CNS 1090

CREW CHARACTERISTICS AND SHIP CONDITION
(Maintenance Personnel Effectiveness Study (MPES))

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The productivity of enlisted personnel aboard ships is estimated as a function of their personal characteristics. Ship readiness is measured by the material condition of shipboard equipment. Up to now, little has been known about the relative value of different kinds of personnel. The goal of this study is to improve on the assumptions underlying Navy personnel policies. Casualty reports from 91 cruisers, frigates, and destroyers are used to study how the productivity of enlisted personnel varies systematically with high school graduation, entry test scores, paygrade, experience, Navy training, race and marital status. Six occupations and three subsystems are

[20] examined separately. Equipment complexity, ship age, and overhaul frequency are accounted for. Implications are drawn for Navy policies regarding recruitment, retention, manning, rotation, and pay.

[7] Contributors: Nancy Harris, Barbara Measell, Steven Naron, Mark Ripma, Peter Roane, Sue G. Ross

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20 OCT 1977

From: Chief of Naval Operations
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Subj: Maintenance Personnel Effectiveness Study; promulgation of

Encl: (1) CNA Study 1090, "Crew Characteristics and Ship Condition" (Maintenance Personnel Effectiveness Study Report)

1. The Maintenance Personnel Effectiveness Study examines the relative effectiveness of men who differ in such characteristics as education, mental ability, training, experience, paygrade, marital status, and race. The study analyzes the effectiveness of maintenance personnel in engineering, weapons, and ASW areas using CASREPT downtime of 91 cruisers, frigates, and destroyers as a proxy for material condition. The study relates variations across ships in the condition of equipment to differences in the characteristics of crew members responsible for maintenance. Relationships are derived for six ratings: BT, MM, FT, GM, ST, and TM. Quantitative estimates of the effects of ship age, ship overhauls, and equipment complexity on material condition are also derived.

2. This study is one step in the Navy's continuing effort to analyze and evaluate the importance of the many determinants of readiness, as well as a source of useful analytical information for examining policies related to recruitment, training, and assignment of maintenance personnel. This study has been successful in going beyond the standard assumption that the relationship between personnel effectiveness, LOS, and paygrade is measured by salary. Many previously suspected relationships are substantiated and others refuted by the study. Specifically it was found that:

a. High quality personnel are, in general, more valuable on ships with the most complex equipment. On ships with relatively simple equipment, having a full complement of men may be more valuable.

b. The determinants of material condition varied substantially across ratings and subsystems. Sea experience, for example, is most important for STs maintaining sonar equipment.

c. Entry test scores and high school graduation reflected personnel effectiveness in approximately half of the ratings studied.

d. In two ratings, BT and ST, single men were more productive than married men. (Productivity, as used throughout the study, refers to maintenance effectiveness of personnel).

e. Navy training improved personnel performance. For some ratings NEC-granting schools were more valuable than other schools.

f. Independent of each other, additional Navy experience and higher rank relate strongly to personnel effectiveness.

3. The following must be considered when reviewing the analyses:

a. The results should be treated as indicative rather than conclusive as the findings are based on data from only 91 ships of the Navy. None of the estimates is precise; some deserve more confidence than others. All the results in the study are dependent upon the use of CASREPT downtime as the measure of material condition of shipboard equipment. Only cruisers, destroyers, and frigates were studied.

b. The study does not take account of all factors that influence material condition. Supply is not explicitly addressed. Leadership and morale are not addressed, but there is no reason to believe that these omissions lead to improper treatment of those factors that are addressed.

c. Care must be taken in interpreting the study results. Estimated coefficients indicate the effect of personnel characteristics on material condition when other things are held constant. They do not register the full effect. For example, graduation from an additional school is likely to increase the probability of promotion. Calculation of the value of additional schooling requires consideration of both the direct effect via the estimated schooling coefficient and an indirect effect via the paygrade coefficient. Similar adjustments are necessary when the total effect of additional service is being discussed.

4. Enclosure (1) is forwarded.

D. C. DAVIS
Director
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SECTION I

INTRODUCTION

The need to document quantitative relationships between fleet readiness and resources is being stressed by the Congress, OMB, and OSD. This study documents such a relationship by relating variations among ships in the condition of equipment to differences in crew members responsible for maintenance. The results can be used to improve management of the Navy's enlisted force and the material condition of ships in the fleet. Ships were the units of observation in the analysis. The examination was confined to cruisers and destroyers: 40 destroyers (DDs), 18 guided missile destroyers (DDGs), 17 frigates (FFs), 4 guided missile frigates (FFGs), and 12 cruisers (CGs). These 91 ships are all the active ships of these types that underwent overhauls in fiscal years 1972, 1973, and 1974. (The ships in the sample along with some information about them, are listed in appendix A.)

The period of observation for the condition of equipment was either the entire time between a ship's overhaul in FY 1972, 1973, or 1974 and its previous overhaul, or as much of this period as possible.[1] For the personnel variables, the entire inter-overhaul period was used, since the condition of a piece of equipment depends not only on the care it is getting now, but also on the care it received in the past.

Casualty Report (CASREPT) information was used to derive measures of the condition of equipment.[2] CASREPT downtime per month was our key measure. CASREPT downtime is the number of casualties a ship had, multiplied by the average time it took to fix CASREPTs on that ship. CASREPT downtime per month is equivalent to the average number of CASREPTs outstanding.[3]

We also examined data on material condition derived from 3-M corrective maintenance reports, Overhaul Departure Reports, and INSURV reports (reports of the Board of Inspection and Survey). These are discussed in more detail in section 4.

Rather than study entire ships, we concentrated on several subsystems. The subsystems chosen are common to a large number of cruisers and destroyers and are maintained by men in a small number of ratings. The subsystems are boilers, engines, gun systems, missile systems, antisubmarine warfare (ASW) systems, and sonars. Table 1 shows the ratings of the personnel who are reponsible for the maintenance of these subsystems.

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[1]The data we used on the condition of shipboard equipment were not available for the years before 1970. Thus, we were not able to look at the entire inter-overhaul period for some ships. At least 18 months of data were available for all the ships. We assume that the material condition of a ship is not a major factor in determining when it is overhauled.

[2]Ships are directed to file a CASREPT when their ability to perform a mission is degraded because of equipment failure.

[3]CASREPT downtime per month equals the average number of CASREPTs outstanding times the number of hours in the month.

As the table shows, the same ratings are sometimes responsible for part of the maintenance of more than one subsystem. To analyze both crew performance and subsystem condition, we allocated CASREPTs both by rating--BT, MM, FT, GM, ST, TM--and by subsystem--gun, missile, ASW. We used 3-M data on all reported corrective maintenance actions taken from 1970 to 1975 on the 91 ships to determine which rating most often repaired a piece of equipment. The resulting assignment of equipment to ratings is presented in appendix B.

TABLE 1

SUBSYSTEMS STUDIED

Subsystem	Associated Rating
Boilers	Boiler Technician (BT)
Engines	Machinist's Mate (MM)
Gun systems	Fire Control Technician (FT) Gunner's Mate (GM)
Missile systems	Fire Control Technician (FT) Gunner's Mate (GM)
ASW systems	Gunner's Mate (GM) Sonar Technician (ST) Torpedoman's Mate (TM)
Sonars	Sonar Technician (ST)

The personnel analysis relied on crew histories compiled from the Navy's Enlisted Master Record (EMR). To build these histories, we reviewed the records of the entire enlisted force for 1967, 1968, 1969, 1971, 1973, 1974, and 1975, and picked out the men on the 91 ships. We then developed aggregate statistics describing the characteristics of each crew by rating. This required weighting the characteristics of individuals by the fraction of the observation period they were assigned to the ship.[1]

The personnel characteristics examined are shown in table 2, along with the other factors included in our analysis. The treatment of some of these characteristics deserves clarification.

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[1]When characteristics changed during an individual's tour aboard one of the ships (e.g., LOS, paygrade), the change was taken into account. In many cases, we could not tell when men left the ships because they left the Navy and were not observed on subsequent EMRs. People who have been out of the Navy for six months are deleted from the EMR. Since there were one and two year gaps between the EMRs that we used, many men were dropped from the record before we could observe their dates of departure from the ships. When this happened, it was necessary to approximate their departure dates from information on when they were likely to have left the Navy. In rare cases, information on personnel aboard DDs was taken from semi-annual Bureau of Naval Personnel Enlisted Distribution and Verification Reports (BuPers Form 1080). Use of these data will be identified in context.

TABLE 2

DETERMINANTS OF MATERIAL CONDITION STUDIED

Personnel characteristics[a]	
	Number of enlisted personnel
	High school graduation
	Entry test scores
	Paygrade profile
	Length of service (LOS)
	Time aboard this ship
	Time aboard other ships
	Number of Navy schools attended
	Number of NECs attained[b]
	Race
	Marital status
Other factors	
	Shipage
	Overhaul frequency
	Equipment complexity

[a]Data were also gathered on the age of enlisted men and on the number of officers aboard the ships. These factors did not prove to be important.

[b]Some Navy Enlisted Classification (NECs) on individuals can be gained only via school attendance; others can be earned on the job. We differentiated between these two types, and used the number of NECs of each type that men possessed as a measure of the extent of advanced training.

Since more-experienced men are more likely to be in higher paygrades, an analysis which focused only on paygrade, for example, would be unable to determine how much of the added productivity of senior men reflected selection of the best men for promotion and how much was merely the result of experience. By including both paygrade and LOS in the analysis, we were able to disentangle the quality dimension of higher paygrade from the effect of experience. We did not assume that more experienced (or higher ranked) men continuously get better at their jobs. We examined the possibility that, after a break-in period, junior men reach a higher level of proficiency beyond which they tend not to improve, or that further significant improvement only occurs after a considerable time.[1] Our estimates of the relationships between paygrade, LOS, and productivity allowed an alternative to the assumption that the pay of different kinds of enlisted men reflects differences in their productivity.[2]

[1]Continuous linear and logarithmic forms were tried for the LOS variable. Then men were divided into eight LOS groups: under one year, 1-2 years, 2-3 years, 3-4 years, 4-5 years, 5-7 years, 7-10 years, and over 10 years. These groups were then aggregated to find the relationship that best predicted downtime. A similar aggregation procedure was used for paygrades.

[2]This assumption is used fairly widely. See, for instance, "Formal and On-the-Job Training for Navy Enlisted Occupations," by R. Weiher and S. Horowitz, CNA Professional Paper 83, Nov 1971.

Experience at sea may be more important in increasing the productivity of enlisted men than shore duty. We examined whether ships with crews that have had more prior sea duty tend to have less CASREPT downtime. We also examined whether ships with more-stable crews, those whose men have been aboard longer, have less downtime. If either of these variables reflects higher productivity, the Navy's policy regarding sea-shore rotation will be open to question.

If blacks receive poorer educations, more blacks, holding educational attainment constant, may be associated with worse maintenance. If the Navy's entry tests discriminate against blacks, more blacks, holding test scores constant, may be associated with better maintenance. We hoped to discover whether the Navy's use of high school graduation and of entry tests as guides to recruitment and assignment is equally appropriate for blacks and whites.

Usually the differences between ships in their equipment correspond to differences in ship type or class; sometimes they do not. Obviously this may influence ships' maintenance histories. In general, more complex equipment is expected to be down more often. Because of the possibility that personnel contributions to maintenance were different for ships with different kinds of equipment, dummy variables were introduced describing the kinds of equipment aboard the ships in the sample.[1] Equipment variations will be discussed along with the empirical results.

For each of nine groups (BT, MM, GM, FT, TM, ST, guns, missiles, ASW), we estimated a relationship of the following form:[2]

$$\text{Downtime} = f(\text{age},\ \text{ovh diff},\ \overline{\text{equipment}},\ \overline{\text{pers}})\ , \qquad (1)$$

[1]This was done by multiplying each personnel variable by all the equipment dummy variables (for the relevant rating or subsystem). The variables thus created were entered separately into the equation being estimated. If this procedure did not improve the explanatory power of the equation, its results were discarded.

[2]We also examined the connection between operating tempo and material condition. No direct connection was found. In addition, the relative condition of ships based on the east and west coasts was examined. The west coast ships appeared to have less CASREPT downtime (they also steamed significantly more). Finally, using a procedure for looking at all our ratings simultaneously, we checked for whether there were systematic tendencies for some ships to be better than others in all areas. In some cases there were. Inclusion of these operating tempo, coast, and ship variables did not have a large effect on the impact of the variables in equation (1) on CASREPT downtime, and so we have concentrated on the results of the estimating formulation in the equation. The results of including the variables mentioned here are discussed in section 5 and CNA Memo 76-0537.20.

where

downtime = average CASREPT downtime per month;

age = age of the ship (in years) at the time of its overhaul in FY 1972-74;

ovh diff = number of months between overhauls;

$\overline{\text{equipment}}$ = a vector of dummy variables reflecting the kinds of equipment deployed on the ships;

$\overline{\text{pers}}$ = a vector of the enlisted personnel variables listed in table 2.

We estimated equation (1) by use of ordinary least squares.

PART ONE

MAIN ANALYSIS

SECTION 2

GENERAL CONCLUSIONS

The condition of shipboard equipment was affected by the complexity and age of the equipment, the length of time since it was last overhauled, and the number and characteristics of the men who operate and maintain it. Crew characteristics that influenced the productivity of enlisted men included high school graduation, entry test scores, race, marital status, length of service, paygrade, sea experience, and advanced training. Not all of these factors made a difference for all kinds of equipment, but in all cases some of them mattered.

Our results are summarized in table 3. It displays the characteristics found to influence the productivity of men in each of the six ratings examined. It also shows other factors that affected the condition of equipment handled by men in each of the ratings. An "X" signifies a relationship that was unexpected; a check means that it was not. A blank means that no relationship was found.[1]

Equipment complexity was a major influence affecting the condition of all kinds of equipment. An important facet of our results not captured by table 3 is that higher skill levels reflected in education, test scores, experience, or training frequently increased productivity only when men handled relatively complex equipment. On the other hand, variations in crew size seemed to make the most difference on simpler ships.

In all ratings, men in higher paygrades were more productive than their juniors, even when length of service was held constant. Except for TMs, some measure of LOS related positively to productivity. For STs, sea duty was the only kind of experience found to increase productivity. Sea duty was also important in several other ratings.

The results regarding paygrade and experience must be interpreted carefully. They mean that men who get promoted under existing promotion policies are more productive than men who do not. They do not mean that more men should be promoted. The mere act of promotion does not make men more valuable.

In calculating productivity differences for men with different lengths of service, other factors that differ with LOS must be considered. For example, men who have been in the Navy ten years are likely to be in higher paygrades than men who have been in five years. The probability of promotion and the estimated additional productivity of men in higher paygrades must be taken into account in comparing the value of men with different lengths of services.

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[1]In the rare cases where we found a relationship in a subsystem equation (guns, missiles, or ASW) that was not in the corresponding rating equation, it was assigned to the relevant rating in table 3. Some of these estimated effects are more statistically reliable than others. Details of statistical significance are addressed in appendix C and section 3.

TABLE 3

DETERMINANTS OF PERSONNEL PRODUCTIVITY AND EQUIPMENT CONDITION AS MEASURED BY CASREPT DOWNTIME

Crew characteristics or other determinant of material condition	BT	MM	GM	FT	TM	ST
Crew size	✓	✓		✓	✓	
High school graduation				✓		✓
Entry test scores	✓		✓	✓		
Paygrade	✓	✓	✓	✓	✓	✓
Length of service	✓	✓	✓	✓	X	
Sea experience: aboard prior ships		✓	✓			✓
Sea experience: aboard current ship		✓				
Training: number of schools attended	✓	X	X		✓	✓
Training: number of NECs attained	✓	✓	✓			
Marital status	✓					✓
Race				✓		
Ship age	✓	✓			✓	
Time between overhauls			✓	✓	✓	
Equipment complexity	✓	✓	✓	✓	✓	✓

FTs and STs were more productive when they were high school graduates. In less technical ratings, high school graduates were not found to be more productive than other men of the same paygrade and LOS. Entry test scores predicted the performance of BTs, GMs, and FTs.

Variations in productivity reflected variations in training in all of the ratings except FTs. Perhaps FTs are so highly trained that variations do not matter much. When paygrade and LOS were held constant, however, additional school attendance helped MMs and GMs only when it led to attainment of an NEC. (Interestingly, these were two ratings where sea experience was more valuable than shore duty in increasing men's productivity.) Some of the value of training may have been picked up by paygrade variables. This will be the case if some men benefit from training and others do not, and if those who benefit are more likely to be promoted.

Single STs and BTs were found to be more productive than married men in those ratings.

Entry tests may discriminate against black FTs, who were more productive than expected on the basis of test scores and high school graduation. The effect was not found in other ratings.[1]

Older ships had more CASREPT downtime, particularly in engineering. Ships with longer gaps between overhauls also had more downtime, especially in weapons.

Our results have implications for what policies should be followed to improve the management of enlisted personnel. In many cases, discovery of the precise nature of these implications requires calculation of the cheapest way to improve material condition. This, in turn, requires that estimates of differences in productivity be combined with estimates of differences in the cost of personnel with various levels of education, ability, experience, and training. In other cases, the implications of our results are apparent without further analysis:

- Place a higher proportion of senior men and highly trained men on ships with complex equipment. This would both cut total equipment downtime and increase the availability of high-performance equipment.
- Pay more attention to the level of manning on ships with less complex equipment. We would not recommend manning cuts where we found no effect of crew size, however, because maintenance is not the only task men have.
- Do not screen men so carefully on the basis of high school graduation and entry test scores in ratings where these characteristics do not seem to increase productivity.
- Try to get STs to spend more time at sea by paying special sea pay selectively to certain ratings.
- Although higher entry test scores do not always indicate higher productivity, they usually do not seem to discriminate against blacks. FTs are an exception. Perhaps give blacks waivers to become FTs, even if they do not quite meet the usual criteria.
- Re-examine the policy of paying single men less than married men. Currently, housing allowances and other benefits (PX privileges, medical care) favor married men. Wherever we found a difference in productivity between single and married men, the single men were better.
- Pay more attention to the maintenance implications of introducing complex new equipment.

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[1]CNA Study 1039, "Enlisted Selection Strategies," by R.F. Lockman, found that entry tests are relatively poor predictors of the success of blacks in electronics schools in the Navy (p. 10).

SECTION 3

DISCUSSION OF RESULTS BY RATING AND SUBSYSTEM

In this section, the results of estimating equation (1) for each of the six ratings and three subsystems will be treated.[1] The explanatory variables differ across groups because variables that did not improve the prediction of CASREPT downtime per month were deleted.

ENGINEERING

For the most part, the ships have one of four kinds of propulsion plants. All of the DDs in the Forrest Sherman Class, all the DDGs, and all the CGs have 1200 p.s.i. main propulsion plants and two screws. The older DDs also have two screws, but 600 p.s.i. plants. The FF 1052 class has one screw and 1200 p.s.i. plants, while the FF 1040 (Garcia) class and FFGs have one screw and pressure-fired boilers.[2] Distinguishing among these kinds of systems proved to be very important in explaining the material condition of boilers as measured by CASREPT downtime.

Table 4 lists the CASREPT downtime for different kinds of plants. The more complicated 1200 p.s.i. plants obviously have more boiler trouble than 600 p.s.i. plants. Because boiler downtimes for the two types of one-screw plants were similar, they have been treated together in the rest of the analysis. We suspect that the FRAM DDs have more engine downtime because their engine rooms contain equipment that is in the fire rooms of other ships and so MMs do work that BTs do elsewhere.

Boiler Technicians

The predictive relationships estimated for equipment maintained by BTs are displayed in table C-1 in appendix C. The coefficients are the best estimates of the effect of a one-unit change in each of the explanatory variables on the average number of hours of boiler CASREPT downtime per month. These results are never in an unexpected direction and are often quite significant.

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[1] Both linear and semilogarithmic forms for the regressions were tested. The functional form that predicted best for a group is the one used.

[2] The 91 ships included one diesel-powered ship, one 600 p.s.i. ship with one screw, and one Forrest Sherman ship without automatic combustion control. All three ships were deleted from the BT analysis.

TABLE 4

CASREPT DOWNTIME FOR ENGINEERING SYSTEMS

Ship classes or types	Number of ships	Kind of equipment	Average CASREPT downtime (hrs/mo) BT-related	MM-related
CG, DDG, Forrest Sherman destroyers (except DD 933)	36	2 screws, 1200 p.s.i.	730[a]	222
FRAM destroyers	33	2 screws 600 p.s.i.	218	349
FF 1040, FFG 1	11	1 screw, 1200 p.s.i. pressure fired	318	279
FF 1052	8	1 screw, 1200 p.s.i.	301	143

[a] 730 is approximately the number of hours a month. This means that, on the average, these ships have one boiler CASREPT outstanding. Since they have four boilers, three are usually CASREPT-free. In any case, existence of a CASREPT does not necessarily imply complete inability to operate. 75 percent of all CASREPT downtime is C-2, implying minor degradation of mission-essential equipment. If equipment is C-3, it is termed marginally ready. C-4 means not ready. In this study all three types of CASREPTs have been aggregated together.

Equipment complexity affected not only material condition, but also the effect of the crew on material condition. Crew quality, as measured by entry test scores, paygrade, training, and length of service, seems to have mattered much more on 1200 p.s.i. ships, particularly those with two screws. We estimate that an increase of one percentage point in the average Shop Practices Test scores of BTs on two-screw, 1200 p.s.i. ships would lower CASREPT downtime by an average of 138 hours per month. There is also a very high payoff to having rated personnel. A one percentage point drop in the fraction of BTs who are unrated (E-3 or below) is associated with a drop of 25.19 hours in CASREPT downtime per month. Married BTs are less productive than single BTs on two-screw, 1200 p.s.i. ships. Perhaps they are less willing to put in the long hours the job requires. Training was important on one-screw ships, though not as important as on two-screw, 1200 p.s.i. ships. If a quarter of the BTs attended one extra school, we estimate that CASREPT downtime would fall by 72 hours a month on the one-screw ships. Crew size, on the other hand, was more important on 600 p.s.i. ships. We estimate that an additional BT would reduce downtime by 71 hours per month.[1]

These results do not mean that crew size makes no difference on 1200 p.s.i. ships or that Navy training makes no difference on 600 p.s.i. ships. They do mean that variations in these characteristics within the ranges observed in the fleet are not likely to make much difference.

Not surprisingly, we found that, other things equal, older ships had significantly more boiler problems.

Table 5 gives our best estimate of how personnel policies could be changed to cut boiler-related CASREPT downtime by 50 hours per month on destroyers with different kinds of fire rooms. The greater the indicated statistical significance (1 percent is more significant than 5 percent), the more confident we are that movement in the indicated direction would improve material condition. Our estimates indicate that it would be fairly easy to accomplish such an improvement in material condition, especially in the most complex fire rooms. This may be because the two-screw, 1200 p.s.i. plants are in relatively poor condition to begin with.

Machinist's Mates

In examining the determinants of the condition of engines, we distinguished among different kinds of main propulsion plants in the same way we did for boilers. As might be expected, steam pressure played a smaller role in engine condition than it did in boiler condition. Table 4 demonstrated this.

Factors that influence CASREPT downtime seem to be quite similar on all two-screw ships. Table C-2 displays our estimated relationship; table 6 shows its implications for improving the condition of engines.

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[1] The data on crew size that were used here came from BuPers Form 1080. We gathered this information only for the DDs in the sample. Perhaps if we had had it for all 88 ships in this analysis, crew size would have appeared more important for the 1200 p.s.i. ships. (There were six 1200 p.s.i. DDs in this sample.) When data on crew size from the Enlisted Master Record were used, no effect of crew size was found. Usually the EMR and Form 1080 measures of crew size correlated quite highly (an average of .67). Here, the only rating for which Form 1080 data were used, the correlation was only .48.

TABLE 5

POTENTIAL WAYS TO CUT BT-RELATED CASREPT DOWNTIME BY 50 HOURS PER MONTH

Type of propulsion plant	Crew characteristic	Observed level	Required level
Two screws, 1200 p.s.i.	Average score on Shop Practices Test[e]	55	56
	Percent E-4 or below[c]	33	31[a]
	Percent E-8 or above	3.8	5.2[a]
	Percent with LOS under 1 year[b]	6.9	5.8[a]
	Percent with LOS 1-10 years	72.6	67[a]
	Average number of school-related NECs per man[e]	.46	.49
	Percent single[c]	47	49
One screw	Percent with LOS under 10 years	79.4	73.8
	Average number of Navy schools attended per man[a]	1.90	2.07
Two screw, 600 p.s.i.	Crew size[c]	22.4[b]	23.1
	Percent with LOS under 10 years	79.4	73.8

[a]Significant at the 10 percent level.
[b]Significant at the 5 percent level.
[c]Significant at the 1 percent level.

TABLE 6

POTENTIAL WAYS TO CUT MM-RELATED DOWNTIME
BY 50 HOURS PER MONTH

Type of plant	Crew characteristic	Observed level	Required level
All steam plants	Percent with LOS under 3 years[a]	52	44
Two screws	Average time on this ship (months)	15	17
	Average number of NEC-granting schools attended	.37	.59
	Average number of non-school NECs attained	.14	.25
Two screws, 1200 p.s.i.	Average number of MMs	22	28
	Average prior sea experience (months)[a]	27	32
Two screws, 600 p.s.i.	Average number of MMs[b]	24	26
	Percent of E-3 or below	29	24

[a] Significant at the 10 percent level.
[b] Significant at the 1 percent level.

Experience seems to be the most important characteristic of MMs. Not all experience is equally important, however. On all 89 ships in this sample,[1] it helped to have men who have been in the Navy over 3 years. For all but the one-screw ships, sea experience was apparently more valuable than shore duty. Frequent rotation seemed to detract from maintenance. On two-screw, 1200 p.s.i. ships in particular, sea duty had a high payoff. Even holding LOS and time in current billet constant, having fewer unrated men helped on 600 p.s.i. ships.

Having more MMs on board improved material condition on the two-screw ships. Apparently larger crews were more important on the 600 p.s.i. ships. This is similar to our finding for BTs. Perhaps this illustrates the greater importance of the number of workers when there is a less complex capital plant -- a kind of substitution of labor for capital.

Training was found to improve the productivity of MMs in some cases. Holding the number of NECs constant, additional schooling was estimated to detract from maintenance. This may reflect the attendant decrease in valuable sea experience.[2] When an NEC was attained, however, the gain more than made up for the loss due to school attendance. NECs that do not require formal schooling may be particularly valuable, although the cost of picking up skills on the job is very hard to measure and may be quite high.[3] Once again, older ships were in significantly worse shape.

GUNS AND MISSILES

Because both FTs and GMs are responsible for part of the operation and maintenance of both guns and missiles,[4] analysis of these systems is a bit more complicated than analysis of the engineering systems where different ratings are responsible for boilers and engines. As noted earlier, we used 3-M data to assign CASREPTs to the rating

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[1]The Forrest Sherman destroyer (DD 933) without automatic combustion was included in this sample.

[2]Sometimes men attend schools while they are assigned to ships. In such cases our sea experience variable will overstate actual sea experience. The school variable may pick this up.

[3]See Weiher and Horowitz, "The Relative Costs of Formal and Job Training for Navy Enlisted Occupations," CNA Professional Paper 83, Nov 1971.

[4]GMs also work on ASW equipment.

responsible for the equipment, regardless of what subsystem it is part of. The equations we derived from this assignment by rating are our best estimates of the influence of crew characteristics on maintenance. They do not, however, allow us to address questions regarding how best to improve the condition of particular subsystems.

To address these questions, we have also estimated equations by subsystem. Thus, the material condition of guns is studied as a function of the characteristics of both GMs and FTs, as is the material condition of missiles.[1] These subsystem equations do not associate men with all the work they do, but they allow us to analyze the condition of specific weapons systems.

Table 7 shows the large number of combinations of gun and missile equipment on the 91 ships. It is clear that CASREPT downtime varies widely among ships with different kinds of equipment. The systematic patterns embodied in the table may be less obvious. Table 8, which summarizes table 7, makes them more apparent. Ships with 5" 54 guns have more GM and gun downtime. This is especially true of Forrest Sherman ships, which also have 3" 50 guns. Missile ships with the Mk 72 fire control system have much more FT and missile downtime than other ships. These ships are equipped to use the Navy Tactical Data System (NTDS). 5" 54 guns also seem to be associated with fire control problems, except on the FF 1052 class, which has only one mount and the simplest missile system.

The rest of this section presents our estimated relationships--first, the determinants of productivity by rating and then, the determinants of material condition by sub-system.[2]

Gunner's Mates

Despite the substantial differences in GM-related downtime between ships with different kinds of equipment, the effect of crew characteristics on downtime appears to be similar on all the ships we examined. Experience seems to be the best predictor of the value of GMs. Table C-3 shows the estimated equation for predicting the CASREPT downtime of equipment operated and maintained by GMs. Table 9 shows alternative ways to cut GM downtime by 50 hours per month, assuming our estimates are correct. Men with less than one year of service bring about much higher levels of CASREPT downtime. Other first termers also significantly degrade material condition. Both here and elsewhere in the paper, the relationship between LOS and productivity is not a continuous one, but is better captured as a number of discrete steps.[3]

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[1] We did not distinguish between, for example, GMMs and GMGs because the distinction disappears above paygrade E-6.

[2] In all cases, ships with unique equipment in the area being studied were omitted from the sample. The DD 933 and FF 1036 and 1037 were always omitted. CG 26 was omitted from the samples for the GM and FT regressions.

[3] Recall that continuous forms were tested. They did not predict as well as the step functions.

TABLE 7

MATERIAL CONDITION OF GUNS AND MISSILE EQUIPMENTS
(CASREPT downtime, hours per month)

Ship or ship class	Number of ships	Gun equipment	Missile equipment	GM[a] down-time	FT down-time	Gun down-time	Missile down-time
FRAM DDs	33	Two twin mounts 5"38	None	191	175	256	n.a.
FF 1040 class	7	Two single mounts 5"38	None	180	112	182	n.a.
Forrest Sherman DDs (except DD 933)	6	Three mounts 5"54 One mount 3"50	None	558	310	869	n.a.
DD 933	1	Two mounts 5"54 One mount 3"50	None	606	576	807	n.a.
FF 1052 class	8	One mount 5"54	Mk 25 missile launcher, Mk 115 missile fire control system	211	117	249	25
CG 16 class	4	One mount 3"50	Two Mk 10 missile launchers, Mk 72 fire control system	179	1033	76	947
CG 26 class (except CG 26)	5	One mount 5"54	Mk 10 launcher, Mk 72 fire control system	170	811	342	753
CG 26	1	Two mounts 5"54	Mk 10 launcher, Mk 72 fire control system	91	566	231	503
DDG 37 class	2	One mount 5"54	Mk 10 launcher, Mk 72 fire control system	169	1051	428	941
DDG 31 class, DDG 35 class	4	One mount 5"54	Mk 13 launcher, Mk 74 fire control system	178	206	304	185
DDG 2 class	14	Two mounts 5"54	Mk 11 launcher, Mk 74 fire control system	298	415	306	376
FF 1036	1	Two mounts 3"50	None	84	0	84	n.a.
FF 1037	1	One mount 3"50	None	234	29	225	n.a.
FFG 1	4	One mount 5"38	Mk 22 launcher, Mk 74 fire control system	163	178	69	250

[a] Includes some ASW equipment.

TABLE 8

SUMMARY OF TABLE 7

	Number of ships	Gun downtime	GM downtime
Forrest Sherman class DDs	7	860	567
Others with 5"54 guns	34	302	237
All others	50	212	184
	91		

	Number of ships	Missile downtime	FT downtime
Ships with Mk 72 FCS	12	828	905
Other DDGs (5"54 guns)	18 }	318	{ 369
FFGs	4 }		{ 178
FF 1052 class (5"54 guns)	25		117
Forrest Sherman class (5"54)	7		348
All others	42		164
	91		

The presence of E-8s and E-9s was associated with improved material condition. This may reflect the inherent ability of men who reach those paygrades. To some extent it may reflect their training. We point this out as a warning against too simplistic a view of our results here regarding training. As was the case for MMs, attending more schools was associated with more equipment downtime--when paygrade and LOS were held constant. Schooling may, however, play an important role in making senior people better than junior people. Our results indicate that men who reach senior status with less schooling are better than those who require more schooling to reach the same position. Once again, we find that attainment of NECs reflects improved performance, whether or not school attendance was a requirement.

Table 9 shows that it would probably be considerably harder to decrease GM-related downtime by 50 hours per month than it would be to achieve similar improvements in engineering. The new levels of personnel characteristics listed are so substantial as to be at or beyond the limits observed in the fleet.[1] They may indicate what is needed to improve the condition of GM-related equipment.

[1] For instance, no ship averaged over 2 NECs per GM.

TABLE 9

POTENTIAL WAYS TO CUT GM-RELATED DOWNTIME
BY 50 HOURS PER MONTH

Determinant of material condition	Observed level	Required level
Percent of GMs in the Navy under 1 year[b]	5	0.1
Percent of GMs in the Navy 1-4 years[a]	60	49
Percent of GMs in paygrades E-8 or above[a]	1	4
Average of school-related NECs acquired by GMs	.46	2.07
Average number of non-school-related NECs acquired by GMs	.06	.41
Average number of months between overhauls[a]	37	25

[a]Significant at the 5 percent level
[b]Significant at the 1 percent level.

Fire Control Technicians

The relationship between the characteristics of FTs and the amount of CASREPT downtime suffered by equipment in their care seems to vary considerably among ship classes, as table 10 shows.[1] In general these variations reflect differences in the complexity of equipment. NTDS ships, i.e., CGs and the DDG 37 class, seem to need high quality personnel more than other ships.

Paygrade and experience are the only personnel characteristics estimated to be important on all ships, although these estimates did not pass standard tests of statistical significance. More frequent overhauls also seemed to cut FT-related downtime on all ships. Paygrade seemed to relate to proficiency in two discrete steps (except on FF 1052 class ships): men who have not reached E-5 are less proficient than those in paygrades E-5 through E-7; E-8s and E-9s are yet more proficient. Variation (in the range we observed) in the number of FTs seemed to cut CASREPT downtime only on FRAM destroyers and FF 1040 class frigates, among the least complex ships studied. This is similar to our findings for the engineering ratings. The use of high quality recruits as FTs was important, especially if they were assigned to NTDS ships. High school graduates and men who scored well on the Arithmetic Reasoning Test were associated with less CASREPT downtime.

Somewhat surprisingly, since almost all of them score quite high, variation in the entry test scores of FTs mattered. The importance of entry tests is reinforced by the finding that, on some guided missile ships, black FTs are estimated to be more productive than whites. FTs are the only rating where a racial difference was observed. This may mean that, because high ability blacks have more trouble with the entry test, blacks who do score high enough to become FTs are better than whites who meet the screening criterion.

Among those listed in table 10, the easiest way to cut the amount of fire control downtime would be to screen out non-high-school-graduates even more carefully and to find more blacks who meet the FT requirements. As in most of the other ratings we have examined, shifting high quality personnel to the most complex ships would be expected to decrease fire control downtime on a fleet-wide basis.

Guns

As expected, the factors that affect the material condition of guns are similar to those that have just been discussed in the sections on gunner's mates and fire control technicians. Several differences were discovered, however. The relationship between the experience of GMs and equipment condition is a bit different when only guns are

[1] As does table C-4.

TABLE 10

POTENTIAL WAYS TO CUT FT-RELATED DOWNTIME
BY 50 HOURS PER MONTH

Ship types or classes	Determinants of material condition	Observed level	Required level
All ships	Percent of FTs in the Navy under 2 years	21	1
	Percent of FTs in paygrades E-8 or above	2	9
	Length of time between overhauls[a]	37	23
All ships except FF 1052 class	Percent of FTs in paygrades E-4 or below[b]	55	40
All missile ships (DDG, CG, FFG)	Percent of FTs who are black[b]	2	3
NTDS ships plus FFGs	Percent of FTs scoring over 50 on the arithmetic entry test	72	94
NTDS ships	Percent of FTs who are high school graduates[a]	98	99
FRAM and FF 1040 class	Number of FTs relative to allowance on the ship's manning document[c]	.73	.90

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

analyzed than when all the equipment that GMs deal with is considered. Part of this difference is an estimated association between the amount of prior sea experience GMs have had and the condition of their guns. This relationship was only apparent on ships with 5" 54 guns.[1]

Other differences between the results for guns and those for GMs and FTs are that high school graduation and entry test scores were not determinants of gun condition. On the other hand, ship age was found to be a significant determinant of gun condition, even though it did not enter either the GM or FT equation.

Table 11 displays our best estimates of how CASREPT downtime for guns could be cut by an average of 50 hours per month. The payoff to the training of GMs appears much higher here than it did when we looked at all GM-related equipment.

Missiles

Although both gun condition and missile condition depend on the characteristics of FTs and GMs, missile condition is much more dependent on the attributes that men possess when they enter the Navy.[2]

The entry test scores of both FTs and GMs are likely determinants of missile downtime.[3] High school graduation is important in FTs. It is in missile maintenance that the previously discussed superiority of black FTs shows up. Considerable seniority must be attained before the productivity of missile operators and maintainers is enhanced. FTs who are E-5s or above and GMs with over 5 years of service are more productive than more junior personnel.

As we mentioned in disucssing total fire control downtime, high quality people are most important on ships with the most complex equipment. Indeed, we could not explain any of the variation in downtime among the simplest ships in this sample, the FF 1052 class ships. However, across all 42 ships, we explained 85 percent of the intership variation in CASREPT downtime for missiles.

As table 12 shows, we estimate that equivalent improvements in the material condition of missiles could be made in several ways. A comparison of table 12 with table 10 indicates that race was not as important in the missile equation as it had been in the FT equation, though it still seems that blacks who meet the standards are particularly effective FTs.

Fairly small changes in the seniority mix of either FTs or GMs are estimated to yield sizable payoffs in decreasing CASREPT downtime for missiles.

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[1]Table C-5 shows the estimated relationship for guns.

[2]Our examination of the CASREPT downtime of missiles of course covered only CGs, DDGs, FFGs, and the FF 1052 class, 42 ships in all.

[3]Table C-6 shows the estimated relationship for missiles.

TABLE 11

POTENTIAL WAYS TO CUT GUN DOWNTIME
BY 50 HOURS PER MONTH

Ship types or classes	Determinant of material condition	Observed level	Required level
All ships	Percent of GMs in the Navy under 2 years[a]	24	14
	Percent of GMs in paygrades E-8 or above[a]	1	3
	Average number of school-related NECs attained by GMs	.46	.64
	Average number of non-school-related NECs attained by GMs[a]	.06	.18
	Percent of FTs in the Navy under 1 year	3	*
	Percent of FTs in paygrades E-8 or above[a]	2	5
	Length of time between overhauls (months)[a]	37	28
Ships with 5"54 guns	Average prior sea experience of GMs (months)	27	35
FRAM and FF 1040 class ships	Average number of FTs	7.1	9.7

[a]Significant at the 5 percent level.

*According to our estimates it is impossible to lower this proportion enough to cut gun downtime by 50 hours per month.

TABLE 12

POTENTIAL WAYS TO CUT CASREPT DOWNTIME FOR MISSILES BY 50 HOURS PER MONTH

Ship types or classes	Personnel characteristics	Observed level	Required level
DDGs, CGs, and FFGs	Percent of GMs scoring above 50 on the general entry test	68	98
	Percent of FTs scoring above 50 on the arithmetic entry test[a]	72	88
	Percent of FTs who are black	2	5
	Percent of FTs who are in paygrades E-4 or below[b]	43	38
On CGs and Coontz class DDGs (NTDS ships)	Percent of FTs who are high school graduates[b]	98	99
	Percent of GMs in the Navy under 5 years[b]	67	64

[a]Significant at the 5 percent level.

[b]Significant at the 1 percent level.

ANTISUBMARINE WARFARE

The operation and maintenance of ASW equipment is performed by men in three ratings: sonar technicians, torpedoman's mates, and gunner's mates. The ASW tasks handled by GMs have already been included in our estimates of the relative productivity of different kinds of GMs. GMs will also be included in this section, along with TMs and STs, to estimate the contribution that they make to the material condition of ASW equipment.

Three relationships are discussed in this section: one each for equipment maintained by STs and TMs, and one for ASW equipment as a whole. Sonar equipment is excluded from this last relationship although fire control equipment maintained by STs is included.[1] As before, the kind of equipment on board appears to be an important influence on CASREPT downtime.

Our ships had two kinds of sonars, SQS-23 and SQS-26.[2] Ships with the SQS-26 had substantially more ST-related downtime than those with the SQS-23, an average of over 250 hours per month, compared to 94 hours per month.

All 91 ships had Mk 32 torpedo tubes. Most had Mk 16 ASROC launchers. Table 13 shows how downtime varied according to equipment.

The ASROC ships had much more ASW downtime than the others. Although SQS-26 sonars were associated with more sonar downtime, they may have had less ASW fire control downtime. ASROC ships with SQS-26s had less ASW downtime than those with SQS-23s, and the same pattern was observed on non-ASROC ships.

Torpedoman's Mates

As table 13 shows, equipment maintained by TMs has very little CASREPT downtime. Some ships do not have one TM on board at all times, and thus, not much equipment is the responsibility of TMs. Still we were able to find significant connections between TMs and the condition of their equipment on ships equipped with ASROCs.[3] Ships that had more TMs had less CASREPT downtime.

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[1] This was done because we feared that sonar downtime would be such a large part of the total that its inclusion would overwhelm differences in the condition of other equipment.

[2] The FF 1036 had an SQS-32 sonar. It was omitted from the ST regression, but included in the TM and ASW regressions.

[3] Table C-7 shows the estimated relationship for TMs.

TABLE 13

DOWNTIME FOR DIFFERENT KINDS OF ASW EQUIPMENT
(CASREPT downtime, hours per month)

	Ship classes	Number of ships	TM downtime	ST downtime	ASW downtime
SQS-26 sonar plus ASROC	FF 1037 class, FF 1040 class, FF 1042 class, FFG 1 class	20	18 (combined for SQS-26 and SQS-23 plus ASROC)	268	103
SQS-23 sonar plus ASROC	FRAM destroyers, DD 933, DDG 2 class, DDG 31 class, DDG 35 class, DDG 37 class, CG 16 class	58		95	127
SQS-26 sonar without ASROC	CG 26 class	6	10 (combined for SQS-26 and SQS-23 without ASROC)	234	2
SQS-23 sonar without ASROC	Forrest Sherman DDs, except for DD 933	6		83	37

The effect of experience on the productivity of TMs is unusual. The equal coefficients of opposite sign for LOS greater than seven years and paygrade E-6 or above means that, other things equal, junior personnel are better than their seniors unless senior men reach first class status. This indicates that TMs should not be encouraged to sign up for a third term unless they have made E-6.

TMs who attended more schools are estimated to be more productive, although this result is of low statistical significance.

Older ships and ships that go longer between overhauls have more TM-related CASREPT downtime.

Table 14 shows alternative ways to cut TM downtime on ASROC ships by five hours per month. The table includes the apparently counter-intuitive finding, discussed above, that downtime could be cut by reducing the proportion of senior personnel from its already low level.

Sonar Technicians

Equipment complexity has a great deal to do with how frequently sonar equipment is down. Equipment maintained by STs has more CASREPT downtime on ships with SQS-26 sonars and on ASROC ships.[1] Surprisingly, the impact of differences in the characteristics of STs was estimated to be the same on all 90 ships in this sample, regardless of their equipment.

STs who have graduated from high school are more productive than non-graduates.

Sea duty is the key element in the experience of STs. Longer length of service and higher paygrade are associated with higher productivity only if they reflect more sea experience. A related finding is that single STs are more productive than married men. This may be due to a lesser aversion to sea duty.

In table 15 we show how ST-related downtime might be cut 25 hours per month. Such an improvement could be obtained by insisting that STs be high school graduates, by encouraging sea duty or by selectively choosing single men.

ASW Equipment

Our estimates of the factors that determine the condition of ASW equipment are quite complicated. This is because men in three ratings are responsible for different parts of the subsystem. Thus, characteristics of all three ratings must be included in the relationship.

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[1] Table C-8 shows the estimated relationship for STs.

TABLE 14

POTENTIAL WAYS TO CUT TM-RELATED CASREPT DOWNTIME
BY 5 HOURS PER MONTH

Type of equipment	Determinant of material condition	Observed level	Required level
ASROC ships only	Average number of TMs[a]	2.16	2.67
	Percent of TMs in the Navy over 7 years[b]	14	10
	Percent of TMs in paygrades E-6 or above[b]	7	11
	Average number of schools attended by TMs	1.43	2.20
All ships	Average number of months between overhauls	37	32

[a]Significant at the 10 percent level.

[b]Significant at the 1 percent level.

TABLE 15

POTENTIAL WAYS TO CUT ST-RELATED CASREPT DOWNTIME BY 25 HOURS PER MONTH

Crew characteristic	Observed level	Required level
Percent of STs who graduated from high school[a]	95	100
Average prior sea experience of STs (months)[b]	17.9	22.5
Percent of STs who are single[a]	50	60

[a]Significant at the 5 percent level.

[b]Significant at the 1 percent level.

We were unable to determine any sources of variation in the material condition of ASW equipment on ships without ASROC. As table 13 showed, they had very little ASW CASREPT downtime. On ASROC ships, the characteristics of TMs, STs, and GMs helped explain differences in material condition. As noted earlier, sonars were not included in this analysis, but ASW fire control equipment handled by STs was.[1]

More characteristics of GMs entered the relationship than did those of STs and TMs. The condition of ASW equipment is estimated to depend on TM manning and the experience and training of GMs and STs. Very junior GMs are less productive than other first-termers, who are less productive than more senior personnel. Our estimate of the determinants of GM-related downtime (table C-3) showed that, holding experience constant, additional schooling without the attainment of NECs was detrimental. This effect also appears in the ASW relationship.

Possible ways to reduce ASW downtime by 25 hours per month are listed in table 16. Perhaps the easiest way to achieve this improvement would be to leave STs at sea longer.

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[1] Table C-9 shows the estimated relationship for ASW equipment.

TABLE 16

POTENTIAL WAYS TO CUT CASREPT DOWNTIME OF ASW EQUIPMENT BY 25 HOURS PER MONTH ON ASROC SHIPS

Crew characteristic	Observed level	Required level
Average number of TMs	2.16	3.00
Average prior sea experience of STs (months)[b]	17.9	20.7
Average number of schools attended by STs	3.14	4.07
Percent of STs who are high school graduates	95	*
Percent of GMs who score above 50 on the Mechanical Comprehension Test[a]	58	72
Percent of GMs in the Navy under one year[a]	5	1
Percent of GMs in the Navy 1-4 years	61	52
Average prior sea experience of GMs (months)[a]	23.3	29.7
Average number of school-related NECs attained by GMs	.43	1.55
Average number of non-school-related NECs attained by GMs[b]	.06	.28

[a]Significant at the 10 percent level.

[b]Significant at the 1 percent level.

*This large an improvement in material condition cannot be achieved by this mechanism.

PART TWO

COLLATERAL ANALYSES

SECTION 4

ALTERNATIVE MEASURES OF MATERIAL CONDITION

In the course of this study four kinds of data bearing on the condition of shipboard equipment were considered: Casualty Reports (CASREPTs), Overhaul Departure Reports, reports of the Board of Inspection and Survey (INSURV reports), and reports of corrective maintenance actions through the 3-M data system. The analysis presented in part one has used one measure of material condition, CASREPT downtime per month. Alternative measures were potentially available from all four data sets. This section discusses their strengths and weaknesses.

Casualty Reports

The raw records of CASREPTs we received included data on every reported casualty the 91 ships in our sample had suffered since January 1970. The information on every action included how long it took for the casualty to be corrected and the portion of this time that was spent waiting for needed parts to arrive. Thus, we could have analyzed the number of CASREPTs, supply downtime, and maintenance downtime (the portion of downtime not spent waiting for parts).

It has been suggested that the characteristics of shipboard personnel ought to affect only maintenance downtime, not supply downtime. We did not consider this assertion compelling for two reasons. If higher quality personnel lead to fewer CASREPTs, they will influence the total amount of time spent waiting for parts. In addition, if a good crew is more able to diagnose what's wrong and order the correct part the first time, less supply downtime will occur. Since crew characteristics may well influence total supply downtime, it was inappropriate to focus solely on maintenance downtime.

In our preliminary work we separately studied the determinants of the number of CASREPTs occurring, maintenance downtime, and supply downtime.[1] Although the results were not identical for all three measures, they were fairly similar.

In the present work we chose to examine only total downtime because it was the best overall indicator we had. Conceptually it comes close to measuring how often a ship is unable to perform its missions. To the extent that men can decrease this inability they are being productive. It is this productivity that we wanted to estimate.

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[1] "Maintenance Personnel Effectiveness in the Navy," CNA Professional Paper 143, Jan 1976.

Overhaul Departure Reports

Initially we planned to use the amount of money spent on various kinds of equipment when a ship went through overhaul as an index of the condition of the ship before the overhaul. This is the approach taken by CNA's Ship Overhaul Cost Estimating Relationships (SOCER) Study.[1]

We were forced to abandon this approach because of the unavailability of much of the necessary data. Overhaul Departure Reports list work done in overhauls on an action by action basis, with work center and EIC identification of each action. Summary statistics for the entire ship are also provided. The SOCER Study used the summary data. We intended to aggregate individual actions as we did with CASREPTs. Severe problems were encountered.

A complete record of Overhaul Departure Reports is not kept anywhere. Although they are initially computerized by the overhaul yard, the tapes are discarded. We were able to amass many reports (in hard copy) from NavSea and (more often) from ComSurfLant and ComSurfPac. In many cases portions of the reports were illegible. In others inadmissable work center and EIC codes were the norm. Rather than throw ships out of our sample, and because of the massive effort required to tabulate the data by hand, we discarded the idea of using overhaul data.

We believe that, with only a little attention, Departure Reports could be made a source of detailed information on material condition. Someone, perhaps FMSO, could be given responsibility for storing the computerized data prepared by the overhaul yards. Not only would this facilitate tracking of the material condition of ships, but it might assist in configuration management. Since shipyards already bear the reporting burden, it seems a shame to waste the reports. Even if the data were available, however, it would be hard to tell whether the amount of work performed depended more on the condition of material than on the authorized level of funding for overhauls.

INSURV Reports

The Board of Inspection and Survey is widely respected for its impartial inspections of the condition of shipboard equipment. Each inspection provides a list of discrepancies, coded by EIC, to be corrected. Serious (part I) discrepancies are distinguished from less serious ones (part II). Discrepancies are supposed to be entered into the 3-M data system.

We received 3-M data from FMSO on the 78 relevant inspections performed on our 91 ships between 1970 and 1975. We planned to use the number of INSURV discrepancies

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[1] CNA Study 1034, Oct 1974.

as a dependent variable in our analysis. Unfortunately, it was discovered that, in general, Pacific Fleet ships were reporting discrepancies to the 3-M system at a much lower rate than Atlantic Fleet ships.[1] Because of this reporting problem, we were left with 38 Atlantic Fleet inspections. Rather than perform a full-blown regression analysis of these observations, we decided to check the correlation between INSURV and CASREPT data for these 38 inspections. Finding a high correlation means that CASREPT history is a good measure of material condition as measured by the INSURV Board.

To be precise, we calculated the correlation between the number of serious discrepancies discovered by INSURV with the level of CASREPT downtime per month between the overhaul preceding the inspection and the month before the inspection. This correlation was performed for each of the six ratings and three subsystems we used in the regression analysis. Table 17 shows our results.

TABLE 17

CORRELATIONS BETWEEN NUMBER OF INSURV DISCREPANCIES AND CASREPT DOWNTIME PER MONTH

Rating or subsystem	Correlation coefficient
BT	.23[a]
MM	.32[b]
GM	.09
FT	.49[c]
TM	.30[b]
ST	.09
Guns	.06
Missiles	.51[c]
ASW	.08

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

The correlation between INSURV discrepancies and CASREPT downtime per month is positive in all nine cases - something very unlikely to happen by chance. The individual correlations are significant at the 10 percent level, or greater, five of the nine times.

[1]Our comparison of 3-M data on discrepancies with the discrepancies listed in the original INSURV reports revealed a sizable difference. The INSURV Board then investigated further and discovered that ships of the Pacific Fleet were not reporting discrepancies that could be corrected in 30 days.

A ship's CASREPT history seems to be a good predictor of its success in INSURV inspections. We expect that the characteristics of equipment and personnel that are associated with less CASREPT downtime will also be associated with fewer INSURV discrepancies.

3-M Data

The 3-M data system regularly collects information on a sample of corrective maintenance actions performed by the fleet. We received all 3-M records from the 91 ships for 1970-1975. Every record includes information on the rating of the man who performed the work. We used this information along with the Ship's Manning Document to decide which items of equipment were the responsibility of what ratings for each of the ship classes in our sample. More information on this assignment of equipment to ratings is included in appendix B.

We also intended to use measures of material condition derived from 3-M data as dependent variables in our analysis. Such a course was decided against because of substantial variations in our sample in the fraction of maintenance actions ships are required to report to the 3-M system. For example, ships under 20 years old were required to report all actions performed on material on a list of selected equipment. Older ships (until May 1974) did not have to pay particular attention to the Selected Equipment List.[1]

Although we did not use 3-M measures as dependent variables in our analysis, we did examine their relationship to measures derived from CASREPT information. Table 18 shows that the number of corrective maintenance actions recorded in the 3-M system has a significant correlation with the number of CASREPTs in all nine cases. CASREPT downtime always correlates positively with hands-on repair time for all corrective maintenance actions. This correlation is significant in seven out of nine cases.

Speaking generally about the table, ships with more CASREPTs also have more total corrective maintenance. Measures of material condition derived from 3-M data vary across ships similarly to measures derived from CASREPT data. Despite all its flaws, the 3-M system provides data that systematically describes variations in material condition.

[1]For a discussion of variations in reporting to the 3-M system, see "Changes in 3-M Reporting Requirements," CNA Memorandum 76-1757.10, Feb 1977.

TABLE 18

CORRELATIONS OF MEASURES OF MATERIAL CONDITION FROM 3-M AND CASREPT DATA

	Number of 3-M actions per month and number of CASREPTs per month	3-M repair time per month and CASREPT downtime per month	3-M downtime per month and CASREPT downtime per month
BT	.41[c]	.39[c]	.51[c]
MM	.39[c]	.16[a]	.17[a]
GM	.26[c]	.10	-.03
FT	.75[c]	.50[c]	.47[c]
TM	.19[b]	.006	-.08
ST	.18[b]	.33[c]	.004
Guns	.53[c]	.36[c]	.26[c]
Missiles	.89[c]	.78[c]	.72[c]
ASW	.32[c]	.19[b]	.02

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

Conclusion

We carefully examined maintenance information from many sources. We realize that CASREPTs have their drawbacks. Reporting may vary by ship (although an earlier analysis indicated that this was not an important source of bias to our preliminary results[1]). Reporting may depend on what a ship is doing when an equipment failure occurs. CASREPTs may be used as a way to get priority for parts orders. Still, we think that our policy of using CASREPT downtime over an entire overhaul cycle provides the best measure of material condition currently available for all the ships in the fleet.

[1]"Personnel Characteristics, Ship Maintenance and Management," CNA Memorandum 76-0537.20, Jun 1976.

SECTION 5

THE EFFECTS OF INCLUDING OPERATING TEMPO AND COAST AS VARIABLES IN THE ANALYSIS

It is widely believed that more intense ship operation is associated with improved readiness because of greater opportunities for training. Some evidence of such an effect is presented in a recent paper by CNA.[1] Here we are concerned with the relationship between operating tempo and the material condition of shipboard equipment as measured by CASREPT downtime. This is a partial proxy for readiness, but it is less likely to be favorably influenced by intense operations than more complete measures. For one thing, driving equipment harder may make it more likely to break, offsetting the beneficial effects of improved training.

Operating tempo has not been included in our main analysis for three reasons. For one thing, there were some gaps in the data on operating tempo that we received. For another thing, the direction of casualty is not completely clear; perhaps ships in better condition are able to operate more intensely. Finally, as this section shows, the relationship between operating tempo and material condition rarely attained statistical significance.

The coast on which a ship's home port is located was also omitted from the analysis in part one. There are two reasons why it might have been included. Fleet commanders have some discretion over the conditions under which CASREPTs are sent, and more off-ship assistance in maintenance and supply may have been available on the west coast than on the east, systematically influencing material condition. Even if there are important inter-coast differences of these sorts omitting the coast factor from the analysis could only affect the validity of our personnel-related estimates if ships were manned differently on the east and west coasts. To some extent they were. In the period we studied, west coast ships were manned better, since they were more likely to see action in Vietnam.[2] In five of six ratings, manning relative to the Ships Manning Document was higher on west coast ships. Average LOS was also higher in five of six cases. If more material resources were available on the west coast, this preferential manning could have caused us to label some of the effects of coast variation on material condition as the result of better crew characteristics. Thus, omitting a west coast variable could bias our analysis.

On the other hand, inclusion of a coast variable where it is inappropriate would cause us to underestimate the value of personnel. This would happen if differing fleet reporting policies and differing availability of off-ship assistance are not important determinants of CASREPT downtime. In this case the only reason why west coast ships are in better condition is that they have better personnel.[3] Thus, including a west coast variable could bias our analysis.

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[1] "A Model for Predicting Operational Readiness Evaluation Scores for Surface Escorts," LCdr. Walter J. Kirsch, CNA Memorandum 77-154, Feb 1977.

[2] East coast ships also served in Vietnam. We attempted to get explicit data on operating in Vietnam. The historical data file was not adequate for our purposes.

[3] Since our measures of personnel characteristics were subject to considerable measurement error, the coast variable could reflect actual personnel conditions better than the personnel variables.

TABLE 19

EFFECTS ON CASREPT DOWNTIME PER MONTH OF INCLUDING OPERATING TEMPO AND COAST AS EXPLANATORY VARIABLES

	BT	MM	GM	FT	TM	ST	Guns	Missiles	ASW
Coefficient of operating tempo variable*	-532 (-0.97)	-354 (-1.01)	+ .72 (1.48)	+ .94 (1.73)[a]	- .16 (-1.19)	+ .33 (1.01)	+ .56 (0.82)	+ 1.07 (1.48)	+ .21 (0.57)
Coefficient of West Coast variable	-255 (-3.37)[c]	- 78 (-1.48)	-77 (-1.67)[a]	-177 (-4.01)[c]	-17 (-1.46)	-101 (-3.94)[c]	-164 (-2.70)[b]	-131 (-2.27)[b]	-53 (-1.55)
Average percent change in coefficients of other variables	- 11.5	- 18.1	-11.9	- 16.3	- 7.8	+ 3.9	- 16.4	+ 0.4	-14.5
Average percent change in t-statistic of other variables	- 3.3	-18.2	-14.5	- 9.6	- 6.4	+ 11.1	- 14.9	+ 1.7	-16.1

*For BTs and MMs operating tempo is measured by the fraction of months in which steaming occurred. For the other ratings and subsystems, the average number of hours steamed per month was used to measure operating tempo.

Note: t-values are in parentheses.

[a] Significant at the 10 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 1 percent level.

Because sound arguments can be advanced for including operating tempo and coast in the analysis of the determinants of material condition, relationships including them were estimated. The results are presented here. Table 19 gives an overview of the effect of including the two additional factors.

For the engineering ratings our measure of operational tempo is the fraction of months in which steaming occurred. For the other ratings and subsystems we used average steaming hours per month. The latter measure seemed inappropriate for engineering because the number of steaming hours is at least as likely to be the result of CASREPT downtime as its cause. (This problem exists to a lesser extent in the measure we used, and thus, the estimates for BTs and MMs probably overstate the effect of steaming on CASREPT downtime.)

West coast ships had less CASREPT downtime than east coast ships. This may be the result of better attention to maintenance when combat is more likely. It might just as easily be the result of more maintenance resources, or even reporting differences by coast. Alternatively, it may reflect better crews.

Another hypothesis is that west coast ships were in better condition because they were operated more intensely; perhaps the west coast variable captured the effect of increased steaming. On the average, west coast ships steamed 268 hours a month compared to 219 for east coast ships. This difference is significant at the 1 percent level, and would seem to show that additional steaming improves readiness. Such an improvement ought to be apparent when coast of operation is held constant. It was not.

We found little direct evidence that faster operating tempo improves material condition. Most of the time more intense operations were associated with more CASREPT downtime. For fire-control equipment this relationship was significant at the 10 percent level. The negative relationship between steaming and material condition may be the result of reporting variation. Since CASREPTs represent mission degradation, a ship operating lightly - with no imminent important mission - may not report equipment failures that more intensely used ships do. We are uncertain about the effect of operating tempo on readiness.

The inclusion of coast and tempo variables generally decreased the estimated effects of the other variables in our analysis. The third row of table 19 shows the extent of this decrease. Over all nine equations, the average decrease of the coefficients was only 10.2 percent. The average decrease of the t-values, our measures of statistical significance, was 7.8 percent. Thus, while our estimates in appendix C may be too high, the extent of the error due to omitting coast and operating tempo is not very large. To the extent that the coast variable is picking up the effects of other factors in the analysis, the coefficients of the other variables when coast is included in the analysis underestimate their true effects.

Tables 20 through 28 display the complete results of adding the coast and tempo variables. The estimates presented there can be substituted for those in appendix C if one is so inclined. Generally this substitution will not make much difference.

TABLE 20

DETERMINANTS OF MATERIAL CONDITION FOR BOILERS
(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On two-screw, 1200 p.s.i. ships		
Average score on shop entry test	-141	-3.76[c]
Percent of BTs who are E-3 or below	28.02	3.59[c]
Percent of BTs who are E-8 or above	- 40.73	-1.56
Percent of BTs with under one year in the Navy	26.18	1.97[b]
Average number of school-related NECs per BT	-1486	-4.28[c]
Percent of BTs who are single	- 14.86	-2.21[b]
On one-screw ships		
Average number of Navy schools attended by BTs	-263	-1.84[a]
On two-screw, 600 p.s.i. ships		
Average number of BTs	- 61.49	-3.49[c]
On all ships		
Percent of BTs with under 10 years in the Navy	5.85	0.90
Non-personnel variables		
Equipment complexity		
Two-screw, 1200 p.s.i. plant	7747	3.87[c]
Logarithm of ship age (years)	408	2.73[b]
Percent of months in which steaming underway occurred	- 5.32	-0.97
West Coast ship	- 255	-3.37[c]
Constant	350	

Corrected $R^2 = 0.60$
Degrees of freedom = 74

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

TABLE 21

DETERMINANTS OF MATERIAL CONDITION FOR ENGINES
(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of MMs in the Navy under 3 years	4.50	1.48
On all two-screw ships		
Average time spent on this ship by MMs (months)	-12.35	-0.76
Average number of Navy schools attended by MMs	232	2.29[b]
Average number of NECs attained by MMs	-398	-1.13
On two-screw, 1200 p.s.i. ships		
Average number of MMs	-8.92	-0.99
Average prior time spent on ships by MMs (months)	-10.47	-1.83[a]
On two-screw 600 p.s.i. ships		
Average number of MMs	-30.17	-2.57[b]
Percent of MMs E-3 or below	8.20	1.16
Non-personnel variables		
Equipment complexity		
One-screw plant	-308	-0.77
Logarithm of ship age (years)	180	1.91[a]
Percent of months in which steaming underway occurred	- 3.55	-1.01
West Coast ship	-77.77	-1.47
Constant	397	

Corrected R^2 = .27
Degrees of freedom = 76

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

TABLE 22

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY GUNNER'S MATES

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of GMs in the Navy under 1 year	11.37	3.23[c]
Percent of GMs in the Navy 1-4 years	4.20	1.94[a]
Percent of GMs in paygrade E-8 or above	-19.09	-2.11[b]
Average number of schools attended by GMs	81.28	1.73[a]
Average number of NECs attained by GMs	-73.37	-0.59
Non-personnel variables		
Equipment complexity		
Three turrets with 5"54 guns and one turret 3"50	429	6.80[c]
Two turrets with 5"54 guns plus missiles	139	3.08[c]
Length of time between overhauls (months)	3.48	1.83[a]
Average number of steaming underway hours per month	.72	1.48
West Coast ships	-77.49	-1.67[a]
Constant	-473	

Corrected R^2 = .42
Degrees of freedom = 76

[a] Significant at the 10 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 1 percent level.

TABLE 23

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY FIRE CONTROL TECHNICIANS

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of FTs in the Navy under two years	1.63	0.87
Percent of FTs in paygrades E-8 or above	- 6.34	-1.20
On all CGs, DDGs, and FFGs		
Percent of FTs who are black	-36.60	-2.65[b]
On CGs, FFGs, and DDG 37 class ships		
Logarithm of the fraction of FTs scoring over 50 on the arithmetic entry test	-165	-1.12
On all ships except the FF 1052 class		
Percent of FTs in paygrade E-4 or below	2.39	2.13[b]
On CGs and DDG 37 class ships		
Percent of FTs who are high school graduates	-46.25	-2.12[b]
On FRAM and FF 1040 class ships		
Number of FTs (as a percent of the allowance in the Ships Manning Document)	- 2.82	-3.49[c]
Non-personnel variables		
Equipment complexity		
Mk 72 missile fire control systems	5174	2.43[b]
5"54 guns and other missile fire control systems	198	2.80[c]
Length of time between overhauls (months)	1.51	0.74
Average number of steaming under hours per month	0.94	1.71[a]
West Coast ship	-177	-4.01[c]
Constant	-28	

Corrected R^2 = .77
Degrees of freedom = 74

[a]Significant at the 10 percent level.
[b]Significant at the 5 percent level.
[c]Significant at the 1 percent level.

TABLE 24

DETERMINANTS OF MATERIAL CONDITION FOR GUNS

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of FTs in the Navy less than 1 year	5.05	1.09
Percent of FTs E-8 or above	- 17.48	-2.82[c]
Average number of schools attended by GMs	64	0.96
Average number of NECs attained by GMs	-247	-1.33
Percent of GMs in the Navy less than 2 years	3.59	1.56
Percent of GMs in paygrades E-8 or above	- 22.78	-2.20[b]
On ships with 5"54 guns		
Average prior sea experience of GMs (months)	- 6.56	-1.11
On FRAM destroyers and FF 1040 class ships		
Average number of FTs	- 17.6	-1.27
Non-personnel variables		
Equipment complexity		
Three turrets 5"54 plus one turret 3"50	885	4.13[c]
Two turrets 5"54	353	2.06[b]
Logarithm of ship age (years)	85.9	1.86[a]
Length of time between overhauls (months)	3.03	1.23
Average number of steaming underway hours per month	.56	0.82
West Coast ship	-164	-2.70[b]
Constant	-162	

Corrected R^2 = .57
Degrees of freedom = 73

[a]Significant at the 10 percent level.
[b]Significant at the 5 percent level.
[c]Significant at the 1 percent level.

TABLE 25

DETERMINANTS OF MATERIAL CONDITION FOR MISSILES

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On ships with Mk 10 missile launching systems and Mk 72 missile fire control systems (NTDS ships)		
Percent of FTs who are high school graduates	-72.5	-4.04[c]
Percent of GMs in the Navy under 5 years	21.5	3.38[c]
On DDGs, GCs, and FFGs		
Percent of FTs scoring above 50 on the Arithmetic Reasoning Test	- 1.70	-1.33
Percent of FTs who are black	-15.0	-1.25
Percent of GMs scoring above 50 on the General Classification Test	- 2.34	-1.48
Percent of FTs who are E-4 or below	10.8	4.77[c]
Non-personnel variables		
Equipment complexity		
Mk 10 missile launching system and Mk 72 fire control system	6252	3.46[c]
Average number of steaming underway hours per month	1.07	1.48
West Coast ship	-131	-2.27[b]
Constant	-123	

Corrected R^2 = .86
Degrees of freedom = 32

[a]Significant at 10 percent level.
[b]Significant at 5 percent level.
[c]Significant at 1 percent level.

TABLE 26

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY TORPEDOMAN'S MATES

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On ASROC ships		
Number of TMs	- 9.70	-1.78[a]
Percent of TMs in the Navy over 7 years	1.06	3.07[c]
Percent of TMs E-6 or above	- 1.02	-2.26[b]
Number of Navy schools attended	- 9.92	-1.60
Non-personnel variables		
Equipment complexity		
ASROC ships	138	3.76[c]
Ship age (years)	0.90	1.70[a]
Logarithm of the number of months between overhauls	19.9	0.95
Average number of steaming underway hours per month	- 0.16	-1.19
West Coast ship	-17.1	-1.46
Constant	-24.6	

Corrected R^2 = .24
Degrees of freedom = 81

[a] Significant at the 10 percent level.
[b] Significant at the 5 percent level.
[c] Significant at the 1 percent level.

TABLE 27

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY SONAR TECHNICIANS

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of STs who graduated from high school	- 4.59	-2.50[b]
Logarithm of average prior experience of STs on ships (months)	- 97.4	-2.86[c]
Percent of STs who are single	- 2.61	-2.83[c]
Non-personnel variables		
Equipment complexity		
SQS-26 sonar	178	7.19[c]
ASROC ships	77.9	2.48[b]
Average number of steaming underway hours per month	0.32	1.01
West Coast ship	-101	-3.94[c]
Constant	840	

Corrected R^2 = .52
Degrees of freedom = 82

[a] Significant at the 10 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 1 percent level.

TABLE 28

DETERMINANTS OF MATERIAL CONDITION FOR ASW EQUIPMENT
(Except for Sonar)

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On ASROC ships		
Logarithm of the average number of TMs	- 31.5	-1.26
Percent of STs who are high school graduates	- 2.11	-0.86
Logarithm of average previous sea duty for STs (months)	-176	-4.13[c]
Average number of schools attended by STs	- 18.4	-0.81
Percent of GMs who scored above 50 on the mechanical entry test	- 1.57	-1.61
Percent of GMs in the Navy under 1 year	6.39	2.04[b]
Percent of GMs in the Navy 1-4 years	2.24	1.10
Logarithm of average previous sea duty for GMs (months)	- 89.5	-1.60
Number of schools attended by GMs	61.7	1.61
Number of NECs attained by GMs	- 68.5	-0.76
Non-personnel variables		
Equipment complexity		
ASROC ships	1026	2.58[b]
Average number of steaming underway hours per month	0.21	0.57
West Coast ship	- 53.5	-1.56
Constant	- 10.1	

Corrected R^2 = .37
Degrees of freedom = 77

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[a] Significant at the 10 percent level.

[b] Significant at the 5 percent level.

[c] Significant at the 1 percent level.

APPENDIX A

SHIPS IN SAMPLE

TABLE A-1

SHIPS IN SAMPLE

	Ship	Coast	Year of commissioning	Class		
DD 714	William R. Rush	A	1945	Gearing (DD 710) "FRAM I"		
715	William M. Wood	A	1945	"	"	"
716	Wiltsie	P	1946	"	"	"
717	T.E. Chandler	P	1946	"	"	"
719	Epperson	P	1949	"	"	"
724	Laffey	A	1944	Sumner (DD 692) "FRAM II"		
743	Southerland	P	1944	Gearing (DD 710) "FRAM I"		
782	Rowan	P	1945	"	"	"
783	Gurke	P	1945	"	"	"
785	Henderson	P	1945	"	"	"
786	R.B. Anderson	P	1945	"	"	"
788	Hollister	P	1946	"	"	"
789	Eversole	P	1946	"	"	"
821	Johnston	A	1945	"	"	"
822	Robert H. McCord	A	1946	"	"	"
824	Basilone	A	1949	"	"	"
825	Carpenter	P	1946	Carpenter (DD 825)		
826	Agerholm	P	1946	Gearing (DD 715) "FRAM I"		
841	Noa	A	1945	"	"	"
842	Fiske	A	1945	"	"	"
843	Warrington	A	1945	"	"	"
844	Perry	A	1946	"	"	"
845	Bausell	P	1947	"	"	"
846	Ozbourn	P	1946	"	"	"
853	Charles H. Roan	A	1946	"	"	"
864	Harold J. Ellison	A	1945	"	"	"
866	Cone	A	1945	"	"	"
868	Brownson	A	1945	"	"	"
871	Damato	A	1946	"	"	"

TABLE A-1 (Cont'd)

	Ship	Coast	Year of commissioning	Class
DD 873	Hawkins	A	1945	Gearing (DD 715) "FRAM I"
876	Rogers	P	1945	" " "
878	Vesole	A	1945	" " "
883	Newman K. Perry	A	1945	" " "
931	Forrest Sherman	A	1955	Forrest Sherman (DD 931)
933	Barry	A	1956	" " "
942	Bigelow	A	1957	" " "
944	Mullinnix	A	1958	" " "
945	Hull	P	1958	" " "
946	Edson	P	1958	" " "
951	Turner Joy	P	1959	" " "
DDG 4	Lawrence	A	1962	Charles F. Adams (DDG 2)
5	C.V. Ricketts	A	1962	" "
6	Barney	A	1962	" "
7	Henry B. Wilson	P	1960	" "
8	Lynde McCormick	P	1961	" "
9	Towers	P	1961	" "
10	Sampson	A	1961	" "
11	Sellers	A	1961	" "
12	Robinson	P	1961	" "
13	Hoel	P	1962	" "
15	Berkeley	P	1962	" "
18	Semmes	A	1962	" "
20	Goldsborough	P	1963	" "
21	Cochrane	P	1964	" "
33	Parsons	P	1959	Converted Forrest Sherman (DDG 31)
34	Somers	P	1959	" " " "
35	Mitschner	A	1953	Converted Mitschner (DDG 35)
36	John S. McCain	P	1960	" " "
37	Farragut	A	1960	Coontz (DDG 40)
46	Preble	P	1953	" "

TABLE A-1 (Cont'd)

	Ship	Coast	Year of commissioning	Class
FF 1036	McMorris	P	1960	Claude Jones (FF 1036)
1037	Bronstein	P	1963	Bronstein (FF 1037)
1040	Garcia	A	1964	Garcia (FF 1040)
1041	Bradley	P	1965	" "
1043	Edward McConnel	A	1965	" "
1044	Brumby	A	1965	" "
1048	Davidson	P	1965	" "
1049	Koelsch	A	1967	" "
1051	O'Callahan	P	1968	" "
1052	Knox	P	1969	Knox (FF 1052)
1053	Roark	P	1969	" "
1054	Gray	P	1970	" "
1055	Hepburn	P	1969	" "
1056	Connole	A	1969	" "
1057	Rathburne	P	1970	" "
1058	Meyercord	P	1969	" "
1060	Lang	P	1970	" "
FFG 1	Brooke	P	1966	Brooke (FFG 1)
2	Ramsey	P	1967	" "
3	Schofield	P	1968	" "
4	Talbot	A	1967	" "
CG 16	Leahy	A	1962	Leahy (CG 16)
17	Harry E. Yarnell	A	1963	" "
21	Gridley	P	1963	" "
24	Reeves	P	1964	" "
26	Belknap	A	1964	Belknap (CG 26)
27	Josephus Daniels	A	1965	" "
28	Wainright	A	1966	" "
31	Sterrett	P	1967	" "
32	W.H. Standley	P	1966	" "
33	Gox	P	1966	" "

TABLE A-2

OBSERVATION DATES

Ship	Overhaul: Latest start date (mo./yr.)	Overhaul: Previous finish date (mo./yr.)	Overhaul: No. of mos. bet. overhauls	CASREPT observation period[a]	INSURV inspection date[b]
DD 714	7/71	10/68	32.6	19	2/73
715	9/71	3/69	29.9	21	4/74
716	8/71	11/68	33.6	20	11/73
717	5/72	2/69	39.1	29	9/71
719	4/72	2/69	38.3	28	7/73
724	7/71	11/68	31.4	19	3/71
743	6/72	12/69	29.7	30	3/72
782	4/73	4/70	35.5	37	4/74
783	8/72	1/70	30.5	32	4/74
785	3/72	5/69	34.1	27	--
786	5/73	10/69	43.0	41	4/74
788	9/71	3/69	30.8	21	8/71
789	9/71	5/69	28.3	21	3/73
821	5/72	4/69	36.3	29	12/71
822	9/72	4/69	41.0	33	--
824	8/71	5/68	39.0	30	6/71
825	9/72	2/70	31.3	32	5/72
826	7/72	12/69	31.2	31	5/72
841	7/72	6/68	48.5	31	2/72
842	3/72	5/68	46.4	27	9/71
843	9/71	4/69	29.5	21	8/71
844	7/71	11/67	43.5	19	3/73
845	6/73	11/69	43.7	42	4/74
846	9/71	3/69	29.8	21	1/73
853	7/71	11/68	31.2	19	4/73
864	2/73	3/70	34.9	36	12/72
866	1/72	3/69	34.0	25	12/71
868	9/71	6/68	38.3	21	6/73
871	9/72	2/67	66.9	33	--
873	3/72	1/69	38.1	27	9/73
876	4/72	11/69	28.5	28	9/73
878	7/72	8/68	46.6	31	3/74
883	9/72	12/67	56.7	33	11/73

TABLE A-2 (Cont'd)

Ship	Overhaul: Latest start date (mo./yr.)	Overhaul: Previous finish date (mo./yr.)	Overhaul: No. of mos. bet. overhauls	CASREPT observation period[a]	INSURV inspection date[b]
DD 931	11/71	7/68	40.7	23	2/73
933	2/72	4/69	44.8	26	9/71
942	6/73	7/70	35.1	36	--
944	1/73	9/68	52.0	25	2/71
945	4/74	11/70	41.2	42	3/73
946	5/72	11/69	30.7	29	3/72
951	2/72	3/69	35.7	26	1/74
DDG 4	9/71	1/69	31.9	21	5/73
5	4/74	9/70	42.9	44	6/73
6	4/74	5/70	46.6	48	6/71
7	10/73	2/70	33.5	45	4/73
8	7/72	3/70	28.0	29	5/72
9	6/73	10/67	68.0	42	8/71
10	1/72	5/68	43.1	25	4/74
11	6/74	10/70	44.6	45	9/73
12	3/73	2/70	36.9	38	--
13	7/71	3/69	28.1	19	9/74
15	1/73	9/69	40.0	37	--
18	11/74	3/71	34.1	35	10/73
20	3/74	3/70	47.3	49	6/72
21	6/73	7/70	34.3	36	--
33	6/74	4/71	38.8	39	11/72
34	8/71	3/69	37.0	20	1/73
35	3/72	4/70	23.5	24	2/72
36	2/73	9/70	28.3	30	--
37	11/73	3/71	31.7	33	--
46	6/74	2/71	40.2	41	--
FF 1036	9/71	5/69	39.7	21	--
1037	10/71	9/68	37.1	22	8/71 9/74
1040	2/72	1/69	37.1	26	4/71 11/73
1041	11/71	5/69	30.2	23	--
1043	7/72	2/69	40.6	31	4/71 5/74
1044	7/71	12/66	71.6	19	9/74
1048	3/73	1/70	38.0	39	3/72 1/74

TABLE A-2 (Cont'd)

Ship	Overhaul: Latest start date (mo./yr.)	Overhaul: Previous finish date (mo./yr.)	Overhaul: No. of mos. bet. overhauls	CASREPT observation period[a]	INSURV inspection date[b]
FF 1049	6/74	12/70	42.1	43	6/73
1051	1/72	5/69	42.4	25	--
1052	6/72	1/70	28.7	30	5/74
1053	3/74	8/70	43.6	44	5/73
1054	6/74	11/70	43.6	44	7/73
1055	3/73	4/70	34.2	36	1/73
1056	11/73	7/70	39.6	41	9/74
1057	9/73	1/71	31.5	33	6/73
1058	10/73	9/70	37.2	38	8/73
1060	7/73	1/70	30.8	43	5/73
FFG 1	1/74	2/71	34.9	36	2/72
2	10/73	3/71	31.2	32	2/72
3	9/71	3/70	18.2	19	8/71
4	2/73	3/70	34.5	36	--
CG 16	11/72	5/69	50.7	35	10/73
17	4/74	4/70	48.1	47	5/73
21	2/73	10/70	27.9	29	--
24	11/73	3/71	31.9	33	--
26	3/72	4/69	35.8	27	4/74
27	9/73	9/69	47.7	45	--
28	9/73	2/70	42.8	44	--
31	2/74	3/71	34.2	36	11/71
32	1/73	5/70	32.1	33	3/74
33	12/73	10/69	49.1	48	10/72

[a]Number of months of interoverhaul period since January 1970.

[b]Inspections for which data was utilized.

APPENDIX B

ASSIGNMENT OF EQUIPMENT TO RATINGS AND SUBSYSTEMS

TABLE B-1

ASSIGNMENT OF EQUIPMENT TO RATINGS

BT

F100
F301*
F303*
F305*
F307
F308*
F309*
F30A*
F30B
F30C*
F30E
F30J*
F30L
F30N*
F400
F500
F600
FB05
FJ00
TD00

MM

310C
310D
310E
310R
310T
3115
3116
3117
3400
F306
F30D
F30G
F30H
F800
F801
F803
F804
F805
FA00
FB01
FB03
FB04
FC00
FD00
FE00
TK00

GM

5A00
5E00
5M00
8000
8500
8800
8900
8A00
8B00
9000
GB00
GE00
GW00
GX00
JC00
JF00
JFCA
JJ00

FT

5B00
5C00
5D00
5F00
5H00
5K00
5L00
G100
G600
G700
GL00
GQ00
GR00
GT00
GU00
GY00
GZ00

TM

9C00
9D00
9E00
JD00
JG00
JF01

ST

AF00
JM00
JN00
JP00
R000

*BT rating on 1200 p.s.i. ships and MM rating on 600 p.s.i. ships.

TABLE B-2

ASSIGNMENT OF EQUIPMENT TO SUBSYSTEMS

Guns

8000
8600
8800
8900
8A00
8B00
G000
G100
G600
G700
GB00
GE00
GL00
GQ00
GR00
GU00
GX00
GY00
GZ00

Missiles

5000

ASW

8500
9000
9C00
9D00
9E00
J000
JC00
JD00
JF00
JF01
JF03
JFCA
JG00
JJ00
JM00
JN00
JP00
JV00
JY00
JZ00

TABLE B-3

GLOSSARY OF EQUIPMENT IDENTIFICATION CODES

310C	Generator set, 60 Hz, steam turbine driven
310D	Lube oil system
310E	Condenser, auxiliary
310R	Generator set, 400 Hz, steam turbine driven
310T	Condenser, auxiliary
3115	Generator set, d.c., steam turbine driven
3116	Lube oil system
3117	Condenser, auxiliary
3400	Generating plants, special
5000	Surface missile systems
5A00	Launcher systems
5B00	Fire control radars and directors
5C00	Fire control computers
5D00	WDS designation/weapons direction equipments
5E00	Training equipments
5F00	Special test, checkout recording equipment
5H00	Miscellaneous
5K00	Switchboards, missile fire control
5L00	WDS optical and ancillary equipments
5M00	Guided missiles
8000	Specialized ordnance equipment
8500	Ammunition/weapon handling equipment, CNTNR (UWS)
8600	Ammunition/weapon handling equipment, CNTNR (AAWS)
8800	Ammunition/weapon handling equipment, CNTNR (SWS)
8900	Ammunition/weapon handling equipment, CNTNR/multi. purp. uses
8A00	Landing force equipment
8B00	Small arms/mortar/machine guns
9000	Expendable ordnance
9C00	Torpedoes, missiles and launching accessories
9D00	Depth charges
9E00	Mines
AF00	Sonar dome
F100	Steam generator and controls
F301	Pump unit, cntfgl (single stage), TD - main feed
F303	Pump unit, cntfgl (multistage), TD - main feed
F305	Pump, recip (liquid end modified), steam - main/aux fd
F306	Pump, recip, steam generator feed, low pressure
F307	Pump, recip, steam - port boiler feed
F308	Pump unit, centrifugal, TD - main feed booster
F309	Pump unit, cnetrifugal, mtrdn - main feed booster
F30A	Pump unit, centrifugal, TD - emergency feed
F30B	Pump, reciprocating, steam - emergency feed

TABLE B-3 (Cont'd)

F30C	Pump unit, centrifugal, TD - aux feed booster
F30D	Pump unit, centrifugal, mtrdn - aux feed booster
F30E	Pump unit, centrifugal, mtrdn - reserve feed transfer
F30G	Pump unit, centrifugal, TD - main condensate
F30H	Pump unit, centrifugal, mtrdn - main condensate
F30J	Deaerator group
F30L	Tank, surge and accessories
F30N	Control group, main feed pump
F400	Air supply system, combustion, main propulsion
F500	Fuel oil service system, main propulsion
F600	Uptakes (smoke pipes), main propulsion
F800	Turbines, steam and controls
F801	Turbine, high pressure, main propulsion
F803	Turbine, low pressure, main propulsion
F804	Turbine, cruising, main propulsion
F805	Pump unit, centrifugal, mtrdn - main SW cooling
FC00	Gears and clutches, main propulsion (detached)
FD00	Lubricating oil system, main propulsion
FE00	Shafting, mech cplg, brg, seals, prop, and prpln jet pump
FJ00	Controls, centralized main propulsion/aux machinery
G100	Fun Fire Control System Mk 68
G600	Target Designation System Mk 3
G700	Target Designation System Mk 5
GB00	Gun mounts
GE00	Gun rocket launchers
GL00	Gun Fire Control System Mk 37
GQ00	Gun Fire Control System Mk 54
GR00	Gun Fire Control System Mk 56
GT00	Gun Fire Control System Mk 63
GU00	Gun Fire Control System Mk 67
GW00	Ammo handling equipment
GX00	Training equipment
GY00	Surface warfare system test equipment
GZ00	Miscellaneous fire control equipment
JC00	ASW launcher, rocket equipment
JD00	ASW launcher, torpedo equipment
JF00	ASW handling equipment, ship installation
JF01	Equipment, torpedo handling
JFCA	Crane, loader, ASROC
JG00	UW launching equipment
JJ00	Launching Group Mk 16 (ASROC)
JM00	ASW Fire Control System Mk 105
JN00	ASROC Fire Control Group Mk 111
JP00	ASROC Fire Control Group Mk 114
JZ00	Miscellaneous ASW/UW fire control equipment
R000	Sonar systems
TD00	Filling, vent and transfer system - fuel/diesel oil
TK00	Distilling plants

APPENDIX C

DETAILED RESULTS

TABLE C-1

DETERMINANTS OF MATERIAL CONDITION FOR BOILERS
(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On two-screw, 1200 p.s.i. ships		
Average score on Shop Practices Test	- 138	-3.34[c]
Percent of BTs who are E-3 or below	25.19	3.00[c]
Percent of BTs who are E-8 or above	- 34.06	-1.19
Percent of BTs with under one year in the Navy	35.65	2.50[b]
Average number of school-related NECs per BT	-1586	-4.26[c]
Percent of BTs who are single	- 23.20	-3.29[c]
On one-screw ships		
Average number of Navy schools attended by BTs	- 287	-1.87[a]
On two-screw, 600 p.s.i. ships		
Average number of BTs	- 71	-3.72[c]
On all ships		
Percent of BTs with under 10 years in the Navy	8.94	1.29
Non-personnel variables		
Equipment complexity		
Two-screw, 1200 p.s.i. plant	7924[1]	3.60[c]
Logarithm of ship age (years)	515	3.22[c]
Constant	- 635	

Corrected R^2 = .52
Degrees of freedom = 76

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

[1]The coefficient of 7924 does not mean that two-screw, 1200 p.s.i. ships have on average 7924 more hours of downtime a month than other ships. In cases like this, where different coefficients are estimated for different types of equipment, or where the characteristics that enter the predictive relationship differ by equipment type, one cannot look at the coefficient of an equipment-type dummy variable as reflecting the differential downtime of that kind of equipment. To derive the average difference in downtime per month by equipment type, one must use the entire relationship to estimate average downtimes for different kinds of equipment at reasonable values of the independent variables. A comparison of the numbers in the third column of table 3 gives a good indication of the impact of equipment complexity on the material condition of boilers.

TABLE C-2

DETERMINANTS OF MATERIAL CONDITION FOR ENGINES
(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of MMs in the Navy under 3 years	6.28	2.16[b]
On all two-screw ships		
Average time spent on this ship by MMs (months)	- 24	-1.58
Average number of Navy schools attended by MMs	230	2.32[b]
Average number of NECs attained by MMs	-459	-1.33
On two-screw, 1200 p.s.i. ships		
Average number of MMs	- 9	-1.03
Average prior time spent on ships by MMs (months)	- 10	-1.71[a]
On two-screw 600 p.s.i. ships		
Average number of MMs	- 34	-2.85[c]
Percent of MMs E-3 or below	10.26	1.44
Non-personnel variables		
Equipment complexity		
One-screw plant	-492	-1.23
Logarithm of ship age (years)	215	2.34[b]
Constant	74	

Corrected R^2 = .25
Degrees of freedom = 78

[a]Significant at the 10 percent level.
[b]Significant at the 5 percent level.
[c]Significant at the 1 percent level.

TABLE C-3

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY GUNNER'S MATES

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of GMs in the Navy under 1 year	10.25	2.96[b]
Percent of GMs in the Navy 1-4 years	4.68	2.17[a]
Percent of GMs in paygrade E-8 or above	- 19.06	-2.10[a]
Average number of schools attended by GMs	111	2.78[b]
Average number of NECs attained by GMs	-142	-1.22
Non-personnel variables		
Equipment complexity		
Three turrets with 5"54 guns and one turret 3"50	441	7.03[b]
Two turrets with 5"54 guns plus missiles	143	3.15[b]
Length of time between overhauls (months)	4.10	2.25[a]
Constant	-401	

Corrected R^2 = .41
Degrees of Freedom = 78

[a]Significant at the 5 percent level.

[b]Significant at the 1 percent level.

TABLE C-4

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY FIRE CONTROL TECHNICIANS

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of FTs in the Navy under two years	2.46	1.20
Percent of FTs in paygrades E-8 or above	- 7.10	-1.24
On all CGs, DDGs, and FFGs		
Percent of FTs who are black	- 37.79	-2.50[b]
On CGs, FFGs, and DDG 37 class ships		
Logarithm of the fraction of FTs scoring over 50 on the Arithmetic Reasoning Test	-190	-1.18
On all ships except the FF 1052 class		
Percent of FTs in paygrade E-4 or below	3.20	2.69[b]
On CGs and DDG 37 class ships		
Percent of FTs who are high school graduates	- 45.96	-1.93[a]
On FRAM and FF 1040 class ships		
Number of FTs (as a fraction of the allowance in the Ship's Manning Document)	-288	-3.36[c]
Non-personnel variables		
Equipment complexity		
Mk 72 missile fire control systems	5180	2.23[b]
5"54 guns and other missile fire control systems	230	3.05[c]
Length of time between overhauls (months)	3.87	1.82[a]
Constant	46.9	

Corrected R^2 = .72
Degrees of freedom = 76

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

TABLE C-5

DETERMINANTS OF MATERIAL CONDITION FOR GUNS

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of FTs in the Navy less than 1 year	5.28	1.11
Percent of FTs E-8 or above	-16.67	-2.59[a]
Average number of schools attended by GMs	152	2.51[a]
Average number of NECs attained by GMs	-429	-2.36[a]
Percent of GMs in the Navy less than 2 years	4.83	2.08[a]
Percent of GMs in paygrades E-8 or above	-21.24	-1.98[a]
On ships with 5"54 guns		
Average prior sea experience of GMs (months)	6.61	-1.09
On FRAM destroyers and FF 1040 class ships		
Average number of FTs	18.9	-1.31
Non-personnel variables		
Equipment complexity		
Three turrets 5"54 plus one turret 3"50	894	4.04[b]
Two turrets 5"54	355	1.99[a]
Logarithm of ship age (years)	116	2.51[a]
Length of time between overhauls (months)	5.36	2.22[a]
Constant	-365	

Corrected R^2 = .53
Degrees of freedom = 75

[a]Significant at the 5 percent level.

[b]Significant at the 1 percent level.

TABLE C-6

DETERMINANTS OF MATERIAL CONDITION FOR MISSILES

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On ships with Mk 10 missile launching systems and Mk 72 missile fire control systems (NTDS ships)		
Percent of FTs who are high school graduates	-69.14	-3.77[b]
Percent of GMs in the Navy under 5 years	17.61	2.75[b]
On DDGs, CGs, and FFGs		
Percent of FTs scoring above 50 on the Arithmetic Reasoning Test	- 3.07	-2.72[a]
Percent of FTs who are black	-15.71	-1.26
Percent of GMs scoring above 50 on the General Classification Test	- 1.66	-1.10
Percent of FTs who are E-4 or below	10.91	4.88[b]
Non-personnel variables		
Equipment complexity		
Mk 10 missile launching system and Mk 72 fire control system	6299	3.41[b]
Constant	31	

Corrected R^2 = .85
Degrees of freedom = 34

[a]Significant at the 5 percent level.

[b]Significant at the 1 percent level.

TABLE C-7

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY TORPEDOMAN'S MATES
(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On ASROC ships		
Number of TMs	- 9.8	-1.73[a]
Percent of TMs in the Navy over 7 years	1.30	3.68[c]
Percent of TMs E-6 or above	- 1.29	-2.80[c]
Number of Navy schools attended	- 6.49	-1.05
Non-personnel variables		
Equipment complexity		
ASROC ships	154	4.13[c]
Ship age (years)	1.06	1.97[b]
Logarithm of the number of months between overhauls	33.9	1.62
Constant	-125	

Corrected R^2 = .17
Degrees of freedom = 83

[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

TABLE C-8

DETERMINANTS OF MATERIAL CONDITION FOR EQUIPMENT MAINTAINED BY SONAR TECHNICIANS
(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On all ships		
Percent of STs who graduated from high school	- 4.88	-2.45[b]
Logarithm of average prior experience of STs on ships (months)	-111	-3.01[c]
Percent of STs who are single	- 2.58	-2.61[b]
Non-personnel variables		
Equipment complexity		
SQS-26 sonar	166	6.54[c]
ASROC ships	60.4	1.80[a]
Constant	950	

Corrected R^2 = .42
Degrees of freedom = 84

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[a]Significant at the 10 percent level.

[b]Significant at the 5 percent level.

[c]Significant at the 1 percent level.

TABLE C-9

DETERMINANTS OF MATERIAL CONDITION FOR ASW EQUIPMENT
(Except for sonar)

(CASREPT downtime, hours per month)

Explanatory variable	Coefficient	t-value
Personnel variables		
On ASROC ships		
Logarithm of the average number of TMs	- 29.6	-1.18
Percent of STs who are high school graduates	- 2.51	-1.03
Logarithm of average previous sea duty for STs (months)	-174	-4.09[c]
Average number of schools attended by STs	- 26.8	-1.20
Percent of GMs who scored above 50 on the Mechanical Comprehension Test	- 1.80	-1.87[a]
Percent of GMs in the Navy under 1 year	6.06	1.95[a]
Percent of GMs in the Navy 1-4 years	2.74	1.36
Logarithm of average previous sea duty for GMs (months)	-103	-1.86[a]
Average number of schools attended by GMs	93.7	2.92[c]
Average number of NECs attained by GMs	-116	-1.37
Non-personnel variables		
Equipment complexity		
ASROC ships	1071	2.70[b]
Constant	19.6	

Corrected R^2 = .37
Degrees of freedom = 79

[a]Significant at the 10 percent level.
[b]Significant at the 5 percent level.
[c]Significant at the 1 percent level.