to harvest parts off a surface ship are "determine harvesting needs," "plan equipment removal," "fund parts harvesting," "remove equipment from decommissioning ship," "store equipment (warehousing)," "ship equipment," "document in Navy enterprise resource planning (ERP)," "refurbish harvested material," "dispose of unnecessary components," and "measure harvesting effectiveness." While each of these functions is explained in further detail in Chapter IX, a brief overview follows.

The "determine harvesting needs" top-level function is the means to document and plan on the components to be harvested from a ship to be dismantled. Six sub-functions "determine harvesting needs." The first sub-function is "review supportability data," which entails a review of metrics, such as casualty reports (CASREPs), mean time between failure (MTBF), mean logistics downtime (MLDT), and obsolescence. The second sub-function is to "determine material challenges" to determine critical systems and/or components that currently or will in the future fail to meet operational availability (Ao) requirements. The third sub-function is to "determine sparing requirement," which is a review of critical systems and required sparing to meet requirements. The fourth sub-function is to "conduct ship check." This function entails various subject matter experts (SMEs) visiting the ship to be dismantled to assess the condition of the equipment that ideally would be harvested. The fifth sub-function is to “perform harvesting business case analysis (BCA)” to ensure the lowest cost means to support the ship systems, with respect to parts harvesting, is utilized. The sixth sub-function is to “consolidate inputs,” which integrates each stakeholder input into a single list.

The “plan equipment removal” top-level function outlines the strategy that each entity will implement to remove components during harvesting operations. Four sub-functions comprise “plan equipment removal.” The first sub-function is to “establish harvesting availability, which provides a period in time set aside specifically to accommodate parts harvesting operations. The second sub-function is to “plan ships force (SF) equipment removal.” This function outlines the strategy that SF will use to remove smaller components from the decommissioning ship. The third sub-function is to “plan government entity (GE) equipment removal.” This function outlines the strategy that the regional maintenance centers (RMCs) or in service engineering agent (ISEA) will use to harvest components. The fourth sub-function is “plan industrial activity (IA) equipment removal.” This function outlines the development of the work specification utilized by the contractor that will harvest critical components.

The “fund parts harvesting” top-level function is the means to compensate for both planning and execution of parts harvesting operations. Three sub-functions comprise “fund parts harvesting.” The first sub-function is to “submit a program objective memorandum (POM) issue paper” to ensure adequate funds are in place to harvest parts off a ship during the window of opportunity just prior to the ship being dismantled. The second sub-function is to establish the contract vehicle utilized to fund the appropriate contractors to accomplish the harvesting operations. The third sub-function is to “fund planning and execution” of the harvesting operations. This function ensures that both the planners and the executing activities are paid for services rendered.

The “remove equipment from decommissioning (DECOM) ship” top-level function is the process of actually physically removing components from the vessel. The “remove equipment from DECOM ship” function contains three sub-functions. The first sub-function is “SF remove equipment,” which consists of Navy Sailors physically removing equipment from the ship. The second sub-function is “GE remove equipment,” which is government personnel removing equipment from a ship. The third sub-function is “industrial activity remove equipment.” This function involves government contractors removing equipment from a ship.

The “store equipment (warehousing)” top-level function includes storing the harvested equipment immediately after removal from the ship, at a location awaiting repair (if applicable), and after equipment is restored (if applicable).

The “ship equipment” top-level function consists of all packaging and shipping harvested components to the appropriate destination.

The “document in Navy ERP system” top-level function is the process of ensuring harvested material is documented back into the Navy’s material system of record to ensure all entities can have visibility of available parts and condition. This process includes documenting both ready for issue (RFI) and non-RFI material.

The “refurbish harvested equipment” top-level function encompasses the assessment and repair of equipment reclaimed from a DECOM ship. The “refurbish harvested equipment” function comprises three sub-functions. The first sub-function is “RMC refurbish equipment,” which entails the local U.S. Navy lead maintenance center shops to assess/repair harvested components. The second sub-function is “industrial activity refurbish equipment,” which necessitates that government contractors restore reclaimed material from a ship. The third sub-function is “government depot refurbish equipment,” at which government run facilities make required repairs to harvested equipment.

The “dispose of unnecessary components” top-level function is the discarding of no longer needed components. This disposal can be due to a harvested component found to be beyond economical repair after assessment, an excess component required due to a higher percentage of assets harvested found to be able to be repaired than originally expected, or a component damaged during shipment to the point of rendering it useless.

The final top-level function is to “measure harvesting effectiveness.” This function comprises three sub-functions. The first sub-function is “measure harvested parts usage,” which covers calculating which harvested parts have been put back into use to meet a fleet need. The second sub-function is “measure Ao improvement.” This function determines if the parts harvested had any influence on system Ao. The third sub-function is “measure cost avoidance,” which determines the amount of cost savings (if any) for parts harvesting.

D. MCM-1 CLASS MATERIAL CHALLENGES

MCM-1 Avenger class ships are designed to operate within both a mine danger area (MDA) and mine danger environment (MDE). Therefore, the ships must be “magnetically silent” to prevent being destroyed or severely damaged while conducting MIW operations due to magnetic influence and combined influence mines. For that reason, these ships’ hulls and structures are actually made of wood. The installed machinery utilizes components, to the greatest extent possible, that have a very low (less than 2.0) permeability (United States Navy Sea Systems Command 2003). This requirement means several of the onboard machinery components are non-magnetic. Getting repair parts from industry for the non-magnetic components is very difficult. In several cases, the production line was shut down several years ago, as the commercial companies were not seeing sufficient business to stock or even create the parts. Even within the U.S. Navy, only 11 remaining MCM-1 class ships use these components. An example of such a part is the lube oil (LO) purifier. Most U.S. Navy surface ships have a LO purifier onboard. However, only the MCM-1 class ships utilize a non-magnetic purifier bowl (just recently, the MCM class ships started replacing the LO purifier with a LO polisher). All the other ship classes help provide sufficient parts demand to the supply system that keeps industry incentivized to stock or make required LO purifier repair parts. The MCM-1 class parts demand for similar equipment is minimal in comparison. In some instances, even the reverse engineering of critical components has been required to keep an MCM operational. Reverse engineering of components is very time consuming and expensive in most cases. These challenges make it very difficult to maintain the MCM-1 class machinery and can cause lengthy repair timelines due to logistics delays.

E. SHIP DESIGN SINGLE POINT FAILURE CHALLENGES

Further exacerbating the MCM-1 class repair parts challenges is, in some cases, the design of the ship. Typical U.S. Navy ships are designed to have redundant components to ensure the ship can meet operational commitments even with some of the equipment out of commission. MCM-1 class ships, on the other hand, were designed with various single point of failure (SPF) components. For example, one of the MIW tenants that an MCM must be able to perform is magnetic influence sweeping for mines, which entails towing a cable that actuates magnetic influence mines and disposes of them by explosion. Sweeping for mines is a quick way to clear a minefield for certain mine types. The AN/SLQ-37(V3) or “sweep” system onboard an MCM depends on the magnetic minesweep gas turbine generator (MMGTG), which consists of a single gas turbine and a generator (AC or DC dependent on hull number), minesweep switchboard, solid state pulse generator (SSPG), influence sweeping waveform generator, magnetic sweep cable reel, minesweeping winch, and the magnetic influencing sweeping cable (United States Navy Sea Systems Command 2003). Of the nine components previously listed, only the SSPGs contain a backup unit to perform the function. Everything else is in series and is a SPF. While somewhat simplified, peripheral equipment, such as the MMGTG LO cooler, cable fairleads, and roller chalks, are not included. All that material must work as well. This design makes it very difficult to obtain a highly reliable system. To that end, Ao is generally what leadership uses to gauge the system health, as the ability to repair the components quickly will still allow a ship to complete its tasking. Further examples of SPF on MCMs only increase the challenge of meeting platform level requirements.

F. OPERATIONAL AVAILABILITY REQUIREMENT

Ao is the primary means of readiness for U.S. Navy surface ship systems. The governing instruction regarding Ao is OPNAV INST 3000.12A, which includes the Operational Availability Handbook. The Ao concept is described as:

> A_o provides a measure of time or probability that a system’s capabilities will be available for operational use when needed. A_o is a critical, dominant element of the overall capability a system provides. It determines the real and sustainable capability that system users can

> realistically achieve in an operational environment within planned resource levels. (Office of the Chief of Naval Operations 2003, 1)

The equation for *Ao* is depicted as:

$Ao = MTBF / (MTBF + MTTR + MLDT)$ (Office of the Chief of Naval Operations 2003, 5)

> Operational Availability is the supportability calculation of the equipment/system (hardware & software) in terms of predicted Reliability (R) called Mean Time Between Failure (MTBF) and predicted Maintainability (M) in terms of Mean Time To Repair (MTTR) and designed supportability, called Mean Logistics Delay Time (MLDT). (Office of the Chief of Naval Operations 2003, 4)

The Ao requirement for the MCM-1 Avenger class ships is 75%. This requirement is outlined in the MCM-1 class Top Level Requirements:

> 2.8.3 (U) Ship Operational Availability
>
> (U) The MCM ship operational availability is defined as the probability that the ship will be in a satisfactory operating condition to commence any of the mission phases shown in Fig. 2–1 at a random point in time. The ship and its mission equipment shall be designed to have a minimum average availability (A) of 0.75. (Department of the Navy Office of the Chief of Naval Operations 1993, 26)

The 75% Ao platform level objective is extremely important to understand when looking at reliability block diagrams (RBDs), which is discussed in further detail in Chapter IX of this report. Each system and system of systems must have sufficient Ao to meet the objectives. When platform Ao objectives are not being met, the RBDs make understanding the problem and where to apply resources much clearer.

G. HARVESTING IMPORTANCE

The benefit of harvesting material from MCM-1 class ships as they decommission is to help increase system Ao to meet the top-level requirement by decreasing logistic down time, addressing obsolescence issues when a component can no longer be purchased from commercial vendors and potential cost avoidance savings occur from procuring a more expensive new component. Harvesting components is a means to ensure critical parts will be available for required repairs on the remaining in-service ships and minimize the MLDT component of the Ao equation:

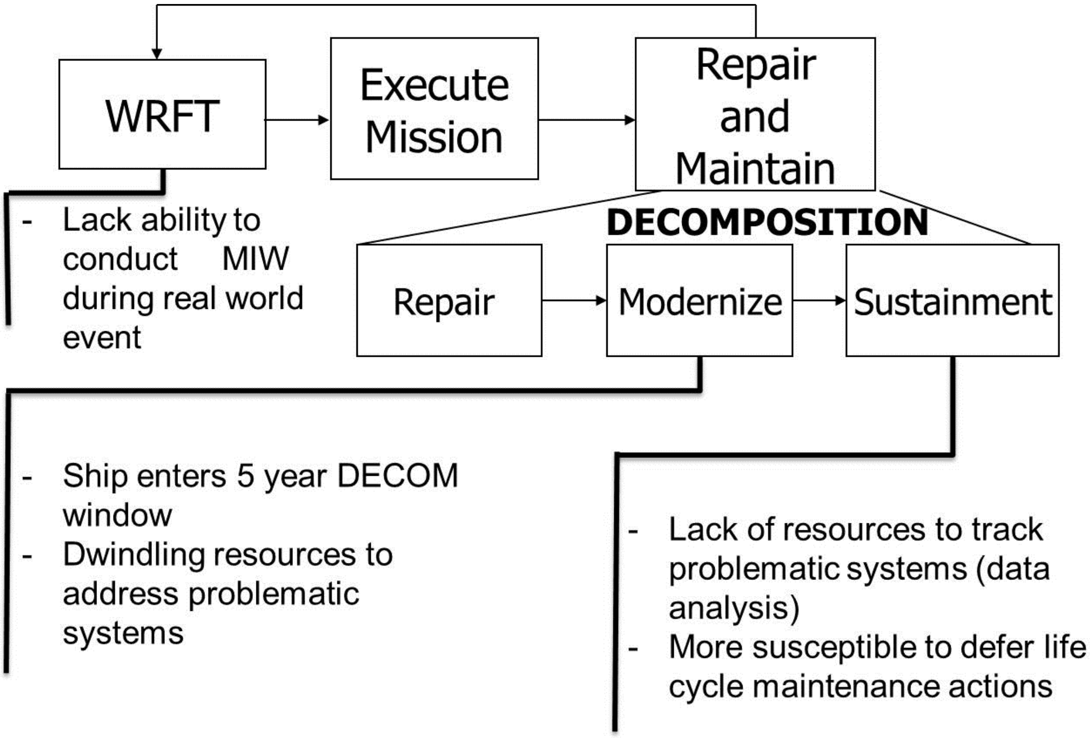
$$A_o = MTBF / (MTBF + MTTR + MLDT)$$

The remaining in-service ships will be sustainable at a reasonable cost while meeting operational requirements. Neither will be possible without a process for making efficient use of components from dismantled, decommissioned ships. Further, using a systems engineering approach to harvest such parts off decommissioning MCMs provides resource sponsors the confidence that resources applied will have a significant return on investment, both financially and operationally, to result in a warship ready for tasking (WRFT). To know what material should be harvested, the risks of not harvesting the equipment must first be analyzed. Risk management entails answering five basic questions.

- What can go wrong?
- What is the probability the event will happen?
- What are the consequences?
- What can be done about it?
- Is it affordable?

To identify what can go wrong, this report utilized scenario-based risk identification techniques as they apply to a parts harvesting process, as seen in Figures 14 and 15.

Figure 14. Scenario-Based Risk Identification–Repair and Maintain Scenarios

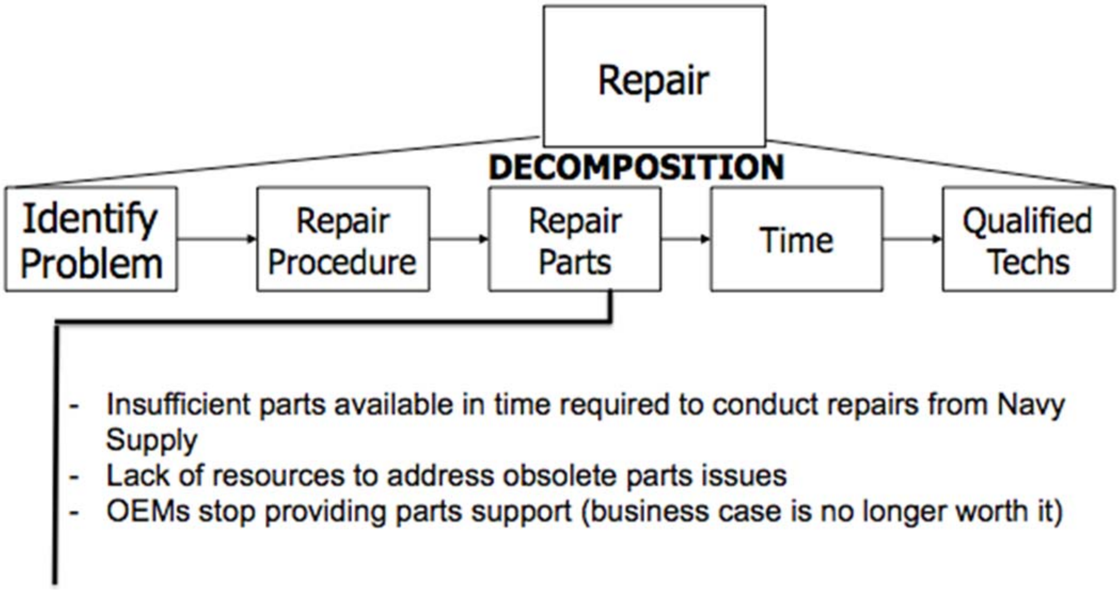


- Lack ability to conduct MIW during real world event

- Ship enters 5 year DECOM window
- Dwindling resources to address problematic systems

- Lack of resources to track problematic systems (data analysis)
- More susceptible to defer life cycle maintenance actions

Figure 15. Scenario-Based Risk Identification–Repair Parts Scenarios



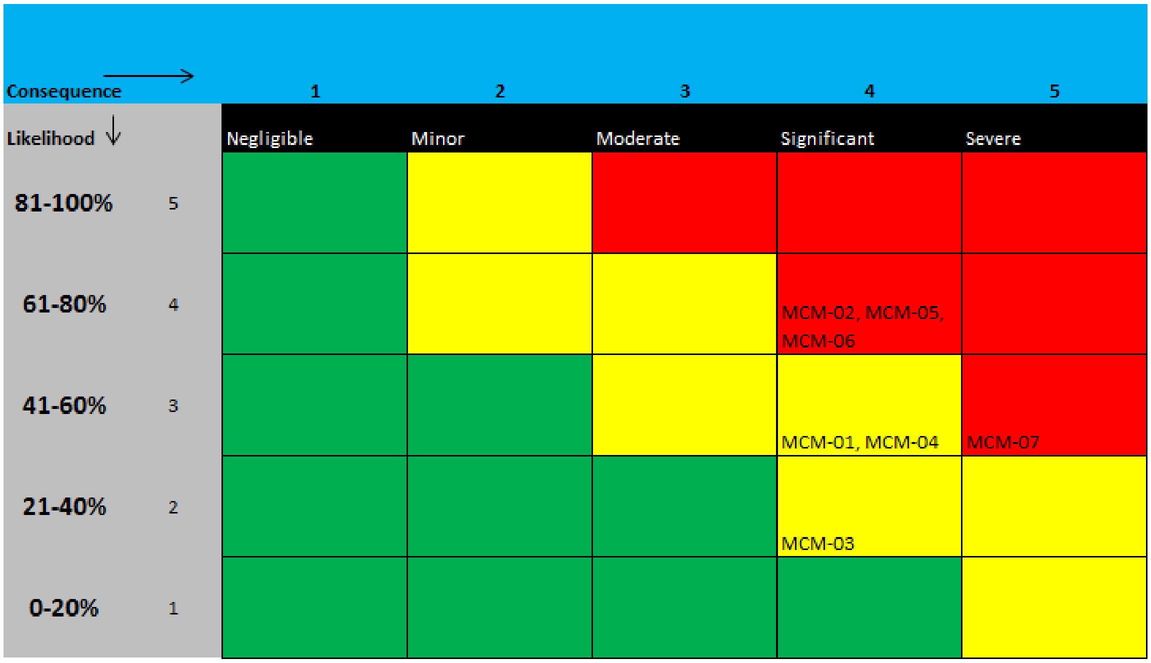
- Insufficient parts available in time required to conduct repairs from Navy Supply
- Lack of resources to address obsolete parts issues
- OEMs stop providing parts support (business case is no longer worth it)

Eight risk areas have been identified from Figures 14 and 15. One additional risk area not outlined in these figures is the risk of not accomplishing harvesting operations prior to the dismantling of an MCM (MCMs do not sit idle for years in INACTSHIPs the way the rest of the surface Navy typically does after decommissioning). Thus, nine risk areas are identified. Now that the risk areas have been identified, the consequence and likelihood must be reviewed and understood as outlined in Table 1 and Figure 16. It is worth noting that the consequence and likelihood are both on a scale of 1 to 5. A consequence of 1 would result in a very minor consequence while a 5 would result in challenges of the highest magnitude. A likelihood of 1 would have an extremely low probability of happening, while a likelihood of 5 would almost certainly happen.

Table 1. MCM Parts Harvesting Risks

ID No.	Activity	Consequence	Likelihood
MCM-01	If a ship is not properly funded for repairs, then it may not be able to meet its operational availability requirement	4	3
MCM-02	If parts have gone obsolete and there are not sufficient spares on the shelf or available for a lifetime buy prior to end of sale, then parts may fail with no replacement	4	4
MCM-03	If a part fails at a higher rate than accounted for in the PARM's sparing plans , then there may not be sufficient spares available for ships to maintain their required Ao	4	2
MCM-04	If a ship's life cycle maintenance actions are deferred or impacted due to planned decommission, then it may not maintain its required Ao	4	3
MCM-05	If failed part is unrepairable with no spare or purchase option, then it may have to be reverse engineered at a large cost and delay	4	4
MCM-06	If parts are not harvested from a ship during its parts harvesting window, then the opportunity for cost savings and improved availability may be missed	4	4
MCM-07	If LCS MIW mission package is delayed and MCM-1 class ships fail to meet Ao requirements then operational MIW needs may not be met	5	3

Figure 16. MCM Parts Harvesting Risk Assessment Matrix



Consequence →		1	2	3	4	5
Likelihood ↓		Negligible	Minor	Moderate	Significant	Severe
81-100%	5	🟩	🟨	🟥	🟥	🟥
61-80%	4	🟩	🟨	🟨	🟥 MCM-02, MCM-05, MCM-06	🟥
41-60%	3	🟩	🟩	🟨	🟨 MCM-01, MCM-04	🟥 MCM-07
21-40%	2	🟩	🟩	🟩	🟨 MCM-03	🟨
0-20%	1	🟩	🟩	🟩	🟩	🟨

MCM parts harvesting operations are a relatively cheap solution to sustaining the class and aid in mitigating the challenges and risks outlined previously. Having a process in place is necessary, as the ship will be dismantled shortly after decommissioning (parts will no longer be available for use after dismantling).

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IV. CONCEPT OF OPERATIONS

This chapter analyzes the various characteristics of an MCM-1 class ship parts harvesting process. The concept of operations is vital for understanding the system boundaries, stakeholders, purpose, utilizations, assumptions, and constraints. The concept of operations also proves that parts harvesting is in fact executable, as it is already being accomplished in ad hoc fashion in the Surface Navy today.

A. SYSTEM PURPOSE AND BACKGROUND

In the past three years, the following ship classes have experienced various parts harvesting initiatives: frigates (FFG-7), cruisers (CG-47), Osprey-class coastal minehunters (MHC-51), and mine countermeasure (MCM-1)

With that in mind, overarching instructions are currently not available for outlining the processes the Navy should use to remove parts effectively from ships slated for dismantling or simply available for scavenging to support the in-service fleet. Not surprisingly, various challenges were encountered during these projects.

- "It is proposed that SEA 21 initiate an FFG 7 Class critical equipment harvesting program" (Glova 2013, 2). The presentation "proposed" SEA21 lead the efforts because a document outlining which organization within the Navy is in charge of harvesting operations is not available. Harvesting operations outlined above have had different organizations lead the efforts.
- "Use recently completed CG 47 Class equipment harvesting as a model" (Glova 2013, 2). In the absence of a documented procedure, a past "model" will be used with no guarantee that lessons learned will be applied or that an efficient process will be used.
- "SEA 21 Leadership has not approved the funding or execution of the FFG harvesting proposal" (Glova 2013, 2). Harvesting operations need to be planned and resources allocated through the POM submission process when possible.
- "Schedule: Funding required in May 2013 to initiate and execute a contract by September 2013 for equipment harvesting of ex-HAWES (FFG 53), which is designated for dismantling" (Glova 2013, 4). The lack of a documented procedure and plan can result in rushed evaluation of what equipment should be harvested.

- "Continue funding warehouse space of harvested material" (Stimson 2013, 8). The harvesting of applicable MHC parts to support MCM-1 class ships required unplanned warehousing costs.

The aforementioned topics are just a sampling of challenges experienced. A need exists for a repeatable parts harvesting procedure that effectively evaluates what components should be harvested, the removal and refurbishment of appropriate harvested equipment, the costs and benefits of harvesting, and the measures of effectiveness to ascertain if the need was met. The purpose of this paper is to develop and propose a procedure to fulfill the need. The procedure is developed utilizing system engineering processes and tools to ensure the process is executable and resource-efficient. The need for mine countermeasure capabilities, and specifically, sufficient repair parts, makes development and utilization of the parts harvesting procedure absolutely essential.

B. LOCATION

This thesis argues that the process developed should be incorporated into a NAVSEA instruction that covers the entire Surface Navy parts harvesting operations. Therefore, the physical location of the harvesting procedure should be on the NAVSEA instruction website (http://www.navsea.navy.mil/NAVSEAInstructions.aspx) in portable document format (PDF). This location was chosen based on which Navy organization should be the procedure owner. However, this location also includes the following benefits:

- Open access that does not require a user login or common access card to open the file
- Version control is facilitated (only the latest approved revision will be posted)
- The website and data is backed up periodically

Additionally, the source file for the PDF should be homed in a protected folder on either a NAVSEA network drive backed up periodically or a protected folder on the iNAVSEA website. Finally, both models in the Appendix should also be placed into version control and homed in the same location as the PDF's source file.

C. ATTRIBUTES

The harvesting procedure comprises a few attributes. The first is the procedure will consist of four electronic files, with date, and revision for version control. The published version file type should be in PDF format. The source file of the published instruction should be a word processing file, as it will facilitate instruction maintenance and periodic updating. The two files in the Appendix shall both be in Microsoft Excel format. NAVSEA Surface Ship Readiness and Sustainment Program office (PMS 443) will own the instruction and tools.

D. PERFORMANCES AND UTILIZATIONS

The harvesting procedure comprises various performances and utilizations. The procedure will provide guidance and support as follows:

- Provides a defendable and repeatable process that supports infrequent MCM-1 class ship parts harvesting operations.
- Assists system life cycle managers and other stakeholders in determining what equipment should be harvested.
- Gives economical means to acquire additional repair parts for critical systems to meet Ao requirements and to reach ESL.
- Outlines major steps and notional timeline to accomplish each task.
- Accounts for periodic updating of the procedure.

E. LIFE CYCLE OF PROBLEM

The life cycle of the problem (build a procedure that facilitates effective parts harvesting of decommissioning MCM-1 class ships) dates from today until the last MCM-1 class ship is decommissioned, currently planned for year 2024. The procedure life cycle includes a design and development phase proposed in this thesis, a verification, and validation of the procedure following execution of the next parts harvesting operation that should commence in FY16 to support the execution in FY19. Following the first parts harvesting execution using this process, a feedback phase will be included to make appropriate procedure modifications based on lessons learned. This evolutionary process will continue until the last MCM is dismantled or until this procedure is modified to include all surface ships.

F. LIFE CYCLE OF NEED

The life cycle of the need for a procedure to harvest parts off a decommissioning MCM-1 class ship to sustain the in-service or FMS customer ships is currently FY24. However, if this procedure were to be modified at a later date to include all surface ships, the life cycle of the need might be indefinite.

G. ASSUMPTIONS AND CONSTRAINTS

Various assumptions were made in the development of this procedure. Some of the major assumptions are as follows:

- The problem (lack of procedure that facilitates effective parts harvesting of decommissioning MCM-1 class ships) is worthy of the resources required to solve.
- The problem as stated previously is the correct problem to solve.
- Parts harvesting will improve or help to maintain system operational availability.
- Stakeholders will utilize the tools provided to determine which components should be harvested.
- The resources (e.g., labor, equipment, time, money) required to execute this procedure will be available.
- Harvesting operations integrated product team (IPT) members will be qualified and empowered to represent their organization or system(s).
- The scope of the third party planning (3PP) contract will allow for work package development in support of harvesting operations availability.
- NSWC Corona will be funded to build (RBDs for the MCM-1 class ships as part of the “sustainment-common operating picture” development that is currently in process with SEA21 oversight.
- The RBDs will be static for the remainder of the MCM-1 class ships’ service life.
- The RMC will customize availability milestones where required to support the parts harvesting availability, but will, at a minimum, conduct a work

package execution review (WPER) 30 days in advance of the availability in accordance with Joint Fleet Maintenance Manual (JFMM) policy.

- MCM-1 class ships will be dismantled shortly following decommissioning (less than six months later).

This project also faces various constraints as well. The major constraints are the following:

- Budget allocated to harvesting operations.
- Time to harvest ship between last operational mission and ship dismantling (minimum time required is influenced both by the scope of harvesting operations and availability of resources required to execute the removal of equipment from the decommissioning ship).
- Industrial activity (e.g., shipyards, repair contractors) workload and facility availability (drydocks).
- SME availability during harvesting operations to oversee critical component removal.
- Ships must be "tow-worthy" to facilitate movement to scrapping yard facility.
- Part demand history is not consistently documented.

H. TIMEFRAME

The timeframe for this project is a total of three years (130 weeks). This project is divided into 10 major phases. The notional schedule is outlined in Table 2.

Table 2. Notional MCM-1 Class Parts Harvesting Operations Schedule

Phase	Task	Task Wks	Total Wks	Months from harvest avail start	Notes
Determine Harvesting Needs			**16**	A-30	Harvesting manager should evaluate if the process should start even sooner based on when the harvesting availability will occur and meeting the POM submission timeframe requirements.
	Analyze RBD (assumes NSWC Corona created RBD via S-COP efforts)	1			
	Perform FTA	2			
	Determine Critical Parts	1			
	Determine Sparing Reqs	1			
	Determine Current Stock	1			
	Determine Number Needed	1			
	Identify Number Avail to Purchase and Cost	3			
	Identify Number Avail to Harvest and Cost	1			
	Perform Optimization	1			
	Consolidate SH Inputs Into Single Spreadsheet	3			
	Shipchecks (if applicable)	1			

Phase	Task	Task Wks	Total Wks	Months from harvest avail start	Notes
Plan Equipment Removal			**8**	A-26	
	Plan SF equipment removal (does not count against task timeline as it does not require a POM issue paper)	2			
	Plan RMC equipment removal	4			
	Plan IA equipment removal to include estimating efforts **(NOTE: estimate required for POM issue paper submittal)**	8			
Fund Parts Harvesting			**36**	A-24	
	Submit POM issue paper	6			Must be submitted 2 FYs prior to execution year
	Establish contract vehicle (RFP solicitation, review RFP submittals, award)	36			
	Fund Planning/Execution	2			
Remove Equipment from DECOM ship				A-0	
	SF Remove Equipment		25		

Phase	Task	Task Wks	Total Wks	Months from harvest avail start	Notes
	RMC Remove Equipment	8			
	Industrial Activity Remove Equipment (Repair contractor)	12			
	Transit from Repair Contractor Facility to Scrapping Facility	3			
	Industrial Activity Remove Equipment (Scrapping contractor)	10			
Store Equipment				A+6	
	Store RFI Equipment	Life of system			Timeline not critical to removal of equipment prior to dismantling
	Store Non-RFI Equipment	Life of system			Timeline not critical to removal of equipment prior to dismantling
Ship Equipment					Timeline not critical to removal of equipment prior to dismantling
	Ship Equip to WH	1			Timeline not critical to removal of equipment prior to dismantling
	Ship Equipment to Repair Facility	1			Timeline not critical to removal of equipment prior to dismantling
Document in ERP		4			Timeline not critical to removal of equipment prior to dismantling
Refurbish Harvested Equipment					
	RMC Refurb Equip	Varies			Timeline not critical to removal of equipment prior to dismantling
	IA Refurb Equip	Varies			Timeline not critical to removal of equipment prior to dismantling
	Gov"t Depot Refurb Equip	Varies			Timeline not critical to removal of equipment prior to dismantling
Dispose Unnecessary		Varies			Timeline not critical to removal of equipment prior to dismantling

Phase	Task	Task Wks	Total Wks	Months from harvest avail start	Notes
Components					
Measure Harvesting Effectiveness		Varies			Timeline not critical to removal of equipment prior to dismantling

Project Total	**85**

I. SYSTEM BOUNDARIES

It is important to define the boundaries of the system. The boundaries of the process begin with a MCM-1 class ship being slated for decommissioning and dismantling. As the process continues, the boundaries include those with the various stakeholders, users, and customers of the process. The process cannot direct any of these stakeholders to utilize the process; it is simply a tool available to the decision makers.

With respect to funding, this process outlines a single entity (PMS 443) to submit a POM issue paper for all equipment removal in support of the parts harvesting effort. However, while this procedure discusses the need to refurbish the equipment harvested, the funding for harvested component refurbishment would be outside the system boundaries. Each PARM or fleet would be responsible for component refurbishment.

Further, the parts harvesting procedure is not attempting to re-write guidance where existing instructions already apply. For example, the JFMM already outlines the various stakeholder roles and responsibilities for availability execution, as well as major availability milestones. This procedure acknowledges the function must be performed but will only provide guidance where required to facilitate the parts harvesting operation and account for major differences from the normal operating procedures.

Finally, at the other end of the process, is the boundary at which the part is entered into ERP and refurbished. Once the equipment is at this point, the standard Navy supply system sparing processes take over. Additionally, once a part is identified for disposal, the disposal process for that part is initiated and is no longer part of the harvesting procedure system.

J. STAKEHOLDER ANALYSIS

A matrix of the identified stakeholders with impact area is shown in Table 3. This matrix includes stakeholders and impact area to the harvesting process via appropriate top-level function.

Table 3. Stakeholder Matrix

Stakeholders	**Impact Area To Harvesting Process**									
	Determine Harvesting Needs	**Fund Parts Harvesting**	**Plan Equip Removal**	**Remove Equip**	**Refurb Equip**	**Store Equip**	**Ship Equip**	**Meas. Effectiveness**	**End Use**	**Secondary Impact**
MARAD										X
USCG										X
MCMRON 3, 5, 7	X		X	X					X	
Maintenance Team	X			X	X				X	
Port Engineer	X		X						X	
RMC Project Manager (PM)	X		X	X	X	X	X		X	
In-service MCM ship crews	X		X	X		X	X		X	
NSWCs	X		X		X	X	X		X	
NSWC Corona	X							X	X	
SPAWAR	X	X	X	X	X	X	X	X	X	
SEA21	X	X	X	X	X	X		X	X	
SEA21I			X						X	X
SEA05 (DFSs) TWHs	X		X		X	X	X	X	X	
CNSP/CNSL (Surface Forces Type Commander)	X	X	X	X	X	X	X	X	X	
C3F, C5F, C7F										X
NAVSUP	X				X	X	X	X	X	

Stakeholders	Impact Area To Harvesting Process									
	Determine Harvesting Needs	**Fund Parts Harvesting**	**Plan Equip Removal**	**Remove Equip**	**Refurb Equip**	**Store Equip**	**Ship Equip**	**Meas. Effectiveness**	**End Use**	**Secondary Impact**
DLA	X				X	X	X	X	X	
OPNAV N95		X						X	X	
Participating Acquisition Manager (PARM)	X	X	X	X	X	X	X	X	X	
RMCs		X	X	X	X	X	X		X	
NAVSEA PMS 326 (FMS)	X	X			X	X	X		X	X
Repair Shipyards			X	X	X	X	X		X	
Ship-breaking Shipyards			X	X		X	X		X	
3PP contractor			X	X					X	

A stakeholder analysis is a critical tool that aids in understanding stakeholder needs with respect to a given project. Understanding stakeholder roles and needs also helps to identify impacts to a project based on these needs. Some of the major stakeholders for MCM sustainment, and more specifically, MCM parts harvesting operations are the following.

1. Department of Transportation—Maritime Administration

The Maritime Administration (MARAD) role is described as:

> Promote the development and maintenance of an adequate, well-balanced United States merchant marine, sufficient to carry the Nation's domestic waterborne commerce and a substantial portion of its waterborne foreign commerce, and capable of service as a naval and military auxiliary in time of war or national emergency. The Maritime Administration also seeks to ensure that the United States maintains adequate shipbuilding and repair services, efficient ports, effective inter-modal water and land transportation systems, and reserve shipping capacity for use in time of national emergency. (U.S. Department of Transportation Maritime Administration 2015)

Both in peace and war, MARAD needs the U.S. Navy to keep waterways open for commercial traffic. A critical component of this need is the ability to deter and respond to enemy MIW tactics or practices utilizing the MCM-1 class ships.

2. Department of Homeland Security—U.S. Coast Guard

The United States Coast Guard (USCG) has 11 separate mission areas in their roles with Department of Homeland Security and Defense. The USCG needs mine-free waterways to fulfill the missions successfully: ports, waterways, and coastal security, drug interdiction, aids to navigation, search and rescue, living marine resources, marine safety, defense readiness, migrant interdiction, marine environmental protection, ice operations, and other law enforcement (United States Coast Guard 2015).

3. Department of Defense—Mine Countermeasure Squadrons (MCMRONs) 3, 5, and 7

MCMRONs act as the Immediate Superior in Command (ISIC), as delegated by the Type Commander (TYCOM), to ensure all ships under their cognizance are properly manned, trained, and equipped to fulfill MIW missions. To accomplish this role, MCMRONs need fully functional MCM-1 class ships with highly trained crews that can respond to Combatant Commander (COCOM) MIW requirements. Further, MCMRONs need to provide fleet input when determining parts harvesting needs.

4. Maintenance Team

The maintenance team (MT) is the direct interface with SF to ensure the appropriate maintenance is being accomplished to keep the ship at the highest state of material readiness possible within operational and budgetary constraints. As per the JFMM, "The primary responsibility of the Maintenance Team is to manage the advanced planning and planning of the maintenance and modernization process in accordance with the maintenance policies, directives and business rules of the Fleet Commander, TYCOM and the Naval Supervisory Authority (NSA)" (Commander U.S. Fleet Forces Command 2013, VI-41–3). To fulfill these roles, the MT needs procedural compliance with maintenance requirements and contracts, as well as appropriate spare parts to plan, execute, and provide quality assurance that work was accomplished in accordance with all standards for both planned and unplanned maintenance actions on U.S. Navy surface ships.

5. Port Engineer

The ship's port engineer (PE) "validates, screens and assigns all maintenance and modernization, including assessments, requiring off ship assistance. Ensures the Program Manager (PM) has visibility of all assigned work. For all combat systems related maintenance and modernization the Ashore Ship's Maintenance Manager (PE) will coordinate with the Combat Systems Port Engineer" (Commander U.S. Fleet Forces Command 2013, VI-41–1). The PE needs appropriate parts to ensure repairs can be made to shipboard equipment.

6. RMC Project Manager

The ship's project manager "leads the project team (PT), including the Maintenance Team members, during the maintenance availabilities. Acts as the availability management team point of contact for outside agencies seeking information relating to the project, the contractor's performance or technical issues under review" (Commander U.S. Fleet Forces Command 2013, VI-41–9). The PM needs to manage the parts harvesting availability on behalf of the RMC.

7. In-Service MCM Ship Crews

The role of the in-service MCM ship crews is to operate and maintain the MCM platform to perform MIW operations as directed by the ISIC. The crews need materially sound vessels that operate as per design. Further, they need to document adequately all material deficiencies to ensure 1) appropriate off-ship assistance can be provided (if required), and 2) order repair parts to support required repairs.

8. Naval Surface Warfare Centers

The Naval Surface Warfare Centers' (NSWCs) role is:

> Supply the technical operations, people, technology, engineering services and products needed to equip and support the fleet and meet the warfighters" needs. The Warfare Centers are the Navy's principal research, development, test and evaluation (RDT&E) assessment activity for surface ship and submarine systems and subsystems. In addition, the Warfare Centers provide depot maintenance and in-service engineering support to ensure the systems fielded today perform consistently and reliably in the future. (Naval Sea Systems Command 2015b)

The NSWCs need fleet feedback as to how the systems are operating to determine the best method of providing support to ensure systems are designed appropriately and will meet expected service life in the most economical means possible. Further, ISEAs that work for the NSWC's need to provide input on their specific system(s) when developing parts harvesting requirements.

9. NSWC Corona

NSWC Corona tracks and maintains the metrics for the surface Navy that articulate material condition. These metrics include Ao, MTBF, MLDT, mean time to repair (MTTR) among others. NSWC Corona's role is:

> Using a rigorous, disciplined independent assessment process, Corona provides the fleet, program managers and acquisition community with the objective assessment needed for the Navy to gauge warfighting capability of ships and aircraft, assess warfare training and analyze new defense systems—even those systems in the concept phase. This commitment to independent assessment allows the Navy to achieve the greatest value for acquisition, material readiness and life cycle management programs—for Today's Navy, the Next Navy, and the Navy After Next. (Naval Sea Systems Command 2015b)

NSWC Corona needs to provide metrics that clearly articulate the surface ship sustainment measures of effectiveness.

10. Space and Naval Warfare Systems Command

The Space and Naval Warfare Systems Command (SPAWAR) strategic plan describes the command as

> the Navy's Information Dominance Systems Command providing capabilities in the fields of intelligence, surveillance, and reconnaissance; cyber warfare; command and control; information and knowledge management; communication systems; and enabling technologies including meteorology and oceanography. SPAWAR programs and projects cover the full life cycle from research and development, system-of-systems engineering, test and evaluation, acquisition, installations and in-service support. SPAWAR works closely with the fleet, systems commands, and Navy partners to deliver capability seamlessly and effectively by acquiring and/or integrating sensors, communications, weapons, information and control systems for existing and future ships, aircraft, submarines, and unmanned systems. (Space and Naval Warfare Systems Command (SPAWAR) 2012, 2)

SPAWAR needs fleet feedback as to how the systems are operating to determine the best method of providing support or system modernization to ensure systems operate as per design and will meet expected service life in the most economical means possible. Further, ISEAs who work for SPAWAR need to provide input on their specific system(s) when developing parts harvesting requirements.

11. NAVSEA 21

The official NAVSEA website states:

> NAVSEA 21 is the dedicated life cycle management organization for the Navy's in-service surface ships and is responsible for managing critical modernization, maintenance, training, and inactivation programs. SEA 21 provides wholeness to the fleet by serving as the primary technical interface to ensure surface ships are modernized with the latest technologies and remain mission relevant throughout each ship's service life. The organization also maintains inactive ships for future disposal, donation, or transfer, to include follow-on technical support to our partner navies. (Naval Sea Systems Command 2015c)

SEA21 needs feedback from the fleet to ensure systems life cycle management can be accomplished. To ensure the ships remain mission relevant during their service life, they need to understand which parts are SPF, the component mission criticality, and actively managed obsolescence challenges throughout the surface fleet.

12. Navy Inactive Ships Office

The Navy Inactive Ships Office (NAVSEA 21I) is the division within NAVSEA 21 that takes control of a Navy surface ship following decommission.

According to the NAVSEA official website, "The Navy Inactive Ships Office (SEA 21I) manages U.S. Navy ships and craft that have reached the natural end of their life cycle. SEA 21I is responsible for the planning, programming, budgeting, and execution of the Navy's inactivation and disposal of conventionally powered surface ships and craft" (Naval Sea Systems Command 2015d).

NAVSEA 21I needs harvesting stakeholders to adhere to 1) Naval Ships Technical Manual (NSTM) Chapter 050, Readiness and Care of Inactive Ships Revision 3, 2) the U.S. Navy Towing Manual (Technical Manual # SL740-AA-MAN-010, Revision 3, and 3) OPNAV Instruction 4770.5H, Inactivation, Retirement, and Disposition of U.S. Naval Vessels during harvesting operations.

13. NAVSEA 05

"The Naval Systems Engineering Directorate (SEA05) is responsible for providing the engineering and scientific expertise, knowledge, and technical authority necessary to design, build, maintain, repair, modernize, certify, and dispose of the Navy's ships, submarines, and associated warfare systems" (Naval Sea Systems Command 2015a). SEA 05 TWHs need to minimize the number of technical departure from specifications (DFSs) that exist on ships due to a lack of available technically acceptable (i.e., shock qualified, vibration certified) repair parts and that ships are being maintained while adhering to all appropriate technical requirements.

14. Commander Naval Surface Forces Pacific/Commander Naval Surface Forces Atlantic

Both Commander Naval Surface Forces Pacific/Atlantic are the Surface Navy TYCOM). The TYCOMs provide "Combat Commanders with lethal, ready, well-trained, and logistically-supported Surface Forces to assure, deter and win" (Commander Naval Surface Force, U.S. Pacific Fleet and Commander Naval Surface Forces, U.S. Atlantic Fleet 2015, 4). The TYCOMs need to have appropriate maintenance replacement parts to ensure Naval surface ships can logistically support having WRFT.

15. Combatant Commanders

COCOMs are responsible for their area of responsibility (AORs) with a role to "protect and defend, in concert with other U.S. Government agencies, the territory of the United States, its people, and its interests." This responsibility is accomplished "by promoting security cooperation, encouraging peaceful development, responding to contingencies, deterring aggression, and, when necessary, fighting to win. This approach is based on partnership, presence, and military readiness" (U.S. Pacific Command 2015). COCOMs need to have materially sound ships prepared to conduct missions to protect U.S. territories and interests.

16. Naval Supply Systems Command

Naval Supply Systems Command's (NAVSUP's) role is:

> To deliver sustained global logistics and quality-of-life support to the Navy and Joint warfighter." NAVSUP provides "responsive and agile support through a myriad of actions and responsibilities, including material management, acquisition and positioning, husbanding support, services contracting, ammunition, fuel, uniforms, food, integrated logistics, mail, NEX, Navy Lodge, and more. (Naval Supply Systems Command 2015, 3)

NAVSUP needs clear demand history of all parts purchased to sustain MCM-1 class ships. This demand history is critical to ensuring appropriate stocking levels can be met based on fleet usage. If SF or contracted repair facilities procure parts for maintenance outside of the Naval Supply system, a demand-only requisition needs to be submitted to ensure demand is captured. Policy adherence is critical to preventing situations in which inaccurate component requirements lead to the part no longer being stocked by NAVSUP.

17. Defense Logistics Agency

The Defense Logistics Agency's (DLA's) role is:

> …provides the Army, Navy, Air Force, Marine Corps, other federal agencies, and combined and allied forces with the full spectrum of logistics, acquisition and technical services. The Agency sources and provides nearly 100 percent of the consumable items America's military forces need to operate, from food, fuel and energy, to uniforms, medical supplies, and construction and barrier equipment. DLA also supplies more than 85 percent of the military's spare parts. In addition, the Agency manages the reutilization of military equipment, provides catalogs and other logistics information products, and offers document automation and production services. (Defense Logistics Agency 2015)

DLA needs clear demand history of all parts purchased to sustain MCM-1 class ships. This demand history is critical to ensuring appropriate stocking levels can be met based on fleet usage. If SF or contracted repair facilities procure parts under DLA cognizance for maintenance outside of the DLA managed supply system, a demand-only requisition needs to be submitted to ensure demand is captured. Policy adherence is critical to preventing situations in which inaccurate component requirements lead to the part no longer being stocked by DLA.

18. Office of the Chief of Naval Operations

Office of the Chief of Naval Operations (N95) is the Navy's resource sponsor for expeditionary warfare. The organization establishes requirements, sets priorities, and directs overall planning and programming for expeditionary warfare systems and related manpower, training, and readiness. Specifically, the directorate oversees manpower, training, procurement, sustainment, and R&D appropriates for the Naval Special Warfare, Mine Warfare, Amphibious Warfare, Navy Expeditionary Combat and Maritime Preposition Forces (Dawnbreaker Inc. 2013, 1).

N95 needs a clear and complete list of requirements to support MCM-1 class ships to ensure they have adequate resources to fulfill their missions.

19. Participating Acquisition Manager

The participating acquisition manager (PARM) consists of "Activities tasked and funded with the responsibility for providing government furnished equipment (GFE), Government Furnished Information (GFI), or engineering data to support ship acquisition/modernization or system/equipment acquisition programs" (Commander Naval Sea Systems Command 1990, 2–2). The term "PARM" does not appear to be consistently used throughout the Navy. Therefore, the PARM could also be the system program manager authorized representative. For the remainder of this thesis, the "PARM" is referred to as the individual responsible for a given system's life cycle management. The PARM needs to understand what parts support is required for a system to meet both Ao requirements and to reach ESL.

20. Regional Maintenance Centers

The RMCs are the first responders to fleet maintenance requirements. The RMCs are "the command with overall responsibility for efficient planning, brokering and execution of all ship maintenance and modernization for assigned ships is the local RMC. The RMC is a subordinate command to the Fleet Commander" (U.S. Fleet Forces

Command 2013, II-II-1–1). RMCs need to manage and execute the parts harvesting availabilities. With respect to components that the RMC will harvest and refurbish from a ship, the RMCs need to plan for this work.

21. NAVSEA PMS 326

The NAVSEA PMS 326 foreign military sales (FMS) program office provides support to ships that have been sold via foreign military sales. The PMS 326 mission is to manage execution of FMS cases that require further support through the ships' life cycle. FMS needs to identify parts that their customers would like to harvest and provide funding for component removal accordingly as opportunities present themselves.

a. Commercial Shipyards

Two different types of shipyards might be stakeholders in the parts harvesting operations. The first is repair shipyards that conduct vital repairs on U.S. Navy ships on a daily basis. The repair shipyards need to provide a service (ship repair) to make money. The second type is ship-breaking shipyards that dismantle and scrap U.S. Navy ships. The ship-breaking shipyards also need to provide a service, as well as sell/recycle stripped material to make money.

b. Third Party Advanced Planning Contractor

The 3PP contractor is responsible for planning all work regarding surface ship maintenance and modernization. This contract is currently being solicited as the Navy transitions these planning duties from the current multi-ship-multi-option (MSMO) contractor. The 3PP contractor needs to develop work specifications that will facilitate parts harvesting maintenance availabilities and provide detailed cost estimates for the parts harvesting efforts (Naval Sea Systems Command 2014, 30).

Table 4 summarizes all stakeholders and their respective needs. The purpose for the identification of stakeholders and their needs is to assure that the requirements defined and derived for the solution to the problem satisfy the needs of the stakeholders. In effect, this satisfaction of needs is a compliance issue in systems engineering.

Table 4. Stakeholder Needs Analysis

STAKEHOLDER	Need
MARAD	MARAD needs the U.S. Navy to keep waterways open for commercial traffic. A critical component of this need is the ability to deter and respond to enemy MIW tactics or practices utilizing the MCM-1 class ships.
USCG	The USCG needs mine-free waterways to fulfill their various roles successfully.
MCMRON 3, 5, 7	Fully functional MCM-1 class ships with highly trained crews that can respond to COCOM MIW requirements. Further, MCMRONs need to provide fleet input when determining parts harvesting needs.
Maintenance Team	Procedural compliance with maintenance requirements, as well as appropriate spare parts to conduct both planned and unplanned maintenance actions.
Port Engineer	The PE needs appropriate parts to ensure repairs can be made to shipboard equipment.
RMC Project Manager	The RMC project manager needs to manage the parts harvesting availability on behalf of the RMC.
In-service MCM ship crews	Materially sound vessels that operate as per design.
NSWCs	The NSWCs need fleet feedback as to how the systems are operating to determine the best method of providing support or system modernization to ensure systems operate as per design and will meet expected service life in the most economical means possible. Further, ISEAs who work for the NSWCs need to provide input on their specific system(s) when developing parts harvesting requirements. Last, the NSWCs need to ensure all harvested material is placed in the Navy ERP for visibility by all applicable entities.
NSWC Corona	NSWC Corona needs to provide metrics that clearly articulate the surface ship sustainment measures of effectiveness.
SPAWAR	SPAWAR needs fleet feedback as to how the systems are operating to determine the best method of providing support or system modernization to ensure systems operate as per design and will meet expected service life in the most economical means possible. Further, ISEAs who work for SPAWAR need to provide input on their specific system(s) when developing parts harvesting requirements. Last, SPAWAR needs to ensure all harvested material is placed in the Navy ERP for visibility by all applicable entities.

Table 4 (cont'd). Stakeholder Needs Analysis

STAKEHOLDER	Need
SEA21—mod and sustainment	SEA21 needs feedback from the fleet to ensure systems life cycle management can be accomplished. In particular, they need to understand which parts are SPF, the component mission criticality, and actively managed obsolescence challenges throughout the surface fleet.
SEA21I	NAVSEA 21I needs harvesting stakeholders to adhere to 1) Naval Ships' Technical Manual (NSTM) Chapter 050, Readiness and Care of Inactive Ships Revision 3, 2) the U.S. Navy Towing Manual (Technical Manual # SL740-AA-MAN-010, Revision 3, and 3) OPNAV instruction 4770.5H, Inactivation, Retirement, and Disposition of U.S. Naval Vessels during harvesting operations.
SEA05 (DFSs) TWHs	SEA 05 technical warrant holders (TWHs) need to minimize the number of technical DFSs that exist on ships due to lack of available technically acceptable (shock qualified, vibration certified) repair parts.
CNSP/CNSL (Surface Forces Type Commander)	The TYCOMs need to have appropriate replacement parts to ensure Naval surface ships can logistically support having WRFT.
C3F, C5F, C7F	COCOMs need to have materially sound ships prepared to conduct missions to protect U.S. interests.
NAVSUP	NAVSUP needs clear demand history of all parts purchased in order to sustain MCM-1 class ships. This demand history is critical to ensuring appropriate stocking levels can be met based on fleet usage. If SF or contracted repair facilities procure parts for maintenance outside of the Naval Supply system, a demand-only requisition needs to be submitted to ensure demand is captured. Policy adherence is critical to preventing situations in which inaccurate component requirements lead to the part no longer being stocked by NAVSUP.
DLA	DLA needs clear demand history of all parts purchased to sustain MCM-1 class ships. This demand history is critical to ensuring appropriate stocking levels can be met based on fleet usage. If SF or contracted repair facilities procure parts under DLA cognizance for maintenance outside of the DLA managed supply system, a demand-only requisition needs to be submitted to ensure demand is captured. Policy adherence is critical to preventing situations in which inaccurate component requirements lead to the part no longer being stocked by DLA.
OPNAV N95	N95 needs clear and a complete list of requirements to support MCM-1 class ships to ensure they have adequate resources to fulfill their missions.

Table 4 (cont'd). Stakeholder Needs Analysis

STAKEHOLDER	**Need**
Participating Acquisition Manager (PARM)	The PARM needs to understand what parts support is required for a system to meet both Ao requirements and to reach expected service life ESL.
RMCs	RMCs need to manage and execute the parts harvesting availabilities.
NAVSEA PMS 326 (FMS)	FMS needs to identify parts that their customers would like to harvest and provide funding for component removal accordingly, as opportunities present themselves.
Repair Shipyards	The repair shipyards need to provide a service (ship repair) to make money.
Ship-breaking Shipyards	The ship-breaking shipyards also need to provide a service, as well as sell/recycle stripped material to make money.
3PP contractor	The 3PP contractor needs to develop work specifications that will facilitate parts harvesting maintenance availabilities and provide detailed cost estimates for the parts harvesting efforts (Naval Sea Systems Command 2014, 30).

K. CUSTOMERS

The customers of the parts harvesting process include NAVSEA PMS 443 and any stakeholder providing funding towards the parts harvesting operations. The funding stakeholders could include SPAWAR, FMS, various NAVSEA program offices, and the TYCOM.

L. USERS

The parts harvesting procedure has several users. As per the stakeholder matrix in Table 4, all stakeholders with the exception of MARAD, USCG, and the fleet commanders (C3F, C5F, C7F), are users of the parts harvesting procedure.

M. TOP-LEVEL USE CASES

The top-level use cases capture the contract between the stakeholders of a system and the system's behaviors. Use cases provide a means of capturing the flow of functions that must be carried out to satisfy a set of requirements. Since the functions have measurable performance(s), the use case provides an end-to-end way of evaluating the efficacy of a proposed implementation of work effort to accomplish what stakeholders need. The use case will start with a single stakeholder called the primary actor and describe the system's behaviors based on inputs from the primary actor. While the primary actor interacts with the system towards an end goal, the system must respond, while still protecting the other stakeholders' interests (Cockburn 2001). The use cases for this parts harvesting process are as follows.

1. Use Case 1: Implement Process

Primary Actor: NAVSEA PMS 443

Scope: NAVSEA PMS 443 defines the process as a directive for use by parts harvesting customers and users.

Stakeholders and Interests: NAVSEA PMS 443 wants to have a defined process for coordinated decisions on parts harvesting needs.

Precondition: The process is defined and documented in the NAVSEA instruction format.

Minimal Guarantee: NAVSEA PMS 443 provides guidance for this process to be followed.

Success Guarantee: The documented process and related tools are posted to NAVSEA instruction website and used each time a MCM-1 class ship is identified for decommissioning/dismantling.

Trigger: NAVSEA PMS 443 releases naval message with guidance for use of the process.

Main Success Scenario:

1. NAVSEA PMS 443 identifies the process as a standard to be followed.
2. The process document is placed under CM control by PMS 443 and posted to the NAVSEA instruction website for use.
3. NAVSEA PMS 443 sends a naval message to all users and customer stakeholders to adhere to this process for all future decommissioning of MCM-1 class ships.

Extensions:

1. PMS 443 adopts the policy but does not advertise and direct its use.
    a. The policy is not consistently used or followed.
2. The process document is not placed under CM or put on the NAVSEA instruction website.

a. Various versions start being circulated and users are confused or following incorrect guidance.

b Users do not follow the process because they did not know where to find it.

  2a.3 Process is lost due to an individual machine failure that is not backed up like the NAVSEA instruction website.

3a. PMS 443 fails to transmit guidance that this process will be used for all follow-on MCM-1 class decommissions.

  3a.1 The process is not utilized each time a MCM is decommissioned resulting in less than optimal critical parts harvesting operations.

2. Use Case 2: Follow Process

Primary Actor: NAVSEA PMS 443Harvesting Manager

Scope: Harvesting manager follows the process, interacting with the key users, customers and stakeholders along the way.

Stakeholders and Interests: See Table 3 for list of stakeholders and needs.

Precondition: Success of use case 1.

Minimal Guarantee: Harvesting manager kicks off the process.

Success Guarantee: The process is followed start to finish and the optimal parts required are harvested, improving MCM-1 class ships' sustainment.

Trigger: MCM-1 class ship is identified for decommissioning/dismantling.

Main success Scenario:

1. Harvesting manager kicks off the process by contacting the PARMs via Naval Message and IPT kick-off meeting.
2. The process is successfully followed.
3. The optimal parts required are harvested, improving MCM-1 class ships' sustainment.

Extensions:

1a. Process users do not properly react to the trigger.

  1a1. The process is not followed.

1b. The harvesting manager only notifies a portion of the PARMs/end users.

  1b1. Only a portion of the critical parts benefit from the process.

2a. The process is not properly executed.

  2a1. The optimal number of parts are not harvested.

  2a2. Cost is not minimized.

  2a3. Remaining MCM-1 class ships do not benefit from improved sustainability.

  2a4. Harvested parts are not properly shipped, repaired, stored, or disposed.

  2a5. The ERP system is not properly updated to reflect harvested parts.

3. Use Case 3: Update/Modify Process

Primary Actor: NAVSEA PMS 443

Scope: NAVSEA PMS 443 modifies the process.

Stakeholders and Interests: NAVSEA PMS 443 desires modifying the process based on experience, lessons learned, and feedback from other stakeholders.

Precondition: Use case 1.

Minimal Guarantee: NAVSEA PMS 443 modifies the process.

Success Guarantee: The documented process is modified under CM controls and the updated process is followed going forward.

Trigger: NAVSEA PMS 443 determines modifications to the process are necessary following parts harvesting operations.

Main success Scenario:

1. NAVSEA PMS 443 identifies updates to the current process with stakeholder inputs.
2. The process document and related tools, under CM control are updated and the new process is made available for use.

Extensions:

2a. The desired changes are not properly made in the process documentation.

  2a1. The updated process is not followed.

2b. The users do not retrieve the updated process from the NAVSEA instruction website.

  2b1. The updated process is not followed.

4. Use Case 4: Discontinued Use

Primary Actor: NAVSEA PMS 443

Scope: NAVSEA PMS 443 decides to no longer adhere to the process.

Stakeholders and Interests: NAVSEA PMS 443 has decided no longer to follow the process due to any number of factors, such as lack of buy-in and support by stakeholders, all funding for sustainment of any sort (including harvesting) is cut, or all critical parts are determined to have enough spares on the shelf for the remaining life of the ship class.

Precondition: Use case 1.

Minimal Guarantee: NAVSEA PMS 443 provides guidance for this process to no longer be followed.

Success Guarantee: The documented process and related tools are removed from the NAVSEA instruction website or noted as obsolete.

Trigger: NAVSEA PMS 443 releases naval message with guidance for discontinued use of the process.

Main success Scenario:

1. NAVSEA PMS 443 determines the process is no longer to be followed.
2. The process document and related tools are removed from the NAVSEA instruction website or marked as obsolete.
3. NAVSEA PMS 443 sends a Naval message to all process users and customers to discontinue use of the process.

Extensions:

2a. The process and tools are not removed or clearly marked for discontinued use.

    2a1. The process continues to be followed.

2b. NAVSEA PMS 443 does not send the message or process users and customers do not receive the message.

    2b1. The process continues to be followed.

V. CONCEPTUALIZATION

Several options for a process in determining which parts, and how many, to harvest from a decommissioning ship were considered. These options are summarized as follows:

- Use consistency across parts and ships—always harvest all parts or never harvest any.
    - This option was quickly dismissed because it does not meet a number of requirements, such as minimizing cost.
- Continue ad hoc process—react each time a ship begins its decommissioning by pulling a small team together and using their best effort to decide which parts seem like strong candidates for harvesting.
    - This option was also dismissed because, while an improvement from option 1, this option also does not meet a number of requirements or maximize the benefits of a well-defined process.
- Utilize the systems engineering process properly to define a parts harvesting process that is structured and inclusive of all parts and stakeholders but also dynamic over time.
    - Ultimately, this option was selected and documented herein.

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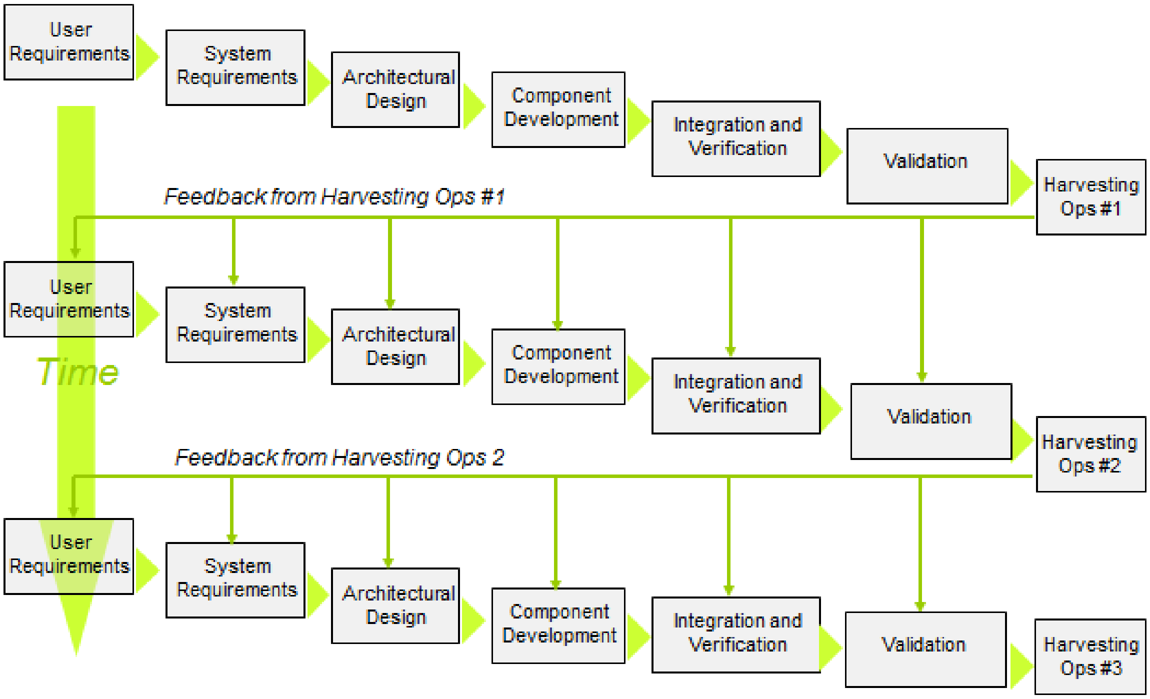
VI. SELECTION OF SYSTEMS ENGINEERING PROCESS MODEL

The evolutionary systems engineering process model is used for the parts harvesting procedure development. The evolutionary systems engineering process is used because the procedure requires periodic updates to keep it relevant. Two types of updates are available. The first is technical updates where something in the procedure is technically incorrect or it is possible to accomplish a given task by better means. The second is administrative changes that could include items, such as a program office code designator change. The evolutionary systems engineering process model for parts harvesting procedure development is depicted in Figure 17.

Figure 17. Parts Harvesting Development Evolutionary Model



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VII. PARTS HARVESTING PROCESS REQUIREMENTS

Following review of the stakeholder analysis and their needs, it is logical to define the process requirements. The requirements for the parts harvesting process can be found in Table 5.

Table 5. Parts Harvesting Process Requirements

UID	Requirement	Type
1.0	The process shall define the steps for performing parts harvesting	Requirement
1.1	The process shall identify critical components	Decomposed
1.2	The process shall define steps for determining the number of spares required	Decomposed
1.3	The process shall define the steps for optimized decision to procure or harvest needed spares	Decomposed
1.4	The process shall have a feedback loop to update the supply system with results of parts harvesting	Decomposed
1.5	The process shall provide steps for disposal of parts harvested but no longer required	Decomposed
2.0	The process shall minimize cost with a systems optimization model	Requirement
3.0	The process shall maintain current or improve MLDT of the MCM	Requirement
4.0	The process shall adhere to all applicable contractual and maintenance standards	Requirement
5.0	The process shall identify the roles and responsibilities of the parts harvesting stakeholders	Requirement
6.0	There shall exist a means of configuration management for the process	Requirement

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VIII. SYSTEM DESCRIPTION

The development of a parts harvesting procedure for DECOM MCM-1 class ships requires a thorough understanding of the ship functions and mapping each function to the appropriate physical form on the ship. This analysis provides the fundamental understanding of the ship class as a system of systems. Further, it supports interpretation of each system block of a reliability block diagram, which is covered in Chapter IX.

To understand what a MCM-1 class ship is designed to do and to relate the material requirements to include parts harvesting operations prior to one of the ship's being dismantled, it is important to understand the ship's functions. The MCM-1 class ship functional decomposition is shown in Figure 18.

Figure 18. MCM-1 Class Ship Functional Decomposition

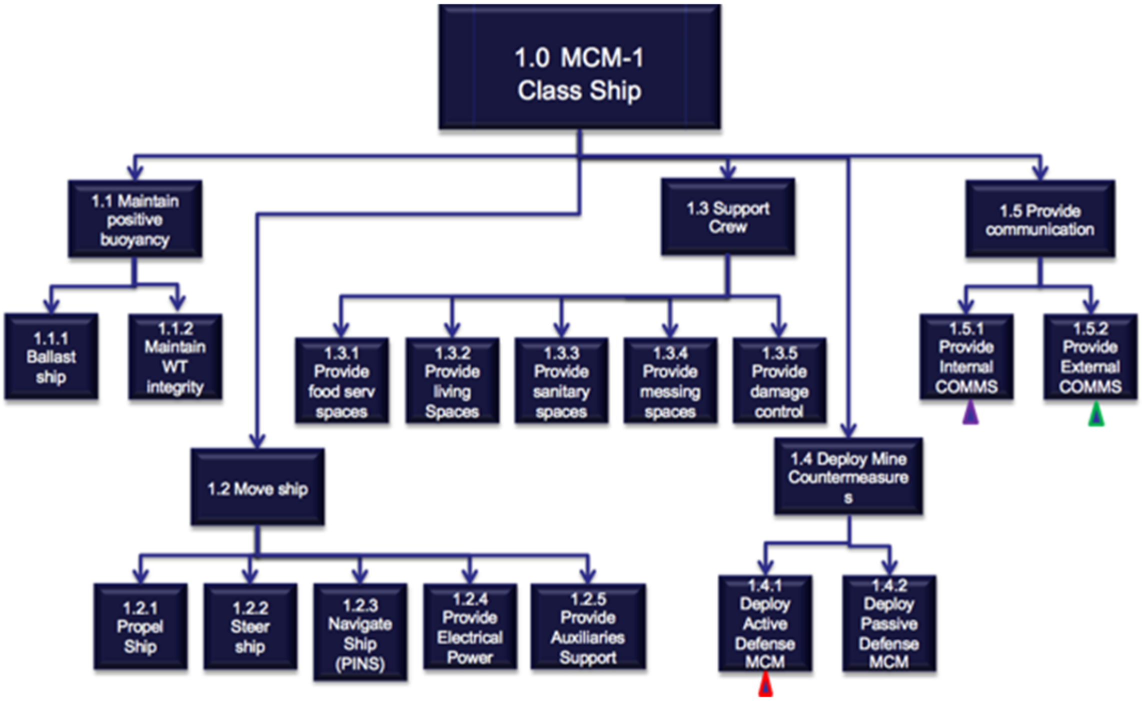
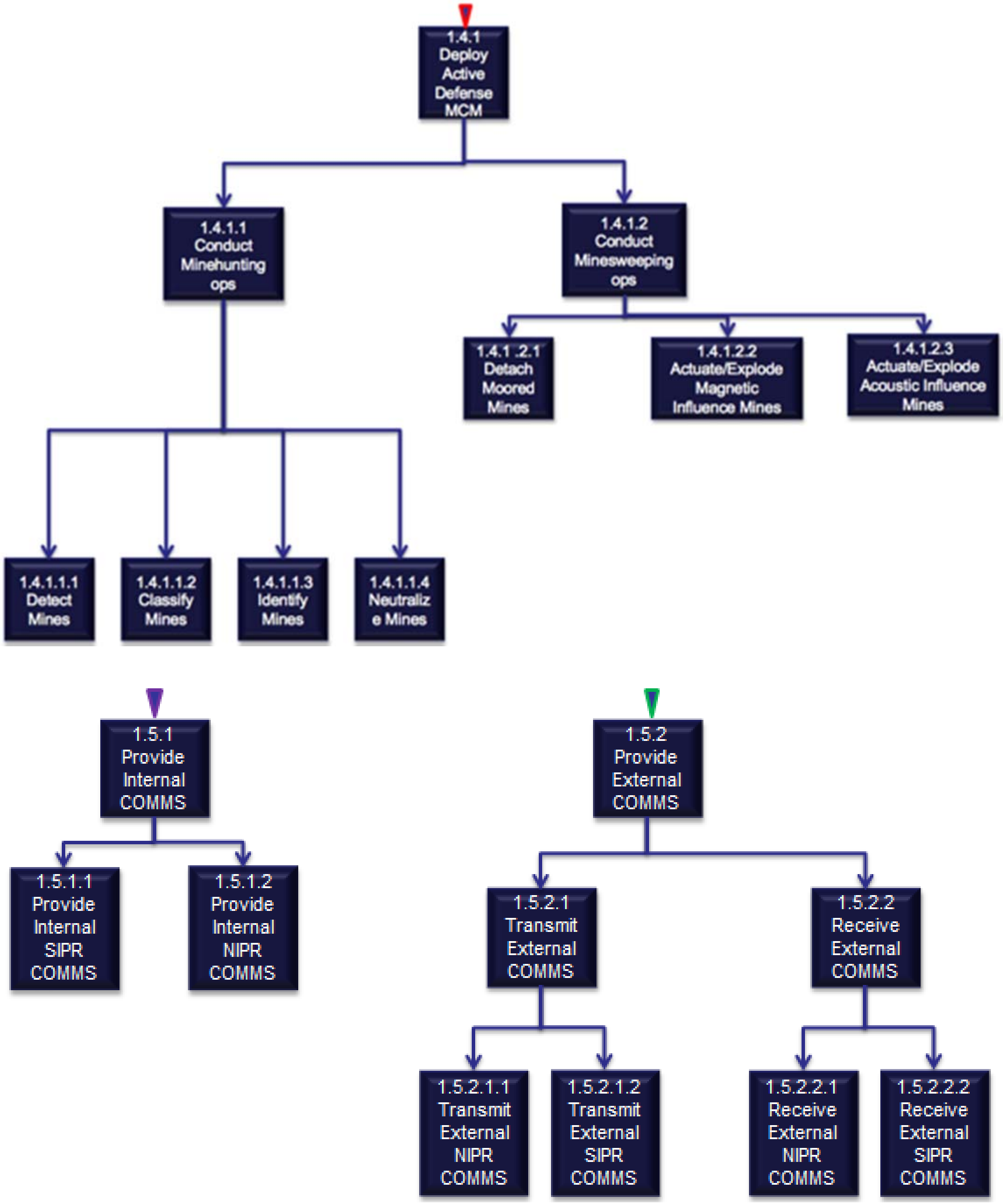


Figure 18 (cont’d). MCM-1 Class Ship Functional Decomposition



The MCM-1 class ship top-level functions are “maintain positive buoyancy,” “move ship,” “support crew,” “deploy mine countermeasures,” and “provide communication.” These functions must be fulfilled for the ship to perform its mission. Each function is characterized by performance(s) that must be achieved, and in turn, each performance may have several quality requirements. For the purpose of this thesis, most performance and quality measures are assumed to be defined and met for actual implementation. A further review of each top-level lower level functions follows.

The function “maintain positive buoyancy” is the single most fundamental function of any ship, as it ensures that the vessel floats on the water. Two sub-functions “maintain positive buoyancy.” The first is to “ballast ship.” This function requires the ship to be loaded out in accordance with the ship’s ballast plan to meet ship design stability requirements. The second sub-function is “maintain watertight integrity,” which prevents uncontrolled flooding of the ship.

The top-level function “move ship” is the ship’s capability to have controlled movement through the water. “Move ship” consists of five sub-functions. The first is “propel ship,” which provides forward and aft direction movement through the water. The second is “steer ship,” which enables movement in the port and starboard directions. The third is “navigate ship,” which is ascertaining the ship’s position and planning/following a specific course. The fourth sub-function is “provide electrical power,” which enables all shipboard systems to operate. The fifth is “provide auxiliaries support,” which provide various operations, such as compressed air, cooling, sewage processing, and oil pollution prevention.

The top-level function “support crew” is the actions required to support sailors that live onboard and operate the ship. The “support crew” top-level function consists of five sub-functions. The first is “provide food service spaces.” This function allows for meal preparation onboard the ship. The second is “provide living spaces,” which includes the spaces where sailors sleep, store personal items, and relax. The third is “provide sanitary spaces,” which includes restroom and bathing facilities. The fourth is “provide messing spaces” that allocates an area for sailors to consume meals. The fifth is “provide damage control.” This function facilitates actions to minimize the impact of accidents or errors.

The top-level function “deploy mine countermeasures” includes protecting the ship from setting off mines and actions that clear mines from a given body of water. The “deploy mine countermeasures” top-level function consists of two sub-functions. The first is “deploy passive mine countermeasures,” which ensures the ship is magnetically “silent” to prevent setting off magnetically actuated mines as it moves through the water. The second is “deploy active mine countermeasures,” which entails the active clearing of mines from a marine waterway based on intelligence and operational orders. The “deploy active mine countermeasures” sub-function can be further divided into two mid-level functions. The first is “conduct minehunting operations,” which outlines the process to find mines actively in a marine waterway. The second is “conduct minesweeping operations,” which utilizes various towing configurations to clear actuate or cut moored mines loose from the seafloor.

Both the “conduct mine-hunting operations” and “conduct minesweeping operations” mid-level functions can further be broken down into low-level functions. The “conduct mine-hunting operations” mid-level function consists of four low-level functions. The first is “detect mines,” which is the search for foreign objects in the water. The second is “identify mines,” which determines if a contact is a mine-like object. The third is “classify mines,” which includes determining the method of mine actuation and position in the water. The fourth is “neutralize mine,” which can be accomplished by defusing or actuating it under controlled conditions.

The “conduct minesweeping operations” mid-level function can be further divided into three low-level functions. The first is “detach moored mines,” which releases moored mines from their tether to the ocean floor. The second is “actuate/explode magnetic influence mines,” which is accomplished by generating a magnetic field to trigger the mine explosion. The third is “actuate/explode acoustic influence mines,” which entails generating appropriate noise to trigger acoustic mines.

The top-level function “provide communication” allows the ship to both send and receive communication signals. The “provide communication” top-level function can be broken down into two sub-functions. The first is “provide internal communications,” which allows for communication within the ship. The second is “provide external communications,” which allows for communication with external entities to the ship. Both these sub-functions can be further decomposed to mid-level functions.

The “provide internal communications” sub-function consists of two low-level functions. The first is “provide internal secure internet protocol router (SIPR) communications,” which allows for secure communications within the ship. The second is “provide internal non-secure internet protocol router (NIPR) communications,” which facilitates non-secure communications within the ship.

The “provide external communications” sub-function consists of two low-level functions. The first is “transmit external communications,” which allows communication signals to be transmitted from the ship to external entities. The second is “receive external communications,” which allows the ship to receive communication signals from external entities. Both these low-level functions can further be decomposed into bottom-level functions.

The “transmit external communications” low-level function consists of two bottom-level functions. The first is “transmit NIPR communications,” which allows for sending non-secure communication signals from the ship to external entities. The second is “transmit SIPR communications.” This function allows for secure communication signals to be transmitted from the ship to external entities.

The “receive external communications” low-level function consists of two bottom-level functions. The first is “receive external NIPR communications,” which allows the ship to receive non-secure communication signals from external entities. The second is “receive external SIPR communications,” which allows the ship to receive secure communication signals from external entities.

The mapping of functions to the appropriate form onboard the ship that performs the specific function is depicted in Table 6.

Table 6. MCM-1 Class Ship Function to Form Mapping

Function	**Form**
1.1 Maintain positive buoyancy	N/A
1.1.1 Ballast ship	oil tanks, water tanks, fuel tanks
1.1.2 Maintain WT integrity	ship structure/hull
1.2 Move ship	N/A
1.2.1 Propel ship	main propulsion diesel engines (MPDE) (4), port and Stbd propulsion shafts (1 each), P/S controllable pitch propeller (CPP) (1 each), 2 electric propulsion motors (LLPMs), P/S main reduction gear, flexible couplings, MPDE clutch, integrated shipboard control system (ISCS)/integrated control assessment system (ICAS)
1.2.2 Steer ship	steering system, rudder, bow thruster
1.2.3. Navigate ship	PINS, electronic navigation systems
1.2.4 Provide electrical power	SSDGs, distribution switchboards, DC distribution, 60 Hz system, 400 Hz system, static frequency converters
1.2.5 Provide auxiliaries support	Lube oil system, fuel oil system, air conditioning (AC) system, auxiliary seawater (SW), chill water (CW) system, start air system, medium pressure air compressors (MPACs), oil pollution control system, potable water (PW) system, reverse osmosis (RO) units
1.3 Support crew	N/A
1.3.1 Provide food services	refrigeration system, griddle, PW system, collection holding & transfer (CHT) system
1.3.2 Provide living spaces	distributed lighting system, AC system, CW system, RO system, CHT system
1.3.3 Provide sanitary spaces	CHT system, heads, commodes, urinals, showers,
1.3.4 Provide messing spaces	AC system, CHT system
1.3.5 Provide damage control	fire main system, AFFF system, main/secondary drainage system,
1.4 Deploy mine countermeasures	N/A
1.4.1 Deploy active defense MCM	N/A
1.4.1.1 Conduct minehunting operations	global command and control system (GCCS), precise integrated navigation system (PINS), MIW (mine warfare) and Environmental decision aids library (MEDAL), battle space profiler (BSP), expendable bathythermograph (XBT)
1.4.1.1.1 Detect mines	SQQ-32, detect console
1.4.1.1.2 Classify mines	SQQ-32, classify console
1.4.1.1.3 Identify mines	SLQ-48 (UCHS, 48 console) or SLQ-60 (identification round), vehicle handling system crane), SQQ-32

Table 6 (cont'd). MCM-1 Class Ship Function to Form Mapping

Function	**Form**
1.4.1.1.4 Neutralize mines	SLQ-48 (UCHS, 48 console, WQC-2, which is a triggering device, mission package - the bomblet) or SLQ-60 (combat round), vehicle handling system Crane), SQQ-32
1.4.1.2 Conduct minesweeping operations	GCCS, PINS, MEDAL
1.4.1.2.1 Detach moored mines	AN/SLQ-38 (float pennants), minesweep winch, stern cranes
1.4.1.2.2 Actuate/explode magnetic influence mines	AN/SLQ-37, Magnetic sweep cable (nomenclature - SLQ-37), cable reel, MMGTG, minesweep control switchboard, solid state pulse generators
1.4.1.2.3 Actuate/explode acoustic influence mines	acoustic power tow cable, TB-35/36, stern cranes
1.4.2 Deploy passive defense MCM	degaussing system, shaft grounding system
1.5 Provide communications	N/A
1.5.1 Provide internal communications	N/A
1.5.1.1 Provide internal SIPR communications	SIPR network
1.5.1.2 Provide internal NIPR communications	NIPR network, 1MC, 21MC, 2JV, internal phone system
1.5.2 Provide external communications	N/A
1.5.2.1 Transmit external communications	N/A
1.5.2.1.1 Transmit external NIPR communications	**HF**—tactical variant switch, HF transceiver (AN/URC-143), HF receive antennae, HF transmit antennae (AS-2537); **VHF—**tactical variant switch, VHF transceiver, VHF antennae; **UHF (LoS)—**tactical variant switch, WSC-3 transceiver, UHF LoS antennae; **UHF (Sat)—**tactical variant switch, Mini DAMA (MD-1329), UHF Sat antennae (OE-82); **SHF (CBSP)**—ISNS, GCCS, ADNS, CBSP, AN/USC-69(V) SSV (small ship variant)

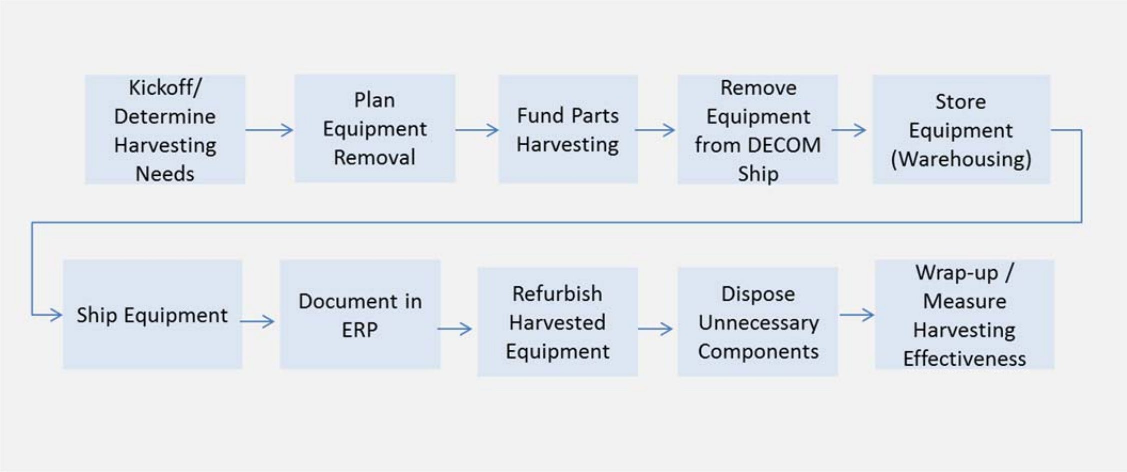
Table 6 (cont'd). MCM-1 Class Ship Function to Form Mapping

Function	**Form**
1.5.2.1.2 Transmit external SIPR communications	**HF**—tactical variant switch, HF transceiver (AN/URC-143), HF receive antennae, HF transmit antennae (AS-2537); **VHF**—tactical variant switch, VHF transceiver, VHF antennae; **UHF (LoS) -** Tactical Variant Switch, WSC-3 transceiver, UHF LoS antennae; **UHF (Sat)** —tactical variant switch, Mini DAMA (MD-1329), UHF Sat antennae (OE-82); **SHF (CBSP)**—ISNS, GCCS, ADNS, CBSP, AN/USC-69(V) SSV (small ship variant); cryptographic device
1.5.2.2 Receive external communications	N/A
1.5.2.2.1 Receive external SIPR communications	**HF**—tactical variant switch, HF transceiver (AN/URC-143), HF receive antennae, HF transmit antennae (AS-2537); **VHF**—tactical variant switch, VHF transceiver, VHF antennae; **UHF (LoS)**—tactical variant switch, WSC-3 transceiver, UHF LoS antennae; **UHF (Sat)**—tactical variant switch, Mini DAMA (MD-1329), UHF Sat antennae (OE-82); **SHF (CBSP)**—ISNS, GCCS, ADNS, CBSP, AN/USC-69(V) SSV (small ship variant); cryptographic device
1.5.2.2.2 Receive external NIPR communications	**HF**—tactical variant switch, HF transceiver (AN/URC-143), HF receive antennae, HF transmit antennae (AS-2537); **VHF**—tactical variant switch, VHF transceiver, VHF antennae; **UHF (LoS)** —tactical variant switch, WSC-3 transceiver, UHF LoS antennae; **UHF (Sat)** —tactical variant switch, Mini DAMA (MD-1329), UHF Sat antennae (OE-82); **SHF (CBSP)** —ISNS, GCCS, ADNS, CBSP, AN/USC-69(V) SSV (small ship variant)

IX. PROCESS DEFINITION

Now that the importance, the stakeholders, and the functions of parts harvesting are delineated, a process for the logical and optimal steps can be defined. This process is the form that maps to the functions of parts harvesting as defined in section III.C. It is thus assumed that a one-for-one direct relationship exists between the top-level functions and the steps in the process, which are illustrated in Figure 19.

Figure 19. Parts Harvesting Process



A. KICKOFF AND DETERMINE HARVESTING NEEDS

SEA21 will be responsible for the parts harvesting project from start to finish. Specifically, the PMS443 surface ship sustainment code shall identify a harvesting manager to lead an IPT that facilitates all requirements of the harvesting process. The IPT shall be established via naval message outlining the opportunity to harvest parts off a decommissioning asset and request appropriate stakeholder support. The message shall outline the ship(s) to be harvested, notional timeline of harvesting operations, time and date of kick-off meeting, expected frequency of recurring meetings, deliverable (prioritized listing of parts to be harvested), and request acknowledgement of the message by sending an e-mail to the message point of contact with each organization’s assigned representative for the IPT. The harvesting manager shall interface with SEA21I (Navy inactive ships) regarding all requirements and timelines for dismantling, to include the latest date the ship can be harvested until it must be moved to the scrapping facility.

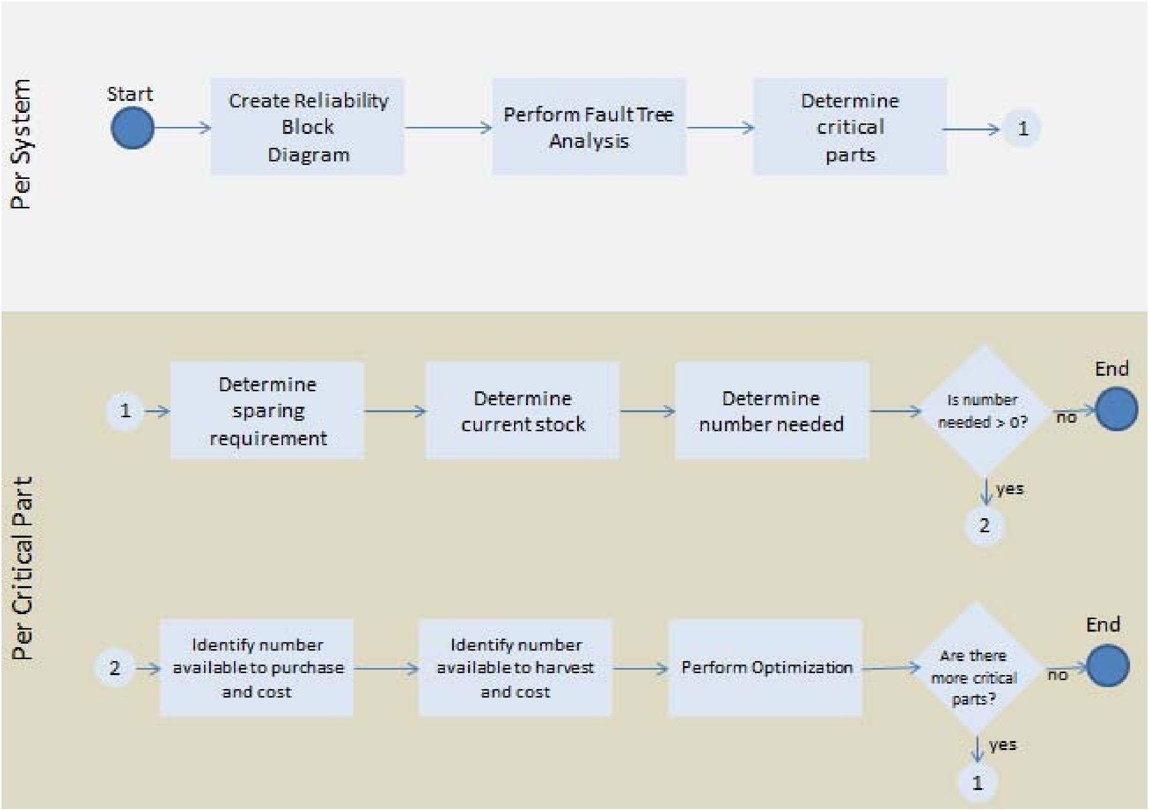
SEA21 shall develop a single spreadsheet that will facilitate documentation of parts harvesting needs. Minimum spreadsheet recommendations are the following:

- Three separate worksheets for combat systems (CS), hull mechanical & electrical (HM&E), and command, control, communications, computers, & intelligence (C4I) components identification.
- Column headings for each worksheet:
    - Equipment functional description (EFD)
    - Location
    - Allowance parts list (APL)
    - Quantity (onboard)
    - Priority 1–3, where 1 is the highest priority (lack of part is ship mission limiting and insufficient spares exist), 2 is medium priority (harvesting and refurbishment is cheaper than purchasing new components or insufficient spares exist, but the system is not ship mission critical), and 3 is the lowest priority (e.g., components needed for training, testing)
    - Shipping address for harvesting components
    - Equipment to be harvested point of contact (POC)
    - Notes

Approximately 30 months prior to the execution of harvesting operations (must have sufficient time to identify harvesting requirements to estimate resources required for POM issue paper), SEA21 shall facilitate setting up the kick-off meeting. The kick-off meeting needs to communicate clearly the harvesting operation intentions to include required participation by all applicable PARMs, TWHs, ISEAs, SMEs, and fleet for parts harvesting submissions. The expectation should be to have all parts harvesting submissions within 90 days. PARMs, with the assistance of other stakeholders, shall provide inputs to the parts harvesting needs list in support of the harvesting operation IPT.

Determining harvesting needs can further be divided into the steps outlined in Figure 20. Figure 20 proposes a data-driven model that utilizes reliability block diagrams, fault tree analysis, evaluation of service life sparing requirements, and systems optimization techniques via a linear program that minimizes cost.

Figure 20. System Critical Component Sustainment Analysis Functional Flow Diagram



Ideally, the PARM would utilize this model to determine what parts should be harvested from a decommissioning asset. This model should be the road map in determining the appropriate components to harvest, overhaul, and warehouse to support system life cycle sparing requirements. This model can be utilized to support analysis upon official declaration that an in-service MCM (or any other ship class) will be slated for decommissioning and dismantling.

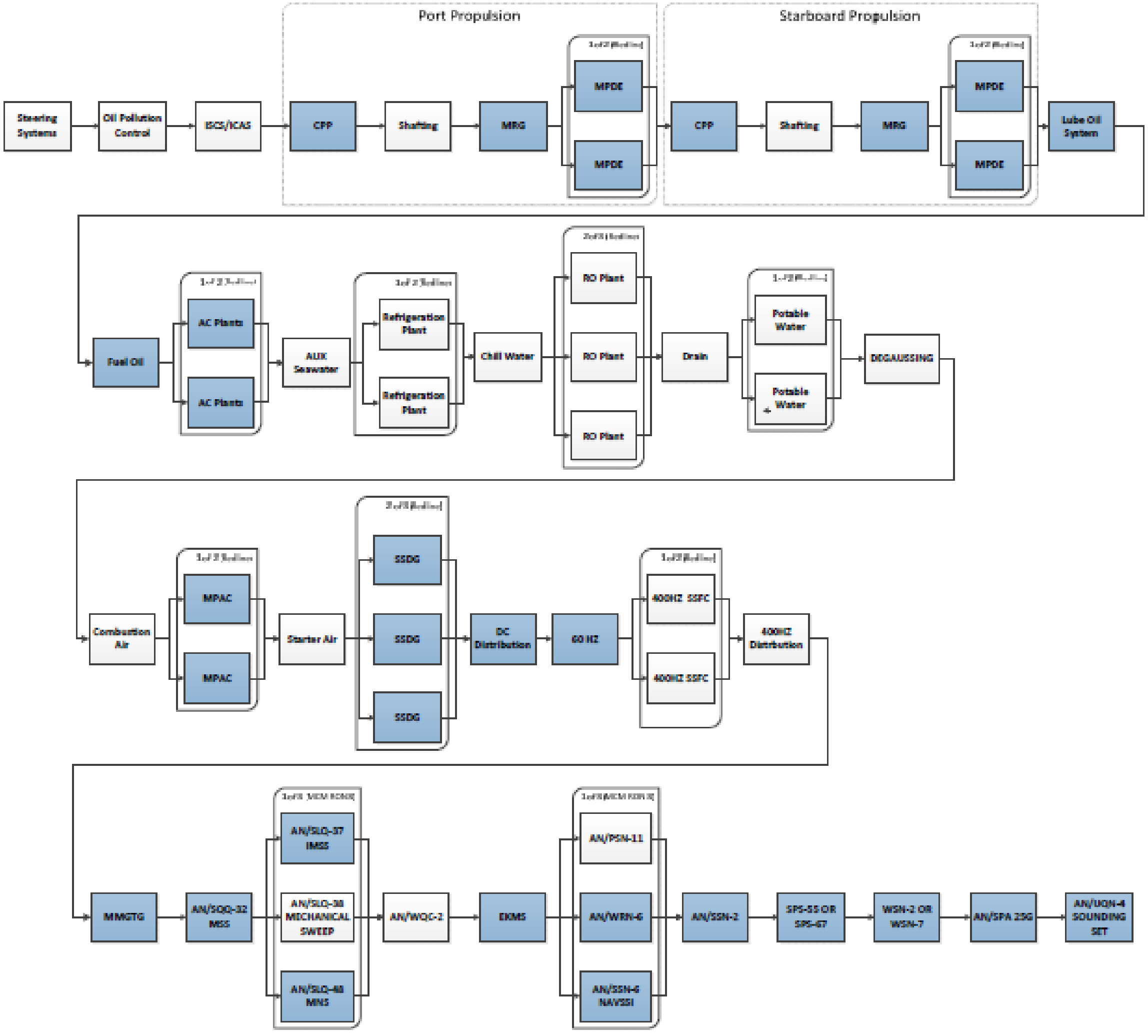
In a general sense, the top section of this model would require the PARM to commence with building a RBD for the system they are responsible for to determine system subcomponents that are limiting system reliability. The next step requires a fault tree analysis (FTA) be performed to each system subcomponent adversely affecting system reliability to help to determine the critical parts of the system.

PARMs would then use the lower section of the model in Figure 20 to determine the sparing requirement of the critical components, the quantity currently available in stock, and the number needed (if any) to meet life cycle demand. If the number required to meet life cycle demand is greater than zero, then the PARM would identify the number available to purchase and associated costs and the number available to harvest from a decommissioning asset with estimated costs. These values would be inputs to a linear program that would determine minimum cost to meet the critical part life cycle demand.

1. System Reliability Block Diagrams

To understand better what components should be harvested from a MCM prior to dismantling, it is critical to look at all factors holistically. For example, it would be beneficial to have a complete reliability block diagram for the remaining in-service ships. NSWC Corona was provided some funding to start this effort for MCMs in 2013. Unfortunately, funding has not been available to continue the effort, but Figure 21 is accurate enough to make some good observations.

Figure 21. MCM-1 Avenger Class RBD

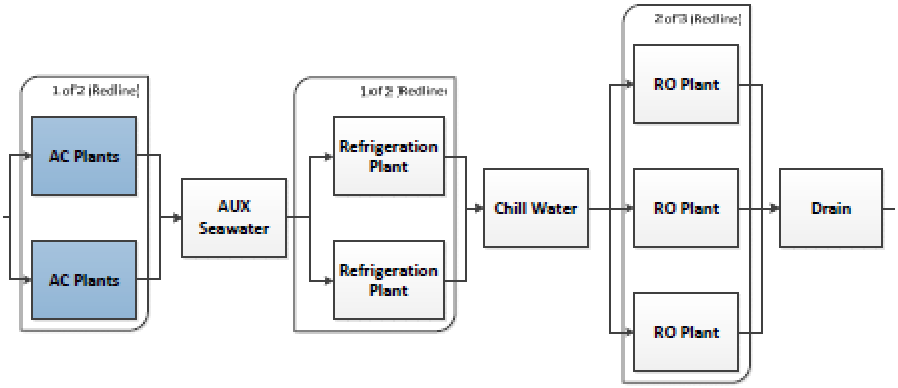


From: NSWC Corona RA16. 2013. *MCM—Platform Reliability Diagram*. 1st ed. Corona, CA: Naval Surface Warfare Center, 4.

Calculating the individual Ao for each sub-system will provide a platform level operational availability. Any in-service ship not meeting the platform 75% Ao objective outlined in Chapter III, Section F requires further analysis as to which sub-systems are impacting readiness. These areas should be scrutinized further and are potential good parts harvesting candidates.

Focusing in on just a single portion of the auxiliaries section results in something similar to Figure 22.

Figure 22. MCM Auxiliaries Section of RBD



From: NSWC Corona RA16. 2013. *MCM—Platform Reliability Diagram*. 1st ed. Corona, CA: Naval Surface Warfare Center, 4.

Breaking the platform level RBD down into manageable subsections for review will facilitate calculating warfare area reliability. To calculate the reliability of the entire platform, warfare area, or even just a small subset of the systems, the following calculations would be used.

Reliability of components in series:

$$R=R_1 \text{ x } R_2 \text{ x}\ldots R_n$$

R = Total Reliability

R_n = Reliability of part n

Reliability of parallel components:

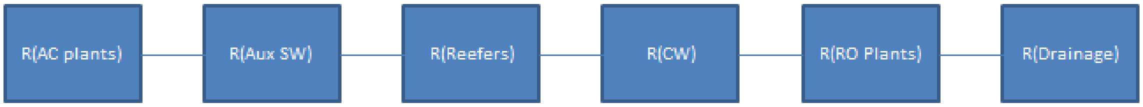
$$R=1-(1-R_1)(1-R_2)\ldots(1-R_n)$$

R = Total Reliability

R_n = Reliability of part n

To solve the reliability of the components in Figure 22, calculate the reliability of the parallel components (AC plants, refrigeration plants, and RO plants). Once the reliability calculations are completed for the parallel components, everything would be in series as per Figure 23.

Figure 23. Series View of Figure 22



This reliability analysis will demonstrate if the components comprising the systems are meeting standards. If not, the components not meeting standards could be a good area to review for possible parts harvesting on the decommissioning asset.

Operational availability of components in series can be calculated with:

$Ao = Ao_1 \text{ x } Ao_2 \ldots Ao_n$, and

Ao = Total operational availability

Ao_n = Operational availability of part n

operational availability of components in parallel:

$Ao = 1-(1-Ao_1)(1-Ao_2)\ldots(1-(Ao_n)$

Ao = Total operational availability

Ao_n = Operational availability of part n

It is important to understand, as the Ao objective is the top-level requirement to be meet. While this objective might not seem too aggressive at first glance, it is worth noting that 40 individual systems (counting the systems in parallel only one time each) are outlined in Figure 5. To meet the 75% platform Ao, each system Ao must average 0.99283375, which was calculated using the following formula.

$Ao_{platform} = .75$

$.75 = Ao_{sys\ avg}\hat{}40$

$Ao_{sys\ avg} = 0.99283375$

$Ao_{platform}$ = Operational availability of the platform

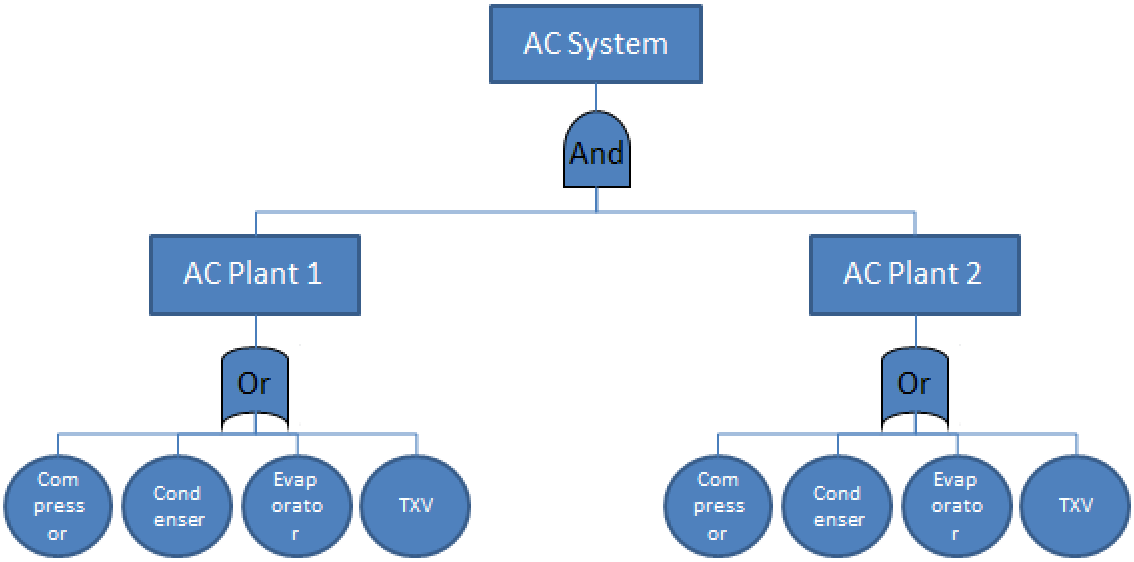
$Ao_{sys\ avg}$ = System average operational availability

Therefore, any system with an *Ao* lower than 0.99283375 should be further reviewed by the system PARM and considered a potential parts harvesting candidate.

2. Fault Tree Analysis

Any area of concern from Figures 21, 22, or 23 can be further scrutinized via FTA. If assuming that the AC plants are not meeting reliability or Ao requirements as outlined previously, a FTA can be performed to determine the components with the highest failure rate. A FTA for the AC plants is shown in Figure 24.

Figure 24. AC System Fault Tree Analysis



The fault tree states that both AC Plant 1 and 2 must both fail for the system to fail. Additionally, each AC plant has a compressor, condenser, evaporator, and thermal expansion valve (TXV). If any of these components fail, then that individual AC Plant fails. To determine the failure rate of the above systems, the MTBF figures would be required. Once the MTBF figures are known, the failure rate (λ) can be easily calculated via the equation:

$\lambda = {}^{1}\!/_{MTBF}$.

With the failure rate of the components known, the following equations would apply for system failure.

Quantitative OR Gate:

$$F_{sys} = 1\text{-}(1\text{-}F_1)(1\text{-}F_2)..(1\text{-}F_n) \therefore$$

$$F_{AC\ Plant1} = 1\text{-}(1\text{-}F_{compressor})(1\text{-}F_{condenser})(1\text{-}F_{evap})(1\text{-}F_{TXV})$$

$$F_{AC\ Plant2} = 1\text{-}(1\text{-}F_{compressor})(1\text{-}F_{condenser})(1\text{-}F_{evap})(1\text{-}F_{TXV})$$

Quantitative AND Gate:

$$F_{sys} = F_1 \text{ x } F_2 \text{ x}\ldots F_n \therefore$$

$$F_{AC\ Sys} = F_{AC\ Plant1} \text{ x } F_{AC\ Plant2}$$

$Fsys$ = Failure rate of the system

Fn = Failure rate of part n

3. Determine Critical Parts

While the system failure equations and principles are important, the components having the highest failure rates should be scrutinized as potential candidates for parts harvesting. Additionally, analysis should also include any critical component(s) in the FTA that have long lead times. This thesis argues anything greater than 90 days would be considered a long lead time. If the critical component has a long lead time or is no longer available for procurement (obsolete), and will most likely fail prior to the ship decommissioning, then it also is an excellent candidate for parts harvesting. Increasing the quantity of available critical repair parts can reduce MLDT and increase system Ao. One of the assumptions made in this paper is that the Navy supply system cannot actively keep up with demand. In the event the Navy supply system can in fact keep up with repair part demand, then the component might not be ideal for parts harvesting. The optimization model outlined in Section IX.A.g. will calculate if it is still more cost effective to harvest a given component or not.

4. Determine the Sparing Requirement

Spare parts are required to conduct both corrective and preventative maintenance. If the PARM does not know the sparing requirement for the critical parts, then the following equation will provide the required information:

$$P = \sum_{n=0}^{s} \left[\frac{R(-lnR)^{n}}{n!} \right]$$

"P = probability of having a spare of a particular item available when required

S = number of spare parts carried in stock

R = composite reliability (probability of survival); $R = e^{-K\lambda t}$

K = number of parts used of a particular type

ln R = natural logarithm of R" (Blanchard and Fabrycky 2011, 518)

$$\lambda = \text{failure rate} \left[\frac{number\ of\ \ failures}{total\ operating\ hours} \right].$$

"In determining spare-part quantities, one should consider the level of protection desired (safety factor). The protection level is the P value in the above equation. This is the probability of having a spare available when required. The higher the protection level, the greater the quantity of spares required" (Blanchard and Fabrycky 2011, 518).

A more practical method of determining the number of spare parts required would be to use Appendix A, the Sparing Requirement Quantity Determination Model. The objective of this model is to establish the sparing requirement of a unique critical part. Users of this model will need to input data to facilitate the summation of all $\mathrm{K}\lambda\mathrm{t}$ values where K = the number of parts used of a particular type, λ is the failure rate of the part, and t is operating time left in the system service life. For example, assume 10 MCM-1 class ships remain in-service and a given system (compressed air) has two pieces of identical equipment (MPAC) that have four identical and unique parts per compressor. Therefore, solve for K using the equation:

$K = M$ x P
K = 2 x 4
K = 8 unique parts per ship
K = the number of parts used of a particular type per ship
M = number of MPACs per ship
P = Number of parts used of a particular type per MPAC

Further, the t value (operating time left in system service life) would be based on each vessel's decommissioning date or system service life schedule if the system and/or equipment will be replaced prior to ship decommissioning. Solve for t using the equation:
t for each ship= *# of days remaining in service life* x *operating hours/day*
Therefore, t will have 10 unique values (one per MCM remaining in service). Most likely for this example, λ will remain constant for all 10 entries. To summarize the first example, a total of 10 entries would appear in the Data_Entry worksheet of Appendix A where K would = 8, λ would be the same for each entry in #failures/hr, and t would be the operating time left in the system service life for each ship.

A second example is simply to keep adding to the above example. Assume that the LCS has the exact same MPAC, with the same critical part, which needs to be included in the sparing requirement analysis. In this case, simply find the new value for each variable (K, λ, and t). The total number of entries will be then 10 MCM entries plus the number of LCS entries. All these values will be input into the Data_Entry worksheet.

Once the data entry has been completed in the Data_Entry worksheet of Appendix A, users simply need to click on the Sparing_Requirement worksheet. Go to column G in the worksheet and find "Probability of having a particular spare when required." Find the closest value to the desired probability value and read the corresponding number of spares required from Column F. If the desired probability is between two numbers in the worksheet, round up to the larger number to find the required spares.

5. Determine Current Stock and Number Needed

Once the sparing requirement is understood, the PARM would conduct a stock check of the critical parts available as per Figure 20 to determine the total number of parts needed as per the equation:
$Sparing\ requirement - current\ stock = Total\ critical\ parts\ needed.$
If any instance of the total critical parts needed is > 0, then proceed to the next step in the Figure 20 flow diagram.

6. Identify Number Available to Purchase and Number Available to Harvest and Costs

Now that the total number of critical parts needed is understood, the PARM will need to identify the number available to purchase, and associated costs, as well as the number available to harvest and estimated costs. The associated costs for each should include any contract fees, labor, repair costs, shipment, and storage costs for the estimated shelf life of the part. All these values will be used as input parameters for the optimization model in the next step.

7. Perform Optimization Utilizing Model

At this point, the information gathered through the previous steps will be input into an optimization model to determine the optimal number of parts to procure or harvest given the number available of each.

The objective of the model is to minimize cost as calculated based on the quantity of a part needed, the quantity of that part available for purchase or harvest, the expected repairable rate of harvested parts and cost of repair, the cost to harvest or purchase each, and the cost to store each. The following variables represent these values.

Input Variables:

HPC_i = Estimated cost to harvest each instance of part i

RC_i = Estimated cost to repair harvest part i

PPC_i = Cost to procure one unit of part i

$\%REP_i$ = % of harvested part i estimated to be repairable

DHC_i = Disposal cost of non-repairable harvested parts i

$HWHC_i$ = Estimated cost to warehouse for life of harvested part i

$PWHC_i$ = Estimated cost to warehouse for life of procured part i

Har_Avail_i = Total # of part i available for harvesting

$Mark\_Avail_i$ = Total # of part i available on the market for purchase

$\#Needed_i$ = Total # of part i needed for system service life

Min Cost = $(HPC_i)(H_i) + (RC_i)(H_i)(\%REP_i) + (PPC_i)(P_i) + (HWHC_i)(H_i)(\%REP_i) + (H_i)(1-\%REP_i)(DCH_i) + (PWHC_i)(P_i)$

These values can also be read as follows, since the objective is to minimize cost: where cost is equal to the cost to harvest part i multiplied by the number of parts i harvested, plus the cost to repair harvested parts i multiplied by the number of parts i harvested and the percent of harvested parts i that are repairable, plus the cost of parts i purchased multiplied by the number of parts i purchased, plus the cost to store harvested parts i multiplied by the number of parts i harvested and the percent of harvested parts i that are repairable, plus the number of parts i harvested multiplied by the number of unrepairable parts i and the cost of disposal of those parts i, plus the cost to store purchased parts i multiplied by the number of parts i purchased.

This objective function is subject to the constraints of the following:

- The number of parts harvested must be less than or equal to the number available ($H_i <= Har\_Avail_i$).
- The number of parts purchased must be less than or equal to the number available ($P_i <= Mark\_Avail_i$).
- The number of parts purchased plus the number of parts harvested (factoring in the repairable rate) must be equal to the number needed (H_i x $\%REP_i + P_i <= \#Needed_i$).
- All variables must be greater than or equal to zero (All variables >=0).
- The number of parts harvested and the number of parts purchased must be integers (H_i, P_i are integer values).

8. Iterate/Repeat Process as Necessary

The above processes outlined in Sections 4–8 are repeated for each critical part. At the conclusion, an exhaustive list will exist of the ship's critical components, the sparing requirements, the available stock, and a decision to procure or harvest any parts needed to close the delta between sparing need and spares available.

9. Ship Checks (if Required)

All applicable stakeholders are encouraged to visit the decommissioning ship(s) as resources permit to assess the condition of possible parts harvesting candidates. This assessment will aid in the harvesting spreadsheet development and will prevent unnecessary expenditure of resources where a visual assessment of the equipment is sufficient to know whether it should be harvested.

10. Consolidate Inputs

The PMS 443 harvesting manager is responsible for consolidating all inputs by PARMs and other stakeholders into a single spreadsheet. The harvesting manager shall chair a meeting to review the consolidated listing with the IPT to verify consolidated list accuracy, harvesting priority, confirm candidate component shipping addresses, and entity to harvest components. Further, the harvesting manager shall work with SEA21I to identify all components that must be harvested during the dismantling phase, as opposed to during the harvesting availability. This identification will facilitate developing the dismantling scope of work to include items that can only be removed during the scrapping operation.

B. PLAN EQUIPMENT REMOVAL

1. Establish Harvesting Operation Availability

Once the parts harvesting candidate list has been developed, the planning of equipment removal begins. The harvesting manager shall work with the appropriate TYCOM (Commander Naval Surface Forces Pacific for MCM-1 class ships) to schedule a Chief of Naval Operations (CNO) availability in support of parts harvesting operations no later than 26 months prior to ship decommissioning. The harvesting manager shall notify the TYCOM if the harvesting operations will require the ship(s) to be dry-docked or not. The RMC shall enter the availability into the Navy maintenance database (NMD) at the TYCOM direction.

2. Plan Ships Force Equipment Removal

SF personnel will usually wish to remove some of the smaller components from the ship to be decommissioned that would be beneficial to the rest of the fleet. MCMRON3 shall be the SF advocate and interface with the PMS 443 harvesting manager to coordinate equipment removal. MCMRON3 shall manage SF equipment removal operations to ensure appropriate procedures are followed and custody documentation is filled out accordingly.

3. Plan Government Entity Equipment Removal

Some equipment will be best removed directly by government entities, and could include ISEAs, RMC, or program office assigned personnel. These efforts must be coordinated and communicated by each entity with the harvesting manager no later than 60 days prior to commencement of the parts harvesting availability. The harvesting manager shall ensure all unique efforts are de-conflicted.

4. Plan Industrial Activity Equipment Removal

The TYCOM shall direct one of the MCM-1 class ship PEs to create a job in the validation, screening, and brokering (VSB) program directing the contractor to provide labor, material, and equipment required to harvest, package, and ship the equipment designated for IA removal in the consolidated parts harvesting spreadsheet provided by the PMS 443 harvesting manager. This job shall be screened to the appropriate parts harvesting availability. The RMC assigned project manager will push the job over to the 3PP activity for work specification development.

The 3PP activity will be responsible for developing the work specifications in support of the harvesting operations and providing project estimates. The work specifications shall include the removal of equipment, packaging (as required) and shipment. Specs should require contractor the project manager to coordinate all material shipment with the harvesting manager to ensure the warehouse would be manned accordingly to receive shipments.

NOTE: Some of the equipment to be harvested might require onsite SME oversight. This SME will need to be identified and funding secured to support the availability.

C. FUND PARTS HARVESTING

1. Submit POM Issue Paper

Following the planning activities, PMS 443 shall develop and submit the POM issue paper in accordance with the planning, programming, budgeting, and execution (PPBE) processes to ensure funding will be available during the parts' harvesting year of execution. This thesis argues that PMS443 should provide POMs for all harvested equipment removals to mitigate challenges where stakeholders would submit their own POMs and then only a portion of the harvesting is funded. Further, the execution of the funding of temporary services (security, warehousing, crane support) that is a shared cost across all stakeholders during an availability and any growth or new work funding is significantly simplified. The programmatic estimate for the POM submission can be based on the planning estimate provided by the 3PP.

2. Establish Contract Vehicle

The harvesting manager shall also work with the appropriate RMC to ensure a contract will be developed (if required) and in place to support harvesting operations. The RMC shall develop a contract to support harvesting operations. The technical work specifications to support the Request for Proposal (RFP) shall come from the 3PP.

3. Fund Planning/Execution

PMS 443 shall transfer funds to the appropriate RMC when required to support harvesting execution to include both contract award funding and any growth or new work during the availability. The planning costs will be covered by the MCM-1 class 3PP contract, as per the assumptions outlined in the concept of operations section of this paper.

D. REMOVE EQUIPMENT FROM DECOM SHIP

Now that the desired parts and quantities for harvesting have been identified, the operation has been planned, and funds are in place, the next step in the high-level process is to execute harvesting. This procedure assumes that the RMC will chair a WPER in according with JFMM policy.

1. SF Remove Equipment

SF shall execute the removal of any small components based on the plan that MCMRON3 coordinated with ship crews. MCMRON3 shall ensure all equipment removed is in accordance with the agreed upon plan with the harvesting manager and that all equipment removed has appropriate custody documentation. It is recommended that SF accomplish equipment removals just prior to the harvesting availability if the schedule permits, as it helps to de-conflict with industrial activity or government entity harvesting efforts.

2. GE Remove Equipment

Government entities shall coordinate all equipment removals with the RMC project manager prior to commencing work. The RMC project manager will line up all required onsite support (crane, fork truck, packaging) if required. Government entities will follow all appropriate custody documentation requirements for equipment removed and verify equipment removed with the RMC project manager and PMS 443 harvesting manager upon completion.

3. IA Remove Equipment

The RMC project manager and ship building specialists (SBSs) shall be onsite for the duration of the harvesting availability project at the contractor’s facility and manage the availability in accordance with the JFMM to ensure all work is performed as per the requirements of the availability work package. The entity harvesting equipment is also responsible for identifying, staging, and packaging the components in support of shipping as they are removed from the ship. Additionally, the contractor must keep an accurate inventory of the harvested material, as some changes to the original work scope are likely.

E. STORE EQUIPMENT (WAREHOUSING)

All the components removed during parts harvesting operations must be stored in a laydown or warehouse accordingly. During the availability, the availability work package will outline the storing requirements for all equipment removed to be staged for shipment. Each stakeholder requesting equipment to be harvested shall be responsible for storing equipment upon the completion of the parts harvesting availability and shipment to the respective facility.

F. SHIP EQUIPMENT

Once all material is harvested from the ship, it is packaged and shipped to the appropriate warehouse or repair facility. The requirements for equipment shipping will be outlined in the availability work package. The harvesting manager shall interface with the RMC project manager and each stakeholder who will be having harvested material shipped following the parts harvesting availability to ensure the destination warehouse will be appropriately manned and prepared to receive the components (fork truck operators, crane operators).

G. DOCUMENT IN ERP

All equipment removed from the harvesting operation must be documented into the Navy ERP database in accordance with applicable Operating Materials and Supplies (OM&S) procedures. Each PARM or stakeholder receiving material shall document their respective material in the ERP program.

H. REFURBISH HARVESTED EQUIPMENT

Once all harvested equipment has been shipped to its final destination, it needs to be assessed to determine if it will be overhauled and put back into RFI status, and stripped further for specific component repair/reuse, or discarded. Depending on the organization’s available resources, the refurbishment process will commence once resources are available and fleet need for the component in question. The RMC, industrial activity, and government repair depot are the three major entities that can refurbish material. All material placed into RFI status shall be documented accordingly in the Navy supply databases.

I. DISPOSE UNNECESSARY COMPONENTS

Some of the harvested components or individual component pieces will be slated for disposal following assessment. This material shall be disposed of in accordance with all applicable Navy disposal procedures.

J. WRAP-UP AND MEASURES OF EFFECTIVENESS

1. Wrap-Up

To wrap up the parts harvesting operation, the harvesting manager will conduct a closeout meeting with the IPT stakeholders within 90 days of the harvest availability end date. The meeting purpose is to provide a final consolidated listing of all parts harvested and to solicit feedback to improve the process. PMS 443 shall make any appropriate procedure updates, which will be an iterative process until the MCM-1 class ships are all dismantled.

2. Measures of Effectiveness

To determine how effective the parts harvesting process was in supporting the MCM-1 class ships, certain data shall be collected. This thesis argues that three major metrics should be tracked and analyzed to determine the parts harvesting effectiveness. The first is usage rate over time, which simply tracks the harvested parts used to make system repairs. This metric shall be tracked by each PARM. The usage rate over time metric is fundamental to improving the next two metrics, cost avoidance, and system operational availability. The cost avoidance metric calculates the costs avoided due to the availability of the harvested component. The cost avoidance equation proposed to be used is:

$CA_i = PPC_i - (AHPC_i + ARC_i + AHWHC_i$

CA_i = Cost Avoidance for part i

PPC_i = Cost to procure one unit of part i

$AHPC_i$ = Actual cost to harvest each instance of part i

ARC_i = Actual cost to repair each instance of part i

$AHWHC_i$ = Actual cost to warehouse harvested part i.

The cost avoidance metric shall also be tracked by the appropriate PARM.

The final measure of effectiveness metric is system operational availability. As stated in section III.F. of this thesis, the *Ao* equation is:

$A_o = MTBF / (MTBF + MTTR + MLDT)$.

Ao = Operational Availability

$MTBF$ = Mean time between failure

$MTTR$ = Mean time to repair

$MLDT$ = Mean logistics downtime

NSWC Corona shall track the system Ao metric. The parts harvesting manager shall poll the appropriate PARMs and NSWC Corona every 12 months to consolidate the measures of effectiveness and share them with the original IPT.

X. CONCLUSION

A. HARVESTING PARTS USING A SYSTEMS ENGINEERING PRINCIPLE-BASED PROCESS IS WORTHWHILE

This thesis began by outlining the history, threat, and importance of MIW. These three topics are the foundation as to why a parts harvesting process to help sustain the MCM-1 class ships is critical to protecting the war fighter, Navy resources and assets, U.S. allies, and this country's national security. MIW has proven to be a commonly used weapon by U.S. adversaries, has caused the most damage to U.S. Navy surface ships since WWII, and can result in significant negative impacts from economic upheaval, sea-lane restrictions, and even loss of life. Sea mines are the weapons that wait; they are costly and time consuming to clear or neutralize once laid, and can shut down traffic through a body of water just based on the threat that one exists. The U.S. ability to project force by patrolling MCM-1 class ships in a given body of water is extremely valuable in deterring an adversary of using the sea mine weapon.

The MCM-1 class ships' ability to perform mine countermeasure operations is vital to the United States and its allies. To fulfill the mission, appropriate repair parts are required to ensure the ship class is operationally ready and will meet requirements throughout ESL. One of the means to ensure adequate repair parts are available for MCM-1 class ships is to harvest components from a decommissioning ship. In some cases, it is the only economical means to obtain mission critical repair parts required to support the remaining in-service MCM-1 class ships. Due to the unique low permeability requirements, coupled with several SPFs in the MCM-1 class ships, it is extremely difficult to have adequate repair parts at the ready for some of the mission critical MCM-1 class ship systems. Several systems are so unique, such as AC compressors, that commercial suppliers will only agree to supply more if a lifetime order is placed all at once. This type of order simply is not realistic or affordable for all these parts. Without an effective parts harvesting strategy that can be implemented on each of the MCMs as they decommission, the Ao calculations will continue to decline unless exorbitant amounts of money are spent on the reverse-engineering of needed components. Therefore, parts harvesting is essential for all MCM-1 class ships to meet their ESL and provide the U.S. Navy with mine countermeasure capabilities.

To that end, this thesis proposes a procedure to harvest parts from a decommissioning MCM-1 class ship using a systems engineering process. Utilizing systems engineering principles to develop the harvesting procedure increases the probability that the procedure is executable and cost-effective. To aid in the process development, six questions were answered as follows.

- What is parts harvesting?

Parts harvesting or reclamation involves removing installed material from a decommissioning asset for re-use on in-service platforms prior to dismantling or scrapping operations.

- Why is harvesting of material from MCM-1 class ships important?

Harvesting material from decommissioning MCM-1 class ships is critical to ensuring adequate repair parts are available for the remaining in-service ships since some of these components are obsolete. Without parts harvesting, some of these components would have to be reverse-engineered, which is both costly and very time consuming. Ultimately, the lack of MCM-1 class repair parts would affect the operational availability of in-service MCM-1 class ships, which could lead to significant security and economic challenges for U.S. and allied interests.

- Does a cost effective means exists to determine what should be harvested off a decommissioning ship?

This thesis does propose a cost-effective means to harvest components off decommissioning MCM-1 class ships by predominantly using both Appendix A (Sparing Requirement Quantification Model) and Appendix B (Parts Harvesting System Optimization Model). Appendix A is a tool that determines the sparing requirement of a unique critical part by considering the quantity of a given part in use, the failure rate of the part, and the operating time left in the system service life. Using Appendix A will decrease the risk of harvesting or procuring either too many or too few unique critical parts. The quantity required is based on the aforementioned outlined criteria, coupled with a selected probability that the component will be available at a specific time.

Appendix B accounts for costs to either procure or to harvest and refurbish equipment, to include warehousing costs for either option to determine the quantity to procure and/or harvest while minimizing cost for each component. The model ensures the most cost-effective route is chosen to fulfill calculated sparing requirements. Cost-effective parts harvesting helps control sustainment costs, while still striving to meet operational availability objectives for the class.

- What systems engineering applications or principles can be applied to effectively harvest parts from MCM-1 class ships to sustain the remaining in-service ships through expected service life?

Various systems engineering principles were utilized to develop the parts harvesting procedures. The first step was to identify the problem that outlined the fact that a parts harvesting procedure does not currently exist, which led to a stakeholder analysis and stakeholder needs. Other fundamental tools utilized included functional decomposition for holistic system understanding, mapping of functions to facilitate understanding the importance and integration of the ships' systems, identification of system boundaries, and documenting assumptions and constraints, to name a few. All the systems engineering principles utilized were extremely valuable for the problem analysis required to develop the parts harvesting procedure. Using systems engineering principles confirmed the problem is worthy of solving and led to a solution that it is both executable and a cost-effective in reducing the risk of MCM-1 class ship readiness degradation prior to reaching end of service life.

- What are the constraints to an effective parts harvesting system/process?

Several assumptions and constraints must be acknowledged and accounted for when harvesting parts off decommissioning MCM-1 class ships. None is more important than recognizing the time to harvest parts from a decommissioning ship from the last operational mission to ship dismantling. This constraint is critical, as it puts a hard stop end date that harvesting operations must be completed by. One of the other important constraints is the budget allocated for the harvesting operation. If insufficient funds are provided, then some critical components will not be harvested prior to the ship being dismantled. Therefore, the opportunity will not be available again until the next ship in the class decommissions that will increase the risk of not having a critical component to support in-service ship sustainment. It is worth re-iterating that the harvesting process proposed in this thesis was designed to minimize the cost for obtaining the critical components while striving to meet Ao objectives. Failure to remove a required component recommended by the process and models provided will most likely result in increased sustainment cost than if the part had been harvested as planned. Various other constraints and assumptions were mentioned in this thesis that are important for stakeholders to understand for efficient harvesting operations.

- What are the measures of effectiveness?

The measures of effectiveness needed to measure parts harvesting efficacy are usage rate over time, cost avoidance, and system operational availability. These three metrics will clearly determine if the parts harvesting efforts are achieving the desired result, and ultimately, facilitate MCM-1 class ships fulfilling required operational commitments.

B. RECOMMENDATIONS

This thesis recommends that the Surface Navy commit to sustaining the MCM-1 class ships by implementing the parts harvesting procedure described in Chapter IX to reclaim required components off decommissioning assets. While the Navy has conducted various harvesting operations in the past few years, they have all been accomplished in an ad hoc fashion with varying results. The parts harvesting procedure outlined in Chapter IX can be implemented to support harvesting components from the next planned MCM-1 class ship decommissioning in FY19. Based on the notional timeline provided in Chapter IV.H, the identification of components to harvest and estimated cost to support the POM process would have to commence in the second quarter of FY16. Establishing the harvesting operation integrated product team will be one of the first actions. Primary stakeholders that would fulfill the major functions are depicted in Table 7.

Table 7. Parts Harvesting Operation Major Functions to Stakeholders Mapping

PARTS HARVESTING OPERATION

Harvesting PM: SEA21 PMS443

Phase	Stakeholders
Determine Harvesting Needs	PMS443, System PARMs
Plan Equipment Removal	PMS443, RMC, 3PP
Fund Parts Harvesting	PMS443, OPNAV N95
Remove Equipment from DECOM ship	RMC, PMS443, Repair contractor
Store Equipment	System PARMs
Ship Equipment	Repair Contractor
Document in ERP	System PARMs
Refurbish Harvested Equipment	RMC, Repair KTR, Sys. PARMs
Dispose Unnecessary Components	System PARMs
Measure Harvesting Effectiveness	NSWC Corona, System PARMs, PMS443

C. AREAS FOR FURTHER STUDY

Three main areas are recommended for further study. The first is to utilize the MCM parts harvesting procedure outlined in this thesis and modify it to facilitate a surface-wide Navy NAVSEA instruction to facilitate cost-effective parts harvesting operations that will provide the following:

- Help sustain all Surface Navy ships by providing mission critical spare parts.
- Reduce re-work trying to figure out how to go about harvesting parts due to a lack of written guidance.
- Employ technical rigor that includes a feedback loop for procedure improvement.
- Provide leadership confidence that infrequent harvesting operations are adequately planned and managed to achieve the desired outcome.

The second area for further study is the need for the Surface Navy to utilize RBDs as the means for systematic evaluation of surface ships at the platform level. Utilizing RBDs to analyze a system of systems provides clarity on which areas/systems require further analysis via FTA to determine problematic components. This analysis is critical to sustaining the various classes of ships and ensuring initiatives to improve readiness are actually working.

The third and final area for further study is the need to investigate whether the MCM-1 class ships should be placed in an inactive status and remain pier-side until the entire class decommissions versus being dismantled immediately following decommissioning. If this option were deemed feasible (not currently part of any known Surface Navy plans), parts could be taken off the decommissioned ships as budgets and port industrial workload supported. This process could potentially save money when compared to parts harvesting operations all at once prior to dismantling. However, any potential savings would be countered by the costs to maintain the ships in an inactive status pier-side. These costs would have to be calculated to determine if any true cost savings could be realized. Lastly, it is worth mentioning that the ability to extend the MCMs' service life if need be due to any delays in LCS MIW MP, unforeseen budget cuts, or some other unknown event, would be much more feasible if the decommissioned assets were available for extensive harvesting operations or even re-activation.

XI. SUPPLEMENTAL

A. MODEL FOR DETERMINING SPARING QUANTITY REQUIREMENTS

The purpose of this model is to establish the sparing requirement of a unique critical part based on the quantity of that part in service, the anticipated failure rate, and the remaining service life. This is a Microsoft Excel model with three tabs. The first tab provides instructions to the user on how to complete the inputs and run the model. The Data_Entry tab is where the user will enter the known or estimated quantity of a critical part on the ship, expected failure rate of the part, and remaining service life of the ship. There is one entry for each ship. Once the data entry has been completed, users simply need to click on the Sparing_Requirement worksheet. Go to column G in the worksheet and find "Probability of having a particular spare when required." Find the closest value to the desired probability value and read the corresponding number of spares required from Column F. If the desired probability is between two numbers in the worksheet, round up to the larger number to find the required spares. This can be repeated for each critical part on the ships. This information will then be used in the Model for Parts Harvesting System Optimization. Those interested in obtaining this supplemental model should contact the NPS Dudley Knox Library.

B. MODEL FOR PARTS HARVESTING SYSTEM OPTIMIZATION

The purpose of this model is to provide a decision of the quantity of a given part to either harvest from a decommissioning ship or purchase to help maintain the operational units at the lowest cost. The objective is to minimize cost as calculated based on the quantity of a part needed, the quantity of that part available for purchase or harvest, the expected repairable rate of harvested parts and cost of repair, the cost to harvest or purchase each, and the cost to store each. It is also a Microsoft Excel model with two tabs. The first tab provides instructions to the user on how to complete the inputs and run the model. The user will input the appropriate values on the Parts Harvesting Model tab and then use Solver to run the model and obtain an optimal solution for quantity of procuring or harvesting a given part that can be repeated for each critical part on the ships. Those interested in obtaining this supplemental model should contact the NPS Dudley Knox Library.

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