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The Economics of Naval Ship Automation: An Analysis of Proposed Automation of the DE-1052

Robert Shishko

A Report prepared for

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Rand
SANTA MONICA, CA. 90406

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PREFACE

This report was prepared as part of Rand's DoD Training and Manpower Management Program, sponsored by the Human Resources Research Office of the Defense Advanced Research Projects Agency (ARPA). With manpower issues assuming an ever greater importance in defense planning and budgeting, the purpose of this research program is to develop broad strategies and specific solutions for dealing with present and future military manpower problems. This includes the development of new research methodologies for examining broad classes of manpower problems, as well as specific problem-oriented research. In addition to providing analysis of current and future manpower issues, it is hoped that this research program will contribute to a better general understanding of the manpower problems confronting the Department of Defense.

In 1973 Rand was asked by the Human Resources Research Office and the Tactical Technology Office of ARPA to evaluate on economic grounds a specific proposal by a Purdue University team, headed by Prof. Theodore J. Williams of the Laboratory for Applied Industrial Control, to automate the DE-1052 class destroyer escort. At that time, the Navy was already funding a number of surface ship automation programs, but none of these was designed to look at the "maximum" automation of a Navy surface ship. The full state-of-the-art automation of a Navy ship was the goal of ARPA and the Purdue group. Assisting the Purdue group in this effort was a group from Specialized Systems, Inc. of Mystic, Connecticut, with extensive experience in shipboard personnel matters. Rand worked closely with both groups but reported its findings directly to ARPA.

SUMMARY

The objective of this study is to provide an economic analysis of a proposal to automate the DE-1052 class destroyer escort. While the study is directed toward a specific proposal from the Purdue Laboratory for Applied Industrial Control, several larger lessons can be drawn from it concerning future naval ship automation.

The principal benefit of shipboard automation is the reduction in the manpower necessary to operate and maintain the ship. To realize this reduction, R&D expenditures must be made and automation hardware must be acquired, installed, and brought to operational status. Whether the shipboard automation is economically advisable depends upon the dollar value of the manpower savings attributable to automation, the dollar costs of the automation, and the timing of these savings and costs.

The manpower reduction attributed to automation was estimated and was converted to a dollar figure by multiplying the number of enlisted personnel saved in each rating and pay grade by an estimate of the total annual cost (in 1974 dollars) for each rating and pay grade.

While some equipment for the proposed automation is off-the-shelf hardware, other equipment as well as software will have to be developed and tested. Precise estimates of the cost of the proposed automation are therefore not possible. For the DE-1052, nonrecurring development engineering costs were estimated to be between \$3.5 and \$5 million. The per ship conversion costs, which include hardware acquisition, installation, checkout and sea trials, were estimated to be between \$3.0 and \$4.25 million. The reason for the range of estimates is uncertainty as to the details of the specifications required to gain Navy acceptance. The low estimate (\$3.0 million) reflects an expectation that "ruggedized" versions of commercial hardware but with some equipment built to military specifications (mil-spec) will be acceptable, while the high estimate (\$4.25 million) reflects the expectation that strictly mil-spec equipment will be required. The Navy of course will affect the costs of the hardware by the very way it writes the specifications.

The personnel-related savings and automation costs were combined by calculating the present discounted value (PDV) in 1974 dollars of the proposed automation project. At a recommended discount rate of 10 percent, the proposed automation has a decisively negative PDV when the cost of automation is \$4.25 million (the high estimate); when the cost of automation is \$3.0 million (the low estimate), the proposed automation has a small positive PDV. At a discount rate of 5 percent, the proposed automation has a small but positive PDV at the high estimate and a decisively positive PDV at the low estimate. This suggests that the PDV is moderately sensitive to the choice of the discount rate and to the cost of automation. At a discount rate of 15 percent, the proposed automation has a negative PDV at both the high and low cost estimates.

Further sensitivity analyses revealed that at the high estimate for the cost of automation and a discount rate of 10 percent, the PDV (in constant dollars) is still negative even if (1) the personnel-related savings were underestimated by 10 percent or (2) the rate of inflation in military wages is unrealistically and persistently larger than that for military equipment over the next 20 years.

The analysis of the proposed automation of the DE-1052 confirms the obvious point that the desirability of any particular automation scheme depends not only on the number of individuals but on the kinds of individuals saved. The optimal degree of automation of the DE-1052 is not revealed by the present analysis. While "total" automation of the DE-1052 does not seem to be worthwhile, selective automation of certain functions *may* be. One very promising area for improvement is interior communications. However, for a number of reasons, the economics of automation of future naval surface ships is quite a bit more favorable than automation of existing ships.

ACKNOWLEDGMENTS

The author primarily wishes to thank the men and officers of the USS Roark (DE-1053) and the USS Barbey (DE-1088) for their time and cooperation. Special thanks are due Lt. Comdr. Griffin Hamilton, former Commanding Officer, USS Roark; Lt. Comdr, Jerry Lyle, former Executive Officer, USS Roark and Comdr. Theodore B. Shultz, former Commanding Officer, USS Barbey.

For assistance in interpreting the personnel requirements of the DE-1052 class destroyer escort, the author gratefully acknowledges the assistance of Capt. Donald Kern, USN (ret.) and Capt. Maylon T. Scott, USN (ret.) of Specialized Systems, Inc., Mystic, Connecticut; and Prof. Theodore J. Williams of Purdue University's Laboratory for Applied Industrial Control.

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Responsibility for any errors remains, of course, exclusively the author's.

CONTENTS

LIST OF NAVY OCCUPATIONAL CODES (RATINGS) RELATED TO THE DE-1052

Boatswain's Mate (BM) *Master Seaman*

Boilermaker (BR) *Repairs marine boilers*

Boiler Technician (BT) *Operates marine boilers*

Commissaryman (CS) *Prepares food and supervises food service operations*

Damage Controlman (DC)

Disbursing Clerk (DK) *Payroll clerk*

Electrician's Mate (EM) *Electrician*

Electronics Technician, Radio (ETN)

Electronics Technician, Radar (ETR)

Engineman (EN) *Propulsion equipment engineer*

Fire Control Technician, Gunner (FTG) *Maintains electronic equip. in gun systems*

Fire Control Technician, Missile (FTM) *Maintains electronic equip. in missile systems*

Fireman (FN)

Fireman Apprentice (FA)

Gunner's Mate (GM) *Operates and maintains complex weapons systems*

Gunner's Mate, Gunner (GMG)

Hospital Corpsman (HM) *Medical assistant*

Hospital Corpsman, Assistant (HN)

Interior Communications Electrician (IC) *Operates and maintains various types of intercom systems*

Machinery Repairman (MR) *Manufactures machinery parts*

Machinist's Mate (MM) *Operates and maintains machinery*

Personnelman (PN) *Personnel clerk*

Postal Clerk (PC) *Postman*

Quartermaster (QM) *Navigation Assistant*

Radioman (RM) *Radio operator*

Seaman (SN)

Seaman Apprentice (SA)

Ship's Serviceman (SH) *Maintains retail and personal service activities facilities*

Signalman (SM) *Operates visual signal equipment*

Sonar Technician, Gunner (STG) *Operates special ocean sounding devices*

Steward (SD) *Prepares food and supervises food service operations*

Storekeeper (SK) *Repair parts manager and supply management*

Torpedoman's Mate (TM) *Maintains and operates electrical and mechanical torpedo-launching equipment*

Yeoman (YN) *Administrative assistant*

I. INTRODUCTION

Of great concern to military planners is the dramatic increase in the cost of military manpower that has accompanied the move toward the All-Volunteer Force (AVF). In view of tighter military budgets, one response to this rise in the price of military personnel could be a reduction in force size and capability. An alternative and perhaps more palatable response is to seek opportunities to substitute other resources whose prices have not risen as much. Indeed economic theory suggests that the response to an increase in the price of a productive factor should be to substitute other, relatively cheaper factors. If the cost of manpower rises relative to the cost of capital (equipment, machinery, vehicles, buildings, land, and so on) then the correct action is to substitute capital for manpower.[1] Similarly, if the cost of some types of manpower have risen relative to others, then opportunities for substituting the relatively cheaper manpower for the more expensive manpower should be considered as well.

Automation--the substitution of capital equipment for manpower--may be one way of achieving greater economic efficiency within the Navy. Recent development of "lower cost" systems necessary for the automation and control of complex boiler and power plant processes reenforces this logic.

The objective of this study is to provide an economic analysis of proposed automation[2] of the DE-1052 class destroyer escort[3] and, in particular, to determine the dollar value of manpower savings attributable to particular automation schemes. The method of analysis is to

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[1]In economists' language, a rise in the price of labor shifts the cost-minimizing (efficiency maximizing) point in the direction of a higher capital-labor ratio.

[2]This proposed automation is the product of a design study performed by the Purdue Laboratory for Applied Industrial Control under an ARPA-funded contract.

[3]In this report I shall refer to the DE-1052, but I mean any ship belonging to the DE-1052 class (also known as the Knox class) destroyer escort.

compare the automated DE-1052 with an efficiently manned existing DE-1052, holding ship effectiveness constant. The automated DE-1052 should be selected if the net dollar savings are positive.

There are a number of reasons for choosing the DE-1052 as the crucible for an analysis of shipboard automation of existing Navy surface ships. First, the DE-1052 is the largest single class of ships in the Navy. As a result, R&D expenditures can be averaged over a large number of ships and potential manpower reductions could be substantial in absolute terms.[1] Second, the DE-1052 is a fairly new ship with many years of useful operational life still remaining over which investment expenditures for automation could be recouped. Third, the 1200 psi power plant in the DE-1052 is common to a number of other Navy surface ships, including several modern aircraft carriers.

This report possesses the characteristics of a cost-benefit analysis. Although the analysis is directed toward a particular automation scheme, several larger lessons can be drawn from it about future naval ship automation. As with any cost-benefit study, the analyst must bring together both quantitative and qualitative information. The costs (in this case principally the investment in retrofitting the DE-1052) and the benefits of the project (in this case the manpower savings that might result) must be measured. These components must be combined so as to make a decision possible, and the analyst's assumptions must be varied to test the sensitivity of the results. This kind of study can be likened to a puzzle. This report is organized so that each section deals with a part of that puzzle. Section II deals with some general methodological problems, limitations, and issues. In Section III, the detailed manning structure of the automated DE-1052 is compared with the current manning in order to derive manpower reductions. The effect of automation on retention by Navy rating is also analyzed. Section IV deals with the cost of Navy manpower with particualr attention to training costs; in Section V the cost of the proposed automation is

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[1]According to the FY 1978 Navy Program for Ships, Cruiser-Destroyer shipboard manning will be about 51,500, slightly more than 20 percent of which will be on board DE-1052 class ships.

presented. In Section VI all of the components of the analysis are brought together, and the sensitivity of the results to various assumptions is tested. Section VII contains some general observations about automation.

II. ISSUES IN THE AUTOMATION OF THE DE-1052

In any study, careful formulation of the problem and issues involved is a crucial step. Occasionally limitations the analyst imposes reduce the generality of the results but increase the applicability of the analysis to the immediate problem. In this section some of the issues in evaluating shipboard automation are raised and addressed.

MANNING OF THE DE-1052

One of the chief issues in this economic evaluation is how much manpower will be saved by the automation of the DE-1052. This clearly involves a comparison of the ship's "unautomated" manning with the "automated" manning. A number of manning concepts could be chosen as the baseline unautomated manning, including the organizational manning, the authorized manning, the "fair share" manning, and the actual manning.[1] The view taken in this report is that the relevant unautomated manning should be the minimum manning necessary to maintain the level of effectiveness that a DE-1052 attains with its current actual manning. This level of manning I call "austere manning." By actual manning, I

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[1]The organizational manning is commonly referred to as SMD manning (Ships Manning Document). The SMD is prepared by the Chief of Naval Operations for major classes of ships and is supposed to delineate the manpower necessary to perform required operational capabilities. The SMD is prepared by a careful analysis of projected workloads taking into account the ship's configuration and operational environment.

The authorized manning, also known as the MPA manning (Manpower Authorization), is supposed to reflect budgetary and end-strength limitations. As a result, the MPA manning is generally below the SMD manning.

Ideally, the MPA manning should correspond to the actual manning; but because of personnel shortages, differing priorities, and a host of real constraints, only a "fair share" of scarce manpower assets can be assigned to a given activity. The distribution and assignment of enlisted personnel according to the "fair share" doctrine is therefore vested in the Navy Manning Plan (NMP). Because of timing, training, and real problems of implementation, the NMP manning may differ from the actual manning of a ship.

These four manning concepts are discussed more fully in Scott, Kern, and Williams (1974).

mean the typical actual manning for a standardized DE-1052 in fleet operations. This rules out DE-1052s configured for special or priority missions.

The reason for examining austere manning is that the proposed manning for the automated DE-1052 is also based on the minimum manning necessary to maintain ship effectiveness. Comparison of the austere manning structure with the manning structure of an automated DE-1052 permits ascertaining of the *net* contribution of automation to manning reduction.

EFFECT OF AUTOMATION OF PERSONNEL STRUCTURE

Shipboard automation is likely to affect the personnel structure by (1) altering the mix of skills--perhaps raising the average skill level--needed to man the ship; (2) shifting the experience level of the enlisted personnel between, say, first termers and careerists; (3) altering the officer-enlisted mix; and (4) changing the availability of training billets. The effect of these changes largely depends on the kind of automation that is installed and on the number of ships that are automated relative to fleet size.

Shipboard automation that replaces low skill, easily trained personnel with high skill personnel whose training is long and costly is not likely to yield a positive economic return, even though that replacement is on a less than one-for-one basis.[1] Fleetwide automation of this kind will raise manpower skill requirements to where they cannot be realistically fulfilled. Enlisted personnel capable of learning highly technical skills will probably remain in short supply in the Navy; high demand for these skills in the civilian economy makes this kind of manpower expensive and costly to retain. Automation must take this into account if it is to be economically successful.

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[1]While such automation may be *technologically efficient* in the economist's sense of producing a given output with the smallest complement of manpower for a given amount of capital, it is not *economically efficient* if that output is not being produced at minimum total cost. It is also possible for such automation to be technologically inefficient if both more capital *and* more manpower than needed are used to produce the given output. In that case it is both technologically and economically inefficient. A fuller discussion of this distinction is in Shishko (1974), pp. 41-65 (unpublished).

When automation of a substantial portion of the fleet shifts the requirement for personnel with more than one term of service, total manpower costs will be difficult to predict. The reason for this is that required retention rates will increase if more second termers are required from the same (or a smaller) supply of first termers. Required retention rates may increase even if fewer second termers are needed, provided the (fixed) inventory of first termers is reduced by automation more than proportionately. Required retention rates could fall if the automation saves proportionately more experienced personnel.[1] *The success of shipboard automation depends not only on how much manpower requirements are reduced but also on the kinds of manpower saved.*

FLEETWIDE AUTOMATION

As the above discussion suggests, analyzing the economic effect of automation of the entire surface fleet is inherently more difficult than analyzing the effect if only a few ships are automated because automation of the entire surface fleet is not a marginal change. Analyses that fail to account for the larger picture will be incorrect.

This study is simplified by the fact that automation of the entire surface fleet is not being suggested--only the retrofitting of automated equipment on the DE-1052. In Sections III and VI, I will refer to two automation options. The first is the automation of the DE-1052 (Knox) class only; 46 ships in this class are planned. The second option is the automation of the DE-1052 (Knox) class and related classes--the DE-1040 (Garcia) class (10 ships) and DEG-1 (Brooke) class (6 ships).[2] In total, these classes contain 62 first-line ships.

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[1] It is easy to illustrate realistic examples showing how the total manpower could fall after automation with the average skill level either rising or falling, and independent of that total manpower costs either rising or falling. The key is the experience level question and the implied retention problems. The outcome depends on the elasticity of retention rates with respect to wages.

[2] The DE-1040 (Garcia) destroyer escort class is almost identical in design to the DE-1052 (Knox) class, but it is slightly smaller because of a slightly different boiler. The DEG-1 (Brooke) class destroyer escort is identical to the DE-1040 class except for the Tartar missile system (in lieu of a second 5-inch gun mount) and different electronic equipment.

COST OF NAVY MANPOWER

To determine the dollar savings attributable to automation-related manpower reductions, the cost of Navy personnel by rating and pay grade must be known. These costs are developed in the cost model of Section IV. At issue here is really whose costs should be counted. Most manpower costs are borne by the Navy, but some--such as retirement--are borne by DoD, and some--such as veterans' benefits and tax advantages--are paid for by non-DoD government departments and agencies. In this study, manpower costs reflect only Navy and DoD expenditures for two reasons: First, retirement benefits can be viewed as deferred wages. That these benefits come from a separate DoD fund is of only administrative and historical significance. Second, non-Navy/DoD personnel costs are only a small fraction of the total[1] and may be viewed not as compensation but as transfer payments to a particular segment of society.

EVALUATING COSTS AND SAVINGS IN FUTURE YEARS

The problem of making dollar costs or savings occurring in different years commensurable has received wide attention in economics and engineering literature. The general solution is to select an appropriate discount rate and calculate all dollar amounts in present discounted value (PDV). If r is the discount rate, then a stream of dollar values $V_1, V_2, \ldots, V_n$ has a present discounted value given by:

$$\mathrm{PDV} = \sum_{t=1}^{n} V_t (1 + r)^{-t} , \tag{1}$$

where V_t is the dollar value occurring in year t. For a particular project, V_t can be viewed as the dollar benefits occurring in year t less the dollar costs occurring in year t. A PDV exceeding zero guarantees that the total benefits of a project are greater than the total cost of the project. In the past an artificially low discount rate was used to justify projects that were inherently uneconomic or at

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[2]This contention is demonstrated in Section IV.

least prematurely considered.[1] A project that shows a positive PDV at a 3 percent discount rate may show a negative PDV at a 6 percent discount rate. At stake then in the choice of the discount rate may very well be the acceptance or rejection of a particular project even when all are agreed on the costs and benefits of the undertaking.

Economists are not in complete agreement on what the discount rate for government projects should be; in fact, there are two substantially different views on how the discount rate should be calculated. To some economists the discount rate reflects society's relative preference for current consumption over future consumption. Put another way, real resources saved in 1976 are not as valuable as the same resources saved in 1975, and the sacrifice of resources today is more painful than the sacrifice of the same resources next year. The rate at which society is willing to make this tradeoff is the discount rate.

Other economists take the view that the discount rate should be the rate of return that the resources used would otherwise earn in the private sector--the opportunity cost rate of the project. This view results from the logical principle that resources should not be taken out of one project and put into another project with a lower rate of return.

Between these two views there is a fundamental dilemma, because only under special assumptions[2] would both give the same number. Although I do not plan to reconcile these two views, I believe that some general resolution is possible: If a public project is a perfect substitute for a private project, then the opportunity cost rate should be used as the discount rate. This would imply a discount rate of at least 10 percent and perhaps as high as 30 percent. If a public project is not a perfect substitute for a private project, then the

[1]As a partial indication of the inefficiencies that can result from an inappropriate discount rate, Fox and Herfindahl (1964) found that at the alternative discount rates of 4, 6, and 8 percent, respectively 9, 64, and 80 percent of the projects authorized by Congress in 1962 for construction by the Army Corps of Engineers had present discounted values less than zero.

[2]These special assumptions include the absence of taxes on capital, risk, and both production-based and consumption-based externalities.

appropriate discount rate lies *between* the rate the government must pay to borrow money--the rate on long-term government bonds[1]--and the opportunity cost rate. National defense projects are usually not undertaken by the private sector, so a discount rate somewhat less than the opportunity cost rate seems appropriate.

In testimony before the Subcommittee on Economy in Government of the Joint Economic Committee, several noted economists suggested that a discount rate between 7.5 and 12.5 percent be used for government projects.[2] It is my belief that the use of a 10 percent discount rate will yield a better decision regarding the proposed automation of the DE-1052 than the use of historically lower rates.

HANDLING UNCERTAINTY

The automation of the DE-1052 represents an investment that can produce a return over a 20-year period. Over such a long period, many uncertainties are present, some strategic and some economic. In this study, I have chosen to ignore such uncertainties as potential combat losses and whether ocean-going escort ships like the DE-1052 will have a mission to perform over their remaining physical life (or the utility of that mission).[3] Instead I will concentrate on long-term economic uncertainties. The important uncertainty over this time horizon is how

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[1]Here I am referring to the real rate--that is, the coupon rate less the long-term expected rate of inflation. This rate is assumed to reflect society's willingness to forgo current consumption in order to increase future consumption.

[2]Joint Economic Committee (1968). Further evidence on the views of economists can be found in Hirshleifer and Shapiro (1968). The authors cite recommendations for the discount rate ranging between 5 percent and 13.5 percent. A rationale for a 10 percent discount rate is presented in Baumol (1968).

[3]Many economists have recommended that a "risk premium" be added to the discount rate to account for this kind of strategic uncertainty. Proponents of this view argue that hedges against this kind of uncertainty are at best imperfect, even considering the large number of projects undertaken by the public sector. The argument is stronger for defense projects because the uncertainty arises not simply from an unpredictable but benign Nature, but also from another decisionmaker actively seeking to reduce the usefulness of the project. This line of reasoning suggests that the discount rate of 10 percent recommended in the previous subsection is, if anything, too low.

the relative price of military manpower versus military equipment (capital) will change. Since all costs and savings in this study are in constant 1974 dollars, already adjusted to reflect real purchasing power, we need be concerned only about relative price changes, not general changes in the price level. This kind of uncertainty requires and receives careful treatment in Section VI.

III. MANPOWER SAVINGS ATTRIBUTABLE TO AUTOMATION

SOME GROUND RULES FOR MANNING CHANGES

In this chapter, I describe how the manning reduction attributable to automation was determined. To aid in this determination, certain ground rules were established. First, base case manning of a DE-1052 was set at 247 enlisted personnel and 16 officers. This figure reflects the typical actual manning of a DE-1052 without LAMPS.[1] While many factors determine the actual manning of a U.S. Navy ship, the driving force behind the establishment of manning criteria is the ability of the crew to operate the ship in a variety of environments called Conditions of Readiness. For the DE-1052, it is safe to say that the numbers and types of personnel required to operate the ship and its weapons in Conditions I and III determine the overall manning of the ship. Condition I is also known as *General Quarters*; in this Condition the ship is under attack, engaging the enemy, or preparing to do so. Condition III is often referred to as *Wartime Steaming*; in this Condition, the ship must be prepared to defend itself in case of attack.[2] Condition I requires the greatest number of personnel in terms of stations

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[1]LAMPS means Light Airborne Multi-Purpose System. The actual manning of a DE-1052 varies considerably from ship to ship depending on whether the ship has been augmented for combat or has drawn an overseas assignment; different manning could also be the result of imperfections in the personnel assignment system. For a more detailed discussion of this problem see Scott, Kern, and Williams (1974).

[2]The principal Conditions of Readiness are further defined as follows:

(a) Condition I. No maintenance expected except that routinely associated with watchstanding (e.g., changing lube oil strainers) and urgent repairs. All possible operational systems manned and operating. Maximum expected endurance 24 continuous hours.

(b) Condition II. Accomplishment of most routine underway preventive maintenance and repairs, and necessary administrative work expected. Four to six hours of rest expected per man per day. Subject to the foregoing conditions, all possible operational systems manned and operating. Maximum expected endurance 10 continuous days.

(c) Condition III. Normal underway maintenance and administration expected. Eight hours of rest expected per man per day. Subject to to be manned. However, even though far more stations are manned under Condition I than under Condition III, Condition III stations must be manned continuously by three eight-hour shifts. This necessitates having some additional personnel on board who have *no* assignment in Condition I. There are other personnel who are needed in Condition I but not in Condition III simply because some skills are not fungible. If only one skill and skill level were required by the Navy, total assigned manning would be the manning in the Condition that had the greatest demand for manpower.

In addition to assigned personnel, each ship has unassigned personnel principally to perform various hotel functions. Total enlisted manning then is made up of the assigned and unassigned enlisted personnel. Appendix Table A-1 shows the Condition I and Condition III assigned manning by station for the base case DE-1052. This appendix supports the figure of 247 enlisted personnel.

The second ground rule was established that the manning of any alternative DE-1052 configuration must be such as to support the ship in Conditions I and III. In other words, just as Conditions I and III determine the assigned manning in the base case, they also determine the revised manning of assigned personnel on the automated DE-1052.

Third, some but clearly not all[1] unassigned personnel were variable according to the total manning of the ship.

In addition to these ground rules, several constraints were imposed on the analysis. Weapons systems were assumed to be sufficiently automated so no changes in manning were considered. No changes in officer billets were considered either; and changes in manning in the

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the foregoing conditions, all possible operational systems manned and operating. Maximum expected endurance 60 continuous days.

(d) Condition IV. Peacetime steaming. Normal underway maintenance and administration expected.

(e) Condition V. In-port Watch. Provision for ship security and readiness expected.

[1]Of the 32 unassigned enlisted personnel, 14 were considered variable with the total shipboard manning. Most of these perform various hotel functions, the demand for which depends on the size of the population to be served. If only one individual on board had a given rating--for example the disbursing clerk (DK)--that individual could not be eliminated. Nonvariable unassigned personnel also included ratings principally engaged in maintenance functions.

Combat Information Center (CIC), Communication Control (CC) and Damage Control (DC) parties were allowed only at interfaces with other departments. For example, if a *1JV Talker* were eliminated from the bridge, then the *1JV Talker* at DC Central would presumably no longer be required either and could be eliminated.

As with all limitations, these constraints have their implicit or shadow costs. For example, not permitting the number of officer billets to be changed may make automation appear less valuable than it in fact is. Of these constraints, the fixing of officer billets was the most limiting. The others were of little practical significance in evaluating the proposed automation schemes. Because the automated DE-1052 was required to be as "effective" and as "risk-minimizing" as current DE-1052s, weapons, CIC, CC, and DC departments were best left intact.

MANNING OF ALTERNATIVE DE-1052 CONFIGURATIONS

To establish the enlisted manning required for any alternative DE-1052 configuration, three numbers were needed. The first was the number of enlisted personnel required for Condition I only. To that were added the *additional* complement of enlisted personnel necessary for Condition III and the unassigned personnel. The total manning was established for four configurations of the DE-1052--the base case DE-1052, the automated DE-1052, and two intermediate configurations, called the austere DE-1052 and the austere DE-1052 with an enhanced interior communication system. The austere DE-1052 possesses *no* additional hardware, but manning has been set at the minimum deemed to provide the same operational effectiveness as the base case DE-1052. In other words, the austere DE-1052 configuration eliminates enlisted personnel whose contribution to operational effectiveness is deemed negative or marginal.[1]

An austerely manned DE-1052 on which the same wireless interior communication system proposed for the automated DE-1052 has been installed is the second intermediate configuration. Manning for this configuration is the same as for the austere DE-1052 except that the personnel whose sole function was to provide interior communication

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[1]See Appendix A for how this was determined.

links have been removed. Thus the operational effectiveness of this configuration is the same as for the austere (and base case) DE-1052.[1]

The automated DE-1052 is described in "A Plan for the Automation of DE-1052 Class of Naval Surface Ships."[2] The proposed automation involves the installation of four minicomputers, thirteen microprocessors, four "data highways," as well as sensors, actuators, and associated displays.

Table 1 shows the assigned enlisted personnel required for Condition I only, for the four DE-1052 configurations by control function. For the base case DE-1052, a total of 197 enlisted personnel are needed to operate the ship;[3] about 25 percent of these are eliminated on the automated DE-1052. On the austere DE-1052 some personnel, primarily from the bridge and engineering departments, are eliminated; but the DE-1052 augmented with the wireless interior communication system requires substantially fewer personnel than the base case. Appendix A provides the detailed manning by station to support these numbers.

As noted earlier, Condition I does not determine the total manning of the ship. Additional enlisted personnel necessary to perform Condition III tasks and unassigned personnel must be added to the figures in Table 1 to obtain total manning for each configuration. This is shown in Fig. 1. Note that the base case total manning is the 247 figure cited earlier. The differences between the austere manning[4]

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[1]One of the operational advantages of the wireless interior communication system, which contributes positively to effectiveness, is the ability of the command structure to communicate directly with the department heads, eliminating delays in transmitting messages and distortions in relayed messages.

[2]Halverstadt, Kern, and Williams (1974).

[3]Scott, Kern, and Williams (1974), use a figure of 190. I have added seven previously unassigned enlisted personnel to the undermanned messing section.

[4]The austere manning of 234 enlisted personnel and 16 officers corresponds roughly to the actual manning of the DE-1082 (USS Montgomery) as of December 31, 1973, which had a crew of 237 enlisted personnel and 16 officers. The importance of this is to show that austere manning is not just wishful thinking on the part of the analyst. For a breakdown of the DE-1082's manning, see Scott, Kern, and Williams (1974), pp. vi - 10.

Table 1

SHIPBOARD MANNING BY CONTROL FUNCTION

Control Function[a]	Assigned Enlisted Personnel Required for Condition I Only			
	Base Case DE-1052	Austere DE-1052	Austere DE-1052 Augmented with Interior Communication System	Automated DE-1052
Ship	18	13	7	3
Combat information	24	24	21	21
Communications	18	18	16	14
Electronic casualty	4	4	4	4
ASW[b]	22	22	22	22
Weapons	27	27	27	27
Engineering	29	21	16	10
Damage control	43	43	36	36
Combat support	12	12	23	10
TOTAL	197	184	161	147

[a]Grouping enlisted personnel by control function is a reasonably self-explanatory way of showing how many men are employed in a particular functional category.

[b]Anti-Submarine Warfare.

(234) and the automated manning (189) is the net reduction attributable to automation (45). What is important is not so much the number of individuals saved by automation but the kinds of personnel saved. The cost of highly skilled or experienced personnel may be substantially greater than the cost of low skilled or inexperienced personnel, or some ratings may be more difficult to retain than others. Appendix Table A-2 delineates the rating and rate of the manpower eliminated under austere manning and automated manning.

Several important observations can be made if one looks at the rough distribution of skill levels and experience categories of the enlisted personnel eliminated on the austere DE-1052 and the automated DE-1052. Table 2 shows this distribution for these skill levels and three experience categories corresponding to first termers, second termers, and third termers and above. Ratings were assigned to the three skill levels based on the number of training hours--two to four

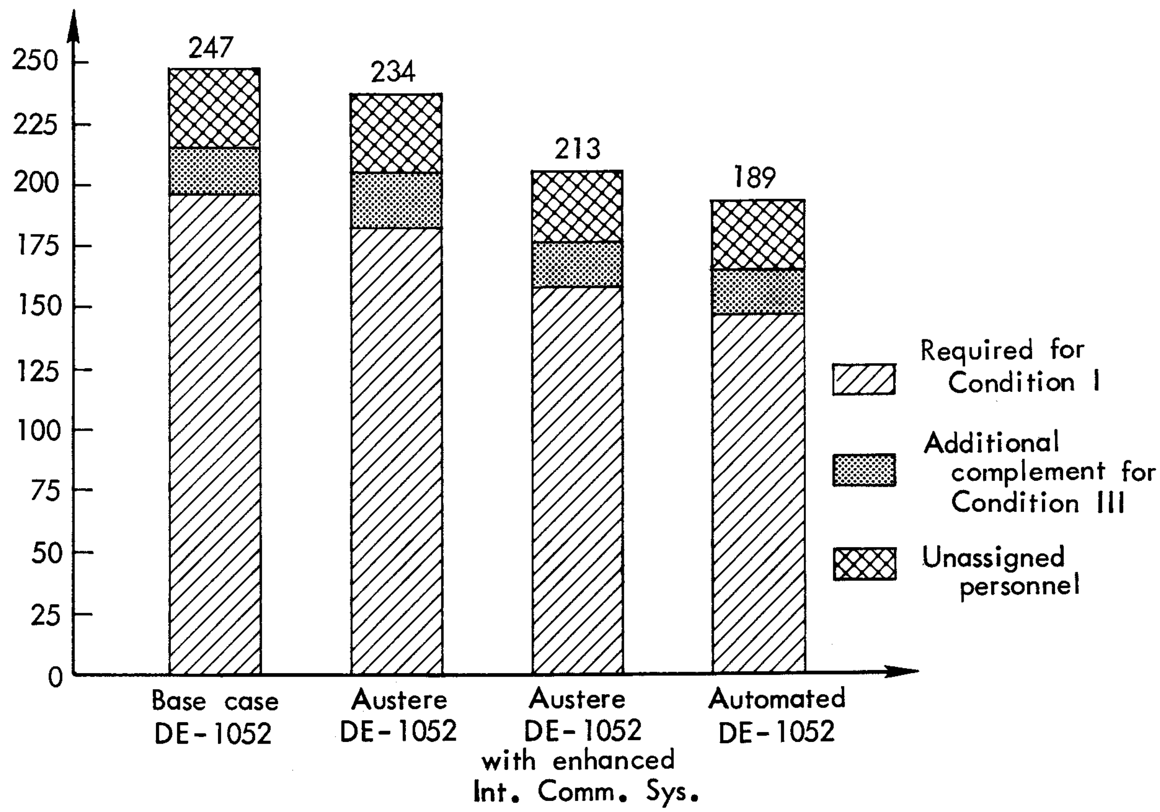

Fig. 1 — Total manning for alternative DE-1052 configurations

Table 2

CHANGES IN SHIPBOARD MANNING FROM BASE CASE DE-1052 FOR AUSTERE AND AUTOMATED DE-1052s

	Austere DE-1052		
	Experience (term of service)		
Skill Level	1st	2nd	3rd and Above
High[a]	-1	-1	0
Medium[b]	-1	0	0
Low[c]	-8	-1	-1

	Automated DE-1052		
	Experience (term of service)		
Skill Level	1st	2nd	3rd and Above
High[a]	-2	-1	0
Medium[b]	-6	-4	-2
Low[c]	-40	-2	-1

[a]Includes IC rating.

[b]Includes BM, BT, EM, EN, MM ratings.

[c]Includes QM, SK, SM, SN/FN, YN ratings.

hundred hours for low skill, four to six hundred hours for medium skill, and more than six hundred hours for high skill.[2]

The manpower saving attributable (solely) to the proposed automation is obtained by subtracting the manpower savings under austere manning from the manpower savings under automated manning. Table 3 shows the result of this calculation by skill level and experience categories. Most of the manpower savings (71 percent) occur in the low skill-low experience category. Further, in the medium skill ratings, the mix of personnel saved is fairly rich in second and third termers. This should have a favorable effect on retention problems. (In the next subsection, I shall show that at least no unfavorable effects are

[1]At least for the DE-1052, this breakdown of ratings passes the ultimate test of reasonableness.

Table 3

PERSONNEL CHANGES ATTRIBUTABLE TO AUTOMATION BY SKILL LEVEL AND EXPERIENCE

	Experience (term of service)		
Skill Level[a]	1st	2nd	3rd and Above
High	-1	0	0
Medium	-5	-4	-2
Low	-32	-1	0

[a]Each skill level includes the ratings shown in notes to Table 2.

likely.) Finally, Table 3 indicates proposed automation has little effect on the truly high skilled ratings--that is, those ratings concerned with the maintenance of complex hardware.

In Section IV, I convert the manpower savings into dollar savings by computing the cost of various kinds of Navy enlisted personnel.

RETENTION UNDER AUTOMATION

The automation of a single DE-1052 is of course of little interest, but what will be the effect on the personnel structure if, say, all 46 DE-1052s are automated, or if all 62 DE-1052 and DE-1052-like ships are automated? Is automation likely to improve retention of ratings now in short supply, or will it exacerbate the retention problem? To answer this question, I investigated what I call the "gross retention ratio." This parameter is defined for each rating as the (end of FY 1973) inventory of second-term personnel to first-term personnel. The gross retention ratio is the proportion of a cohort of first termers who would have to remain in the Navy to maintain the same proportion of second termers in that rating. Implicitly the gross retention ratio concept is useful only when sustaining the existing mix of first and second termers is considered desirable.

The proposed automation will alter the gross retention ratio for each rating depending on whether the manpower savings described in the previous section are first-term-intensive or second-term-intensive. Table 4 shows how the gross retention ratio will change for the ten ratings affected by automation under the 46 ship program and the 62 ship program. A decrease in the gross retention ratio means that retention is likely to be easier because a smaller proportion of first termers need to reenlist to maintain the same balance of first termers to second termers.[1]

Table 4 indicates, first, that with the exception of the QM and SM ratings, none of the gross retention ratios are significantly altered by automation. This is perhaps best illustrated by the MM rating. The percentage change in the gross retention ratio is negligible because the ratio of first termers to second termers saved under automation is approximately the same as the ratio of first termers to second termers in the total force inventory. For the difficult-to-retain ratings BT, EM, EN, IC, and MM, the percentage change in the gross retention ratio under automation is small but in the direction of lower required retention rates. Automation, therefore, is not likely to have an adverse effect on the Navy's efforts to retain individuals in these ratings while holding the line on bonus payments.

Second, for the two ratings that seem to have significant changes in the gross retention ratio, QM and SM, automation may be helpful in eliminating some retention problems. In fact, the automation of the DE-1052 may have a *fleetwide* effect by allowing for a reduction in the Selective Reenlistment Bonus (SRB) paid to all individuals in the QM and SM ratings independent of whether they serve on a DE-1052.

Since it is not possible to know whether the current gross retention ratios for these two ratings represent the desired balance between

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[1]Implicit in this conclusion is an assumption about the form of the supply function of second termers, which is the behaviorial relationship between wages and the number of first termers who reenlist. This is often expressed in econometric studies in terms of the reenlistment rate, the number who reenlist divided by the number who were eligible. The assumption I have made is that the reenlistment rate is a positive function of military wages or of the ratio of military to civilian wages.

Table 4

RETENTION UNDER AUTOMATION

Rating	Term	End FY 73 Inv.	Gross Retention Ratio	Gross Retention Ratio with Automation (46 ships)	Percent Change	Gross Retention Ratio with Automation (62 ships)	Percent Change
BT	1st	5,665	.180	.172	-4.49	.169	-6.06
	2nd	1,021					
EN	1st	3,576	.384	.376	-2.10	.373	-2.84
	2nd	1,372					
EM	1st	5,644	.396	.388	-2.06	.385	-2.78
	2nd	2,234					
IC	1st	2,475	.345	.339	-1.74	.336	-2.38
	2nd	853					
MM	1st	12,134	.280	.278	-0.60	.277	-0.81
	2nd	3,392					
BM	1st	2,311	.700	.745	+6.36	.761	+8.76
	2nd	1,618					
QM	1st	2,507	.174	.153	-12.13	.146	-16.25
	2nd	437					
SK	1st	3,048	.424	.430	+1.53	.433	+2.07
	2nd	1,292					
SM	1st	1,564	.199	.180	-9.46	.173	-13.04
	2nd	311					
SN/FN	1st	94,267	<.01	<.01	0	<.01	0
	2nd	741					
YN	1st	5,024	.322	.331	+2.82	.334	+3.84
	2nd	1,616					

first termers and second termers, and consequently whether the current gross retention ratios are transitory, I did not attempt to estimate how much of a dollar savings this fleetwide effect might yield.[1]

Overall one must conclude that the proposed automation is likely to have small but positive effects on the retention of critical skills. The effect would, however, be significantly greater if automation could be focused more on eliminating (high-skill and) high-experience personnel.

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[1]The elasticity of supply of these two ratings would also have to be known with reasonable accuracy. Various supply elasticities have been estimated in Enns (1975).

IV. ESTIMATING THE COST OF NAVY MANPOWER

In this section, I calculate the cost of the manpower saved by automation. While the skills (ratings) and experience levels that were reduced or eliminated by automation are only a small part of all possible combinations of Navy skill and experience levels, the model I present can be applied generally. Because there are many kinds of costs of manpower, many different accounting systems depending on the purpose to which the cost figures are to be put, and many possible assignments of costs to various skill and experience combinations, there are numerous pitfalls in building a manpower cost model. Certainly there is neither a single cost model that can serve every purpose nor a single "correct" cost figure for a particular manpower slot. Insofar as possible, I have constructed a manpower cost model that reflects the *long-run marginal cost* of a particular skill and experience combination. This concept is needed to evaluate the proposed automation because it is the best estimate of the manpower dollars that will be saved by a *modest* reduction of the number of active enlisted personnel.

Some manpower costs depend exclusively on pay grade, while some depend on rating; others depend on length of service or term of service. Many costs depend on a combination of two or more of the above considerations. I have made total annual cost in 1974 dollars the sum of five separate, annualized costs--basic, training, retirement, reenlistment, and Permanent-Change-of-Station (PCS) costs. Each of these will be explained in detail.

BASIC COSTS

Basic costs are composed of base pay, Basic Allowance for Quarters (BAQ), special pays, and miscellaneous costs. Base pay was computed for each pay grade. The 1974 statutory rates of pay by length of service were weighted by the proportion of Navy enlisted personnel having served that amount of time. The weights were calculated from the inventory profile by DoD Occupational Area of Navy enlisted personnel on active duty as of June 30, 1973. This means that average base pay for each pay grade was taken to be the same for Navy ratings within the same DoD Occupational Area--for example the MM and BT ratings. Ratings in different DoD Occupational Areas usually had different average base pay.[1] For E-1s through E-3s, no distinction by rating was possible.

Basic Allowance for Quarters was taken to be the statutory rate for enlisted personnel with no dependents.[2] Special pays[3] were estimated for each pay grade from the average amount of such pays for Navy enlisted personnel.

Miscellaneous costs are an agglomeration, including Basic Allowance for Subsistence (BAS), Station Allowance, Family Separation Allowance, Social Security Payments (FICA), subsistence-in-kind, and clothing allowance. These costs were calculated on an average cost per Navy enlisted man based on the FY 1975 budget justification submitted to OASD (Comptroller). In addition, miscellaneous costs include certain costs that vary with pay grade, such as lump-sum leave, Basic Maintenance Allowances (BMA), and Standard Maintenance Allowances (SMA). Appendix Table B-1 presents the basic cost of Navy enlisted personnel by pay grade and cost element.

TRAINING COSTS

Training costs are a significant part of the annual cost of a skilled journeyman. They are included early in the first term of service and represent an investment in human capital. The return on this investment is the additional productive capability of a journeyman during the useful part of his first term of service.

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[1] It was possible to calculate an average base pay based on length of service for each rating separately. However, this figure might reflect a transitory condition in the length of service distribution for that rating that would seriously bias the calculation from a longer term estimate. A larger grouping of ratings could avoid this problem. Generally the difference in average base pay between any two DoD Occupational Areas for a given pay grade was less than $10 per month.

[2] This figure was chosen as the best representative of the long-run marginal cost.

[3] Special pays include sea duty, foreign duty, hostile fire pay, and diving pay, but do not include reenlistment bonuses.

Training may be viewed conceptually as a fixed cost that can be amortized over some time horizon. Figure 2, which may help to elucidate this idea, depicts the movement over the first term of service of an individual from an E-1 basic recruit to an E-4 third-class petty officer (PO3). Early in this enlisted tour, the individual receives basic training as an E-1, then attends an A-school as an E-2. Upon completion of the basic courses leading to a particular rating, an A-school graduate is assigned to the fleet for on-the-job training (OJT). After an unspecified amount of time, training, and study, this individual reaches a level of proficiency sufficient to take the third-class petty officer examination.[1]

The primary cost of training is the pay and allowances of the trainee during the training period. This is shown in Fig. 2 as the dollar amount above the horizontal axis. In addition, there are other direct training costs, such as the pay and allowances of instructors while the trainee is attending school. This is shown as the dollar amount below the horizontal line. During the period of OJT, the trainee starts out as an individual who must be closely supervised and in the process consumes real training resources by requiring that more experienced personnel be allocated away from productive shipboard work to supervisory duties. Over time, the trainee requires less supervision and begins to produce a *positive net output*. In Fig. 2, this occurs at time t_0. Direct training costs during OJT are also shown in Fig. 2 as the dollar amount below the horizontal line.[2] Total training costs for this individual, then, are shown by the shaded area of Fig. 2.

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[1]The Navy Bureau of Personnel requires that a man demonstrate a mastery of his specialty and be recommended before being allowed to take the PO3 examination. Here I am concerned with the point in the training process where he possesses the skills of a PO3. Of course not all of those who take and pass the PO3 examination come from A-schools. It is quite common to attain PO3 status by OJT and correspondence courses only. Calculating training costs as I have done--the A-school route--is in keeping with the long-run marginal cost concept.

[2]For a more complete discussion of the learning process during OJT, see Gay (1974). An alternative view attributes a zero opportunity cost to supervisory time during OJT. Proponents of this view argue that while supervisors do spend time in an instructional manner, there is not much else they can do with this time. This does not imply, however,

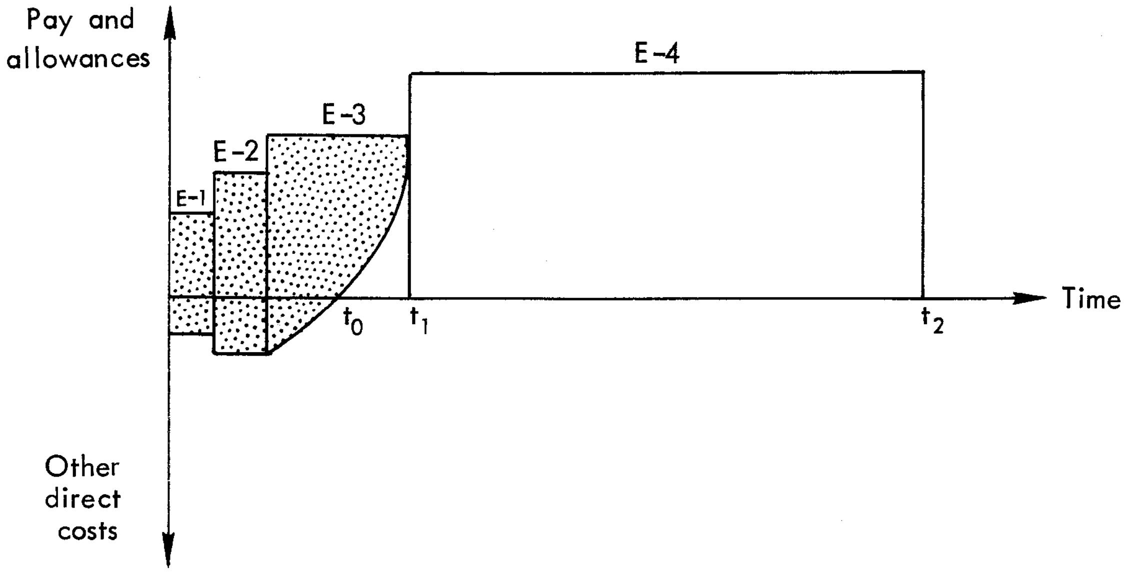

Fig. 2— True training cost

This lump sum dollar amount[1] must be amortized over the *remaining* portion of the first term of service. Beyond the first term, the value of this training is captured in the pay, allowances, and bonuses of second-term enlisted personnel, so the relevant period for amortization is in fact $t_2 - t_1$, where t_2 is the time at which the first term of service ends.

Because the exact curve of on-the-job learning is not known, I estimated training cost by calculating the shaded area shown in Fig. 3, as *this* calculation is operationally feasible. The calculated lump-sum training cost differs from the true lump-sum training cost only to

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that supervisory manning can be reduced because at the peak demand for supervisory services--e.g., during Condition I--the effectiveness of the ship would be impaired if supervisors were eliminated.

The effect of not counting supervisory time as a cost of training is to *reduce* the personnel-related savings when automation is introduced. My rough guess is that the annualized cost of training for those attaining third-class petty officer status might be lowered by 15 to 25 percent. This in turn would lower the total annual cost of a third-class petty officer by approximately 5 to 8 percent.

[1]Technically, if the training period is long enough, the correct lump sum is calculated by "forward discounting" training costs to time t_1 in Fig. 3.

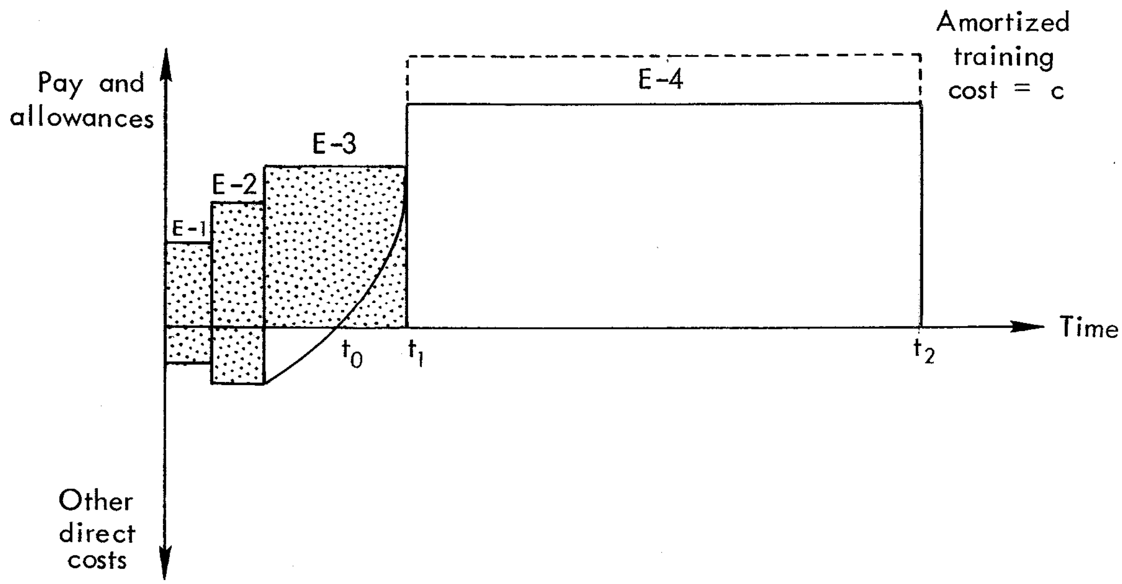

Fig. 3—Calculated training cost

the extent that the two triangular-shaped areas in Fig. 3 differ. Given the calculated lump-sum training costs V^*, it is more useful to know the annual increment to pay and allowances c, which, when discounted over the period $t_2 - t_1$, equals V^*. To find c, we must solve

$$V^* = \int_0^x c(x,V^*,r)e^{-rt}\,dt\,, \tag{2}$$

where $x = t_2 - t_1$ and r is the discount rate. Integrating Eq. (2), we obtain

$$c = \frac{rV^*}{1 - e^{-rx}}\,. \tag{3}$$

To calculate V^*, I used a standard Navy reference on training time and costs by rating[1] and adjusted the reported direct training costs to 1974 dollars. To obtain students pay and allowances, I multiplied

[1]Clary (1970).

student training time by the appropriate annual basic cost found in Appendix Table B-1. A training cost that includes accession and accession travel, recruit training, and initial uniform issue was charged equally to all ratings. Average OJT time was estimated for each rating from a study on OJT versus A-school training.[1] This length of time multiplied by the annual basic cost of an E-3 is my estimate of total OJT costs as explained in Fig. 3. For certain ratings, all training is OJT. For these, I modified the training cost methodology so that only a part of the trainee's time was charged to training. In doing this, I in effect assumed that useful work was performed during the other portion of on-duty time.

Both lump-sum and annualized training costs for third class petty officers are shown in Appendix Table B-2 for various Navy ratings. Training costs for the SN and FN ratings are also presented.

Personnel who are beyond the first term of service receive training as well, though this training is usually acquired during a regular shore rotation and tends to cover advanced topics leading to an NEC. Because no specific NECs are saved by automation, advanced training costs were not counted as cost of DE-1052 personnel.

RETIREMENT COSTS

Individual retirement costs were calculated by multiplying average base pay by (1) the probability the individual will remain until retirement and (2) the proportion of this year's base pay that must be set aside to meet the expected future retirement benefits. For Navy enlisted personnel this proportion is .292.[2] The probability an individual will remain in the Navy until retirement as a function of pay

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[1] Weiher and Horowitz (1971). One of the conclusions of this study is that although all ratings can be learned on the job, A-school graduates take less time to become proficient in the skill than nongraduates. This does not necessarily imply that A-schools are the better way of training individuals, because the A-school selection process may favor the higher quality recruit to begin with.

[2] A 5 percent discount rate was used to calculate this proportion. At a 10 percent rate, a lower proportion would be required, but the precise figure is not available on a consistent basis.

grade[1] was obtained from the OASD (M&RA) Actuarial Consultant. Average base pay was calculated separately (as in Appendix Table B-2) for different DoD occupational areas. Appendix Table B-3 shows the calculation of retirement costs.

REENLISTMENT COSTS

Reenlistment costs represent the annualized equivalent of a lump-sum Selective Reenlistment Bonus (SRB) or Regular Reenlistment Bonus (RRB) payment. For each rating, I assumed a four year initial reenlistment and calculated the lump-sum SRB as the product of four, the SRB code number, and the monthly base pay of an E-4 at four years of service. Let X^* be the lump-sum SRB, then the annualized equivalent, b, is given by

$$b = \frac{rX^*}{1 - e^{-4r}} , \qquad (4)$$

where r is the discount rate. This is essentially the same as Eq. (3). This annual cost was charged to second-class petty officers (PO2).[2]

The annualized equivalent of a regular reenlistment bonus for a second four-year reenlistment was charged to first-class petty officers (PO1) and chief petty officers (CPO). The lump-sum RRB was calculated as four times two-thirds of the monthly pay of an E-5 or E-6, each with more than six years of service. Equation (4) was then applied to obtain the annual cost. Appendix Table B-4 shows the reenlistment cost by rating and pay grade.

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[1]Although it would be desirable, it was not possible to obtain these probabilities by rating as well as pay grade.

[2]The SRB by law is the monthly base pay times the SRB code number for each year of reenlistment. Under current administrative practice, SRB's are paid in equal annual installments such that the undiscounted stream of payments equals the lump-sum bonus. RRBs are still being paid as a lump sum. Recent changes in the SRB law were designed to phase out the RRB program by combining it with the SRB program. For more details on these changes, see Enns (1975).

PERMANENT CHANGE OF STATION COSTS

PCS costs are not included in the basic cost of Navy enlisted personnel. To the extent that PCS costs vary with total Navy manpower, they should be included in the cost model. To account for PCS costs, I took the total budgeted amount for FY 1975 for Navy enlisted personnel and divided by the total Navy enlisted manyears. This yielded an average annual cost figure of $157.

NON-DOD COSTS

Non-DoD costs were not included in the cost model. Whether this omission seriously affects the estimate of manpower costs depends on the relative magnitude of these costs. As Appendix Table B-5 demonstrates, non-DoD costs represent only 5 percent of included costs. A parametric treatment of cost sensitivity is therefore sufficient to counter objections to my omission of non-DoD costs.

SAVING ATTRIBUTABLE TO AUTOMATION

In Table 5, the results of the cost model are shown for various ratings and experience levels. The figures have been rounded to the nearest hundred dollars to avoid spurious accuracy. Appendix Table B-6 shows the details of the cost calculations presented in the table.

Two main observations can be drawn from Table 3. First, there is a wide difference--about 50 percent--between the cost of unskilled and skilled ratings, due, of course, to the cost of training. Second, the differences in cost to the Navy and DoD of first-class, second-class, and third-class petty officers are smaller than might be expected. This, of course, does not mean that a third-class petty officer can be substituted for a first-class petty officer. What the total cost does not show is that a much larger proportion of costs is received by first-class petty officers as income than by third-class petty officers--with training again being the primary difference.

To obtain the net savings attributable to automation, I multiplied the number of individuals saved under automation less the number saved under austere manning in each rating and pay grade by the calculated total cost shown in Appendix Table B-6. The details of this calculation

Table 5

ANNUAL COST OF PERSONNEL BY RATING AND EXPERIENCE[a]

	Experience[b]			
Rating	Third Class (P03)	Second Class (P02)	First Class (P01)	Chief
IC	13,600	12,700	13,400	(c)
MM	13,000	12,700	--	(c)
BT	12,900	12,700	13,400	(c)
EN	12,900	12,200	(c)	(c)
EM	(c)	12,200	(c)	(c)
BM	13,000	(c)	(c)	(c)
SK	11,900	(c)	(c)	(c)
SM	11,300	12,100	(c)	(c)
YN	11,100	(c)	(c)	15,800
QM	10,900	12,300	(c)	16,000
SN/FN	7,800	(c)	(c)	(c)

[a]At a discount rate of 10 percent per year, rounded to nearest $100; 1974 dollars. Only those ratings and experience combinations affected by automation were calculated.

[b]P03 in first four-year term; P02 in second four-year term; P01 and Chief in third four-year term.

[c]Not affected by automation.

are shown in Appendix Table B-7. Table 6 summarizes the results of the calculation in the previously shown matrix of skill and experience categories.

One is immediately struck by the observation that most of the savings--about 62 percent--occur in the low skill-low experience category. Nevertheless, there are significant savings in the medium skill category for all levels of experience, which may make automation attractive.

Table 6

ANNUAL PERSONNEL-RELATED SAVINGS ATTRIBUTABLE TO AUTOMATION[a]

(per ship)

Skill Level[b] ($)	Experience (term of service) 1st ($)	2nd ($)	3rd & Above ($)
High	13,600	0	0
Medium	64,900	49,900	26,700
Low	268,300	12,100	0

[a]At a discount rate of 10 percent; total annual savings per ship, $435,500.

[b]Ratings associated with each of the three skill levels are identical to those in Table 2.

V. INVESTMENT COST OF AUTOMATION

This section presents estimates of the nonrecurring development engineering and investment costs of retrofitting the DE-1052 with the proposed automation equipment. The details of the proposed automation of the bridge and machinery spaces are extensively described in the Purdue report, "A Plan for the Automation of the DE-1052 Class of Naval Surface Ships."[1]

Although some equipment for the proposed automation is off-the-shelf hardware, other equipment as well as software will have to be developed and tested. As a result, precise estimates of the cost of the proposed automation are not possible. The best estimates that could be obtained by Rand represented a range of guesses that were provided by traditional suppliers of this kind of equipment to the Navy.[2] The lack of precise cost estimates need not be a stumbling block if the confidence in the manpower saving estimates is high. The cost uncertainty can be handled by a variety of analytic tools such as sensitivity analysis or breakeven analysis.

Table 7 shows the range of cost estimates obtained. For comparison, I also show an estimate of providing the same or similar equipment to be used on a commercial ship comparable in size to the DE-1052.

For the DE-1052, nonrecurring development engineering costs were estimated to be between $3.5 and $5 million. Even at $5 million, engineering development represents an investment of only $80,000 to $110,000 per ship, depending on whether the R&D is spread among 62 ships, or 46 ships, or somewhere in between. It would be difficult to imagine that the decision to accept or reject automation would depend on this amount. Of obviously greater significance is the per conversion investment cost, which ranges from $3 million to $4.25 million per ship (line

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[1] Halverstadt, Kern, and Williams (1974).

[2] These suppliers preferred to remain anonymous since formal bids had not been requested. Their names would be recognized as important firms in the boiler, marine powerplant, control equipment, and electronics fields.

Table 7

COSTS OF PROPOSED DE-1052 AUTOMATION--BRIDGE AND MACHINERY SPACES

(thousands of 1974 dollars)

			DE-1052	
		Commercial Ship[a]	Commercial Hardware[b]	Mil-Spec Hardware[c]
(1)	Nonrecurring Development Engineering	2400-2500	3500	5000
(2)	Per Conversion[d] Hardware Acquisition	1300-2200	2500	3500
(3)	Installation/ Checkout/Sea Trials	200-500	500	750

[a]Range of estimates by manufacturers for a commercial ship comparable to the DE-1052.

[b]"Ruggedized" commercial hardware, some mil-spec equipment.

[c]Factor of 1.4-1.5 on "commercial."

[d]Some "learning" might be expected in the installation component of per conversion costs, but I have not made any provision for this simply because it is difficult to justify a particular learning rate, and any reasonably chosen figure would have too negligible an effect on the final costs.

(2) + line (3)). In the next section I shall refer to a per ship conversion cost of $3 million as the "low" estimate and to a per ship conversion cost of $4.25 million as the "high" estimate. The range of estimates is due to present uncertainty as to the details of the specifications required to gain Navy acceptance. The low estimate reflects an expectation that "ruggedized" versions of commercial hardware with some equipment built to military specifications (mil-spec) will be acceptable, while the high estimate reflects the expectation that strictly mil-spec equipment will be required. The Navy of course can affect the costs of the hardware by the very way it writes the specifications.

VI. NET RETURN TO AUTOMATION OF THE DE-1052

R&D, RETROFIT, AND OPERATIONAL SCHEDULE FOR THE AUTOMATED DE-1052

It is now possible to calculate the net return to automation by combining the results of the last two sections. To do this, however, it is necessary to specify a schedule for the R&D and retrofit programs. The development and conversion costs of automation are incurred during these phases; as automated DE-1052s are phased into the fleet the dollar savings due to reduced manpower needs are realized. The schedule is an important consideration because costs and savings occurring in different years must be discounted to make them commensurable.

To make the calculation of the net return concrete, I have chosen a schedule consisting of a three-year R&D program, a three-year retrofit program, and a 15-year service life of automated DE-1052s. This schedule is depicted in Fig. 4.

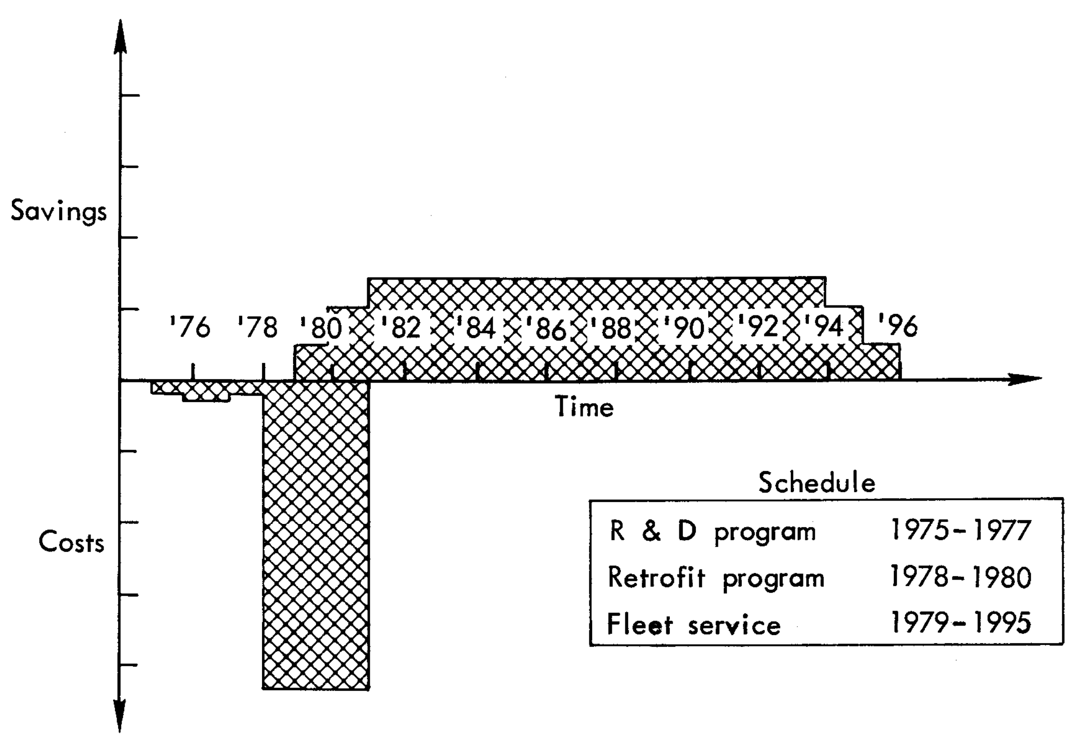

Fig. 4 — Time stream of investment costs and manpower savings

The R&D program covers three years, during the first year of which one-quarter of the development engineering funds are spent. During the second year, one-half of the development engineering funds are spent, and the remaining one quarter is spent during the third year.

The retrofit program also covers three years, during each of which one-third of the programmed ships are automated. Thus some savings occur immediately after the first year of the retrofit program. The retrofitted DE-1052s are assumed to remain in fleet service for 15 years. Retirement of the last automated DE-1052s is completed by the end of 1995. A DE-1052 entering operational status in 1970 will then have been in fleet service for a total of 25 years, which is typical of current Navy practice.

THE PRESENT DISCOUNTED VALUE OF THE PROPOSED AUTOMATION

The presented discounted value (PDV) calculation reduces the stream of costs and savings to a single number so that the proposed automation can be compared with alternative investments having different time paths of costs and savings. If the proper discount rate is used, then the PDV represents the payoff of the proposed project. If the PDV is negative, the project should, of course, not be done because the real resources consumed exceed the savings generated, when costs and savings are measured in commensurable units.

I have calculated the 1974 PDV of the proposed automation of the DE-1052 using 5, 10, and 15 percent discount rates. As discussed earlier, a 10 percent discount rate represents the best choice among these. The discount rate used here should not be confused with the expected rate of inflation.[1] The costs and savings calculated in the two previous sections are in 1974 dollars; therefore the PDV will also be in 1974 dollars. Should the *relative* prices of military equipment and military manpower change, then the PDV in constant 1974 dollars would also change, depending on the timing of the costs and savings. This will be dealt

[1]The nominal discount rate, which equals the real discount rate plus the expected rate of inflation, should be used to discount "then-year" dollars. Since I am dealing with *real* costs and savings, the correct discount rate is the *real* rate.

with somewhat later in this section. So long as these prices change proportionately, the PDV in constant 1974 dollars will remain unchanged.

Table 8 shows the results of the PDV calculation for several selected cases.[1] In these cases the program size, discount rate, and estimated cost of automation are varied over the range of uncertainty that prevails for each.

At a discount rate of 10 percent, the proposed automation has a decisively negative PDV when the cost of automation is at the high end. When the cost of automation is at the low end, the proposed automation has a small positive PDV; if the cost of automation were as little as 8 percent higher than the low estimate--that is, about \$3.24 million instead of \$3.0 million--then this positive PDV would disappear.

At a discount rate of 5 percent, the proposed automation has a small but positive PDV at the high estimate and a decisively positive PDV at the low estimate. This suggests that the PDV is moderately sensitive to the choice of the discount rate and to the cost of automation. At a discount rate of 15 percent, the proposed automation has a negative PDV at both the high and low cost estimates.

Choosing a smaller program in which only the 46 DE-1052s are automated results in a smaller overall PDV (at the low cost of automation and a 5 percent discount rate) but approximately the same PDV per

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[1] The PDV in constant 1974 dollars can be calculated by the following formula: Let r be the discount rate, then

$$PDV = \sum_{t=1}^{n} (-C_t + S_t)(1 + r)^{-t} , \qquad \text{(i)}$$

where C_t is the cost of automation in constant 1974 dollars incurred in year t and S_t is the personnel-related savings in constant 1974 dollars in year t. This can be expanded slightly as written as

$$PDV = \sum_{t=1}^{n} \left(-q_t^m p_o^m + n_t^m w_o^m\right)(1 + r)^{-t} , \qquad \text{(ii)}$$

where p_o^m is the price of military investment goods in the base year 1974, q_t is the quantity of military investment goods purchased in year t; w_o^m is the price of military manpower in the base year, and n_t^m is the quantity of military manpower saved in year t.

Table 8

PDV OF PROPOSED AUTOMATION
(millions of 1974 dollars)

Case[a]	Program Size[b]	Cost of Automation[c]	Annual Discount Rate	PDV	PDV Per Ship
I	62 ships	High	10%	-40.34	-.65
II	62 ships	Low	10%	9.17	.15
III	62 ships	High	5%	6.10	.10
IV	62 ships	Low	5%	68.23	1.10
V	46 ships	Low	5%	49.80	1.80
VI	62 ships	High	15%	-56.61[d]	-.91
VII	62 ships	Low	15%	-16.72[d]	-.27

[a] All cases refer to the schedule proposed in the text and depicted in Fig. 4.

[b] The Knox (DE-1052) class comprises 46 ships; the Knox, Garcia (DE-1040), and Brooke (DEG-1) classes comprise 62 ships.

[c] High and low cost of automation are terms described in Section V.

[d] The net saving attributable to automation was taken to be the same as that in Appendix Table B-7, column (5).

ship.[1] Indeed the only difference is that R&D costs are being spread over fewer ships, which should reduce the PDV per ship just a little.

The sensitivity of the PDV to the discount rate and to the cost of automation is shown in Fig. 5. The horizontal axis is the per ship conversion cost--that is, the cost of acquiring the hardware, installation, and checkout and sea trials. The vertical axis is the PDV for a 62 ship program. The difference between the high and low estimates for the R&D cost--that is, the nonrecurring engineering development--is inconsequential for the PDV. The PDV is more sensitive to the investment cost of automation as the discount rate falls as seen from the change in the

[1] If the PDV is negative, then with the smaller program size the PDV would be negative but smaller in absolute value. The PDV per ship would also be negative but larger in absolute value.

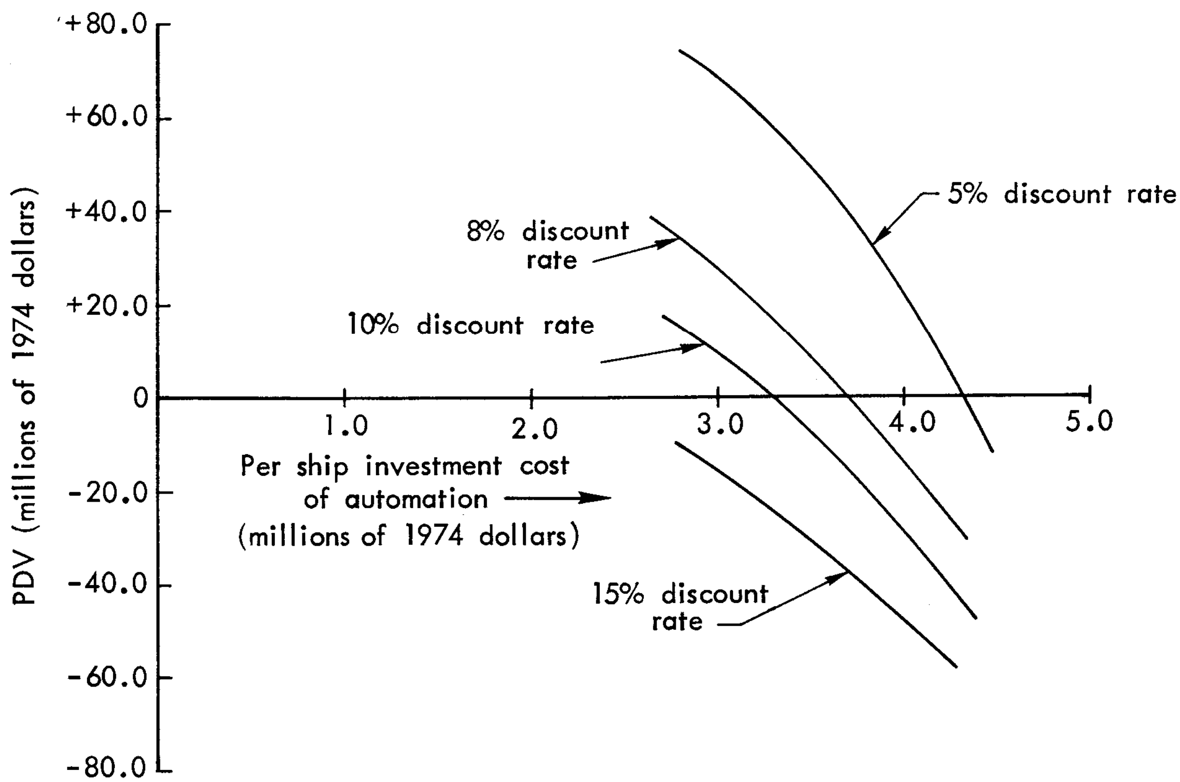

Fig. 5 — Sensitivity of results to investment cost and discount rate

slopes of the curves at any value on the horizontal axis in Fig. 5.[1] The implication of the sensitivity of the PDV to the investment cost of automation is that there is a high value on improving our information on the cost of automation.

SENSITIVITY OF RESULTS TO MANPOWER COST ESTIMATES

The PDV of the proposed automation of the DE-1052 will be different from that reported in Table 8 if the estimate of the cost of Navy manpower is inaccurate. To test the sensitivity of the PDV figures, I parametrically varied the annual personnel-related savings per ship in dollars by ±5 percent and ±10 percent. This can be thought of as a change in the estimated cost of *each* Navy rating/rate by ±5 or ±10

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[1]In technical terms, $\partial^2 PDV/\partial C \partial r > 0$ in the relevant range.

percent, or a balanced change in each Navy rating/rate with the average change in the total equivalent to ±5 or ±10 percent.

The change in the PDV will of course depend on the discount rate since manpower savings occur over several years. Table 9 shows the results of this sensitivity test.

Table 9

CHANGE IN THE PDV FOR A 62 SHIP PROGRAM
(millions of 1974 dollars)

Percentage Change in Annual Personnel-Related Savings Per Ship[a]	Discount Rate, r	
	5%	10%
-10	-21.72	-12.79
-5	-10.86	-6.40
5	10.86	6.40
10	21.72	12.79

[a]Original annual personnel-related savings per ship are $.4355 million at a discount rate of 10 percent, and $.4305 million at a discount rate of 5 percent.

If the original estimate of the cost of Navy personnel was too low then the PDV will be higher than reported; conversely if the original estimate was too high the PDV will be lower. Note that the *change* in the PDV does not depend on the cost of the automation estimate since the cost part of the PDV calculation does not change. At a discount rate of 10 percent, and a cost of automation midway between the high and low estimates, the true PDV is still negative even if the personnel-related savings were underestimated by 10 percent.

SENSITIVITY OF RESULTS TO REAL PRICE SHIFTS

Up to now it was unnecessary to specify the rate of inflation because by assuming the same rate for both military equipment and military manpower, the PDV in real 1974 dollars is unaffected. The long time horizon required to obtain a positive return on the automation generates a great deal of uncertainty about the future course of prices. If, for example, the cost of military manpower rises *relative* to the cost of military equipment over that time horizon, then the proposed automation will look better--that is, have a higher PDV in real 1974 dollars. If, however, the cost of military manpower falls *relative* to cost of military equipment, then the reverse holds.

In the long run, the cost of military equipment, which is produced by the private sector, depends to a large extent on the cost of labor in the civilian economy.[1] *Thus to a large extent by looking at the relative cost of military equipment to military manpower, we are comparing civilian wages in industrial establishments with military wages.* The pay increases accompanying the move to the AVF (All Volunteer Force) were designed to bring civilian and military wages into some sort of "equilibrium." Various mechanisms also allow for adjustments in military pay to maintain this equilibrium. In the long run, one should not expect any significant systematic divergence in the relative price of military equipment to military manpower unless there are important, unforeseen structural changes in civilian or military labor markets.

What would be the effect on the PDV of the proposed automation if there were long-term systematic shifts in relative prices? To answer this question in a general way, I have constructed a quantity that I call the real shift parameter, s, defined as the annual percentage change in the relative price of military personnel to military equipment and assumed to be *constant* over the time horizon. Thus,

$$s = \frac{w_t^m/p_t^m}{w_{t-1}^m/p_{t-1}^m} - 1 , \qquad (5)$$

where w_t^m/p_t^m is the price ratio of military manpower to military equipment at time t. If s equals 1 percent, then each year the *real* price of military manpower rises 1 percent relative to the real price of military equipment. When compounded over 20 years, this would imply a

[1]The cost of military equipment also depends on the prices of raw materials, the rate of return, and the level of production technology in the defense industry.

real shift of over 22 percent. If s equals 2 percent, then over 20 years there would be a real shift of nearly 49 percent.

The change in the PDV of the proposed automation depends on the real shift parameter and the discount rate because as before the timing of personnel-related savings is important.[1]

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[1]To calculate the change in the PDV let the PDV in constant 1974 dollars be given by

$$\text{PDV} = \sum_{t=1}^{n} (-q_t^m p_o^m + n_t^m w_o^m)(1 + r)^{-t} , \qquad \text{(i)}$$

where all of the variables have been defined in footnote 1 on page 36.

With inflation at the rate θ_k in year k, $1 \leq k \leq n$ in both p_o^m and w_o^m, the PDV in constant 1974 dollars is still given by Eq. (i) above since

$$\text{PDV} = \sum_{t=1}^{n} \frac{\left(-q_t^m p_o^m \,\pi_{k=1}^{k=t}(1 + \theta_k) + n_t^m w_o^m \,\pi_{k=1}^{k=t}(1 + \theta_k)\right)}{(1 + r)^t \,\pi_{k=1}^{k=t}(1 + \theta_k)}$$

$$= \sum_{t=1}^{n} (-q_t^m p_o^m + n_t^m w_o^m)(1 + r)^{-t} . \qquad \text{(iii)}$$

However, if inflation in p_o^m is the rate θ_k and in w_o^m is at the rate $\theta_k + \delta_k$, then the PDV in constant 1974 dollars is given by

$$= \sum_{t=1}^{n} \frac{\left(-q_t^m p_t^m + n_t^m w_t^m\right)}{(1 + r)^t \,\pi_{k=1}^{k=t}(1 + \theta_k)}$$

$$= \sum_{t=1}^{n} \frac{-q_t^m p_o^m \,\pi_{k=1}^{k=t}(1 + \theta_k) + n_t^m w_o^m \,\pi_{k=1}^{k=t}(1 + \theta_k + \delta_k)}{(1 + r)^t \,\pi_{k=1}^{k=t}(1 + \theta_k)} . \qquad \text{(iv)}$$

In Eqs. (iii) and (iv) I used the rate of inflation in the civilian economy, θ_k, to deflate all nominal amounts to constant 1974 dollars.

With s defined as in Eq. (5) in the text, observe that

$$s = \frac{1 + \theta_k + \delta_k}{1 + \theta_k} - 1 = \frac{\delta_k}{1 + \theta_k} .$$

Table 10 shows the change in the PDV in real 1974 dollars under various assumptions. At the high cost of automation and a discount rate

Table 10

CHANGES IN PDV FOR ALTERNATIVE USES OF s

Case	Program Size	Discount Rate	Real Shift Parameter, s[a]	Change in PDV
I	62 ships	10%	1%	14.55
II	62 ships	5%	1%	24.04
III	62 ships	10%	2%	31.70
IV	62 ships	10%	-1%	-14.21
V	46 ships	10%	1%	10.80

[a]Annual percentage change in the relative price of military personnel to military equipment.

of 10 percent, even if s is as much as 2 percent, an extremely unlikely event, the PDV of the proposed automation is still negative.

Substituting $s(1 + \theta_k)$ for δ_k in Eq. (iii) yields

$$PDV = \sum_{t=1}^{n} \frac{-q_t^m p_o^m + n_t^m w_o^m (1 + s)^t}{(1 + r)^t} , \tag{v}$$

assuming as I have that s is strictly constant.

Subtracting Eq. (i), the original PDV, from Eq. (v) yields the change in the PDV

$$\Delta\ PDV = \sum_{t=1}^{n} n_t w_o^m \left(\frac{1 + s}{1 + r}\right)^t - \sum_{t=1}^{n} \frac{n_t w_o^m}{(1 + r)^t} . \tag{vi}$$

VII. CONCLUSIONS

This section has two purposes. The first is to summarize the salient conclusions of the analysis, and the second is to indicate the direction automation of naval ships should go.

1. *The desirability of any particular automation scheme depends not only on the number of individuals but on the kinds of individuals saved.* To make this point more dramatically, consider the proposed automation of 62 DE-1052 and DE-1052-like ships. At a discount rate of 10 percent and a high cost of automation, to break even, an additional $135,400 would have to be saved per ship per year. (Note that this is about 30 percent more than the estimated savings.) This dollar figure translates into 11 additional trained individuals in the medium or high skill category, assuming an average annual per capita cost of $12,700. But the same dollar figure translates into 18 additional untrained individuals--that is, SN or FN--at an average annual per capita cost of $7,800.

With the same mix of trained and untrained individuals as the proposed automation already saves, then an additional 15 (or 33 percent more) individuals would have to be saved for the project to break even. This figure was obtained assuming an average annual per capita cost of $9,700.

2. *The PDV of the proposed automation is negative (at the high cost of automation) and marginal (at the low cost of automation) at the recommended discount rate of 10 percent.* The reasons for this are not only because of insufficient manpower savings, the point made above, but also because retrofitting the automation into an existing ship involves at least three additional losses. First, the number of years of operational life remaining on an existing DE-1052 is less than on an entirely new ship, reducing the time over which automation investment expenditures can be recovered. Second, the retrofitting of the automation equipment into an existing DE-1052, even if pursued during a regular overhaul sequence, involves the expensive procedure of removing and

then replacing various parts of the boiler and powerplant;[1] checkout and sea trials must be repeated as well. Installing the automation equipment on a new ship would be considerably easier and less costly; checkout and sea trials could be accomplished as a part of the regular process of bringing the ship to operational status. Third, the automation for a new ship might well be more efficient because designers would not be constrained to adapt it to the DE-1052, a ship that was not necessarily designed with boiler and powerplant automation in mind. In particular, automation may allow for smaller and more fuel-efficient ships, which would lower initial capital and operating costs as well.

How might these considerations change the outlook for naval surface ship automation? To answer this question in an admittedly "back-of-the-envelope" but nevertheless useful way, I made the following hypothetical calculations. Suppose the three-year R&D program depicted in Fig. 4 is followed by a new ship building program to replace the DE-1052. Suppose six ships per year for eight consecutive years are built, making 48 ships in all. These ships then remain in active service for 25 years. The PDV of automating these ships can easily be calculated. I have assumed the same manpower savings as for the proposed automation of the DE-1052. For the cost of automation I have assumed the same R&D and hardware acquisition costs as in Table 7; no additional expenditures for installation, checkout, and sea trials for the automation equipment are counted because presumably these would be the same whether the ship was automated or not.[2] The per ship investment cost of automation then ranges from $2.5 million to $3.5 million, again referred to as the "low" and the "high" estimate. Table 11 shows the results of the PDV calculation, again in constant 1974 dollars discounted to the year preceding the start of the R&D program.

From Table 11 it is clear that even under unfavorable cost conditions, the PDV is positive. Greater manpower reductions will of course

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[1]There might be some salvage value to any components that are not replaced.

[2]It is likely, of course, that the initial group of automated Navy ships would be given extensive sea trials beyond normal practice to check out the entire automation concept and to provide some operational training for officers and crew.

Table 11

PDV OF AUTOMATING 48 DE-1052 REPLACEMENTS
(millions of 1974 dollars)

Case	Discount Rate	Cost of Automation	PDV
I	5%	High	+81.47
II	5%	Low	+116.33
III	10%	High	+6.75
IV	10%	Low	+32.05

improve the PDV even more. Thus, the economics of automation of future naval surface ships is quite a bit more favorable than automation of existing ships.[1]

3. *For the proposed automation of the DE-1052, the PDV is very sensitive to the estimated cost of automation.* This is the one area in which better information would have a very high payoff. The cost estimates used in this analysis are not meant to be upper and lower bounds. An analysis of experiences with a variety of military hardware clearly shows that early cost estimates tend to be too low, and often by a factor of two or more.[2] Therefore it is strongly recommended that better cost estimates be obtained.

4. *The optimal degree of automation is not revealed by the present analysis.* Although "total" automation of the DE-1052 does not seem to be worthwhile, selective automation of certain functions *may* be. For example, automation of the bridge seems to have a large manpower saving relative to the investment required;[3] automation of food handling service may be another high payoff area.

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[1]The automation of future naval ships may allow for smaller and more fuel-efficient ships, which would lower initial capital and operating costs. These savings should be added to any manpower savings that might result from automation. The methodology described in this report would still apply.

[2]For a discussion of the "cost growth" phenomenon in the acquisition of military hardware, see Perry et al. (1971).

[3]There already has been extensive Navy work on automating the DE-1052 bridge. For more details see Dachos (1974), pp. 39-44; and Puckett, Gowen, and Moe (1975), pp. 139-146.

One interesting calculation can be made regarding the austere DE-1052 with the enhanced interior communication system. Examination of the manpower savings attributable to such a wireless system reveals an annual savings of about \$169,600 per ship per year.[1] If no R&D expenditures are required--that is, the equipment is basically off the shelf--then the system would have to cost *more* than (1974) \$1.29 million in order for the system *not* to break even when the discount rate is 10 percent. Because such a system would probably cost considerably less, it too may be an important personnel-reducing investment.

5. *Improved shipboard manpower management may have a high payoff.* Improvements in shipboard manpower management may be possible that will make both unautomated and automated ships less manpower-intensive. In constructing the enlisted personnel assignments for the alternative DE-1052 configurations, I became convinced that manpower could be conserved if some *cross-training* of individuals were possible. By cross-training I mean the training of an individual within a Navy occupational field to perform a variety of different assignments. Cross-training may increase training costs and as such represents an additional investment in "human capital." The benefits, however, will occur in three ways. Cross-training should reduce (1) the number of personnel who are assigned in Condition I but not assigned in Condition III, (2) the number of personnel who are needed for Condition III but who have no Condition I assignment, and (3) the number of unassigned personnel--that is, personnel who have no assignment in either Condition I or Condition III. This assumes that the personnel who would be saved by cross-training are not needed anyway for shipboard maintenance.

Cross-training would seem to have a greater effect on an unautomated than on an automated ship because the larger manning allows for more cross-training possibilities, but this conjecture is by no means certain. The need for personnel just to perform normal underway maintenance clouds the issue. An existing DE-1052 may achieve its capability for sustained operations by having these additional personnel on

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[1] As a result of the wireless interior communication system, 21 additional personnel (234 less 213) are saved. Of these, 20 are in the SN/FN category, and one is an IC3.

board. The result may be that cross-training could reduce shipboard manning only at the expense of material readiness. But if cross-training and automation are complementary investments--if buying one makes the other more valuable--then they should be evaluated as a package. This clearly goes beyond the scope of this report.

Appendix A
MANNING AND MANNING CHANGES

Table A-1 shows the enlisted assignments for each of the four DE-1052 configurations described in Section III. As such it forms the basis for the alternative manning levels shown in Fig. 1 and for the personnel reductions by rating and experience necessary to calculate the annual dollar savings attributable to automation.

For each DE-1052 configuration, Table A-1 lists each enlisted assignment in Condition I with its rating/rate. These enlisted assignments are grouped according to their control function. Manpower totals for Condition I by control function are shown in Table 1 of the text.

Condition III stations to be manned are shown with the personnel assigned for all three 8-hour shifts. If an individual assigned to a station in Condition III also has a Condition I assignment, then that individual is denoted by his Condition I assignment. For example, in the base case DE-1052, the Boatswain's Mate of the Watch station (A6) is manned by a BM3 in Condition I. The same BM3 also takes one of the shifts at the same station in Condition III; a second shift is taken by the BM3 who has station H12 in Condition I; and the third shift is taken by another BM3 who has no Condition I station. In this format the additional complement of enlisted personnel necessary to perform Condition III tasks can be determined by counting the number of Condition III slots that are denoted by a rating/rate rather than a Condition I assignment. The difference in manning by rating/rate between any two DE-1052 configurations can also be determined by comparing total manning (assigned plus unassigned) by rating/rate for those configurations.

The base case DE-1052 enlisted assignments were taken from Tables G and H of "An Analysis of Personnel Effects and Naval Regulation Considerations in the Automation of Naval Surface Ships," by Capt. Maylon T. Scott, USN (ret.) and Capt. Donald Kern, USN (ret.) now of Specialized Systems, Inc. (SSI), Mystic, Connecticut, and Prof. Theodore J. Williams of Purdue University School of Engineering. One change was

Table A-1

ENLISTED PERSONNEL ASSIGNMENTS FOR CONDITIONS I & III FOR FOUR ALTERNATIVE DE-1052 CONFIGURATIONS

Base-Case DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
SHIP CONTROL		
Pilot House		
A1. Asst. Navigator	QMC	
A2. QM of Watch	QM2	A2, A5, A16
A3. Fathometer Op.	STGSN	
A4. EOT Op.	SN	A4, A8, A9
A5. Helmsman	QM3	SN, SN, SN
A6. Boatswain's Mate of the Watch	BM3	A6, H12, BM3
A7. JA Talker	YNC	
A8. LJV Talker	SN	
A9. 61JS Talker	SN	
A10. JL Talker	PC3	A10, A11, H14
A11. JX Talker	SN	
A12. Messenger	SN	A12, F19, F20
Lookouts		
A13. Port Lookout (JL)	SN	A13, A14, F22
A14. Starboard Lookout (JL)	SN	F23, F24, F21
A15. AFT Lookout (JL)	SN	A15, F15, F16
Aft Steering		
A16. Helmsman (LJV)	QM3	
A17. Elect. Repairman	EMFN	
A18. Machinery Repairman	MM3	
INFORMATION CONTROL		
CIC (Surface)		
B1. Supervisor	RD1	B13, B1, B2
B2. Surface Search Op. (21JS)	RD1	B6, B9, B10
B3. DRT Op. (21JS)	RD2	B8, B19, B20
B4. NC-2 Op. (61JS)	RD3	
B5. Surface Summary Plotter	RD3	
B6. ASW Status Board Keeper(61JS)	RD3	
B7. Link 14 Readout Op.	RD3	
B8. PRITAC Recorder	RDSN	
B9. CI Net Talker/Recorder	RD3	
B10. JA Talker	RDSN	
B11. JI Talker	ETRSN	C11, B11, SN
B12. JX Talker	RMSN	

Austere DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
SHIP CONTROL		
Pilot House		
A4. EOT Op.	SN	A4, A8, A9
A5. Helmsman/QM of Watch	QM3	A5, A16, SN
A6. Boatswain's Mate of the Watch	BM3	A6, H12, BM3
A7. JA Talker	YNC	
A8. LJV Talker	SN	
A9. 61JS Talker	SN	
A10. JL Talker	PC3	A10, A11, H14
A11. JX Talker	SN	
A12. Messenger	SN	A12, F19, F20
Lookouts		
A13. Port Lookout (JL)	SN	A13, F15, F22
Aft Steering		
A16. Helmsman (LJV)	QM3	
A17. Elect. Repairman	EMFN	
A18. Machinery Repairman	MM3	
INFORMATION CONTROL		
CIC (Surface)		
B1. Supervisor	RD1	B13, B1, B2
B2. Surface Search Op. (21JS)	RD1	B6, B9, B10
B3. DRT Op. (21JS)	RD2	B8, B19, B20
B4. NC-2 Op. (61JS)	RD3	
B5. Surface Summary Plotter	RD3	
B6. ASW Status Board Keeper(61JS)	RD3	
B7. Link 14 Readout Op.	RD3	
B8. PRITAC Recorder	RDSN	
B9. CI Net Talker/Recorder	RD3	
B10. JA Talker	RDSN	
B11. JL Talker	ETRSN	C11, B11, SN
B12. JX Talker	RMSN	

Interior Communication Enhanced DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
SHIP CONTROL		
Pilot House		
A4. EOT Op.	SN	A4, H14, SN
A5. Helmsman/QM of Watch	QM3	A5, A16, SN
A6. Boatswain's Mate of the Watch	BM3	A6, H12, BM3
Lookouts		
A13. Port Lookout (JL)	SN	A13, F15, F22
Aft Steering		
A16. Helmsman (LJV)	QM3	
A17. Elect. Repairman	EMFN	
A18. Machinery Repairman	MM3	
INFORMATION CONTROL		
CIC (Surface)		
B1. Supervisor	RD1	B13, B1, B2
B2. Surface Search Op. (21JS)	RD1	B6, B9, RDSN
B3. DRT Op. (21JS)	RD2	B8, B19, B20
B4. NC-2 Op. (61JS)	RD3	
B5. Surface Summary Plotter	RD3	
B6. ASW Status Board Keeper(61JS)	RD3	
B7. Link 14 Readout Op.	RD3	
B8. PRITAC Recorder	RDSN	
B9. CI Net Talker/Recorder	RD3	

Automated DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
SHIP CONTROL		
Pilot House		
A5. Helmsman/QM of Watch	QM3	A5, A6, QM3
A6. Helmsman/QM of Watch	QM3	
Lookouts		
A13. Port Lookout (JL)	SN	A13, F15, F22
Aft Steering		
INFORMATION CONTROL		
CIC (Surface)		
B1. Supervisor	RD1	B13, B1, B2
B2. Surface Search Op. (21JS)	RD1	B6, B9, RDSN
B3. DRT Op. (21JS)	RD2	B8, B19, B20
B4. NC-2 Op. (61JS)	RD3	
B5. Surface Summary Plotter	RD3	
B6. ASW Status Board Keeper(61JS)	RD3	
B7. Link 14 Readout Op.	RD3	
B8. PRITAC Recorder	RDSN	
B9. CI Net Talker/Recorder	RD3	

Table A-1--continued

Base-Case DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
CIC (Air)		
B13. AIC/RCO	RDC	
B14. Air Search Op. (22JS)	RD2	B14, B3, B18
B15. Air Vertical Plotter (22JS)	RDSN	B15, B16, B24
B16. Air Vertical Plotter (22JS)	RDSN	
B17. AC Net Talker/Plotter	RD3	
B18. CID Net Talker/Plotter	RD2	
B19. CAP Status Board Keeper	RDSN	
B20. Bogey Tote Board Keeper	RDSN	
B21. BPDMS Controller	FTM1	B21, FTM3, FTMSN
CIC (ECM)		
B22. ECM Op.	RD2	B22, B23, B4
B23. ULQ-6 Op.	RD2	B17, B7, B5
B24. ECM Status Board Keeper	RDSN	
COMMUNICATIONS CONTROL		
Radio Central		
C1. Comm. Supervisor	RMC	
C2. Comm. Teletype/Offline Maintenanceman	RM1	
C3. Comm. Circuit Controller	RM2	C3, C4, C10
C4. Senior Systems Op.	RM2	C5, C6, C7
C5. Second Systems Op.	RM3	C8, C9, C12
C6. Third Systems Op.	RM3	
C7. Fourth Systems Op.	RM3	
C8. Fifth Systems Op.	RMSN	
C9. JX Talker	RMSN	
Emergency Radio		
C10. Radio Operator	RM2	
Transmitter Room		
C11. Supervisor/Operator	ETN3	
C12. Operator	RMSN	
Signal Bridge		
C13. Signal Supervisor	SM1	
C14. Port Signal Op.	SM2	C13, C14, C15
C15. Starboard Signal Op.	SM2	C16, C17, C18

Austere DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
CIC (Air)		
B13. AIC/RCO	RDC	
B14. Air Search Op. (22JS)	RD2	B14, B3, B18
B15. Air Vertical Plotter (22JS)	RDSN	B15, B16, B24
B16. Air Vertical Plotter (22JS)	RDSN	
B17. AC Net Talker/Plotter	RD3	
B18. CID Net Talker/Plotter	RD2	
B19. CAP Status Board Keeper	RDSN	
B20. Bogey Tote Board Keeper	RDSN	
B21. BPDMS Controller	FTM1	B21, FTM3, FTMSN
CIC (ECM)		
B22. ECM Op.	RD2	B22, B23, B4
B23. ULQ-6 Op.	RD2	B17, B7, B5
B24. ECM Status Board Keeper	RDSN	
COMMUNICATIONS CONTROL		
Radio Central		
C1. Comm. Supervisor	RMC	
C2. Comm. Teletype/Offline Maintenanceman	RM1	
C3. Comm. Circuit Controller	RM2	C3, C4, C10
C4. Senior Systems Op.	RM2	C5, C6, C7
C5. Second Systems Op.	RM3	C8, C9, C12
C6. Third Systems Op.	RM3	
C7. Fourth Systems Op.	RM3	
C8. Fifth Systems Op.	RMSN	
C9. JX Talker	RMSN	
Emergency Radio		
C10. Radio Operator	RM2	
Transmitter Room		
C11. Supervisor/Operator	ETN3	
C12. Operator	RMSN	
Signal Bridge		
C13. Signal Supervisor	SM1	
C14. Port Signal Op.	SM2	C13, C14, C15
C15. Starboard Signal Op.	SM2	C16, C17, C18

Interior Communication Enhanced DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
CIC (Air)		
B13. AIC/RCO	RDC	
B14. Air Search Op. (22JS)	RD2	B14, B3, B18
B15. Air Vertical Plotter (22JS)	RDSN	B15, B16, B24
B16. Air Vertical Plotter (22JS)	RDSN	
B17. AC Net Talker/Plotter	RD3	
B18. CID Net Talker/Plotter	RD2	
B19. CAP Status Board Keeper	RDSN	
B20. Bogey Tote Board Keeper	RDSN	
B21. BPDMS Controller	FTM1	B21, FTM3, FTMSN
CIC (ECM)		
B22. ECM Op.	RD2	B22, B23, B4
B23. ULQ-6 Op.	RD2	B17, B7, B5
B24. ECM Status Board Keeper	RDSN	
COMMUNICATIONS CONTROL		
Radio Central		
C1. Comm. Supervisor	RMC	
C2. Comm. Teletype/Offline Maintenanceman	RM1	
C3. Comm. Circuit Controller	RM2	C3, C4, C10
C4. Senior Systems Op.	RM2	C5, C6, C7
C5. Second Systems Op.	RM3	C8, RMSN, C12
C6. Third Systems Op.	RM3	
C7. Fourth Systems Op.	RM3	
C8. Fifth Systems Op.	RMSN	
Emergency Radio		
C10. Radio Operator	RM2	
Transmitter Room		
C11. Supervisor/Operator	ETN3	
C12. Operator	RMSN	
Signal Bridge		
C13. Signal Supervisor	SM1	
C14. Port Signal Op.	SM2	C13, C14, C15
C15. Starboard Signal Op.	SM3	C16, C17, SM3

Automated DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
CIC (Air)		
B13. AIC/RCO	RDC	
B14. Air Search Op. (22JS)	RD2	B14, B3, B18
B15. Air Vertical Plotter (22JS)	RDSN	B15, B16, B24
B16. Air Vertical Plotter (22JS)	RDSN	
B17. AC Net Talker/Plotter	RD3	
B18. CID Net Talker/Plotter	RD2	
B19. CAP Status Board Keeper	RDSN	
B20. Bogey Tote Board Keeper	RDSN	
B21. BPDMS Controller	FTM1	B21, FTM3, FTMSN
CIC (ECM)		
B22. ECM Op.	RD2	B22, B23, B4
B23. ULQ-6 Op.	RD2	B17, B7, B5
B24. ECM Status Board Keeper	RDSN	
COMMUNICATIONS CONTROL		
Radio Central		
C1. Comm. Supervisor	RMC	
C2. Comm. Teletype/Offline Maintenanceman	RM1	
C3. Comm. Circuit Controller	RM2	C3, C4, C10
C4. Senior Systems Op.	RM2	C5, C6, C7
C5. Second Systems Op.	RM3	C8, RMSN, C12
C6. Third Systems Op.	RM3	
C7. Fourth Systems Op.	RM3	
C8. Fifth Systems Op.	RMSN	
Emergency Radio		
C10. Radio Operator	RM2	
Transmitter Room		
C11. Supervisor/Operator	ETN3	
C12. Operator	RMSN	
Signal Bridge		
C13. Signal Supervisor	SM1	
C14. Port Signal Op.	SM2	C13, C14, C15
C15. Starboard Signal Op.	SM3	

Table A-1--continued

Base-Case DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
C16. Port Signal Recorder	SM3	
C17. Starboard Signal Recorder	SM3	
C18. JX Talker	SM3	
ELECTRONIC CASUALTY CONTROL		
D1. Supervisor (ET Shop)	ETC	
D2. Elect. Repairman(CIC)	ETR3	
D3. Elect. Repairman(Radar Trans)	ETR2	
D4. Elect. Repairman(Radio Cent.)	ETN2	
ASW CONTROL		
Underwater Battery Control		
E1. Attack Plotter Op. (61JS)	STG2	E16, E11, E13
E2. Firing Petty Officer (8JP)	STG3	
E3. UBFCS Supervisor	STI	
E4. Data Recorder	STGSN	
Sonar Control		
E5. ASW Officer	Officer	
E6. Sonar Supervisor/SSI-TDI Op.	STCS	E7, E8, E3
E7. "A" Scan Op.	STI	E14, E9, E1
E8. "B" Scan Op.	STI	E10, E2, E15
E9. Passive Op.	STG2	
E10. UNQ-7 Op.	STG3	
E11. UQC Op.	STG3	
E12. Data Recorder	STGSN	
E13. Standby Op.	STG3	E12, E17, A3
Sonar Equipment Rooms #1 & #2		
E14. Supervisor/Repairman	STG2	
E15. Sonar Repairman	STG3	
E16. Sonar Repairman	STG3	
UBFSC Switchboard (CIC Equip. Room)		
E17. Switchboard Op. (8JP)	STGSN	
ASROC Control		
E18. Launcher Captain	GMG1	E18, E19, GMG3
E19. LCCS Op.	GMG2	GMGSN,GMGSN,GMGSN
E20. ASROC Sentry	SN	E20, E17, E18

Austere DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
C16. Port Signal Recorder	SM3	
C17. Starboard Signal Recorder	SM3	
C18. JX Talker	SM3	
ELECTRONIC CASUALTY CONTROL		
D1. Supervisor (ET Shop)	ETC	
D2. Elect. Repairman (CIC)	ETR3	
D3. Elect. Repairman(Radar Trans)	ETR2	
D4. Elect. Repairman(Radio Cent.)	ETN2	
ASW CONTROL		
Underwater Battery Control		
E1. Attack Plotter Op. (61JS)	STG2	E16, E11, E13
E2. Firing Petty Officer (8JP)	STG3	
E3. UBFCS Supervisor	STI	
E4. Data Recorder	STGSN	
Sonar Control		
E5. ASW Officer	Officer	
E6. Sonar Supervisor/SSI-TDI Op.	STCS	E7, E8, E3
E7. "A" Scan Op.	STI	E14, E9, E1
E8. "B" Scan Op.	STI	E10, E2, E15
E9. Passive Op.	STG2	
E10. UNQ-7 Op.	STG3	
E11. UQC Op.	STG3	
E12. Data Recorder	STGSN	
E13. Standby Op.	STG3	E12, E17, STGSN
Sonar Equipment Rooms #1 & #2		
E14. Supervisor/Repairman	STG2	
E15. Sonar Repairman	STG3	
E16. Sonar Repairman	STG3	
UBFSC Switchboard (CIC Equip. Room)		
E17. Switchboard Op. (8JP)	STGSN	
ASROC Control		
E18. Launcher Captain	GMG1	E18, E19, GMG3
E19. LCCS Op.	GMG2	GMGSN,GMGSN,GMGSN
E20. ASROC Sentry	SN	E20, E17, E18

Interior Communication Enhanced DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	
C16. Port Signal Recorder	SM3	
C17. Starboard Signal Recorder	SM3	
ELECTRONIC CASUALTY CONTROL		
D1. Supervisor (ET Shop)	ETC	
D2. Elect. Repairman (CIC)	ETR3	
D3. Elect. Repairman(Radar Trans)	ETR2	
D4. Elect. Repairman(Radio Cent)	ETN2	
ASW CONTROL		
Underwater Battery Control		
E1. Attack Plotter Op. (61JS)	STG2	E16, E11, E13
E2. Firing Petty Officer (8JP)	STG3	
E3. UBFCS Supervisor	STI	
E4. Data Recorder	STGSN	
Sonar Control		
E5. ASW Officer	Officer	
E6. Sonar Supervisor/SSI-TDI Op.	STCS	E7, E8, E3
E7. "A" Scan Op.	STI	E14, E9, E1
E8. "B" Scan Op.	STI	E10, E2, E15
E9. Passive Op.	STG2	
E10. UNQ-7 Op.	STG3	
E11. UQC Op.	STG3	
E12. Data Recorder	STGSN	
E13. Standby Op.	STG3	E12, E17, STGSN
Sonar Equipment Rooms #1 & #2		
E14. Supervisor/Repairman	STG2	
E15. Sonar Repairman	STG3	
E16. Sonar Repairman	STG3	
UBFSC Switchboard (CIC Equip. Room)		
E17. Switchboard Op. (8JP)	STGSN	
ASROC Control		
E18. Launcher Captain	GMG1	E18, E19, GMG3
E19. LCCS Op.	GMG2	GMGSNGMGSNGMGSN
E20. ASROC Sentry	SN	E20, E17, E18

Automated DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
ELECTRONIC CASUALTY CONTROL		
D1. Supervisor (ET Shop)	ETC	
D2. Elect. Repairman (CIC)	ETR3	
D3. Elect. Repairman(Radar Trans)	ETR2	
D4. Elect. Repairman(Radio Cent)	ETN2	
ASW CONTROL		
Underwater Battery Control		
E1. Attack Plotter Op. (61JS)	STG2	E16, E11, E13
E2. Firing Petty Officer (8JP)	STG3	
E3. UBFCS Supervisor	STI	
E4. Data Recorder	STGSN	
Sonar Control		
E5. ASW Officer	Officer	
E6. Sonar Supervisor/SSI-TDI Op.	STCS	E7, E8, E3
E7. "A" Scan Op.	STI	E14, E9, E1
E8. "B" Scan Op.	STI	E10, E2, E15
E9. Passive Op.	STG2	
E10. UNQ-7 Op.	STG3	
E11. UQC Op.	STG3	
E12. Data Recorder	STGSN	
E13. Standby Op.	STG3	E12, E17, STGSN
Sonar Equipment Rooms #1 & #2		
E14. Supervisor/Repairman	STG2	
E15. Sonar Repairman	STG3	
E16. Sonar Repairman	STG3	
UBFSC Switchboard (CIC Equip. Room)		
E17. Switchboard Op. (8JP)	STGSN	
ASROC Control		
E18. Launcher Captain	GMG1	E18, E19, GMG3
E19. LCCS Op.	GMG2	GMGSN,GMGSN,GMGSN
E20. ASROC Sentry	SN	E20, E17, E18

Table A-1--continued

Base-Case DE-1052 Enlisted Assignments		
Condition I Ship Station	Rating/ Rate	Condition III Ship Station
MK 32 AWTT		
E21. Tube Captain (8JP)	TM2	
E22. Port Loader	SA	
E23. Starboard Loader	SA	
WEAPONS CONTROL		
Director 51		
F1. Director Officer (JC)	Officer	
F2. Tracker (2JP)	FTG3	F2, F3, FTGSN
F3. Rangefinder Op.	FTGSN	
MK 68 Plotting Room		
F4. Plotting Room Officer	FTGC	
F5. Radar Op. (2JP)	FTG2	F5, F7, F6
F6. Tracker	FTG3	
F7. Computer MK 47 Op.	FTG3	
Mount 51 - 5"/54		
F8. Mount Captain (JC)	GMGC	H8, F9, F10
F9. OMC Operator (2JP)	GMG2	F25, F14,GMGSN
F10. Gun Captain	GMG2	
Mount 51 Carrier Room		
F11. Carrier Room Controlman	GMG3	
BPDMS Director		
F12. Director Illuminator Op.	GMG2	F12, F13, GMG3
BPDMS Launcher		
F13. Launcher Captain	GMG3	
Projectile Magazine/Handling Room		
F14. Supervisor	GMG3	
F15. Projectile Loader	SN	
F16. Projectile Loader	SN	
F17. Powder Loader	SN	
F18. Powder Loader	SN	
F19. Projectile Passer	SN	
F20. Projectile Passer	SN	
F21. Projectile Passer	SN	
F22. Powder Passer	SN	

Austere DE-1052 Enlisted Assignments		
Condition I Ship Station	Rating/ Rate	Condition III Ship Station
MK 32 AWTT		
E21. Tube Captain (8JP)	TM2	
E22. Port Loader	SA	
E23. Starboard Loader	SA	
WEAPONS CONTROL		
Director 51		
F1. Director Officer (JC)	Officer	
F2. Tracker (2JP)	FTG3	F2, F3, FTGSN
F3. Rangefinder Op.	FTGSN	
MK 68 Plotting Room		
F4. Plotting Room Officer	FTGC	
F5. Radar Op. (2JP)	FTG2	F5, F7, F6
F6. Tracker	FTG3	
F7. Computer MK 47 Op.	FTG3	
Mount 51 - 5"/54		
F8. Mount Captain (JC)	GMGC	H8, F9, F10
F9. OMC Operator (2JP)	GMG2	F25, F14, GMGSN
F10. Gun Captain	GMG2	
Mount 51 Carrier Room		
F11. Carrier Room Controlman	GMG3	
BPDMS Director		
F12. Director Illuminator Op.	GMG2	F12, F13, GMG3
BPDMS Launcher		
F13. Launcher Captain	GMG3	
Projectile Magazine/Handling Room		
F14. Supervisor	GMG3	
F15. Projectile Loader	SN	
F16. Projectile Loader	SN	
F17. Powder Loader	SN	
F18. Powder Loader	SN	
F19. Projectile Passer	SN	
F20. Projectile Passer	SN	
F21. Projectile Passer	SN	
F22. Powder Passer	SN	

Interior Communication Enhanced DE-1052 Enlisted Assignments		
Condition I Ship Station	Rating/ Rate	Condition III Ship Station
MK 32 AWTT		
E21. Tube Captain (8JP)	TM2	
E22. Port Loader	SA	
E23. Starboard Loader	SA	
WEAPONS CONTROL		
Director 51		
F1. Director Officer (JC)	Officer	
F2. Tracker (2JP)	FTG3	F2, F3, FTGSN
F3. Rangefinder Op.	FTGSN	
MK 68 Plotting Room		
F4. Plotting Room Officer	FTGC	
F5. Radar Op. (2JP)	FTG2	F5, F7, F6
F6. Tracker	FTG3	
F7. Computer MK 47 Op.	FTG3	
Mount 51 - 5"/54		
F8. Mount Captain (JC)	GMGC	H8, F9, F10
F9. OMC Operator (2J))	GMG2	F25, F14, GMGSN
F10. Gun Captain	GMG2	
Mount 51 Carrier Room		
F11. Carrier Room Controlman	GMG3	
BPDMS Director		
F12. Director Illuminator Op.	GMG2	F12, F13, GMG3
BPDMS Launcher		
F13. Launcher Captain	GMG3	
Projectile Magazine/Handling Room		
F14. Supervisor	GMG3	
F15. Projectile Loader	SN	
F16. Projectile Loader	SN	
F17. Powder Loader	SN	
F18. Powder Loader	SN	
F19. Projectile Passer	SN	
F20. Projectile Passer	SN	
F21. Projectile Passer	SN	
F22. Powder Passer	SN	

Automated DE-1052 Enlisted Assignments		
Condition I Ship Station	Rating/ Rate	Condition III Ship Station
MK 32 AWTT		
E21. Tube Captain (8JP)	TM2	
E22. Port Loader	SA	
E23. Starboard Loader	SA	
WEAPONS CONTROL		
Director 51		
F1. Director Officer (JC)	Officer	
F2. Tracker (2JP)	FTG3	F2, F3, FTGSN
F3. Rangefinder Op.	FTGSN	
MK 68 Plotting Room		
F4. Plotting Room Officer	FTGC	
F5. Radar Op. (2JP)	FTG2	F5, F7, F6
F6. Tracker	FTG3	
F7. Computer MK 47 Op.	FTG3	
Mount 51 - 5"/54		
F8. Mount Captain (JC)	GMGC	H8, F9, F10
F9. OMC Operator (2JP)	GMG2	F25, F14, GMGSN
F10. Gun Captain	GMG2	
Mount 51 Carrier Room		
F11. Carrier Room Controlman	GMG3	
BPDMS Director		
F12. Director Illuminator Op.	GMG2	F12, F13, GMG3
BPDMS Launcher		
F13. Launcher Captain	GMG3	
Projectile Magazine/Handling Room		
F14. Supervisor	GMG3	
F15. Projectile Loader	SN	
F16. Projectile Loader	SN	
F17. Powder Loader	SN	
F18. Powder Loader	SN	
F19. Projectile Passer	SN	
F20. Projectile Passer	SN	
F21. Projectile Passer	SN	
F22. Powder Passer	SN	

Table A-1--continued

Base-Case DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
F23. Powder Passer	SN	
F24. Powder Passer	SN	
F25. Powder Passer	SN	
F26. Powder Passer	SA	
F27. Powder Passer	SA	
F28. Powder Passer	SA	
ENGINEERING CONTROL		
Central Control		
G1. Engineer Officer of the Watch	Officer	G6, G7, H30
G2. Throttleman (1JV)	MM2	H38, MM3, H3
G3. 1JV Talker	FN	
G4. 2JV Talker	FN	
G5. Log Recorder	FN	H26, H28, G5
Engine Room		
G6. Petty Officer in Charge	MMC	G2, H31, H19
G7. Upper Levelman	MM1	G10, H25, G9
G8. Lower Levelman	MM3	G8, H32, H20
G9. Asst. Lower Levelman	MMFN	
G10. Evaporator Op.	MM3	
Fire Room		
G11. Petty Officer in Charge	BTCM	H41, H7, BT2
G12. Console Op.	BT1	
G13. Checkman 1A	FN	
G14. Checkman 1B	FN	
G15. Upper Levelman/DFT	BT3	G15, G21, H37
G16. Lower Levelman/1A Burnerman	BTFN	G16, G17, H43
G17. Lower Levelman/1B Burnerman	BTFN	
G18. 2JV Talker	FA	
G19. 1JV Talker	YN3	
G20. Log Recorder	FN	G13, G14, G20
G21. Blowerman	BT3	
Electrical Control		
G22. Elect. Controlman	EM2	G23, H9, G29
G23. Diesel Switchboard Op.	EM3	
G24. Diesel Generator Op.	EN2	

Austere DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
F23. Powder Passer	SN	
F24. Powder Passer	SN	
F25. Powder Passer	SN	
F26. Powder Passer	SA	
F27. Powder Passer	SA	
F28. Powder Passer	SA	
ENGINEERING CONTROL		
Central Control		
G1. Engineer Officer of the Watch	Officer	G6, G7, H30
G2. Throttleman (1JV)	MM2	H38, MM3, H3
G3. 1JV Talker	FN	
G4. 2JV Talker	FN	
Engine Room		
G6. Petty Officer in Charge	MMC	G2, H31, H19
G7. Upper Levelman	MM1	MM3, H25, MMFN
G8. Lower Levelman	MM3	G8, H32, H20
Fire Room		
G11. Petty Officer in Charge	BTCM	H41, H7, BT2
G12. Console Op.	BT1	
G15. Upper Levelman/DFT	BT3	G15, G21, H37
G16. Lower Levelman/1A Burnerman	BTFN	G16, G17, H43
G17. Lower Levelman/1B Burnerman	BTFN	
G18. 2JV Talker	FA	
G19. 1JV Talker	YN3	
G20. Log Recorder	FN	H26, H28, G20
G21. Blowerman	BT3	
Electrical Control		
G22. Elect. Controlman	EM2	G23, H9, G29
G23. Diesel Switchboard Op.	EM3	
G24. Diesel Generator Op.	EN2	

Interior Communication Enhanced DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
F23. Powder Passer	SN	
F24. Powder Passer	SN	
F25. Powder Passer	SN	
F26. Powder Passer	SA	
F27. Powder Passer	SA	
F28. Powder Passer	SA	
ENGINEERING CONTROL		
Central Control		
G1. Engineer Officer of the Watch	Officer	G6, G7, H30
G2. Throttleman (1JV)	MM2	H38, MM3, MM3
Engine Room		
G6. Petty Officer in Charge	MMC	G2, H31, H19
G7. Upper Levelman	MM1	MM3, H25, MMFN
G8. Lower Levelman	MM3	G8, H32, H20
Fire Room		
G11. Petty Officer in Charge	BTCM	H41, H7, BT2
G12. Console Op.	BT1	
G15. Upper Levelman/DFT	BT3	G15, G21, H37
G16. Lower Levelman/1A Burnerman	BTFN	G16, G17, H43
G17. Lower Levelman/1B Burnerman	BTFN	
G20. Log Recorder	FN	H26, H27, G20
G21. Blowerman	BT3	
Electrical Control		
G22. Elect. Controlman	EM2	G23, H9, G29
G23. Diesel Switchboard Op.	EM3	
G24. Diesel Generator Op.	EN2	

Automated DE 1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
F23. Powder Passer	SN	
F24. Powder Passer	SN	
F25. Powder Passer	SN	
F26. Powder Passer	SA	
F27. Powder Passer	SA	
F28. Powder Passer	SA	
ENGINEERING CONTROL		
Central Control		
G1. Engineer Officer of the Watch	Officer	G6, G7, H30
G2. Throttleman (1JV)	MM2	H38, MM3, MM3
Engine Room		
G6. Petty Officer in Charge	MMC	G2, H31, H19
G7. Upper Levelman	MM1	H10, H25, H26
G8. Lower Levelman	MM3	G8, H32, H20
Fire Room		
G11. Petty Officer in Charge	BTCM	H41, H7, G11
G15. Upper Levelman/DFT	BT3	G15, BT3, H37
G16. Lower Levelman/1A Burnerman	BTFN	G16, H27, H43
Electrical Control		
G22. Elect. Controlman	EM2	H34, H9, G29

Table A-1--continued

Base-Case DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
G25. Diesel Generator Op.	EN3	
G26. IC/Gyro Watch	IC2	IC3, H16, H40
FWD Auxiliary Machinery Room		
G27. Supervisor/Upper Levelman	MM1	MM2, A18, G30
G28. Lower Levelman/Messenger	FN	G3, G4, H39
G29. Electrician	EM3	
G30. 2JV Talker	MM3	
DAMAGE CONTROL		
DC Central		
H1. Plotter	EN1	
H2. 2JZ Talker	FA	
H3. 1JV Talker	MM3	
H4. Liquid Load Controller	BT1	
Repair II		
H5. Petty Officer in Charge	BMC	
H6. Scene Leader	SF1	
H7. Investigator	BT2	
H8. Investigator	BM2	
H9. Electrician	EM3	
H10. Machinery Repairman	MM2	
H11. Hull Repairman	SF3	
H12. Decontamination Team Hoseman	BM3	
H13. Decontamination Team Hoseman	DC3	
H14. Messenger	SA	
H15. Stretcher Bearer/CO_2 Man	FN	
H16. 2JZ Talker	IC3	
Repair III		
H17. Petty Officer in Charge	EMC	
H18. Scene Leader	DC2	
H19. Investigator/Sounding and Securityman	MM2	H13, H24, H15
H20. Investigator	MM3	
H21. Electrician	FN	
H22. Machinery Repairman	MM2	
H23. Hull Repairman	SF2	

Austere DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
FWD Auxiliary Machinery Room		
G27. Supervisor/Upper Levelman	MM1	MM2, A18, G30
G29. Electrician	EM3	
G30. 2JV Talker	MM3	
DAMAGE CONTROL		
DC Central		
H1. Plotter	EN1	
H2. 2JZ Talker	FA	
H3. 1JV Talker	MM3	
H4. Liquid Load Controller	BT1	
Repair II		
H5. Petty Officer in Charge	BMC	
H6. Scene Leader	SF1	
H7. Investigator	BT2	
H8. Investigator	BM2	
H9. Electrician	EM3	
H10. Machinery Repairman	MM2	
H11. Hull Repairman	SF3	
H12. Decontamination Team Hoseman	BM3	
H13. Decontamination Team Hoseman	DC3	
H14. Messenger	SA	
H15. Stretcher Bearer/CO_2 Man	FN	
H16. 2JZ Talker	IC3	
Repair III		
H17. Petty Officer in Charge	EMC	
H18. Scene Leader	DC2	
H19. Investigator/Sounding and Securityman	MM2	H13, H24, H15
H20. Investigator	MM3	
H21. Electrician	FN	
H22. Machinery Repairman	MM2	
H23. Hull Repairman	SF2	

Interior Communication Enhanced DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
FWD Auxiliary Machinery Room		
G27. Supervisor/Upper Levelman	MM1	MM2, A18, H22
G29. Electrician	EM3	
DAMAGE CONTROL		
DC Central		
H1. Plotter	EN1	
Repair II		
H5. Petty Officer in Charge	BMC	
H6. Scene Leader	SF1	
H7. Investigator	BT2	
H8. Investigator	BM2	
H9. Electrician	EM3	
H10. Machinery Repairman	MM2	
H11. Hull Repairman	SF3	
H12. Decontamination Team Hoseman	BM3	
H13. Decontamination Team Hoseman	DC3	
H14. Messenger	SN	
H15. Stretcher Bearer/CO_2 Man	FN	
Repair III		
H17. Petty Officer in Charge	EMC	
H18. Scene Leader	DC2	
H19. Investigator/Sounding and Securityman	MM2	H13, H24, H15
H20. Investigator	MM3	
H21. Electrician	FN	
H22. Machinery Repairman	MM2	
H23. Hull Repairman	SF2	

Automated DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
FWD Auxiliary Machinery Room		
G27. Supervisor/Upper Levelman	MM1	G27, MM2, H22
G29. Electrician	EM3	
DAMAGE CONTROL		
DC Central		
H1. Plotter	EN1	
Repair II		
H5. Petty Officer in Charge	BMC	
H6. Scene Leader	SF1	
H7. Investigator	BT2	
H8. Investigator	BM2	
H9. Electrician	EM3	
H10. Machinery Repairman	MM2	
H11. Hull Repairman	SF3	
H12. Decontamination Team Hoseman	DC3	
H13. Decontamination Team Hoseman	DC3	
H14. Messenger	SA	
H15. Stretcher Bearer/CO_2 Man	FN	
Repair III		
H17. Petty Officer in Charge	EMC	
H18. Scene Leader	DC2	
H19. Investigator/Sounding and Securityman	MM2	H12, H24, H15
H20. Investigator	MM3	
H21. Electrician	FN	
H22. Machinery Repairman	MM2	
H23. Hull Repairman	SF2	

Table A-1--continued

Base-Case DE-1052 Enlisted Assignments: Condition I Ship Station	Rating/Rate	Condition III Ship Station
H24. Decontamination Team Hoseman	DCFN	
H25. Decontamination Team Hoseman	MM3	
H26. Stretcher Bearer/CO_2 Man	MMFN	
H27. Messenger	FA	
H28. 2JZ Talker	MMFN	
Repair V		
H29. Petty Officer In Charge	BTC	
H30. Scene Leader	MM1	
H31. Investigator	MM2	
H32. Investigator	MM3	
H33. IC Repairman	IC1	
H34. Electrician	EM2	
H35. Machinery Repairman	MR2	
H36. Hull Repairman	SF3	
H37. Decontamination Team Hoseman	BT3	
H38. Decontamination Team Hoseman	MM3	
H39. Messenger	FA	
H40. 2JZ Talker	ICFN	
H41. Boiler Repairman	BT2	
H42. 2JV Talker	FA	
H43. Stretcher Bearer/CO_2 Man	BTFN	
Battle Dressing Station		
H44. Corpsman	HMC	
H45. Asst. Corpsman	HN	
Battle Messing		
H46. Galley Cook	CS2	
H47. Wardroom Cook	SD2	
Supply Stores		
H48. Emergency Spare Pts. Issueman	SK1	
ADDITIONAL ASSIGNMENTS		
AA1. Supply	SK2	
AA2. Ship's Cook	CS3	
AA3. Food Serviceman	SA	
AA4. Food Serviceman	SA	
AA5. Food Serviceman	SA	

Austere DE-1052 Enlisted Assignments: Condition I Ship Station	Rating/Rate	Condition III Ship Station
H24. Decontamination Team Hoseman	DCFN	
H25. Decontamination Team Hoseman	MM3	
H26. Stretcher Bearer/CO_2 Man	FN	
H27. Messenger	FA	
H28. 2JZ Talker	FN	
Repair V		
H29. Petty Officer In Charge	BTC	
H30. Scene Leader	MM1	
H31. Investigator	MM2	
H32. Investigator	MM3	
H33. IC Repairman	IC1	
H34. Electrician	EM2	
H35. Machinery Repairman	MR2	
H36. Hull Repairman	SF3	
H37. Decontamination Team Hoseman	BT3	
H38. Decontamination Team Hoseman	MM3	
H39. Messenger	FA	
H40. 2JZ Talker	ICFN	
H41. Boiler Repairman	BT2	
H42. 2JV Talker	FA	
H43. Stretcher Bearer/CO_2 Man	BTFN	
Battle Dressing Station		
H44. Corpsman	HMC	
H45. Asst. Corpsman	HN	
Battle Messing		
H46. Galley Cook	CS2	
H47. Wardroom Cook	SD2	
Supply Stores		
H48. Emergency Spare Pts. Issueman	SK1	
ADDITIONAL ASSIGNMENTS		
AA1. Supply	SK2	
AA2. Ship's Cook	CS3	
AA3. Food Serviceman	SA	
AA4. Food Serviceman	SA	
AA5. Food Serviceman	SA	

Interior Communication Enhanced DE-1052 Enlisted Assignments: Condition I Ship Station	Rating/Rate	Condition III Ship Station
H24. Decontamination Team Hoseman	DCFN	
H25. Decontamination Team Hoseman	MM3	
H26. Stretcher Bearer/CO_2 Man	FN	
H27. Messenger	BTFN	
Repair V		
H29. Petty Officer In Charge	BTC	
H30. Scene Leader	MM1	
H31. Investigator	MM2	
H32. Investigator	MM3	
H33. IC Repairman	IC1	
H34. Electrician	EM2	
H35. Machinery Repairman	MR2	
H36. Hull Repairman	SF3	
H37. Decontamination Team Hoseman	BT3	
H38. Decontamination Team Hoseman	MM3	
H39. Messenger	PC3	
H41. Boiler Repairman	BT2	
H43. Stretcher Bearer/CO_2 Man	BTFN	
Battle Dressing Station		
H44. Corpsman	HMC	
H45. Asst. Corpsman	HN	
Battle Messing		
H46. Galley Cook	CS2	
H47. Wardroom Cook	SD2	
Supply Stores		
H48. Emergency Spare Pts Issueman	SK1	
ADDITIONAL ASSIGNMENTS		
AA1. Supply	SK2	
AA2. Cook	CS2	
AA3. Food Serviceman	SA	
AA4. Food Serviceman	SA	
AA5. Food Serviceman	SA	

Automated DE-1052 Enlisted Assignments: Condition I Ship Station	Rating/Rate	Condition III Ship Station
H24. Decontamination Team Hoseman	DCFN	
H25. Decontamination Team Hoseman	MM3	
H26. Stretcher Bearer/CO_2 Man	MMFN	
H27. Messenger	BTFN	
Repair V		
H29. Petty Officer In Charge	BTC	
H30. Scene Leader	MM1	
H31. Investigator	MM2	
H32. Investigator	MM3	
H33. IC Repairman	IC1	
H34. Electrician	EM2	
H35. Machinery Repairman	MR2	
H36. Hull Repairman	SF3	
H37. Decontamination Team Hoseman	BT3	
H38. Decontamination Team Hoseman	MM3	
H39. Messenger	ICFN	
H41. Boiler Repairman	BT2	
H43. Stretcher Bearer/CO_2 Man	BTFN	
Battle Dressing Station		
H44. Corpsman	HMC	
H45. Asst. Corpsman	HN	
Battle Messing		
H46. Galley Cook	CS2	
H47. Wardroom Cook	SD2	
Supply Stores		
H48. Emergency Spare Pts. Issueman	SK1	
ADDITIONAL ASSIGNMENTS		
AA1. Supply	SK2	
AA2. Cook	CS3	
AA5. Food Serviceman	SA	

Table A-J--continued

Base-Case DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
AA6. Food Serviceman	SA	
AA7. Wardroom Cook	SD3	
UNASSIGNED		
U1. 3M Data Analyst	E8/9	
U2. Adm. Clerk	YN3	
U3. Personnel Clerk	PN1	
U4. Elec. Tech.	ETN2	
U5. Boatswain	BM1	
U6. Gun Ord. Tech.	GMGSN	
U7. Adm. Clerk	YN3	
U8. Prop. Mach. Op.	MM2	
U9. Supv. Supply Acct.	SKC	
U10. Supply Acct.	SK3	
U11. Supply Acct.	SKSN	
U12. Pay and Records	DK1	
U13. Commissary Supv.	CSC	
U14. Master at Arms	CS1	
U15. Ship's Cook	CS1	
U16. Ship's Cook	CS3	
U17. Ship's Cook	CSSN	
U18. Food Serviceman	SA	
U19. Food Serviceman	SA	
U20. Food Serviceman	SA	
U21. Food Serviceman	SA	
U22. Food Serviceman	SA	
U23. Ship Store Mgr.	SH1	
U24. Ship Laundryman	SH2	
U25. Ship Laundryman	SH3	
U26. Ship Laundryman	SH3	
U27. Ship Laundryman	SHSN	
U28. Ship Barber	SHSN	
U29. Wardroom Cook	SD1	
U30. Food Serviceman	TN	
U31. Food Serviceman	TN	
U32. Food Serviceman	TN	

Austere DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
AA6. Food Serviceman	SA	
AA7. Wardroom Cook	SD3	
UNASSIGNED		
U1. 3M Data Analyst	E8/9	
U2. Adm. Clerk	YN3	
U3. Personnel Clerk	PN1	
U4. Elec. Tech.	ETN2	
U5. Boatswain	BM1	
U6. Gun Ord. Tech.	GMGSN	
U7. Adm. Clerk	YN3	
U8. Prop. Mach. Op.	MM3	
U9. Supv. Supply Acct.	SKC	
U10. Supply Acct.	SK3	
U11. Supply Acct.	SKSN	
U12. Pay and Records	DK1	
U13. Commissary Supv.	CSD	
U14. Master at Arms	CS1	
U15. Ship's Cook	CS1	
U16. Ship's Cook	CS3	
U17. Ship's Cook	CSSN	
U18. Food Serviceman	SA	
U19. Food Serviceman	SA	
U20. Food Serviceman	SA	
U21. Food Serviceman	SA	
U22. Food Serviceman	SA	
U23. Ship Store Mgr.	SH1	
U24. Ship Laundryman	SH2	
U25. Ship Laundryman	SH3	
U26. Ship Laundryman	SH3	
U27. Ship Laundryman	SHSN	
U28. Ship Barber	SHSN	
U29. Wardroom Cook	SD1	
U30. Food Serviceman	TN	
U31. Food Serviceman	TN	
U32. Food Serviceman	TN	

Interior Communication Enhanced DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
AA6. Food Serviceman	SA	
AA7. Wardroom Cook	SD3	
UNASSIGNED		
U1. 3M Data Analyst	E8/9	
U2. Adm. Clerk	YNC	
U3. Personnel Clerk	PN1	
U4. Elect. Tech.	ETN2	
U5. Boatswain	BM1	
U6. Gun Ord. Tech.	GMGSN	
U7. Adm. Clerk	YN3	
U8. Prop. Mach. Op.	MM3	
U9. Supv. Supply Acct.	SKC	
U10. Supply Acct.	SK3	
U11. Supply Acct.	SKSN	
U12. Pay and Records	K1	
U13. Commissary Supv.	CSC	
U14. Master at Arms	CS1	
U15. Ship's Cook	CS1	
U16. Ship's Cook	CS3	
U17. Ship's Cook	CSSN	
U19. Food Serviceman	SA	
U20. Food Serviceman	SA	
U21. Food Serviceman	SA	
U22. Food Serviceman	SA	
U23. Ship Store Mgr.	SH1	
U24. Ship Laundryman	SH2	
U25. Ship Laundryman	SH3	
U26. Ship Laundryman	SH3	
U28. Ship Barber	SHSN	
U29. Wardroom Cook	SD1	
U30. Food Serviceman	TN	
U31. Food Serviceman	TN	
U32. Food Serviceman	TN	

Automated DE-1052 Enlisted Assignments

Condition I Ship Station	Rating/ Rate	Condition III Ship Station
AA6. Food Serviceman	SA	
AA7. Wardroom Cook	SD3	
UNASSIGNED		
U1. 3M Data Analyst	E8/9	
U2. Adm. Clerk	YNC	
U3. Personnel Clerk	PN1	
U4. Elect. Tech.	ETN2	
U5. Boatswain	BM1	
U6. Gun Ord. Tech.	GMGSN	
U8. Prop. Mach. Op.	MM3	
U9. Supv. Supply Acct.	SKC	
U12. Pay and Records	DK1	
U13. Commissary Supv.	CSC	
U14. Master at Arms	CS1	
U15. Ship's Cook	CS1	
U16. Ship's Cook	CS3	
U17. Ship's Cook	CSSN	
U21. Food Serviceman	SA	
U22. Food Serviceman	SA	
U23. Ship Store Mgr.	SH1	
U24. Ship Laundryman	SH2	
U25. Ship Laundryman	SH3	
U26. Ship Laundryman	SH3	
U28. Ship Barber	SHSN	
U29. Wardroom Cook	SD1	
U30. Food Serviceman	TN	
U31. Food Serviceman	TN	
U32. Food Serviceman	TN	

made: seven (previously unassigned) personnel were assigned to the messing section under Condition I.

Enlisted assignments for the other three configurations were constructed by the joint effort of the author, Richard Salter of Rand, Capt. Scott (SSI), Capt. Kern (SSI), Prof. Williams (Purdue), with the assistance of the officers and chief petty officers of the USS Roark (DE-1053) and the USS Barbey (DE-1088).

Visits were made to the USS Barbey by Rand and SSI staff members and to the USS Roark[1] by Rand staff members. Detailed discussion of the effect of the proposed automation on each station was held by the visiting staff members and the officers and chief petty officers of each operating department. Possible manpower reductions or changes were analyzed station by station.

Table A-2 is a summary of manpower changes under automation and under austere manning by rating/rate.

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[1]The USS Roark is a test ship for automation of some ship control functions. The officers and chief petty officers already had some familiarity with the potential manpower reduction from automation, particularly on the bridge. The USS Roark is equipped with dual auto pilots, an anti-collision system, and an electronic log recorder.

Table A-2

SUMMARY OF MANPOWER SAVINGS UNDER AUTOMATION AND AUSTERE MANNING BY RATING/RATE

Rating/ Rate	Number Saved Under Automation Compared with Base Case	Number Saved Under Austere Manning Compared with Base Case
IC3	2	1
IC2	1	1
MM3	2	0
MM2	1	0
BT2	1	0
BT1	2	0
EN3	1	1
EN2	1	0
EM2	1	0
BM3	3	0
SK3	1	0
SM3	2	0
SM2	1	0
YN3	3	0
QM3	-1[a]	0
QM2	1	1
QMC	1	1
SN	20	4
FN	15	4
	58	13

[a]The negative sign indicates personnel must be added.

Appendix B

MANPOWER COSTS AND SAVINGS

Table B-1

BASIC COST BY PAY GRADE AND COST ELEMENT

(1974 dollars)

(1)	(2)	(3)	(4)	(5)	(6)		(7)
					Average Misc. Costs[f]		
Pay Grade[a]	DoD Occupational Area[b]	Average Base Pay[d]	BAQ[e]	Average Special Pay[f]	Fixed	Variable	Basic Cost
E-1	(c)	3,933.4	720.0	55.0	1,219.1	44.0	5,971.5
E-2	(c)	4,382.8	766.8	103.0	1,219.1	73.0	6,544.7
E-3	(c)	4,555.7	867.6	95.0	1,219.1	119.2	6,856.5
E-4	0	5,196.8					7,915.9
	2	5,098.6					7,817.7
	5	5,084.6	9.79.2	298.0	1,219.1	222.8	7,803.7
	6	5,143.0					7,862.1
	7	5,118.3					7,837.4
E-5	0	6,122.1					9,100.6
	2	5,963.5	1,112.4	348.0	1,219.1	299.0	8,942.0
	5	5,957.5					8,936.0
	6	6,074.9					9,053.4
E-6	0	7,667.9					10,841.2
	5	7,685.3	1,148.4	373.0	1,219.1	432.8	10,858.6
	6	7,685.3					10,858.6
E-7	0	9,239.2	1,256.4	356.0	1,219.1	697.8	12,768.5
	5	9,116.8					12,646.1

[a]Only E-1 through E-7 were costed because no E-8 or E-9 billets were affected by automation.

[b]Only those DoD Occupational Areas containing ratings affected by automation were costed.

[c]Differentiation by DoD Occupational Area not possible.

[d]Average base pay computed from 1974 statutory pay tables weighted by length of service data from June 30, 1973 inventory of active duty enlisted personnel.

[e]From 1974 statutory tables.

[f]From FY 1975 budget justification, OASD (Comptroller). These categories are described on p. 23.

Table B-2

TRAINING COSTS BY RATING

(1974 dollars)

(1) Rating[a]	(2) Years in Training[b]	(3) Pay Grade	(4) Basic Cost[c]	(5) Student P&A (2)·(4)	(6) Direct Training Costs[b]	(7) Subtotal (5)+(6)	(8) Undiscounted Total[d]	(9) Years Remaining in First Term[e]	(10) Annualized Training Cost At r = 5%	At r = 10%
IC3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	12,339.9	2.65	4,975.8	5,296.1
	.12	E-2	6,544.7	785.4	348.3	1,133.7				
	.27	E-2	6,544.7	1,767.1	1,688.5	3,455.6				
	.75	E-3	6,856.5	5,142.4	0	5,142.4				
MM3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	11,014.2	2.73	4,302.4	4,608.5
	.19	E-2	6,544.7	1,243.5	569.2	1,812.7				
	.12	E-2	6,544.7	785.4	665.5	1,450.9				
	.75	E-3	6,856.5	5,142.4	0	5,142.4				
BT3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	10,944.9	2.73	4,275.4	4,579.5
	.19	E-2	6,544.7	1,243.5	569.2	1,812.7				
	.12	E-2	6,544.7	785.4	596.2	1,381.6				
	.75	E-3	6,856.5	5,142.4	0	5,142.4				
EN3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	10,893.4	2.73	4,255.2	4,557.9
	.19	E-2	6,544.7	1,243.5	569.2	1,812.7				
	.12	E-2	6,544.7	785.4	544.7	1,330.1				
	.75	E-3	6,856.5	5,142.4	0	5,142.4				
BM3[f]	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	7,075.3	1.79	4,389.3	4,603.4
	1.00 (.33)	E-2	6,544.7	2,181.6	0	2,181.6				
	1.00 (.33)	E-3	6,856.5	2,285.5	0	2,285.5				
SK3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	9,120.5	2.92	3,353.1	3,604.9
	.21	E-2	6,544.7	1,374.4	612.6	1,987.0				
	.66	E-3	6,856.5	4,525.3	0	4,525.3				
SM3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	7,906.8	3.09	2,764.6	2,972.5
	.12	E-2	6,544.7	785.4	536.4	1,321.8				
	.58	E-3	6,856.5	3,976.8	0	3,976.8				
YN3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	7,468.0	3.09	2,611.2	2,807.5
	.17	E-2	6,544.7	1,112.6	798.9	1,911.5				
	.43	E-3	6,856.5	2,948.3	0	2,948.3				
QM3	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	6,917.7	3.21	2,337.1	2,515.5
	.08	E-2	6,544.7	523.6	357.6	881.2				
	.50	E-3	6,856.5	3,428.3	0	3,428.3				
SN/FN	.21	E-1	5,971.5	1,254.0	1,354.2	2,608.2	2,608.2	3.79	753.8	828.0

[a] Calculations were made only for those ratings affected by automation.

[b] Training time and 1969 costs from Clary (1970).

[c] From Table B-1.

[d] The undiscounted total is just the sum of the entries in column (7) for each rating.

[e] Assumes a fixed four-year first term obligation.

[f] Figures in parentheses indicate portion of time actually charged to training activity. Annualized training cost was computed by forward discounting annual costs by year to obtain V*. This was done for the BM rating because the total training time is significantly longer than for the other ratings shown. If the portion of time charged to training were .5 instead of .33, the annualized training cost would be $5583.1 at r = 5 percent and $6034.8 at r = 10 percent.

Table B-3

RETIREMENT COST BY PAY GRADE

(1974 dollars)

(1) Pay Grade[a]	(2) DoD Occupational Area[a]	(3) Base Pay[b]	(4) Probability of Remaining Until Retirement[c]	(5) Retirement Cost (3)×(4)×(.292)[d]
E-2/E-3		4456.6[e]	.142[e]	184.8
E-4	0	5196.8	.219	332.3
	2	5098.6		326.0
	5	5084.6		325.2
	6	5143.0		328.9
	7	5118.3		327.3
E-5	0	6122.1	.479	856.3
	2	5963.5		834.1
	5	5957.5		833.3
	6	6074.9		849.7
E-6	0	7667.9	.856	1916.6
	5	7685.3		1921.0
	6	7685.3		1921.0
E-7	0	9239.2	.955	2576.4
	5	9116.8		2542.3

[a]Only those pay grades and DoD Occupational Areas affected by automation were costed.

[b]From Table B-1.

[c]From "The Economic Cost of Military and Civilian Personnel in the Department of Defense," OASD (Comptroller), Schedule 2--Percentage of Military Personnel on Active Duty 30 June 1972 Expected to Continue on Active Duty to Retirement, by Pay Grade, prepared by OASD (M&RA) (MPP) Actuarial Consultant.

[d]See text p. 27 for origins of this proportion.

[e]Average base pay and probability of remaining until retirement were computed for pay grades E-2 and E-3 together using appropriate manpower weights from the SN and FN ratings.

Table B-4

REENLISTMENT COST BY RATING AND PAY GRADE

(1974 dollars)

(1)	(2)	(3)	(4)	(5)	
				Annualized Reenlistment Cost	
Rating/ Rate[a]	Pay Grade[a]	SRB Code[b]	Lump Sum Payment	At r = 5%	At r = 10%
BT2	E-5	5	8815.5	2431.2	2671.4
IC2	E-5	5	8815.5	2431.2	2671.4
MM2	E-5	5	8815.5	2431.2	2671.4
QM2	E-5	4	7052.4	1945.0	2137.1
SM2	E-5	4	7052.4	1945.0	2137.1
EN2	E-5	4	7052.4	1945.0	2137.1
EM2	E-5	4	7052.4	1945.0	2137.1
YN2	E-5	2	3526.2	972.5	1068.5
BT1	E-6	(c)	1388.8	383.0	420.8
IC1	E-6	(c)	1388.8	383.0	420.8
QMC	E-7	(c)	1530.5	422.1	463.8
YNC	E-7	(c)	1530.5	422.1	463.8

[a]Only those ratings and pay grades affected by automation were costed.

[b]SRB code equals VRB code plus one; VRB code as of June 1974.

[c]Not applicable.

Table B-5

NON-DOD COSTS BY PAY GRADE

(1974 dollars)

(1) Pay Grade	(2) Average Educational Benefits[a]	(3) Income Tax Advantage[b]	(4) Dependency and Indemnity Compensation[c]	(5) Total (2)+(3)+(4)
E-1	300.0	206.0	7.0	513.0
E-2	300.0	227.0	9.0	536.0
E-3	300.0	256.0	15.0	571.0
E-4	300.0	299.0	25.0	624.0
E-5	0	400.0	60.0	460.0
E-6	0	447.0	102.0	549.0
E-7	0	456.0	148.0	604.0
E-8	0	509.0	168.0	677.0
E-9	0	654.0	179.0	833.0

[a]Educational benefits are a VA cost. A figure of \$300 was chosen as a representative cost per year per first-termer independent of rating. Expected educational benefits E(X) were calculated by rating using the following model: let y be the event "reaches four years and leaves"; a, the event "reaches four years"; b, the event "leaves at four years"; and c, the event "uses veteran's educational benefits." Then $E(X) = Prob(y)E(X|y) + [1 - Prob(Y)] E(X|\sim y)$. Prob(y) is given by $Prob(a)Prob(b|a)$. $E(X|y)$ was calculated as Z Prob(c) where Z is the typical value of educational benefits discounted to the time they start. $E(X|\sim y)$ was taken to be zero. From VA data, Z = \$3631.5 at a discount rate of 10 percent (and \$3790.3 at a discount rate of 5 percent), and Prob(c) = .547. Assuming Prob(a) = .9 and $Prob(b|a) = 1 -$ reenlistment rate, E(X) was calculated for the QM, BM, BT, EN, MM, SK, YN, and SN/FN ratings. To convert E(X), which, unlike training, is a back-loaded cost, to an annual cost during four active-duty years, let m denote this annual cost, then

$$m = \frac{rE(X)}{-1 + e^{4r}} = .2033\ E(X) \text{ at } r = 10\% \text{ (and } = .2258\ E(X) \text{ at } r = 5\%).$$

For the eight ratings the annual cost m ranged between \$250.8 and \$363.5, and averaged \$300.8. For six of the eight ratings, m fell between \$280.0 and \$320.0. This value for m is at considerable variance with an OASD (Comptroller) study, "The Economic Cost of Military and Civilian Personnel in the DOD," March 1974, which uses a figure of approximately \$2000 for E-1s through E-4s. The difference results from the incorrect methodology of the OSD report. No doubt some E-5s and above receive educational benefits and the table should be modified to show this. The effect would be to smooth the total (col. 5) as a function of pay grade.

[b]This is a Treasury Department cost because allowances are tax-exempt. The figures were estimated by the OASD(M&RA) Actuarial Consultant.

[c]This is a VA cost and was estimated by the OASD(M&RA) Actuarial Consultant.

Table B-6

ANNUAL MANPOWER COSTS BY RATING AND PAY GRADE

(1974 dollars)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			At a Discount Rate of 5% Per Year				
Rating/ Rate	Pay Grade/ DoD Occupational Area	Basic Cost[a]	Training Cost[b]	Retirement Cost[c]	Reenlistment Cost[d]	PCS Cost	Total (3)+(4)+(5) +(6)+(7)
IC3	E-4/6	7,862.1	4,975.8	328.9	0	157.0	13,323.8
IC2	E-5/6	9,053.4	0	849.7	2,431.2	157.0	12,491.3
IC1	E-6/6	10,858.6	0	1,921.0	383.0	157.0	13,319.6
MM3	E-4/6	7,826.1	4,302.4	328.9	0	157.0	12,650.4
MM2	E-5/6	9,053.4	0	849.7	2,431.2	157.0	12,491.3
BT3	E-4/6	7,862.1	4,275.4	328.9	0	157.0	12,623.4
BT2	E-5/6	9,053.4	0	849.7	2,431.2	157.0	12,491.3
BT1	E-6/6	10,858.6	0	1,921.0	383.0	157.0	13,319.6
EN3	E-4/6	7,862.1	4,255.2	328.9	0	157.0	12,603.2
EN2	E-5/6	9,053.4	0	849.7	1,945.0	157.0	12,005.1
EM2	E-5/6	9,053.4	0	849.7	1,945.0	157.0	12,005.1
BM3	E-4/0	7,915.9	4,389.3	332.3	0	157.0	12,794.5
SK3	E-4/5	7,803.7	3,353.1	325.2	0	157.0	11,639.0
SM3	E-4/2	7,817.7	2,764.6	326.0	0	157.0	11,065.3
SM2	E-5/2	8,942.0	0	834.1	1,945.0	157.0	11,878.1
YN3	E-4/5	7,803.7	2,611.2	325.2	0	157.0	10,897.1
YNC	E-7/5	12,646.1	0	2,542.3	422.1	157.0	15,767.5
QM3	E-4/0	7,915.9	2,337.1	332.3	0	157.0	10,742.3
QM2	E-6/0	9,100.6	0	856.3	1,945.0	157.0	12,058.9
QMC	E-7/0	12,768.5	0	2,576.4	422.1	157.0	15,924.0
SN/FN[e]	E-2/E-3	6,677.8	753.8	184.8	0	157.0	7,773.4

Table B-6 (continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Pay Grade/ DoD		At a Discount Rate of 10% Per Year				
Rating/ Rate	Occupational Area	Basic Cost[a]	Training Cost[b]	Retirement Cost[f]	Reenlistment Cost[d]	PCS Cost	Total (3)+(4)+(5) +(6)+(7)
IC3	E-4/6	7,862.1	5,296.1	328.9	0	157.0	13,644.1
IC2	E-5/6	9,053.4	0	849.7	2,671.4	157.0	12,731.5
IC1	E-6/6	10,858.6	0	1,921.0	420.8	157.0	13,357.4
MM3	E-4/6	7,862.1	4,608.5	328.9	0	157.0	12,956.5
MM2	E-5/6	9,053.4	0	849.7	2,671.4	157.0	12,731.5
BT3	E-4/6	7,862.1	4,579.5	328.9	0	157.0	12,927.5
BT2	E-5/6	9,053.4	0	849.7	2,671.4	157.0	12,731.5
BT1	E-6/6	10,858.6	0	1,921.0	420.8	157.0	13,357.4
EN3	E-4/6	7,862.1	4,557.9	328.9	0	157.0	12,905.9
EN2	E-5/6	9,053.4	0	849.7	2,137.1	157.0	12,197.2
EM2	E-5/6	9,053.4	0	849.7	2,137.1	157.0	12,197.2
BM3	E-4/0	7,915.9	4,603.4	332.3	0	157.0	13,008.6
SK3	E-4/5	7,803.7	3,604.9	325.2	0	157.0	11,890.8
SM3	E-4/2	7,817.7	2,972.5	326.0	0	157.0	11,273.2
SM2	E-5/2	8,942.0	0	834.1	2,137.1	157.0	12,070.2
YN3	E-4/5	7,803.7	2,807.5	325.2	0	157.0	11,093.4
YNC	E-7/5	12,646.1	0	2,542.3	463.8	157.0	15,809.2
QM3	E-4/0	7,915.9	2,515.5	332.3	0	157.0	10,920.7
QM2	E-6/0	9,100.6	0	856.3	2,137.1	157.0	12,251.0
QMC	E-7/0	12,768.5	0	2,576.4	463.8	157.0	15,965.7
SN/FN[e]	E-2/E-3	6,677.8	828.0	184.8	0	157.0	7,847.6

[a]From Table B-1.

[b]From Table B-2.

[c]From Table B-3.

[d]From Table B-4.

[e]Average base pay and retirement cost for pay grades E-2 and E-3 were computed using appropriate manpower weights.

[f]A discount rate of 5 percent per year was implicitly used. Comparable figures for a discount rate of 10 percent per year were not available. Reported figures would be lower for r = 10 percent.

Table B-7

NET SAVING ATTRIBUTABLE TO AUTOMATION
(1974 dollars)

(1) Rating/ Rate	(2) Number Saved Under Automation[a] Compared with Base Case	(3) Number Saved Under Austere Manning[a] Compared with Base Case	(4) Net Savings Attributable to Automation r = 5%[b]	(5) Net Savings Attributable to Automation r = 10%[b]
IC3	2	1	13,323.8	13,664.1
IC2	1	1	0	0
MM3	2	0	25,300.8	25,913.0
MM2	1	0	12,491.3	12,731.5
BT2	1	0	12,491.3	12,731.5
BT1	2	0	26,639.2	26,714.8
EN3	1	1	0	0
EN2	1	0	12,005.1	12,197.2
EM2	1	0	12,005.1	12,197.2
BM3	3	0	38,383.5	39,025.8
SK3	1	0	11,639.0	11,890.8
SM3	2	0	22,546.4	22,130.6
SM2	1	0	11,878.1	12,070.2
YN3	3	0	32,691.3	33,280.2
QM3	-1[c]	0	-10,742.3	-10,920.7
QM2	1	1	0	0
QMC	1	1	0	0
SN/FN	35	8	209,881.8	211,885.2
Total	58	13	430,534.2	435,491.4

[a]From Table A-1.

[b]From Table B-6.

[c]The negative sign indicates personnel that must be added to ship.

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