8696

108236

REPORT BY THE

Comptroller General

OF THE UNITED STATES

The Navy Overhaul Policy -- A Costly Means Of Insuring Readiness For Support Ships

The House Committee on Appropriations requested GAO to compare naval maintenance costs and practices for support craft with those of commercial shipping firms.

Navy maintenance costs for amphibious and auxiliary ships and equipment generally greatly exceed the costs of maintaining their commercial equivalents. Most of these costs are incurred during overhauls to insure reliable equipment operation during the ship's next operating cycle.

Many support ships have missions similar to commercial ones. During mobilization, the Navy plans to use some of these commercial resources. Commercial firms employ a prudent-risk maintenance policy that has reduced maintenance costs significantly and may well have application to naval maintenance.

0 02971

LCD-78-434
DECEMBER 27, 1978

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-133170

The Honorable George H. Mahon
Chairman, Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

This report compares maintenance costs and practices for U.S. Navy support ships with those for American-flag commercial ships, as you requested on October 19, 1977.

This report points out that the Navy's maintenance costs for support ships and equipments greatly exceed the costs of maintaining their commercial equivalents. And, the Navy should consider other alternatives to reduce the maintenance cost of support ships.

As you requested, we did not obtain written comments from the Department of the Navy. However, we did discuss matters contained in the report with Navy and commercial shipping company officials.

As arranged with your office, copies of this report are being sent to the Chairmen, House Committee on Armed Services and Government Operations and to the Chairmen, Senate Committees on Appropriations, Armed Services, and Governmental Affairs. Copies are also being sent to the Director, Office of Management and Budget, and to the Secretaries of Defense and the Navy. Copies will be available, upon request, to other interested parties.

Sincerely yours,

Elmer B. Staats

Comptroller General
of the United States

Pick up committee not chairman

COMPTROLLER GENERAL'S
REPORT TO THE
COMMITTEE ON APPROPRIATIONS
HOUSE OF REPRESENTATIVES

THE NAVY OVERHAUL POLICY--A COSTLY MEANS OF INSURING READINESS FOR SUPPORT SHIPS

D I G E S T

The Navy spends over $3 billion annually on maintenance to keep its fleet of about 460 ships up to date and combat ready. This expensive ship maintenance cost has been a concern of the Congress. To get greater visibility, the Congress directed the Secretary of Defense in the 1978 Defense Appropriations Authorization Act to better relate readiness to the maintenance effort.

In striving to reduce costs, the Navy has adopted the commercial aircraft maintenance concept to perform only those tasks necessary to retain design levels of safety and reliability. Using this concept, commercial airlines have greatly reduced maintenance costs and improved aircraft availability. By applying commercial maintenance practices to Navy support ships having similar mercantile equivalents, such as tankers and cargo vessels, lower maintenance costs may be achieved while still sustaining readiness levels.

Though Navy support ships operated much less than their mercantile counterparts, in general they cost much more to maintain.

--Navy ships are at sea about 20 percent of the time while commercial ships are at sea 40 to 70 percent and

--Navy's maintenance costs per ship average about $2 million a year compared to about $400,000 a year for a commercial ship.

Some of the disparity in cost derives from the difference in mission: Navy ships operate, as in a combat environment, with numerous battle systems and armaments, large crews and extensive equipment backup capability.

However, some of the additional expense is due to the Navy's policy of regularly overhauling

costly but equally effective philosophy. Further, the Secretary should require the Navy to:

--Evaluate the role of support ships in the fleet structure and assess supplemental use of commercial ships.

--Define the mix and reliability requirements of mission-essential equipment.

--Evaluate the costs of various levels of reliability.

--Better define equipment backup capability and requirements according to mission-essentiality and the probability of equipment failure.

--Make detailed engineering analyses to determine the optimum frequency and level of reliability-centered repair for key ship systems and equipment and establish appropriate reliability goals.

--Better determine the impact of deferred maintenance on readiness and maintenance.

--Increase the use of various equipment-monitoring techniques.

AGENCY COMMENTS

As requested by the House Committee on Appropriations, GAO did not solicit written comments from the Departments of Defense and the Navy. However, matters contained in this report were discussed with Navy officials. They said that the report does not take into account the basic differences between the Navy's combat support ships and merchant ships. Navy officials further added that the differences are so extensive that, if properly analyzed, they would clearly show why the Navy's maintenance costs must be greater than those of merchant ships.

The mission differences between Navy support ships and merchant ships as well as some reasons why the maintenance costs for Navy support ships and equipment--a policy related to the need for military readiness during their next operating cycle. Mercantile firms maintain their vessels according to a "prudent-risk" determination that is related to the need for profit and results in significantly lower maintenance costs than those of similar Navy ships.

As commercial vessels are similar in structure and perform some of the same functions as naval support ships, the commercial shipping prudent-risk policy may well have application to naval maintenance.

The Navy has not adequately analyzed its readiness requirements in relation to maintenance expenditures, nor has it developed an adequate system of quantifiably measuring readiness. At present, the Navy does not know what levels of reliability can be obtained and various alternatives have not been adequately considered.

The Navy's maintenance policy has evolved without systematically considering the

--probability of equipment damage and failure,

--maintenance consequences of various types of damage and failure,

--effect of equipment damage or failure on various ship missions and readiness levels, and

--extensive facilities available for repairs between overhauls.

The Navy needs to devise a new, comprehensive ship maintenance policy that incorporates these concerns.

RECOMMENDATIONS

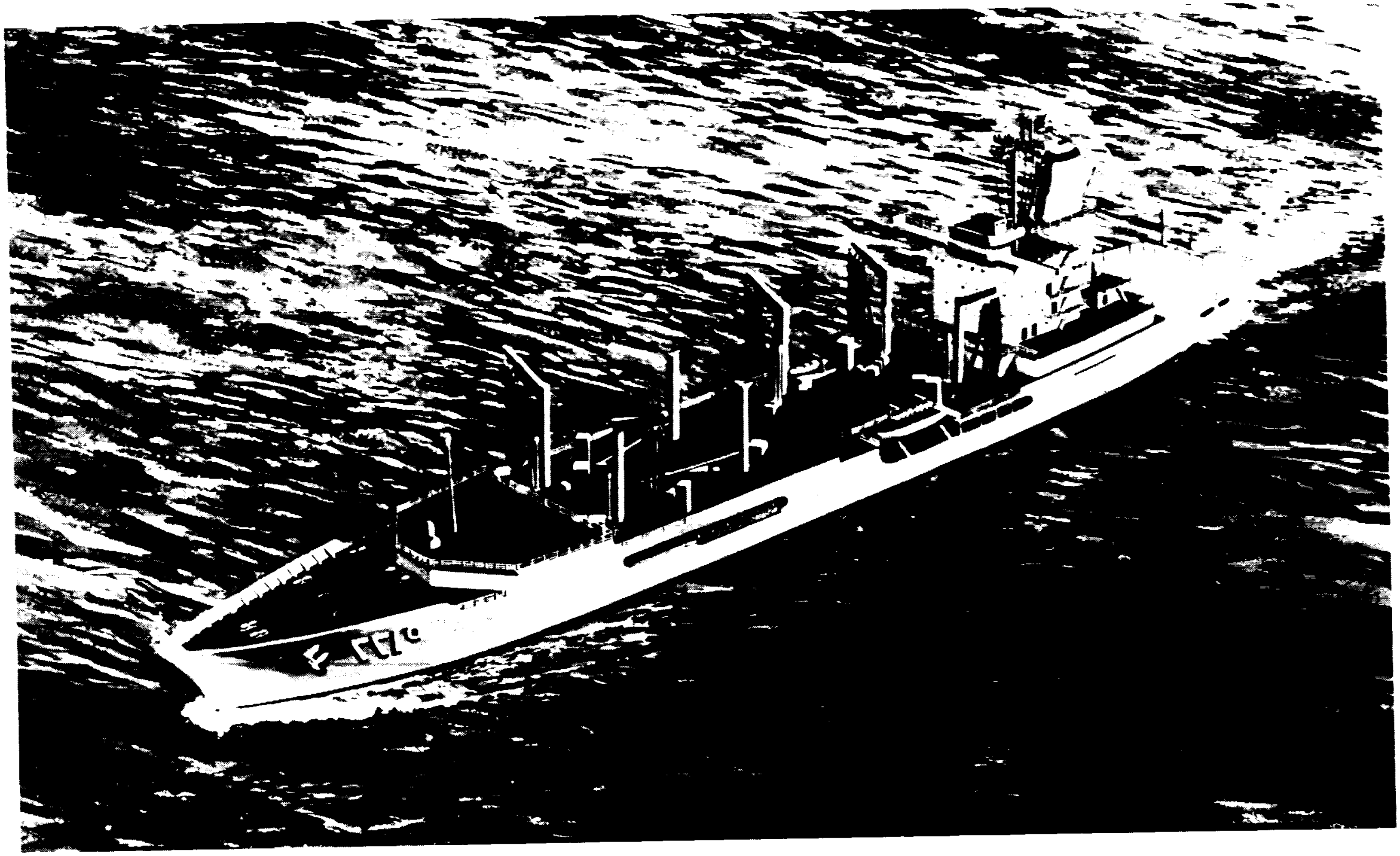
The Secretary of Defense should require the Navy to assess its policy of regularly overhauling amphibious and auxiliary ships with a view toward adopting a potentially less

Contents

ships exceed those of commercial ships are included on pages 28 to 37.

The principle of the reliability-centered maintenance concept, which was first used by the commercial aircraft industry and later endorsed by the Secretary of Defense, is to perform only those tasks necessary to retain design levels of safety and reliability (see p. 13). Using this concept, commercial airlines have greatly reduced maintenance costs and improved aircraft availability. Until the Navy implements a ship maintenance policy that incorporates factors used as part of the reliability-centered maintenance concept, it may well be spending a great deal for a small increase in reliability.

Furthermore, the Navy cannot adequately justify overhauls and other maintenance costs since it cannot link budget requests to readiness levels. The 1978 Department of Defense Appropriations Authorization Act required the Secretary of Defense to develop quantifiable material readiness requirements for the Armed Forces so that resources could be better linked to readiness.



ARTIST'S CONCEPT OF NAVY'S NEW FLEET OILER

COURTESY OF DEPARTMENT OF THE NAVY

Page

APPENDIX

ABBREVIATIONS

AO	Navy tanker
CASREP	casualty report
GAO	General Accounting Office
MSC	Military Sealift Command
NATO	North Atlantic Treaty Organization

CHAPTER 1

INTRODUCTION

The Navy spends a tremendous amount of money and effort keeping ships up to date and combat ready. At the end of fiscal year 1978, the Navy is expected to have an inventory of about 452 ships. This inventory includes aircraft carriers, cruisers, destroyers, frigates, submarines, and various combat support ships, such as oilers and ammunition ships. In fiscal year 1977, the Navy spent about $3.3 billion at the organizational, intermediate, and depot maintenance levels to maintain and modernize its ships.

Over 60 percent of the total ship maintenance and modernization 1/ expenditures are for standard depot-level maintenance. In fiscal year 1977, the depot program was about $2.1 billion. About 70 percent of this budget is used in naval shipyard facilities and about 30 percent is to pay for contracting with private industry for depot-level maintenance.

The high cost of maintenance has become a major concern to the Congress, as well as the Navy. As a result, the Navy must find less costly maintenance strategies that can insure the desired level of fleet readiness. It has already adopted certain commercial aircraft maintenance practices for some Navy airplanes that have reduced their maintenance costs, increased their availability, and attained a desired readiness level.

In light of this, the Chairman of the House Committee on Appropriations requested us to compare maintenance practices for U.S. Navy auxiliary and amphibious ships with those for American-flag commercial ships. The Committee also asked us to obtain and compare statistical data on overhaul costs

---

1/Basic naval policy is to perform ship maintenance at the lowest practical and effective level. There are three maintenance levels: organizational, intermediate, and depot. At the organizational level, the ship's crew performs shipboard maintenance. Intermediate maintenance--by tenders, repair ships, and others--is also performed by Navy personnel. Depot maintenance occurs at shipyards and is performed mainly by civilians.

As the basis of our review, we compared data on 58 Navy support ships 1/ and 151 commercial tankers and general cargo vessels. The selected Navy ships represented a variety of craft, such as oilers and ammunition ships, which support the aircraft carriers, cruisers, destroyers, frigates, and submarines of the fleet. As of January 1978, 169 of the Navy's active fleet were amphibious and auxiliary ships. Of these 169 support vessels, we analyzed 58 (about 34 percent), that fulfilled two criteria:

--They had been scheduled for and completed an overhaul in 1976 and 1977.

--They had undergone a previous overhaul or post-shakedown availability since January 1, 1970.

Appendix IV presents the individual characteristics of these selected ships.

For 1976 and 1977, these support ships represented a maintenance investment of $750 million. The table on the following page breaks down this cost into various maintenance expenditures.

1/We excluded certain Navy ships from our analysis because no commercial equivalents, such as amphibious Assault Ships (LHA), existed. Furthermore, the Navy objected to including other amphibious ships, Command Ships and Transport Docks Ships, in our comparison, but, as can be seen in appendix IV, these ships have certain characteristics similar to many commercial ships. In this report, we use the term support ships to include both auxiliary and selected amphibious ships.

and practices for Navy ships overhauled primarily in private yards with those for similar commercial ships. (See app. I 1/.)

OBJECTIVES OF THE REVIEW

The comparison of the Navy and private maintenance costs and practices led us to review several aspects of the Navy's overhaul policy. As a result, this report deals largely with the Navy's practice of overhauling to insure the readiness of its support ships. In this regard, we addressed the following subjects:

--The essentiality of various equipment to the support missions.

--The effect of equipment malfunction or failure on various ship missions.

--The likelihood of equipment malfunction or failure.

--The built-in equipment backup capability.

--The availability of equipment-monitoring techniques and repair facilities.

--The availability of alternative resources.

Though we limited our review to Navy auxiliary and amphibious ships, some basic issues addressed could be applied to other Navy ship maintenance programs.

SCOPE OF REVIEW

Navy sources

To obtain the information necessary for comparison and review, we met with key Navy personnel at command and support offices. (See app. II.) We also reviewed various Navy documents and procedures concerning ship maintenance, including reports by consulting firms under Government auspices. (See app. III.)

1/GAO report LCD-78-433 covers the portion of the request dealing with the multiyear/multimillion-dollar consulting contract.

reports we requested, the Navy provided only 29. Of the 29 reports provided, only 18 were complete and accurate enough for us to derive cost data for individual equipment. Navy officials said that funding restrictions caused preparation of departure reports to be given low priority.

Commercial sources

To gain data on commercial maintenance procedures we interviewed officials from merchant shipping firms, ship architectural firms, and repair facilities. We also met with representatives from the Maritime Administration, the U.S. Coast Guard, and the American Bureau of Shipping.

Several maintenance studies for the Maritime Administration which we reviewed stated that lack of data had hindered its analyses of commercial ship maintenance practices. However, through the cooperation of the commercial sector and the Maritime Administration we were able to obtain data on ship maintenance policies, practices, and costs.

The commercial ships that we compared with Navy support ships were all chosen from privately owned, active, oceangoing American-flag merchant vessels. As of February 1, 1978, these ships numbered 533. We selected 7 of the larger ship operators for review; in total they operate 151 of the active, private, oceangoing American merchant fleet. Of these, we obtained detailed information from two oil companies and three general-cargo ship operators owning 96 vessels. Individual ship characteristics are presented in appendix IV.

TABLE 1

1976 AND 1977 MAINTENANCE EXPENDITURES FOR 58 NAVY SUPPORT SHIPS (note a)

TYPE OF EXPENDITURE	COST (millions)	PERCENT OF TOTAL
Overhaul repairs	$402.8	53.7
Overhaul modernization	130.6	17.4
Intermediate maintenance and parts	120.1	16.0
Organizational maintenance	95.9	12.8
TOTAL	$749.4	b/100.0

a/ Not included in this analysis is the work done by military personnel during overhaul and during modernization between overhauls.

b/ Does not add due to rounding.

Our analysis of Navy maintenance expenditures was hampered by our lack of confidence in Navy source data. Costs used represent amounts charged to particular accounts, rather than work definitely performed. For example, in March 1978, we reported that naval shipyard labor was being charged to incorrect job codes. 1/ In previous reports, we have also questioned the validity of the Navy's automated statistical systems, such as the Maintenance and Material Management system, used to manage organizational and intermediate maintenance. 2/

In addition, our comparisons of equipment costs were severely restricted by the lack of Navy departure reports. According to Naval Sea Systems Command Instruction 4790.2, overhaul-departure reports must be prepared within 60 days of completing a ship's overhaul. However, of the 58 departure

1/"Naval Shipyards--Better Definition of Mobilization Requirements and Improved Peacetime Operations are Needed," (LCD-77-450, Mar. 31, 1978).

2/"The Navy's Intermediate Ship Maintenance Program Can Be Improved," (LCD-77-412, Sept. 23, 1977).

--What repair capability exists at shore and mobile intermediate levels as well as at the organizational level?

--How much capability exists in friendly ports?

--What are the costs of various reliability levels?

MISSION REQUIREMENTS

Overhaul requirements for support ships must be viewed in the context of the Navy's total need for these ships. In this respect, the Navy has not adequately considered several less costly alternatives that may reduce reliability requirements. These alternatives include reliance on U.S. merchant vessels as well as host-nation support ships.

U.S. merchant vessels--a reliable and less expensive supplement

We believe that U.S. merchant ships are a viable supplement to strict reliance on Navy support ships because:

--The Navy anticipates using commercial assets during wartime.

--Commercial ships are reliable, less costly to maintain, and can perform support missions effectively.

The preamble of the 1936 Merchant Marine Act states that:

> "It is necessary for the national defense and development of its foreign and domestic commerce that the United States shall have a merchant marine * * * capable of serving as a naval and military auxiliary in time of war or national emergency * * *. It is declared to be the policy of the United States to foster the development and encourage the maintenance of such a merchant marine."

While this declaration of policy does not place the burden of achievement on the Navy, the Navy can obviously do much to help the merchant marine serve as a naval auxiliary. One way would be to let the merchant marine provide more fleet support services.

CHAPTER 2

ISSUES ON THE EXTENT OF RELIABILITY

NEEDED FOR NAVY SUPPORT SHIPS

Generally, Navy maintenance costs for amphibious and auxiliary ships and equipment greatly exceed the costs of maintaining equally sized commercial tankers and cargo ships, even though Navy ships operate much less often. Some of the differences can be attributed to the missions assigned. The Navy, as an arm of national defense, must acquire, maintain, and modernize equipment and systems not found on commercial ships, and perform operations peculiar to the military. In the Navy's efforts to maintain combat readiness, it has adopted a maintenance policy which requires periodic, extensive upgrading of vessels and equipment--even those satisfactorily operating--to new condition. The major costs of these efforts, incurred during ship overhauls, are attributable to insuring reliable equipment operation during the next operating cycle. However, the Navy does not know what levels of reliability are attained with various alternative resources. Furthermore, there may be less costly alternatives available to the Navy to meet its needs for support ships, such as greater reliance on U.S. merchant vessels, as well as host-nation support.

A primary issue in determining Navy overhaul requirements is what level of equipment reliability is needed for support ships. In assessing these reliability needs, the Navy has to quantify its readiness requirements as well as the probability and maintenance consequences of equipment failure. Some factors that should be considered are:

--How critical are support missions?

--To what extent can commercial ships be used?

--To what extent will equipment performance be degraded?

--How serious will such degradation be?

--To what extent are backup systems available?

--How many mission areas does the equipment affect?

--What is the likelihood of equipment failure and what level of repair will be required?

--experienced no equipment or machinery casualties.

As discussed in chapter 3, we also found that U.S. merchant ships are less costly to maintain and that they operate more than similar types of Navy support ships. Some of the cost differences result from differences in mission, as discussed in detail in chapter 4.

Navy officials cited numerous reasons for their reluctance to expand the merchant tanker's role in the area of underway replenishment. At the top of the list was the tanker's inability to effectively transfer fuel to any ship in the fleet at a rate compatible with the Navy oiler. Other objections to the use of commercial tankers include

--the lack of features such as armament, greater compartmentation, and redundancy of essential components, systems, and equipment;

--the merchant tanker's inability to do 20 knots;

--lack of necessary communications equipment;

--less command and control compared to Navy ships; and

--the merchant crews inability to conduct operations requiring security clearances.

According to Navy officials, the oiler must be able to operate with the combatant fleet, replenish the fleet with clean fuel, and conduct this operation, when required, in less than ideal sea states and/or in combat situations.

Availability of commercial tankers in a contingency is questionable since there are no provisions for obtaining this capability other than voluntary charter. Several alternatives have been suggested, but not acted on. One means of assured early tanker availability in a contingency is to resurrect an allocation plan under which commercial tankers would be made available to the Department of Defense. Such a plan was last used during the Korean War. It has also been proposed that some tankers be placed in the National Defense Reserve Fleet, thereby reducing the burden that would be on U.S. merchant marines. A recent GAO report 1/ contains a

---

1/"Navy Should Reconsider Plans to Acquire New Fleet Oilers and Ocean Tugs," (LCD-78-234A, Aug. 30, 1978).

The Navy has studied the need for several types of support ships, including oilers and tugs. 1/ Its studies show that U.S. merchant vessels are a viable alternative to strict reliance on Navy support ships. More specifically, these studies found that:

--Merchant ships are more economical than Navy support ships and, if modified, can replenish combat ships almost as quickly as Navy ships.

--Increased reliance on the commercial sector presents a moderate risk, but an effective force is possible.

--In peacetime, if the Navy built or chartered fully modified merchant ships, more than $600 million could be saved over a 10-year period.

Further, the Navy tested and proved the effectiveness of the merchant marine under a charger log program that provides merchant tasks while underway. Between 1971 and 1977, Military Sealift Command (MSC) controlled tankers conducted more than 90 underway replenishment operations, with most of the tankers operated by contract union crews and many of the tankers chartered from the merchant fleet.

The Navy conducted the first demonstration under the charger log program during a 2-month period in 1972. A chartered commercial tanker, the SS Erna Elizabeth, refueled 40 U.S.-and North Atlantic Treaty Organization (NATO) combat ships to show that merchant marine tankers can perform underway replenishment and can resupply naval forces at sea. During this test, the Erna Elizabeth

--delivered about 10 million gallons of petroleum, oil, and lubricants without contamination;

--met all commitments on time;

--sailed more than 12,000 miles;

--maintained replenishment speed;

--experienced no personnel injuries; and

1/Center for Naval Analysis, "Role of Merchant Ships in Wartime Defense Missions," 1972; Chief of Naval Operations (sponsor), "UNREP Requirements and Forces Study--1984," July 1975.

cannot precisely evaluate the effects of differing maintenance strategies on maintenance costs and the performance of operating ships, subsystems, and components. Improvements are underway, but they will not be completed in the near future.

The Navy also has no index of overall material condition, even though the material condition of ships is a major justification for scheduling an overhaul. In a prior report, 1/ we found that the maintenance workload at the intermediate level did not increase during the Vietnam conflict. The Navy said this was because much required maintenance was deferred and the ships operated in a reduced material condition. This Navy response concerning deferred maintenance highlights several factors in overhaul decisions:

--How seriously does equipment degradation affect the ship's missions?

--How critical is certain equipment to support missions, should failure occur?

--How many mission areas will the equipment affect?

--To what extent are backup systems available?

The Navy could better assess its reliability requirements if these factors were adequately considered.

PROBABILITY OF EQUIPMENT FAILURE AND MAINTENANCE CAPABILITY

In determining overhaul requirements, the Navy has not adequately assessed the likelihood of equipment failure, the level of repair that will be required, or the maintenance capability that exists at the intermediate and organizational levels as well as host-nation facilities. The likelihood of equipment failure can be estimated by using equipment-monitoring techniques and by expanding the equipment maintenance data system to apply to overhaul decisions.

However, without these detailed assessments, the Navy has adopted a philosophy of high-cost equipment overhauls to better insure reliability during operating cycles. As a result, equipment that is operating satisfactorily or

---

1/ "The Navy's Intermediate Ship Maintenance Program Can Be Improved," (LCD-77-412, Sept. 25, 1977).

further discussion on the use of the merchant marine to increase Navy capability.

Although the Navy is reluctant to rely on U.S. merchant ships, Navy officials explained they are transferring a Navy fleet oiler (AO 143) to the MSC to be operated by civilians. The fleet oiler is designed to carry and transfer a single petroleum product to other ships, primarily to multiproduct ships, which in turn refuels combatants and other ships. MSC is currently converting the oiler for civilian manning and will convert four additional oilers in fiscal years 1979 and 1980. Navy officials explained that the transfers will continue, at approximately two per year, provided civilian operation of the ships continue to be advantageous to the Navy as a means of lowering costs and military manpower requirements.

Host-nation support

Another supplement to Navy support ships would be the commercial and military fleets of North Atlantic Treaty Organization countries. The Navy assumes that each country will provide support for its navy. However, the NATO vessels at times would probably be available to the U.S. Navy for short missions. Reliance on allies could reduce mission requirements for Navy support ships.

MATERIAL READINESS/ CONDITION REQUIREMENTS

Without quantified material readiness/condition requirements and analyses, the Navy cannot adequately justify overhauls and other maintenance requirements and costs. In this respect, the Congress, in the Department of Defense Appropriations Authorization Act, required the Secretary of Defense to develop quantifiable material readiness requirements for the Armed Forces.

In a prior report, 1/ we found that the Navy's method of defining, measuring, and reporting readiness is in a state of flux. (See app. V for additonal GAO reports on readiness reporting problems). The Department of Defense is currently unable to analytically link alternative resources to levels of readiness. Without this capability, the Navy

1/Letter Report to Chairman, Senate Committee on Armed Services, (B-133170, Mar. 15, 1978).

Navy aircraft, showed an increasing rate of accidents and incidents after periodic depot-level maintenance. Specifically, there was an 8-percent increase in the accident rate and a 24-percent increase in the incident (less serious than an accident) rate during the 5 quarters after depot maintenance, compared with the 5 quarters before depot maintenance.

Less maintenance effort is possible

Reliability-centered maintenance (also called analytical maintenance or condition monitoring) has become an acceptable industry and the Department of Defense means of using maintenance resources. The principle is to perform only those tasks necessary to retain design levels of safety and reliability. The airline industry developed this new maintenance concept to maintain the wide-bodied jumbo jets but found that it also applied to older aircraft. As a result the airlines are now using it widely to achieve economy and increased safety. The Navy is applying this concept to its aircraft. 1/

Before the new concept was developed, airline maintenance of less complex aircraft was dedicated to totally preventing component failure. Maintenance programs were built around various time intervals--flight hours or calendar days--established to prevent component failures. Scheduled maintenance became an extensive disassembly and overhaul of each aircraft. Component parts were replaced without regard to their actual condition. This kind of maintenance was expensive in both labor and material costs.

The advanced-maintenance concept is based on the assumptions that:

--Safety and reliability characteristics are inherent in design, and good maintenance can only preserve these characteristics.

--Scheduled maintenance is not always effective, desirable, or economical.

--A large percentage of aircraft components can fail without degrading flight safety or economy.

1/"Management Action Needed in the Department of Defense to Realize Benefits From a New System of Aircraft Maintenance," (LCD-76-443, Nov. 1976).

with only minor problems may be overhauled. For example, on one ship, the preoverhaul inspection team recommended overhauling a backup (emergency) piece of equipment primarily because this had not been done since the ship's last overhaul. However, the ship's crew stated that the equipment was functioning without any problems, the equipment was not tested during the inspection, and the inspection team had no equipment histories that would indicate a failure was likely in the near future.

In addition to overhauling equipment that is operating satisfactorily, we also found an overhauling philosophy for equipment with minor problems. For example, during one ship's preoverhaul inspection, a pump would not adjust to pressure changes. Although the pump's governor had already been unsuccessfully overhauled twice, the inspection team recommended overhauling the governor, pump, and another major component. The overhauling was expected to correct the pressure problem as well as to increase the pump's reliability during the ship's next operating cycle. This approach to maintaining Navy ships--high cost equipment overhaul--still may not be insuring desired reliability.

A Navy study 1/ has shown that overhauls often do not significantly reduce mission-degrading equipment failures and that some equipment fails even more frequently after overhaul. This study used the Navy's system for reporting mission-degrading failures (CASREP) as one method of analyzing the material condition of eight different pieces of equipment from two ship classes. In this analysis, only one of the equipment types showed a significant decrease in failures after overhaul. Further, the number of failures increased for three types of equipment, while the other four showed no significant change. On the other hand, the study included an analysis of data from the maintenance data system and ships' operating logs that showed decreases in the need for maintenance and the likelihood of equipment failure after overhaul. However, this analysis did not address whether the decreases justified the overhaul costs. For example, maintenance hours following overhaul decreased only about 13 percent.

Findings similar to the CASREP analysis are contained in a study by the Center for Naval Analysis of safety failures for aircraft. This study, covering 3,176

1/ARINC Research Corporation, "Effect on Overhaul on Ship Material Condition," October 1976.

Under this concept each task, which has been selected for the program because it is required or desirable, is designated for either "fixed frequency" or "on-condition maintenance." The remaining tasks are designated for "condition monitoring."

--Fixed-frequency or hard time maintenance applies to those items which demonstrate a predictable relationship between age and reliability degradation. The items are normally removed at their maximum interval for overhaul and/or replacement with new units.

--On-condition maintenance applies to those items for which repetitive inspections or tests can be used to determine their condition. Such inspections or tests are scheduled in the maintenance program.

--Condition monitoring applies to those items which are not subject to an effective maintenance task. The failure history of these may be monitored for indications of a need for reclassification or redesign.

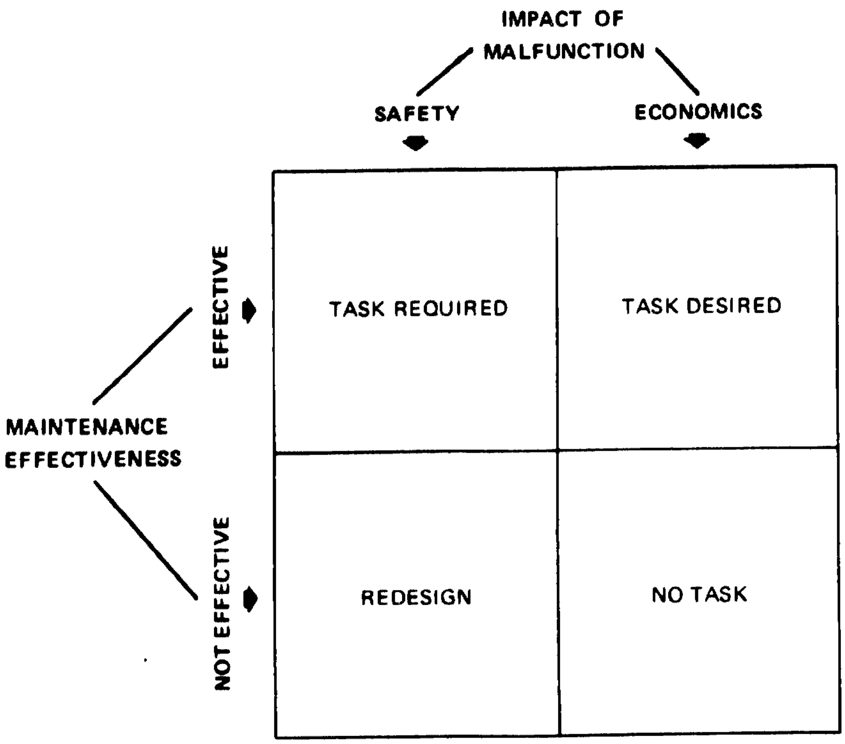
The concept has not degraded safe aircraft operation, but it has greatly reduced maintenance costs and improved aircraft availability for operations.

Need to increase equipment monitoring

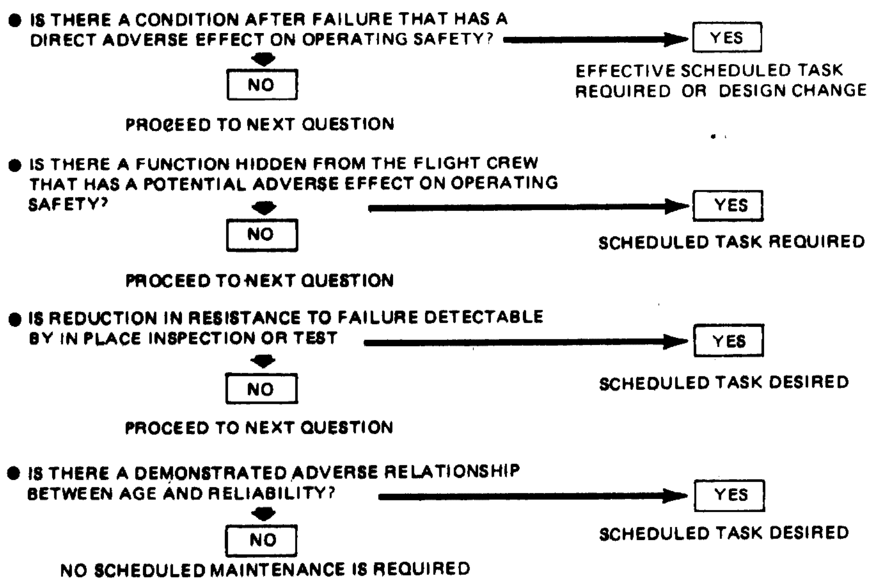
Performance monitoring techniques or analyses of failure histories are the first steps in determining what maintenance is needed. Determining the likelihood of equipment failure may well indicate that repairs are not really needed. In addition, periodic maintenance of some components can be wasteful and may actually be harmful because of the ever present potential for mistakes by maintenance personnel. Maintenance-caused failures occur not only from human error, which results in faulty installations or related system disruptions, but also from defective replacement parts.

Through equipment-monitoring techniques and improved equipment failure histories, the Navy can better estimate failure probabilities and determine maintenance requirements. The Navy has used these techniques in submarines for several years and plans to use them in other ships, such as destroyers. The submarine experience with these techniques has contributed to extending overhaul cycles from the previous 6-year cycle to a current 9-year cycle. These extended cycles have saved about $15 million per year, according to the Navy.

The conceptual model for analyzing components and for deciding whether a maintenance task is required is illustrated in the following diagram.



On the basis of the assumptions and decisions matrix below, analytical maintenance asks a logical series of questions to determine what kind of maintenance should be done for those items on the aircraft that are functionally significant.



The Navy has begun analyzing readiness and repair needs, and we commend the Navy for its actions. We recognize that, in some instances, corrective action will take time. However, in the interim, the Navy should reconsider its policy of overhauling for insurance purposes in light of the many factors inadequately considered and the low maintenance costs achieved by commercial firms with a prudent-risk maintenance philosophy. These differences between Navy and commercial maintenance practices and costs are discussed more fully in the following chapters.

CONCLUSIONS

The Navy overhauls support ships to insure reliability during operations between overhauls. These insurance overhauls are costly, yet the Navy cannot now show that overhauls insure readiness, because it cannot assess the cost effectiveness of overhauling until it develops quantified material readiness and condition requirements. Furthermore, several other supplements have not been adequately addressed including a scientific approach to making decisions on maintenance requirements.

Under the aircraft reliability-centered maintenance concept, a deliberate choice is made whether to repair, replace, or overhaul components. A decision tree logic is employed to ascertain the criticality of the component, extent of backup capability, impact on mission, and past breakdown history. It is only after these factors are considered that a decision is made. We believe the Navy needs to devise a new comprehensive ship maintenance policy that incorporates these factors. Until such a policy is devised, the Navy may well be spending a great deal for a small increase in reliability.

RECOMMENDATIONS

We recommend that the Secretary of Defense require the Navy to assess its policy of regularly overhauling amphibious and auxiliary ships with a view toward adopting a potentially less costly philosophy--performing only those tasks necessary to retain design levels of safety and reliability.

Further, in developing measurable material readiness requirements and determining an acceptable level of risk, we recommend that the Secretary of Defense require the Navy to:

--Evaluate the role of support ships in the fleet structure and assess supplemental use of commercial ships.

Several studies have also indicated a need to expand equipment-monitoring techniques. For example, a 1973 private consultant's study 1/ for the Navy concluded that performance-monitoring techniques of shipboard equipment should be increased. The consultants observed that many components with considerable operating time are as good as new. In fact, maintenance error could lead to malfunction.

A 1977 study for the Maritime Administration 2/ concluded that the Navy should increase its use of available diagnostic procedures to identify performance deterioration. With this identification, the period between required maintenance could be extended as long as performance monitoring justifies continued operation.

Repair level and capability

In addition to assessing the effect of overhauls on equipment failure and degradation, the Navy should also consider the level of repair required for expected failures. For example, the Navy should consider its extensive intermediate- (both mobile and shore-based) and organizational-level repair capability.

In peacetime, the Navy repairs some of its ships at foreign sites, such as Greece and Italy. The officials advised us, however, that they do not and cannot plan to use foreign repair facilities during a contingency. In a prior report, 3/ we pointed out that they should consider the use of allied shipbuilding and ship repair organizations during contingencies to provide intermediate maintenance support. Over 20 shipbuilders or repairers in the European/Mediterranean area could provide this support. In this regard, the Army and Air Force contingency plans provide for allied support for critical operations.

1/Harbridge House, Inc. "Ship Overhaul and Maintenance Study," May 1973.

2/Mystech Associates "Shipboard Systems Operation and Logistics Support Program Phase 1A--Requirements Assessment," June 1977.

3/"The Navy's Intermediate Ship Maintenance Program Can Be Improved," (LCD-77-412, Sept. 1977).

Defense to develop quantifiable material readiness requirements for the Armed Forces so that resources could be better linked to readiness.

Navy officials also said that the material condition of the average merchant ship results from a maintenance policy oriented toward a 20-year life cycle followed by disposal and scrapping.

The data we obtained from two oil companies and three general-cargo ship operators does not indicate that they dispose of ships after 20 years. We found that 27 of 96 commercial ships for which we obtained detailed data were more than 20 years old.

--Define the mix and reliability requirements of mission-essential equipment.

--Evaluate the costs of various reliability levels.

--Better define equipment backup capability and requirements in line with mission essentiality and failure probability.

--Make detailed engineering analyses to determine the optimum frequency and level of repair for key ship systems and equipment in line with reliability-centered maintenance and establish appropriate reliability goals.

--Better determine the readiness impact and maintenance consequences of deferred maintenance.

--Make fuller use of various equipment-monitoring techniques.

AGENCY COMMENTS

Navy officials said that the report does not take into account the basic differences between the Navy's combat support ships and merchant ships. And, the differences are so extensive that, if properly analyzed, they would clearly show why the Navy's maintenance costs must be greater than those of merchants ships.

We believe our report recognizes the reasons why the maintenance costs of Navy support ships are greater than those of commercial ships (see pp. 28 to 37).

The principle of the reliability-centered maintenance concept, which was first used by the commercial aircraft industry and later endorsed by the Secretary of Defense, is to perform only those tasks necessary to retain design levels of safety and reliability (see p. 13). Using this concept, commercial airlines have greatly reduced maintenance costs and improved aircraft availability. Until the Navy implements a ship maintenance policy that incorporates factors used as part of the reliability-centered maintenance concept, it may well be spending a great deal for a small increase in reliability.

Furthermore, the Navy cannot adequately justify overhauls and other maintenance costs since it cannot link resources to readiness levels. The 1978 Department of Defense Appropriations Authorization Act required the Secretary of include changes to combat systems, communications, and firefighting systems. Other modifications may include installation of additional sewage collecting and holding tanks and modification of the propulsion boilers.

In a comparison of similar classes of vessels, Navy maintenance costs again exceed those for similar commercial ships, based on general characteristics, such as hull length, horsepower, and tonnage. (See app. VII for further details on these ship characteristics.) As shown in table 2, these Navy maintenance costs are from about four to eight times more than the average costs for similar commercial ships.

TABLE 2
COMPARISON OF NAVY AND COMMERCIAL MAINTENANCE COSTS

CATEGORY		SHIP TYPE	AVERAGE ANNUAL COST	NAVY TO COMMERCIAL RATIOS
I	NAVY:	Fast combat-support ships and replenishment fleet oilers	$2,474,911	
	COMMERCIAL:	Containerized cargo and large tankers	610,660	4:1
II	NAVY:	Ammunition ships, combat store ships, submarine tenders, amphibious command ships, and amphibious assault ships	2,228,871	
	COMMERCIAL:	Breakbulk cargo and small tankers	282,157	8:1

NAVY EQUIPMENT MAINTENANCE COSTS ARE HIGHER

Differences in ship design, operations, size, and composition of crews could affect comparisons at the ship level. However, at lower levels of design, differences in detail should not significantly influence costs. This assumption of equipment similarity is used by the Navy in its preventive maintenance. The same maintenance requirement card that sets preventive maintenance policy when a component is first installed in one ship is also used when that component is installed in ships of later design--even though the ships are of different types and classes.

CHAPTER 3

NAVY SHIPS ARE MAINTAINED AT GREATER COST THAN COMMERCIAL SHIPS

The Navy spends more to maintain its support ships than commercial operators spend maintaining similar ships. Maintenance costs for Navy support vessels average about $2 million a year, while those for commercial ships average about $400,000 a year, or one-fifth of Navy costs. Further, in some cases, maintenance costs for ship equipment are more than five times greater than commercial firms' costs for the same type of equipment. A 1973 study 1/ performed for the Navy found similar differences between Navy and commercial maintenance costs.

Many factors contribute to the higher Navy maintenance costs, including differences between ships, equipment, crew, and mission requirements.

SHIP COST COMPARISONS

Average annual costs for maintaining Navy and commercial ships vary, but Navy costs generally exceed commercial costs. As shown in appendix VI, the average annual maintenance cost for 58 Navy support ships varied from $200,000 for the Opportune (salvage ship ARS-41) to a high of $5.2 million for the Piedmont (destroyer tender AD-17). The average cost for the 58 ships was about $2 million a year. Conversely, for all ships operated by five commercial companies, annual maintenance costs averaged about $400,000.

Modernization costs, excluded from this comparison, would further inflate the difference between Navy and commercial expenditures. Since some modernizations alleviate the need for repairs, maintenance expenditures are understated in the above comparison; the average Navy cost is thus conservatively figured as five times the commercial cost. Including Navy modernization costs would increase the Navy's average annual maintenance cost to $2.4 million per ship. In contrast, modernization for three commercial companies averaged only $15,245 a year for each ship. This is because commercial ship operators normally modernize only to meet regulations, such as Coast Guard anti-pollution requirements, or to increase cargo capability, or for different trade routes. Navy modifications

---

1/Cooper and Company, "A Demonstration of an Approach to Improvement of Ship Overhaul and Maintenance," July 1973.

equipment types known to be similar for company tankers and Navy AOs. For the equipment that the company repaired, Navy expenditures were about 17 times greater. The smallest cost difference was for nonengine turbines: Navy expenditures were three times as great as commercial costs. (See app. III, p. 43).

CONCLUSIONS

Though we had problems in obtaining valid data, the cost differences are so marked that no refinement of data or approach can significantly alter the broad finding--that the Navy spends more maintaining its ships, including specific equipment.

Navy maintenance costs are greater than commercial costs for similar types of equipment. Commercial shipping maintenance expenditures vary for specific types of equipment, but in virtually all cases the Navy spends more. For example, the average yearly cost of maintaining the main feed pumps is more than four times greater for Navy ships than for comparable commercial ships. For fuel-oil service pumps, average yearly maintenance costs for the Navy are 4-1/2 times greater. (Additional cost comparisons for similar types of equipment maintenance are presented in app. VIII.) In most cases, Navy equipment costs greatly exceed commercial costs.

PREVIOUS STUDY FOUND SIMILAR COST DIFFERENCES

Early in 1973 the Navy contracted with Cooper and Company, a consulting firm, to develop an approach to improve ship maintenance and overhaul. To find acceptable methods of reducing maintenance costs, Cooper compared the impact of different maintenance strategies on the costs and performance of similar ships. Costs included overhaul and interim (between-overhaul) expenditures. Cooper compared tankers operated by the Navy--called AOs--to those operated by a commercial shipping company.

In comparing overhaul and between-overhaul repair costs on a total ship-system basis--excluding shipboard maintenance and alterations--the study found the average annual cost for Navy AOs to be about $1.2 million, or almost 10 times the cost for the company tankers. When these costs were broken down into overhaul and interim expenditures, the Navy costs were still higher. For example, the average annual overhaul costs for Navy AOs were about 10 times greater than for the company's ship overhauls. Further, the interim Navy expenditures were about nine times more costly than the commercial ones. These between-overhaul costs excluded shipboard maintenance, conservatively estimated at more than five times shipboard costs for the company tankers.

The study recognized the significant physical differences between military and commercial tankers. Consequently, Cooper made several additional cost comparisons that adjusted ship costs to account for significantly dissimilar systems, such as electronic, cargo, and weapon systems. However, Navy ship-overhaul costs were still about six times greater than the company's tanker-overhaul costs.

Cooper and Company also compared maintenance expenditures by types of equipment. The study compared the costs for 18

According to the Navy, it bases overhaul duration and frequency on technical information, engineering judgment, operating experience, and modernization requirements. Navy officials have stated that they regularly analyze and restudy these factors according to operation, material, and design to learn whether changes in maintenance cycles are needed. For example, a recent Navy program involving nuclear ballistic-missile submarines resulted in changing their overhaul duration and frequency from 14 and 72 months to 16 and 108 months, respectively. The Navy is making similar analyses under its Ship Support Improvement Project, a long-range effort to improve material condition and extend the operational use of Navy ships while providing readiness at an acceptable cost.1/ However, improving maintenance policy for support ships is not an immediate goal of the project.

The following table presents overhaul operating cycles for different amphibious and auxiliary ships. The actual overhaul duration may vary, depending upon the amount and scope of industrial work needed and the shipyard's workload. In addition, ship operating time will vary according to operational commitments, homeport policy, and shipyard availability.

1/For more information on the Ship Support Improvement Project, (see "The Navy's Ship Support Improvement Project" (LCD-78-433, Sept. 12, 1978).

CHAPTER 4

COMPARISON OF COMMERCIAL AND NAVY

SHIP MAINTENANCE POLICIES

A comparison of Navy and commercial maintenance policies for support vessels revealed major differences in approach, practices, and downtime. Some of the disparity derives from the differences in mission: Navy ships must be prepared to operate as in a combat environment with numerous battle systems and armaments, large crews, and extensive equipment backup capability. However, in the Navy's efforts to maintain combat readiness, it has adopted an overall policy that requires periodic, extensive upgrading of vessels and equipment--even those satisfactorily operating--to new condition. In contrast, although commercial firms repair only as needed and rarely, if ever, make comprehensive overhauls, their ships are able to sustain an acceptable material condition to accomplish their mission. We recognize that the Navy must be combat ready. Furthermore, we believe that costs alone should not determine whether certain ship systems should be repaired. However, we believe Navy ship repairs could more closely parallel those used by commercial ship operators as well as those used by both commerical and DOD components for aircraft--performing only those tasks necessary to retain design levels of safety and reliability.

In the following sections, we will compare naval and commercial maintenance strategies, discuss the differences and the reasons for them, and review the consequences of the Navy's overhaul policy.

NAVY MAINTENANCE POLICY

The Navy bases its maintenance strategy on a schedule of periodic, lengthy ship overhauls with extensive intermediate-level and ship-crew maintenance performed as needed between overhauls. In addition to planned overhauls, ships undergo periodic repairs, called either restricted or technical availabilities.

According to its present policy, the Navy plans regular overhauls to perform all outstanding repairs and major maintenance that will insure reasonably reliable material readiness during the succeeding operational cycle. The overhaul schedule follows an established time frame; certain classes of ships are to be overhauled as often as 3 years, while other classes are to operate up to 10 years between overhauls.

underway or at dockside while handling cargo, and those done in a repair facility when the ship is immobilized.

Repair policies vary for commercial ship operators. Some firms never overhaul their ships; others overhaul annually or biennially, but the overhaul usually lasts less than a month. This drydock maintenance results from two factors:

--The ship's hull normally needs biennial preservation maintenance.

--U.S. Coast Guard and the American Bureau of Shipping requires a biennial survey in drydock.

The American Bureau of Shipping is an international ship classification society that certifies the structural integrity and mechanical soundness of merchant ships, insuring fitness for their intended service. Most U.S.-flag ship operators comply with the periodic American Bureau of Shipping inspections, especially since finance and insurance companies frequently request confirmation of a ship's updated classification certificate. In addition, U.S. cargo vessels must display certificates of inspection by the U.S. Coast Guard. Customs will not clear a vessel to leave the United States if its certificate has expired.

COMPARISON OF REPAIR PERIODS AND OPERATING TIME

On an annualized basis, Navy ships spend more time at repair facilities undergoing major repairs than do commercial ships. As shown below, the Navy ships spend twice as much time in repairs and are thus less available for operations.

TABLE 4
NAVAL VS. COMMERCIAL PLANNED AND ACTUAL REPAIR AND INSPECTION TIMES

	REPAIR TIME (days per year)	
	Planned	Actual
NAVY	27 to 47	30 to 68
COMMERCIAL	2 to 30	11 to 31

TABLE 3

COMPARISON OF PLANNED AND ACTUAL TIME BETWEEN AND DURING OVERHAUL OF NAVAL SUPPORT VESSELS

TYPE OF SHIPS	PLANNED FREQUENCY/DURATION (months)		ACTUAL FREQUENCY/DURATION (months) (note a)		NUMBER OF SHIPS
Destroyer tender, submarine tender	48	5	54.4	6.0	5
Ammunition ships	48	5	53.5	8.3	6
Repair ships	48	4	65.0	10.0	1
Submarine rescue ships	37	4	45.5	4.0	2
Fleet ocean tugs	37	3	43.7	5.7	6
Amphibious cargo ships, amphibious transports, dock landing ships	40	5	43.3	b/9.9	7
Tank landing ships	44	4	50.0	7.3	9

a/Calendar year 1976 and 1977 overhauls. b/Dock landing ship only.

When planning overhauls, the Navy makes a preoverhaul test and inspection to identify repair needs. Inspectors consider the likelihood of equipment failure between this overhaul period and the next. Their repair recommendations are then assembled into the ship alteration and report package which Navy officials use to determine final overhaul requirements.

COMMERCIAL MAINTENANCE POLICY

Mercantile shipping firms try to repair only as needed and limit vessel downtime. To that end, they employ maintenance strategies that minimize the time support ships, such as tankers and cargo vessels, spend in shipyards for maintenance and repairs. Commercial shipping repairs fall into two broad categories: those done while the ship is

Ship equipment requirements

Navy amphibious and support ships require extensive sophisticated and complex military equipment. These include underway replenishment systems, missile and gun systems as well as aviation, antisubmarine-warfare, and electronic-countermeasure systems. Navy ships also have extensive equipment backup capability to replace damaged critical systems in battle. This military equipment requires periodic maintenance and therefore increases naval costs over commercial outlays.

For example, one ship we visited had three large turbine generators, one of which was a reserve for backup capability. One generator had been recently damaged and required extensive depot-level repairs. Although the ship was scheduled to receive an overhaul within 9 months, the generator was repaired immediately because one of the other two generators might fail during upcoming exercises. However, those generators had exhibited no operating problems.

Ship crew requirements

Navy vessels carry large crews. In contrast to commercial ships, which usually have 25 to 46 crewmembers, comparably sized Navy support ships generally require about 400 people. Consequently, the naval ships have greater habitation and support service requirements. For example, Navy laundry, mess, berthing, sanitary, and library areas were much larger than those on commercial vessels, and such Navy shipboard facilities, as tailor and barber shops, are not found on commercial ships.

Maintenance skills

There are differences in the maintenance skills of naval and commercial engineering officers that may contribute to increased Navy maintenance cost. Engineers on board commercial ships are better qualified and have much more experience. They are often intimately familiar with their vessel because they have been assigned to the same ship or similar ship for a considerable period of time--often as much as 5 to 10 years. According to the Navy, the naval engineers have had little formal training and have only been at their job for a year or so.

The ability of these two groups to identify and evaluate their problems and to take meaningful corrective action on their own is significantly different. Having

In addition to being less available, Navy support ships are used less than commercial vessels. The following table contrasts the length of time naval and commercial ships spend in operation and at sea.

TABLE 5
TIME DISTRIBUTION FOR NAVAL AND COMMERCIAL SHIP OPERATIONS

	PERCENT OF TIME		
	Available	In total operation	Operation at sea
NAVY	86	a/50	20
COMMERCIAL			
A	91	90	a/72
B	93	93	62
C	a/high 90's	(note b)	(note b)
D	95	84	c/48
E	97	95	41

a/Estimated

b/Not available

c/Commercial ships spend much of their operational time in port, handling cargo. For example, in 1977, 5 ships of company D traveled over 300,000 nautical miles in 23 voyages. They spent 52% of their time in ports, detentions, and reduced speed conditions.

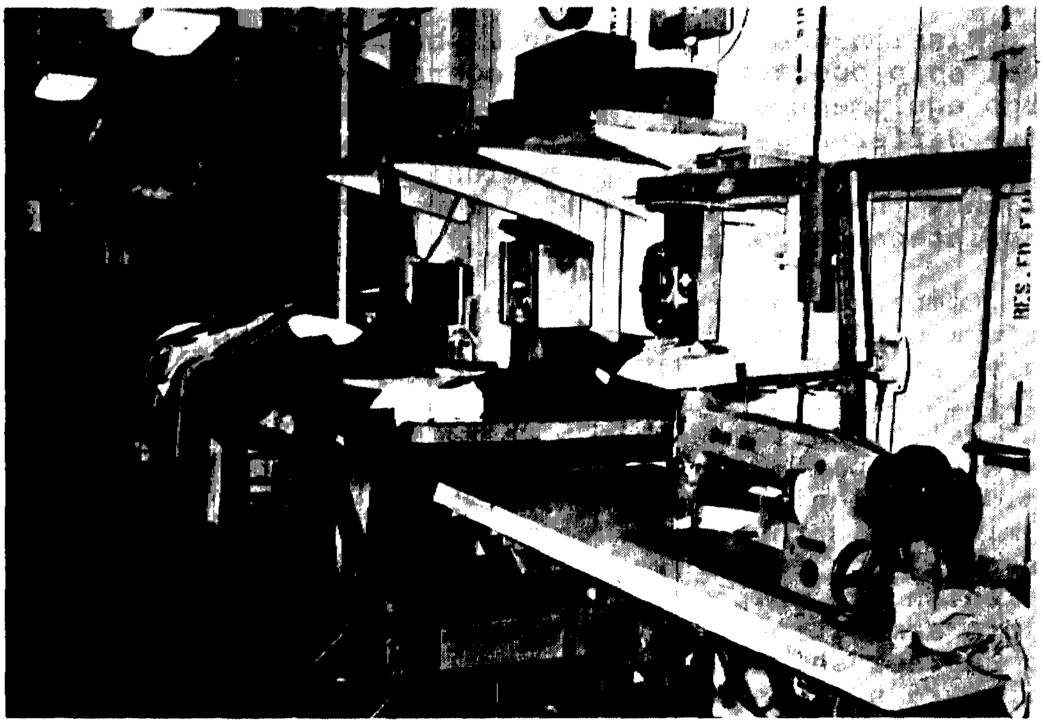
WHY THE NAVY's MAINTENANCE COSTS AND EFFORTS ARE GREATER

The Navy's maintenance policy has resulted in greater cost and less operating time for its support ships in contrast to commercial shipping. Some of these differences result from the differences in mission: the Navy, as an arm of national defense, must acquire, maintain, and modernize equipment and systems not found on commercial ships and perform operations peculiar to the military. We examined the extenuating requirements in terms of equipment, crew, and types of ship operations.

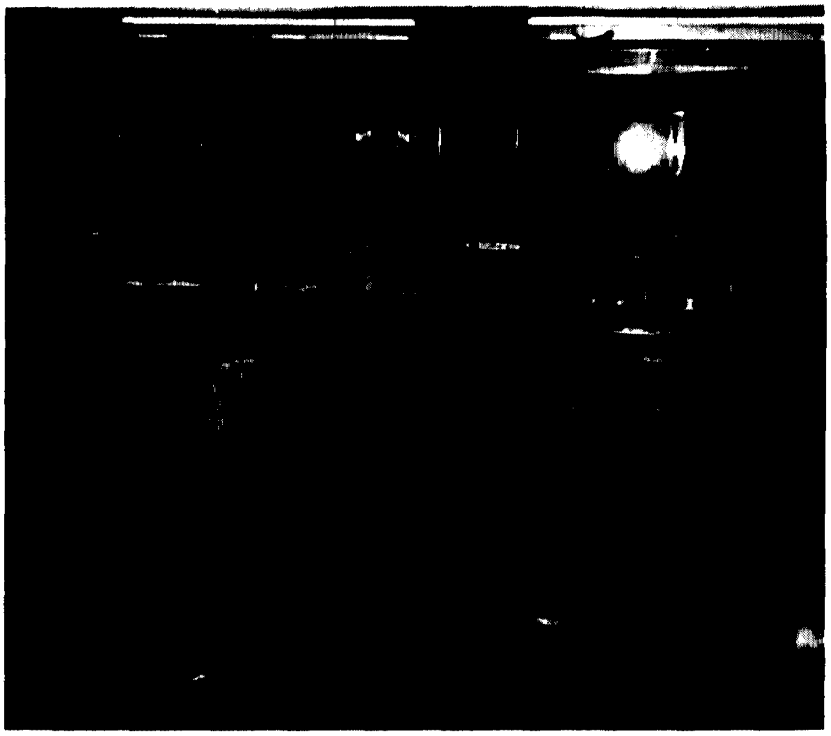
CREW BERTHING ON A NAVY SHIP COURTESY OF DEPARTMENT OF THE NAVY identified the problem, the commercial engineer can do much to solve it while steady steaming between ports while, according to the Navy, the naval engineer can do little while responding to fleet demands.

In addition, the Navy stated the commercial engineer is also assisted by his company's port engineer. This man has also been an engineer, and frequently, on either his ship or a sister ship. He is a licensed engineer with the necessary operating credentials. Informed of a problem, he can direct repairs which are needed far more knowledgeably than his naval counterparts. The port engineer knows first hand the overall condition of all major equipment items on the ships assigned him. The naval personnel may not have been associated with the ship before or have seen the ship for several months.

The Navy stated that being confronted with the requirements of reliability and the uncertainties of the information available, a naval planner will often opt for the insurance overhaul based on the historical problems he has encountered with similar equipments. This is contrasted to the commercial planner with excellent knowledge available from both an experienced chief engineer on board and his own personal involvement with the ship.



NAVY SHIP TAILOR SHOP



OFFICERS' BARBER SHOP ON A NAVY SHIP

COURTESY OF DEPARTMENT OF THE NAVY

Types of ship operations

Mission-derived differences between commercial and naval ship operations include operating time and speeds, cargo equipment usage, and resulting equipment degradation. These differences can affect maintenance costs; however, we could not identify any conclusive studies or other evidence that demonstrated the impact of various operations on maintenance costs.

Compared to similar Navy ships, commercial vessels perform different operations. Merchant ships generally travel at steady speeds between ports and transfer cargo while in port. This type of operation minimizes equipment deterioration. In contrast, Navy support ships must operate as part of a total force and must be able to rapidly replenish combat ships while at sea. This type of mission is thus more demanding than that of commercial vessels. For example, a Navy support ship will often replenish two ships at the same time: it may supply one ship's ammunition from the starboard side while replenishing another ship's oil from port side. In such a situation, shipboard systems must be highly reliable; a failure in navigation, communication, or propulsion systems could result in a three-ship collision. In addition, the speed of replenishment demands rapid startup and shutdown of transfer equipment, thus increasing equipment wear.

Training exercises cause an additional deterioration of equipment not experienced by commercial ships. For instance, during some exercises, Navy ships must change from an all-forward speed to an all-flank to simulate a response to a torpedo attack. The Navy claims that such high-speed changes cause significant equipment wear and increase the possibility of a breakdown at sea.

The Navy has long been concerned that the "tempo" of operations--the length of time at sea and the variety of speeds and maneuvers--for its ships may affect their maintenance costs and efforts. However, no such relationship has been conclusively demonstrated. Of the five Navy studies we reviewed concerning the effect of different operating tempos on maintenance requirements, three found no relationship. The other two found some evidence that tempo affected maintenance.

In 1972, the Logistics Management Institute sought to assess the effect of increased rate of operation on organizational and intermediate-level maintenance. The Institute concluded that operating intensity, as measured by time and fuel consumed while underway, bears little correlation to maintenance hours. 1/

In comparing private and Navy ship overhaul policies and practices, a 1973 Cooper and Company study 2/ hypothesized that differences in overhaul/repair costs might be attributed to differences in tempo. To test its theory, Cooper chose a limited sample of components expected to be unaffected by tempo and compared their costs and repair histories across ships with different tempos. "The total overhaul cost per component category * * * was uniformly highest for AOs (Navy tankers)." Its findings suggested that operating tempo cannot significantly contribute to the cost differences.

As a part of a 1977 study, the Center for Naval Analysis used downtime over the entire overhaul cycle, as documented by CASREP, to study tempo relationships. It concluded that the relationship between operating tempo and material condition rarely attains statistical significance. 3/

On the other hand, previous Center reports had indicated the existence of some relationship. In 1964, the Center studied economic considerations in establishing a ship overhaul cycle. 4/ It found that five factors affect overhaul cost: a ship's age, size, complexity, propulsion and the time elapsed since its previous overhaul. In addition, the need for intermediate maintenance seemed largely determined by a destroyer's age and intensity of usage, while organizational maintenance was affected by ship complexity.

1/Logistics Management Institute, "Assessment of Patrol Frigate Maintenance Policy: Effect of Increased Operating Rate on Organizational and Intermediate Maintenance," (interim report) April 1972.

2/Cooper and Company, "A Demonstration of an Approach to Improvement of Ship Overhaul and Maintenance," July 1973.

3/Center for Naval Analysis, "Ship Condition and Maintenance Policy: Crew Characteristics and Ship Condition (Maintenance Personnel Effectiveness Study (MPES)," March 1977.

4/Center for Naval Analysis, "Economic Considerations in Establishing an Overhaul Cycle for Ships: An Empirical Analysis," April 1964.

Again, in 1974 the Center found some evidence that the tempo of operations affects overhaul repair man-days. 1/ Tempo variables included fuel consumption, average number of hours underway, and deployment to Vietnam during the preoverhaul interval. For two of three ship classes analyzed, a high tempo of operations significantly increased repair mandays. The study also concluded that, for all three classes, "* * * increasing complexity has increased overhaul * * * repair mandays."

Unnecessary equipment repair

The Navy believes that it achieves extremely reliable systems and equipment through periodic lengthy ship overhauls, along with broad intermediate and organizational interim maintenance. During these overhauls, the Navy frequently authorizes extensive disassembly and overhaul of equipment that needs minor or no maintenance. These repairs are recommended to insure reliability during the next operational cycle. For example, on one ship the inspection team recommended overhauling the emergency lube-oil pump to increase its reliability because it had not been overhauled since the ship's last overhaul. This recommendation is questionable for several reasons:

- --The ship's crew had stated that the pump was functioning without any problems.
- --The inspectors did not test the pump.
- --The inspection team did not have access to or know of any equipment failure histories.
- --The Machinery Condition Assessment report 2/ indicated no problems with the pump.
- --The ship had recently been evaluated as above average by the Propulsion Examination Board.

We found similar repair recommendations in another ship's overhaul documentation. For instance, as insurance

---

1/Center for Naval Analysis, "Ship Overhaul Cost Estimating Relationships (SOCER)," October 1974.

2/The Machinery Condition Assessment report indicates the results of various performance tests on machinery.

maintenance one of its main feed pumps was overhauled, even though the only testing documentation available--a vibration analysis--had shown that the pump was operating within specifications.

Besides overhauling equipment that is operating satisfactorily, the Navy overhauls equipment with only minor problems. For example, during one ship's preoverhaul test and inspection, a lube-oil pump would not adjust to pressure changes. This ship's crew had already overhauled the pump's governor, several times, but the problem persisted. The source of the problem was still unknown, yet the inspectors recommended overhauling the governor, the pump, and another major component. The inspectors told us that the comprehensive overhauling would probably correct the pressure problem and also increase the equipment's reliability during the ship's next operating cycle.

In contrast, private shippers generally practice corrective maintenance for equipment with identifiable operating deficiencies and seldom attempt insurance maintenance. According to a commercial shipyard official, if a particular piece of a merchant ship's equipment does not function, its operator will tell the shipyard personnel to make it work or replace it.

CONCLUSIONS

Major differences between Navy and commercial maintenance costs result from contrasts in missions as well as in maintenance philosophies and practices. To keep its ships combat ready, the Navy has adopted an overhaul policy which requires regularly scheduled overhaul of support and combat ships. Further, repairs are sometimes made to equipment which is operating satisfactorily. This is justified on the basis that they may improve its reliability. In summary, the Navy may well be spending a great deal for a small increase in reliability.

In contrast, commercial firms perform only a minimal amount of scheduled maintenance. This practice allows for a prudent-risk and is geared toward being profit oriented. Consequently, they accept a small risk and only repair as needed instead of performing comprehensive overhauls that may increase reliability.

 APPENDIX I

Congress of the United States
House of Representatives
Committee on Appropriations
Washington, D.C. 20515

October 19, 1977

Honorable Elmer B. Staats
Comptroller General of the
United States
Washington, D.C. 20548

Dear Mr. Staats:

The General Accounting Office has completed a number of studies on Navy ship maintenance practices in recent years which have been of considerable assistance to the Committee. It would be appreciated if you would direct a further study which compares maintenance practices for U.S. Navy support type ships with practices employed by American flag commercial ships. The Committee would like to have made available statistical data on overhaul costs and practices of that portion of the U.S. Navy fleet which is for the most part overhauled in private yards (landing ships, LST's, LPD's, oilers, repair ships, ammunition ships, etc.) to compare with any data you can make available on tankers, cargo ships, roll-on-off container ships, etc.) operated by commercial carriers.

The Committee would also appreciate any assistance your organization could provide in evaluating a multi-year/multi-million dollar "consulting" contract covering ship maintenance and overhaul practices awarded by the Navy in fiscal year 1977.

If your staff requires further information on these requests, please have them contact Mr. Derek Vander Schaaf of the Defense Subcommittee staff.

I appreciate your continued assistance.

Sincerely,

George Mahon

Chairman

GAO note: The information requested in the second paragraph of this letter was provided in our report, "The Navy's Ship Suppport Improvement Project" (LCD-78-433, Sept. 12, 1978.)

NAVY LOCATIONS VISITED

Chief of Naval Operations
Washington, D.C.

Commander, Naval Surface Force, Atlantic and Pacific
Norfolk, Virginia and San Diego, California.

Fleet Material Support Office
Mechanicsburg, Pennsylvania.

Offices for Planning and Engineering for Repairs
and Alterations of the Naval Shipyards:

--Hunter's Point, California.

--Bremerton, Washington.

--Philadelphia, Pennsylvania.

--Portsmouth, Virginia.

Ships Parts Control Center
Mechanicsburg, Pennsylvania.

Bureau of Naval Personnel
Alexandria, Virginia.

Commander, Naval Submarine Force, Atlantic
Norfolk, Virginia.

Commander, Naval Sea Systems Command
Alexandria, Virginia.

SYNOPSES OF PERTINENT STUDIES

COMMERCIAL SHIP POLICY

"A Demonstration of an Approach to Improvement of Ship Overhaul and Maintenance," by Cooper and Company. July 1973.

This study compared maintenance costs and practices of Navy oilers (AOs) with maintenance of similar ships by the Military Sealift Command (MSC) and by a commercial company (company A).

Findings, based on as many as 14 AOs, 19 MSC tankers, 9 company A tankers, 2 Navy shipyards, and 2 commercial shipyards during 1967 to 1973 were as follows.

The average time between overhauls was

--42 months for AOs,

--18.5 months for MSC ships, and

--22 months for company A ships.

The average annual cost of overhauls (excluding alterations here and throughout) and of inter-overhaul repairs (excluding shipboard maintenance) was about $1.2 million for AOs. This amount was nearly 4 times the corresponding amount for MSC tankers and almost 10 times the average annual cost for company A. (Results were not greatly different if we consider overhaul and inter-overhaul repairs separately.) The cost of onboard maintenance for AOs was conservatively estimated at more than five times the cost of onboard maintenance for MSC or company A ships.

Omitting from the comparisons those systems which may be significantly different (electronics, cargo, and weapons) did affect the cost picture somewhat. The average annual cost of an AO overhaul in a Navy yard was then about 6.4 times that of company A.

Further, the cost of overhauling an AO was 32 percent higher when performed in a Navy shipyard rather than a commercial yard.

AOs suffered 35 percent more of the serious CASREPs (priorities 3 and 4) than MSC ships. The longer the interval after overhaul, the lower the incidence of

CASREPs. The CASREP rate was 68 percent higher, in the 18 months following overhaul, for AOs overhauled in Navy yards than for those overhauled in commercial yards.

AO downtime due to overhaul was almost twice that for MSC and three times that for company A. AO downtime due to inter-overhaul repairs was almost four times that for MSC and more than six times that for company A.

For the category "main feed pump"--selected randomly as an illustration--it could be shown that, if a CASREP occurred in an AO, the chances were about 50 percent that another CASREP would occur (in a main feed pump, for the same ship) within the same or following calendar month.

For a sample of 18 equipment/component categories selected as common to all 3 groups of tankers, an analysis of overhaul work orders showed that the average costs per work order was, for every category, highest for AOs and lowest for company A. The total overhaul cost per component category (average cost/work order times number of work orders) was uniformly highest for AOs, and with one exception, lowest for company A. The AO overhaul cost per category was, for some categories, 10 to 20 and more times that of company A.

Cost Comparison for Maintaining Similar Equipment on Both Navy and Commercial Ships

Equipment	Navy AO	Company tankers	Navy/company cost ratio
Boiler refractory	$ 40,270.50	$ 2,860.50	14.1:1
Fuel oil service	-	-	-
Fire side	-	-	-
Water sides	47,617.90	2,779.00	17.1:1
Control	6,596.10	-	-
Cargo tanks	16,423.40	-	-
Compressors, high pressure air	7,256.00	-	-
Compressors, refrigeration	11,325.90	-	-
Condenser, main	9,740.00	-	-
Pumps, main feed	32,035.00	618.00	51.8:1
Pumps, cargo	80,380.80	3,328.00	24.2:1
Pumps, fire and flush	25,921.60	1,221.00	21.2:1
Pumps, main condensate	11,029.70	-	-
Pumps, fuel oil service	4,599.00	-	-
Propeller shafts, bearings	36,829.60	2,745.00	13.4:1
Turbines, nonengine	20,823.00	6,394.00	3.3:1
Turbines, ships service generator	66,111.20	4,044.00	16.3:1
Valves, safety	3,620.00	288.00	12.6:1
Total	$420,579.70	$24,277.50	
Average			17.3:1

In summation, the cost of maintaining an AO (no matter how broadly defined) is enormously greater than the cost of maintaining a company A tanker, or even an MSC tanker. At the time, AOs have more CASREPs and lower availability. Cooper and Company was not able to uncover anything that would justify the high cost or low performance of AOs.

"Shipboard Systems Operation and Logistics Support Program. Final Report: Phase IA Requirements Assessment," by Mystech Associates, Inc. June 1977.

This report presented the results of a study to identify the major concerns of the U.S. maritime industry in the areas of shipboard maintenance, repair, and logistics support. The information contained in the study represented inputs from a cross-section of U.S.-flag shipowners/ operators, ship repair facilities, and seafaring unions. Data pertaining to applicable allied industry maintenance, repair, and logistic support procedures was received from selected airlines, central power companies, truck fleets, railroads, and refineries.

Two independent efforts to obtain supportive cost data from the maritime industry, considered necessary to assess the economic impact of identified maintenance and repair problems and their proposed solutions, proved unsuccessful. While a limited amount of data was compiled, it was insufficient to fully substantiate potential courses of action pertaining to new program initiatives. The data available was adequate, however, to provide meaningful trade-off considerations regarding the question of shipboard versus shoreside repair work.

"Maritime Administration Maintenance and Reliability Program," by Dunlap and Associates, Inc.; March 1965

Research was performed toward developing a Maritime Administration Maintenance and Reliability Program for merchant ships. Briefly, the nature of the problem was described as one of economics (excessive merchant ship total construction and operational costs) and a lack of information and techniques adequate for achieving significant improvements. The approach used operations research and systems analysis techniques, together with maintainability and reliability technology, to provide a basis for reducing operating costs. The report primarily emphasized maintenance and reliability aspects and underscored the urgent need for well-developed, planned maintenance systems; systematic, fleetwide maintenance and reliability data collection and analysis; and an integrated data management system. Statistically significant differences were found among ship types, operators, trade routes, and assembly manufacturers. Many suspected causes were cited. However, the limited size of the sample dictated against analyzing either lower levels within the systems or infrequent events at higher levels, or drawing firm conclusions.

"Economic Analysis of the Ship Maintenance Function," by Litton Systems, Advanced Marine Technology Division. January 1969.

This study, as originally planned, was to be conducted in three major phases. The conclusion of the first phase was that, in the absence of a maintenance-management data collection system, the original objectives of the full study could only be partially accomplished. Therefore, it was agreed to terminate the study. This report summarized the results of the initial effort.

READINESS

"Force Readiness Measurement and Control, Phase I," by Institute for Defense Analyses, Systems Evaluation Division. November 1976.

The objectives of the Phase I study were to identify measures of readiness and to establish how the cost of the resources that affect these measures could be determined. The report discussed how relationships could be established between (1) the amount and type of training and measures of personnel performance and (2) the levels of logistic resources and weapon system readiness.

"Improving Operational Readiness Through Increased Reliability and Maintainability," by Lawrence H. Kenney, Defense Systems Management College. 1973.

The purpose of this study was to assess the method used by the Naval Material Command in determining where to invest in increased reliability and maintainability.

The Naval Material Command, through the Detection Action Response Technique program, identifies and prioritizes problem items and allocates funds to correct these problems based on the assigned priorities.

This study concluded that the system could be improved by better relating the impact of poor reliability and maintainability to the loss of operational readiness caused thereby.

SHIP CONDITION AND MAINTENANCE POLICY

"Crew Characteristics And Ship Condition (Maintenance Personnel Effectiveness Study (MPES)," by Center for Naval Analyses. March 1977.

Because little was known about the relative value of different kinds of personnel, the goal of this study was to improve the assumptions underlying Navy personnel policies. The productivity of enlisted personnel aboard ships was estimated as a function of their personal characteristics. Ship readiness was measured by the material condition of shipboard equipment. CASREPs from 91 cruisers, frigates, and destroyers were used to study how the productivity of enlisted personnel varied systematically with high school graduation, entry test scores, paygrade, experience, naval training, race, and marital status. Six occupations and three subsystems were examined separately. Equipment complexity, ship age, and overhaul frequency were accounted for. Implications were drawn for Navy policies regarding recruitment, retention, manning, rotation, and pay.

"The Effect of Overhaul on Ship Material Condition," by ARINC Research Corporation. October 1976.

This report presented the results of a study conducted to determine quantitatively the effect of overhaul onship material condition. The work was done for the Escort and Cruiser Ship Logistic Division of the Naval Sea Systems Command. The overall conclusion of the study was that the positive effect of overhaul on ship material condition can be quantitatively demonstrated. Data from three sources were analyzed: the Maintenance Data System, CASREP histories, and shipboard records of equipment performance. The study showed that, after overhaul, there were significant decreases in the need for maintenance and the likelihood of failure. Also, operational data had potential as a means of assessing material condition, and maintenance parameters were good indicators of material condition. CASREPs, when used alone, did not indicate the effect of ship overhaul on material condition. However, when used with caution and in conjunction with other measures, CASREP analyses gave additional insight into studies of material condition.

"Ship Overhaul Cost Estimating Relationships (SOCER)," by Center for Naval Analyses. October 1974.

The SOCER study was undertaken to determine what factors influence the number of direct labor repair mandays expended on overhauls and how overhaul costs can be more accurately predicted.

The study found that, for the ships analyzed, in general:

--As the ship aged, more direct labor man-days were expended.

--Direct labor repair man-days were not related to intervals between overhauls over the range of intervals observed.

--Increasing complexity had increased overhaul direct labor repair man-days.

--Higher staffing levels were found to reduce repair man-days for some ship types. However, the staffing variable could not measure the effect of the understaffing of specific skills on repair man-days.

"Study Of The Navy Ship Maintenance Program, Volume I-Destroyer Maintenance and Volume II-Measures of Effectiveness of Ship Maintenance Policy," by Logistics Management Institute. 1970-71.

The primary objective of the study was to find a material condition index to serve as a measurement scale by which the effect of alternative maintenance policies could be measured. If an index could not be found, a secondary objective was to define the characteristics of a new index and to evaluate the need for it.

During the course of analyzing available maintenance and operating histories of a large number of destroyers over a 13-year period, it became clear that a material condition index could not be found; that is, at no point in the operating cycle could the material condition of a destroyer be located on a quantitative scale. However, it was found that the cost of destroyer overhaul repairs had been increasing at the rate of 9.2 percent per year, because of increases in the amount of work done, inflation, and shifts in material control. Repair work during overhaul had increased at the rate of 5.6 percent per year. Inflation experienced by a naval shipyard was about 3 percent per year and was equivalent to that experienced by comparable civilian industry. The balance of the increase was believed attributable to shifts of material between accounts. The increase in the amount of repair work being done in overhaul was caused primarily by increased intensity of use, as measured by total fuel used, and secondarily by increases in time between overhauls.

The study concludes that maintenance data should be held and controlled for 11 years or more.

"Assessment Of Patrol Frigate Maintenance Policy. Effect Of Increased Operating Rate On Organizational And Intermediate Maintenance," by Logistics Management Institute. Interim Report, April 1972.

Based upon 171 destroyer records from April 1966 through March 1969, operating intensity, as measured by time and fuel consumed underway, was compared with maintenance staff-hour consumption at the organizational and intermediate level, in staff-hours/month. No correlations were found between either measure of intensity and maintenance expenditures.

Wide variations in both time underway and maintenance staff-hour consumption were found on a month-to-month basis; however, long-term averages showed smaller variations.

"An Analysis Of Maintenance Factors On Selected U.S. Navy Ships," by J.C. Grigsby, Naval Postgraduate School. June 1977.

This study examined certain reported maintenance factors to better understand how they influence the accomplishment of shipboard maintenance in cruisers and guided missile destroyers. This study showed (1) how the accomplishment of preventive maintenance varied as additional maintenance requirements were scheduled, (2) how the accomplishment of preventive versus corrective maintenance changed as funds for repair parts were increased, and (3) how the ships' employment schedules affected their accomplishment of shipboard maintenance.

"Economic Considerations In Establishing An Overhaul Cycle For Ships: An Empirical Analysis," by Institute of Naval Studies, Center for Naval Analyses. April 1974.

Multivariate statistical techniques were applied to cross-sectional data from the U.S. Navy's Atlantic Fleet Destroyer Force in a study of relationships among overhaul cycle, ship maintenance costs, and reliability. The influence of other relevant characteristics--ship age, size, usage, powering mode, and complexity--were held constant as required. Although a purely economic optimum overhaul cycle could not be determined, the range within which an acceptable cycle may be expected to lie was narrowed by cost implications.

"A Study To Determine Annualized Maintenance Cost And Feasibility of Adopting An Extended Overhaul Cycle For Destroyer-Type Ships," by ARINC Research Corporation. April 1974.

This study of destroyer-maintenance history was conducted to determine the current annualized maintenance (repair only) cost for destroyer-type ships and the feasibility of adopting an extended overhaul cycle for these ships. Consideration was given to annual maintenance cost and ship material condition in evaluating overhaul cycle extension.

"Surface Ship Maintenance," by Logistics Management Institute. January 1975.

This report documented the characteristics of the existing intermediate maintenance support structure for surface ships.

Information on the productivity of intermediate maintenance activities and on the amount of intermediate maintenance received by ships was sparse. Also, there was limited knowledge about the amount of intermediate maintenance required by ships and about the effect of a given amount of maintenance on a ship's material condition. For instance, the number of men per ship devoted to intermediate maintenance approximately doubled between 1968 and 1974, yet the material condition of ships did not perceptibly improve during the period. There were many variables (such as quality and quantity of a ship's crew) whose effect on a ship's material condition was not well understood. Therefore, the study recommended that the Navy perform, in vivo, experiments to explore alternative ships' staffing and maintenance policies.

MAINTENANCE PROCESSES AND INSTITUTIONS

"Evaluation Of Ship Overhaul And Maintenance Policy," by PRC Systems Sciences Company. May 1973.

The study attempted to identify, analyze, compare, and evaluate "as written" and "as practiced" overhaul policies.

The "as written" overhaul process was described by tracing both the modernization and repair decisions and identifying the organizations involved at key decision points. Budgets, schedules, and priorities were also discussed. The report presented a similar description of the "as practiced" overhaul process. It also described a number of overhaul policy problems identified during the study. In general, these policy problems were identified instances wherein written policy overlapped, conflicts existed, or significant differences existed between the "as written" and the "as practiced" policy.

"Accomplishing Shipyard Work For The United States Navy: Institutions, Systems And Operations," by Institute For Defense Analyses, Cost Analysis Group. August 1975.

This study examined factors relating to the accomplishment of Navy ship workloads in naval and private shipyards. It was designed to present, in a single document, a comprehensive discussion and evaluation of information from a wide range of areas that affected the accomplishment of Navy workloads.

The study results were presented in three volumes. Volume 1 examined facilities, organizations, and manpower skills required for ship construction versus depot maintenance in both naval and private shipyards; Navy procedures for placing shipyard work; shipyard performance indicators; and the labor market for the shipbuilding and repair industry. Volume 2 was a compilation of appendixes, and Volume 3 was an annotated bibliography.

"Trident System/Surface Ship Maintenance Process Description And Comparison Study," by Naval Ship Research and Development Center. April 1977.

The purpose of this study was to identify and describe the maintenance processes being performed by surface ships (destroyers/frigates) and those contemplated to be implemented by the TRIDENT Submarine System and to compare their salient situations, procedures, and method of handling data in these processes.

The TRIDENT Submarine System is contemplated to be more automated and employ software to a greater extent than surface ships currently do in implementing maintenance processes at the organizational and intermediate levels. The comparison of these maintenance processes was not judged with respect to preferability.

"A Management Approach To Shipyard Overhauls," by George J. Klug, U.S. Naval Postgraduate School. 1964.

The object of this paper was to provide a sequential flow of documented information and events leading to an improved management approach to a well-planned and well-executed ship overhaul.

"Methodology For Evaluating Naval Shipyards, Phase I - Model Feasibility," by Logistics Management Institute. February 1972.

The overall study objective was to develop a methodology for evaluting the relative utility of naval shipyards in terms of cost and effectiveness. Phase I was a review of existing models and data and selection of a model. Phase II was to be full-scale development and testing of the selected model. Phase I concluded that no model could be found which would satisfy the requirement. For this reason, it was recommended that Phase II be canceled.

Four possible models were investigated. The first two, a scheduling-cost model and a linear programing model, were rejected because an essential element, a measure of shipyard productivity, was not available. The third and fourth models, total cost comparison and fixed cost analysis, assumed invariant productivity. The total cost model was found to discriminate inadequately between costs of new construction in private and naval shipyards. The fixed cost analysis assumed that there are fixed costs of operating a shipyard that would be avoided by closing a yard. However, there was not clear evidence that fixed costs are large enough to substantially offset the costs of closing a yard.

"Application Of Decision Analysis To A Maintenance Strategy For Naval Surface Ships," by David W. Barns, Defense Systems Management College. 1974.

The objective was to examine and determine the decision making process in the various aspects of shipboard maintenance planning and accomplishment in order to identify the decision points and investigate the possibility of improvement through the application of the techniques of Decision Analysis.

"Assessment Of Patrol Frigate Maintenance Policy. Capacity Of Intermediate Level Maintenance Forces To Support The Fleet, Including The Patrol Frigate In The 1980's," by Logistics Management Institute. June 1972.

The analysis showed that tender capacity will considerably exceed demand in this period and that the Patrol Frigate will be the largest contributor to this total. The study suggested that a wide-ranging analysis should be performed of the relationships between the various maintenance echelons and how they should be structured to promote military readiness and economy.

PERFORMANCE MONITORING TECHNIQUES

"Feasibility Study For A Diesel Engine Condition Monitoring System For 1179 Class LST's," by National Bureau of Standards. July 1975.

This study of the maintenance costs and practices on the LST 1179 class ship was made to determine if a propulsion diagnostic system would result in cost savings or other advantages to the Navy. In this study, malfunctions of the current propulsion system were found and a listing was prepared of the necessary sensor measures to detect these malfunctions. Based upon this information, a diagnostic system was proposed and found to be cost effective.

A review of ship maintenance practices indicated that, at that time, too little was known of the operating condition of the engine. The proposed diagnostic system would provide such data in a more usable form. This would be of significant benefit to all concerned with ship maintenance and result in the following advantages:

--Improved readiness (approximately 20 percent).

--Improved scheduling of repairs and overhauls.

--Additional input for design modifications.

--Faster evaluation of ship alterations..

--Early diagnosis of unsatisfactory conditions.

"Ship Overhaul And Maintenance Study--Application Of Performance Monitoring Techniques To Shipboard Equipment," by Harbudge House, Inc./Marine Systems Group. May 1973.

The objective of this study was to ascertain the feasibility of reducing the cost of shipyard overhaul through more extensive use of performance monitoring practices--the various techniques used to assess the material condition of shipboard equipment without disassembly. The study focused on the aspects of management and economics in an extension of current practices, rather than on further development of the state of the art.

MANNING AND ORGANIZATIONAL STRUCTURE

"Investigation Of The Potential For Increased Use Of Civilian Manning In Fleet Support Ships," by Information Spectrum, Inc. February 1977.

This study examined the costs, risks, capabilities, and benefits of staffing Navy fleet support ships alternatively with Navy Civilian Service Mariners and commercial contract mariners. This was one of several alternatives being evaluated in the Navy's total force evaluation. Other alternatives included the assignment of women to sea duty and use of naval reserves to augment reduced Navy military ships.

"Combat System Performance Based On 3M Maintenance Data," by Navy Personnel Research and Development Center. April 1975.

The purpose of the research was to compare the maintenance effectiveness achieved by ships having an experimental combat system organizational structure with that achieved by selected control ships having a conventional organizational structure. Overall, the findings failed to demonstrate that improved maintenance effectiveness resulted from implementation of the combat system organizational structure on board pilot ships.

CHARACTERISTICS OF SELECTED SHIPS

Type	Number of ships selected	Age	Full load displacement	Overall length	Extreme beam	Screws/shaft horsepower	Staffing
		(years)		(feet)			
Commercial:							
General cargo:							
Breakbulk	59	10-33	17,210-22,892	470-593	69-76	1/9,90-19,250	38-46
Barge-carrying	9	4-6	55,660-57,083	876-893	100-106	1/32,000-36,000	32-38
Tankers	28	6-24	33,164-151,681	588-895	83-132	1/13,750-20,460	25-33
Navy:							
Auxiliary:							
Destroyer tender (AD-15, 17, and 19)	3	34-38	18,000	530-1/2	73-1/4	2/11,000	1,071
Ammunition (AE 23, 24, 26, 28, 29, and 32)	6	7-19	17,500-19,937	512-564	72-81	1/16,000-22,000	350-411
Combat store ships (AFS 1 and 4)	2	10-15	16,263	581	79	1/22,000	475
Fast combat support (AOE 1, 2, and 4)	3	8-14	52,483	793	107	2/100,000	598
Replenishment fleet oilers (AOR 3 and 4)	2	8	38,100	659	96	2/38,000	389
Repair ship (AR5)	1	37	16,330	530	73	2/12,000	1,335
Salvage ships (ARS 8, 39, and 41)	3	33-34	1,970-2,040	214	44	2/2,440	99-101

APPENDIX IV

Type	Number of ships selected	Age	Full load displacement	Overall length	Extreme beam	Screws/shaft horsepower	Staffing
		(years)		(feet)			
Submarine tenders (AS 11 and 34)	2	13-37	16,050-21,000	530-644	73-85	2/11,200 and 1/20,000	1,112-1,421
Submarine rescue ships (ASR 9 and 14)	2	32-35	2,290	251	44	1/3,000	120
Fleet ocean tugs (ATF 103, 105, 113, 159, 160, and 162)	6	33-34	1,640	205	39	1/3,000	92
Salvage and rescue ships (ATS 1 and 2)	2	6-7	3,125	283	50	2/6,800	100
Amphibious:							
Command ship (LCC 19)	1	8	19,000	620	108	1/22,000	1,438
Amphibious transport docks (LPD 4, 5, 6, 7, 9, 12, and 14)	7	7-13	16,900	569	105-116	2/24,000	473 (plus 904 troops)
Amphibious assault ships (LPH 11 and 12)	2	8-10	18,000	602	84	1/22,000	652 (plus 1,724 troops)
Dock landing ships (LSD 29, 30, 32, 35, 38, 39, and 40)	7	11-24	11,525-13,700	510-555	84-90	2/24,000	397-405 (plus 337-341 troops)
Tank landing ships (LST 1181, 1188, 1189, 1190, 1191, 1192, 1194, 1195, and 1198)	9	6-8	8,400	567	68	2/16,000	186 (plus 431 troops)

APPENDIX IV

EXAMPLES OF READINESS-REPORTING PROBLEMS

IDENTIFIED IN PRIOR GAO REPORTS

"Impaired Readiness of the Navy's Atlantic and Sixth Fleet" (B-146964, June 30, 1970)

--Improvements are needed in the criteria used for measuring and reporting combat readiness in order to increase the usefulness of readiness reports through a more accurate estimate of ship and squadron capabilities.

--Present criteria do not permit uniform application of readiness standards and do not result, therefore, in comparable readiness of similar units.

--There is a need for increased surveillance over the readiness-reporting system.

"Readiness of Navy Air and Surface Units for Antisubmarine Warfare" (B-160877, Mar. 11, 1975)

--The criteria used to measure overall combat capabilities were poorly defined, subject to varied interpretations, and inconsistently applied.

--The Navy has not established objective criteria for determining the status of units' combat readiness in specific mission areas, such as antisubmarine warfare.

"Needs for Improvements in Readiness of Strategic Army Forces" (B-146896, May 8, 1972)

--Readiness reports did not always contain accurate information which would permit the command official at division levels, and at the higher echelons, to adequately evaluate the readiness of the division.

--Revisions need to be made in the criteria used in preparing readiness reports to facilitate their uniform interpretation and to encourage more accurate reporting.

"Another Look at the Readiness of Strategic Army Forces" (B-146896, June 9, 1977)

--Equipment readiness-reporting criteria needs to be revised by (1) rescinding the practice of repairing equipment on paper without actually doing the job and (2) simplifying the equipment serviceability system.

--Personnel readiness-reporting criterion needs to include complete military occupational specialties (MOSs) in computing personnel qualifications.

--Training readiness-reporting criterion needs to require, at least periodically, a realistic evaluation of the resources and time needed to reach a ready-training condition.

"Readiness of First Line U.S. Combat Armored Units in Europe" (B-146896, July 23, 1976)

--Units are not required to report on the readiness condition of their ammunition.

--The Army's reporting system provides for combining key combat personnel and equipment with other less critical, more numerous, and more ready unit resources and for applying judgmental factors by various levels of command. As a result, readiness ratings are not always a reliable indicator of combat readiness.

"Readiness of the Air Force in Europe" (B-146896, Apr. 25, 1973)

--The readiness status of certain aircraft units was lower than reported because the criteria used to measure the units' readiness did not consider all pertinent factors and because some measurable areas, such as manpower and equipment, were not always properly reported.

AVERAGE ANNUAL MAINTENANCE COSTS FOR 58 NAVY SHIPS

Auxiliary ships

	Average annual repair costs (note a)	Overhaul repair costs	Naval shipyard overhauls
Destroyer Tenders:			
AD-15 Prairie	$3,671,664	$11,498,000	
17 Piedmont	5,220,730	6,394,257	
19 Yosemite	2,061,247	3,010,359	
Average	3,651,214	6,967,539	
Ammunition Ships:			
AE-23 Nitro	3,007,635	15,529,788	Naval
24 Pyro	1,338,736	6,900,000	
26 Kilauea	1,584,226	5,760,000	
28 Santa Barbara	1,255,649	5,588,541	
29 Mount Hood	1,195,341	4,710,000	
32 Flint	1,522,037	7,156,000	
Average	1,650,604	7,607,388	
Combat Store Ships:			
AFS-1 Mars	1,729,367	9,504,000	
4 White Plains	1,016,307	4,539,000	Naval
Average	1,372,837	7,021,500	
Fast Combat Support Ships:			
AOE-1 Sacramento	3,783,767	18,095,000	Naval
2 Camden	4,055,872	23,309,000	Naval
4 Detroit	2,643,819	14,448,776	
Average	3,494,153	18,617,592	
Replenishment Fleet Oilers:			
AOR-3 Kansas City	1,246,661	5,628,000	
4 Savannah	645,436	2,378,749	
Average	946,049	4,003,374	
Repair Ship:			
AR-5 Vulcan	2,401,753	4,085,548	

a/The average annual maintenance cost for each ship was computed by dividing the most recent shipyard overhaul repair costs, the intermediate maintenance acitivity hours expended between overhauls at $22 per hour, and the cost of parts used between overhauls by the ship cycle. A $22 per hour cost was used since this was the typical rate charged to private shipping firms by U.S. commercial shipyards. The ship cycle is the number of years from the end of one overhaul to the end date of the most recent overhaul. The average annual cost specifically excludes modernization costs, intermediate maintenance activity, ships force work done during overhauls, and ships force corrective and preventive maintenance performed between overhauls.

	Average annual repair costs	Overhaul repair costs	Naval shipyard overhauls
Salvage Ship:			
ARS- 8 Preserver	$ 550,935	$1,548,697	Naval
39 Conserver	714,376	2,615,000	
41 Opportune	197,008	346,439	
Average	487,440	1,503,379	
Submarine Tenders:			
AS-11 Fulton	4,740,427	8,227,014	Naval
34 Canopus	4,858,197	13,362,292	Naval
Average	4,799,312	10,794,653	
Submarine Rescue Ship:			
ASR- 9 Florixan	747,810	2,661,235	
14 Petrel	1,414,961	4,438,691	
Average	1,081,386	3,549,963	
Fleet Ocean Tugs:			
ATF-103 Hitchiti	494,245	1,536,000	
105 Moctobi	654,558	2,290,000	
113 Takelma	557,515	1,690,000	
159 Paiute	315,424	351,429	
160 Papago	392,326	1,207,000	
162 Shakori	283,311	812,000	
Average	449,563	1,314,405	
Salvage and Rescue Ship:			
ATS-1 Edenton	766,996	3,223,918	
2 Beaufort	1,554,083	6,463,000	
Average	1,160,540	4,843,459	
Auxiliary ship average	1,769,419	6,228,367	

Amphibious Ships

	Average annual repair costs	Overhaul repair costs	Naval shipyard overhauls
Amphibious Command Ship:			
LCC-19 Blue Ridge	$2,237,959	$8,424,000	Naval
Amphibious Transport Docks:			
LPD- 4 Austin	3,439,529	14,366,891	
5 Ogden	1,629,276	4,772,000	
6 Duluth	2,623,050	9,830,000	
7 Cleveland	4,015,908	14,246,000	Naval
9 Denver	3,076,349	10,270,000	Naval
12 Shreveport	1,988,792	8,467,497	
14 Trenton	1,932,585	7,385,700	
Average	2,672,213	9,906,727	
Amphibious Assault Ships:			
LPH-11 New Orleans	2,126,394	8,693,000	
12 Inchon	2,363,054	11,624,301	Naval
Average	2,244,724	10,158,650	
Dock Landing Ships:			
LSD-29 Plymouth Rock	1,759,179	7,965,000	
30 Fort Snelling	2,001,364	8,928,000	
32 Spiegel Grove	2,632,177	10,222,927	
35 Monticello	1,904,334	6,550,000	
38 Pensacola	1,781,102	7,586,924	
39 Mount Vernon	1,882,648	6,578,000	
40 Fort Fisher	2,098,281	6,874,000	
Average	2,008,441	7,814,979	
Tank Landing Ships:			
LST-1181 Sumter	965,324	4,048,439	
1188 Saginaw	1,328,245	5,613,809	
1189 San Bernadino	1,500,698	5,651,000	
1190 Boulder	1,224,807	5,729,000	
1191 Bacine	1,388,654	5,363,000	
1192 Spartanburg County	1,380,709	6,134,843	

APPENDIX VI

	Average annual repair costs	Overhaul repair costs	Naval shipyard overhauls
1194 Lamour County	1,507,825	6,631,741	
1195 Barbour County	1,401,248	5,469,000	
1198 Bristol County	1,671,264	6,050,000	
Average	1,374,308	5,632,315	
Amphibious ship average	1,994,644	7,826,310	
AUXILARY AND AMPHIBIOUS AVERAGE	1,870,382	6,944,686	

NAVY SHIPS WITH SOME CHARACTERISTICS SIMILAR TO COMMERCIAL SHIPS

Ship type	Age (years)	Full load displacement	Overall length	Extreme beam	Screws/shaft horsepower	Staffing
CATEGORY I:						
Commercial:						
Breakbulk cargo	10-33	17,210-22,892	470-593	69-76	1/9,900-19,250	38-46
Smaller tankers	17-24	33,164-41,694	588-743	83-102	1/13,750-20,460	25-33
Navy:						
Auxiliary:						
Ammunition (AE)	7-19	17,500-19,937	512-564	72-81	1/16,000-22,000	350-411
Combat store ships (AFS)	10-15	16,263	581	79	1/22,000	475
Submarine tenders (AS)	13-37	16,050-21,000	530-644	73-85	2/11,200 and 1/20,000	1,112-1,421
Amphibious:						
Command ships (LCC)	8	19,000	620	108	1/22,000	1,438
Assault ships (LPH)	8-10	18,000	602	84	1/22,000	652 (plus 1,724 troops)
CATEGORY II:						
Commercial:						
Cargo (Barge-carrying)	4-6	55,660-57,083	876-893	100-106	1/32,000-36,000	32-38
Tankers (large)	6-18	51,549-151,681	743-895	102-132	1/13,750-19,000	25-33
Navy:						
Fast combat support (AOE)	8-14	52,483	793	107	2/100,000	598
Replenishment fleet oilers (AOR)	8	38,100	659	96	2/38,000	389

APPENDIX VII

APPENDIX VIII

COMPARISONS OF NAVY AND COMMERCIAL MAINTENANCE

COSTS FOR SIMILAR TYPES OF EQUIPMENT

Average annual maintenance cost per ship

Equipment	Navy	Company A (note a)	Company B	Company C	Company D	Company E	Commercial average	Navy/ commercial ratio
Boilers	$135,445	$ 53,121	$ 40,835	$18,454	$14,351	$34,864	$ 33,022	4.1:1
Forced draft blowers	26,699	2,000	1,739	(b)	(b)	(b)	1,580	16.9:1
Main feed pumps	24,503	4,000	7,362	(b)	(b)	(b)	4,183	5.9:1
Main circulating pumps	7,103	5,500	2,755	(b)	(b)	(b)	3,813	1.9:1
Main fuel oil service pumps	7,917	2,600	1,110	(b)	(b)	(b)	1,752	4.5:1
Air compressors	25,555	500	2,908	(b)	(b)	(b)	1,046	24.4:1
Painting	108,811	110,758	a/100,000	30,140	15,371	14,727	55,638	2.0:1
Deck covering	40,568	(b)	(b)	775	1,218	271	685	59.2:1
Commissary and laundry	39,188	(b)	(b)	2,316	2,849	1,578	2,168	18.1:1

a/Estimated.

b/Cost categories were not comparable.

(947302-II)

Single copies of GAO reports are available free of charge. Requests (except by Members of Congress) for additional quantities should be accompanied by payment of $1.00 per copy.

Requests for single copies (without charge) should be sent to:

U.S. General Accounting Office
Distribution Section, Room 1518
441 G Street, NW.
Washington, DC 20548

Requests for multiple copies should be sent with checks or money orders to:

U.S. General Accounting Office
Distribution Section
P.O. Box 1020
Washington, DC 20013

Checks or money orders should be made payable to the U.S. General Accounting Office. NOTE: Stamps or Superintendent of Documents coupons will not be accepted.

PLEASE DO NOT SEND CASH

To expedite filling your order, use the report number and date in the lower right corner of the front cover.

GAO reports are now available on microfiche. If such copies will meet your needs, be sure to specify that you want microfiche copies.

AN EQUAL OPPORTUNITY EMPLOYER

UNITED STATES
GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE,$300

POSTAGE AND FEES PAID
U. S. GENERAL ACCOUNTING OFFICE

U.S.MAIL

THIRD CLASS