AD-A158 289 AN AGGREGATE MANPOWER PROJECTION MODEL FOR LONG-RANGE PLANNING(U) NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO CA M R SHOECRAFT JUL 85 1/1

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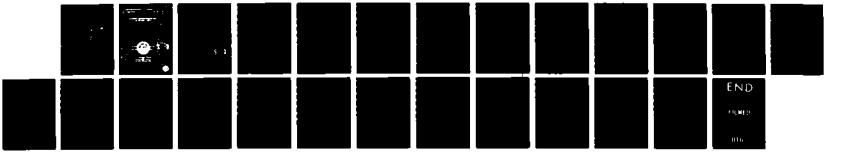

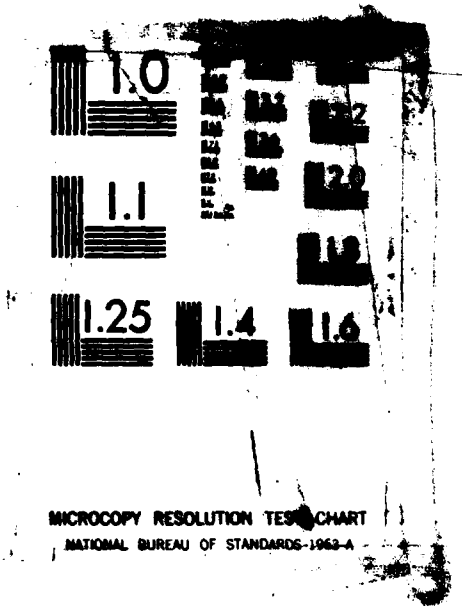
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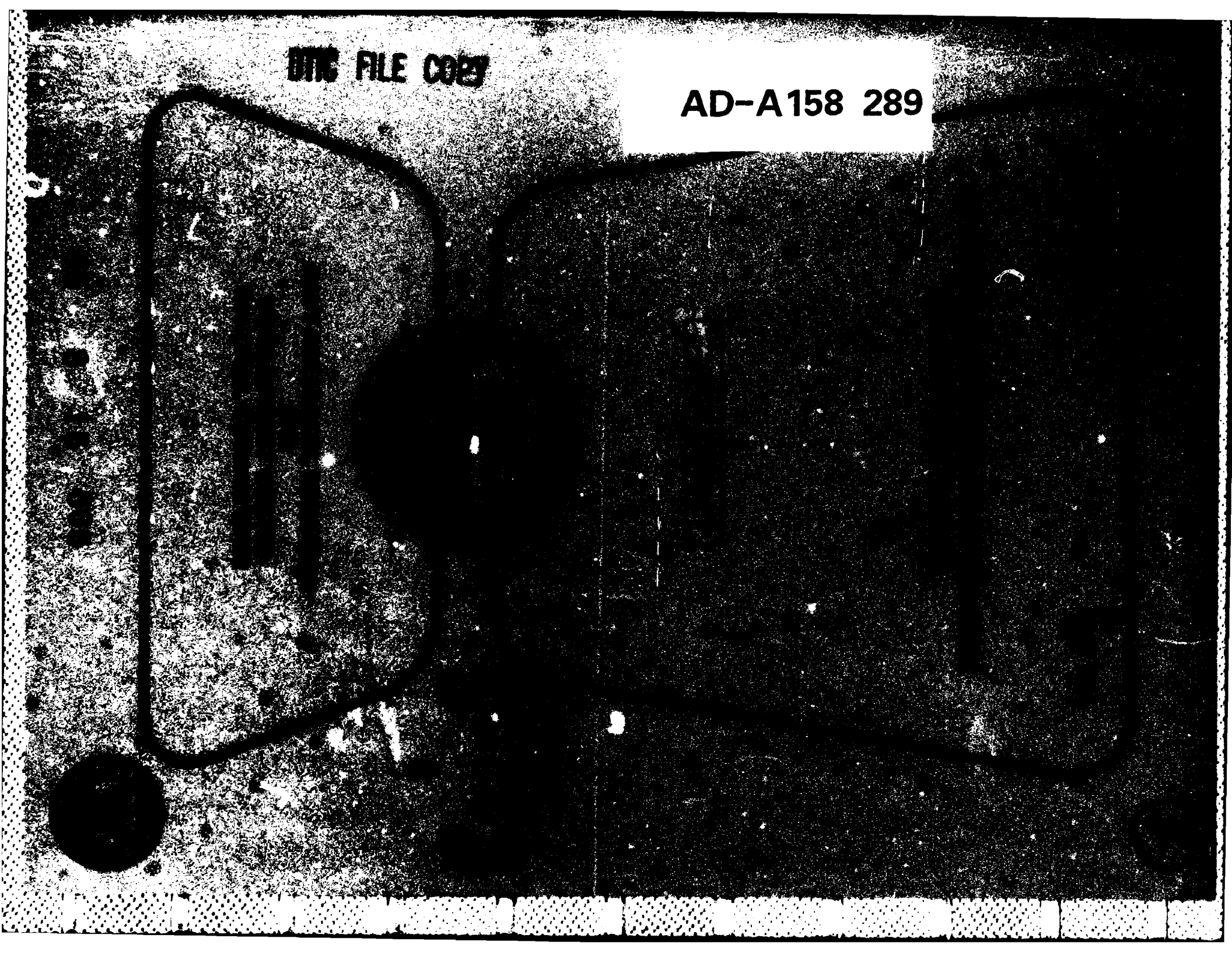
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NPRDC TR 85-25 July 1985

AN AGGREGATE MANPOWER PROJECTION MODEL FOR LONG-RANGE PLANNING

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NPRDC TR 85-25	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Navy Personnel Research and Development Center 6b. OFFICE SYMBOL (*If applicable*) Code 61	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (*City, State, and ZIP Code*) San Diego, CA 92152-6800	7b. ADDRESS (*City, State, and ZIP Code*)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION Chief of Naval Operations 8b. OFFICE SYMBOL (*If applicable*) OP-98/01	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (*City, State, and ZIP Code*) Washington, DC 20350	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 63707N; PROJECT NO. Z1170; TASK NO. -002; WORK UNIT ACCESSION NO.

11. TITLE (*Include Security Classification*)

AN AGGREGATE MANPOWER PROJECTION MODEL FOR LONG-RANGE PLANNING

12. PERSONAL AUTHOR(S)
Shoecraft, Michael R.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (*Year, Month, Day*)	15. PAGE COUNT
Final Report	FROM FY83 TO _____	1985 July	24

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (*Continue on reverse if necessary and identify by block number*)
FIELD	GROUP	SUB-GROUP	
05	01		Manpower requirements, manpower planning, manpower forecasting models, long-range manpower.

19. ABSTRACT (*Continue on reverse if necessary and identify by block number*)

This report describes the development of a quick-response interactive model to estimate long-range total Navy military and civilian manpower, given the number and type of ships and aircraft. The model can be used by Navy manpower managers to evaluate the impact of alternate fleet configurations on support manpower requirements. Application of the manpower projection model (MAPRO) to a 600-ship, 15-battle-group scenario indicates the need to increase total Navy military end strength by 10.4 percent and total Navy civilian end strength by 10.3 percent from FY82 to FY90. MAPRO has been installed at the Argonne National Laboratory computer facility but can be made accessible on other computers.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Shoecraft, Michael R.	22b. TELEPHONE (*Include Area Code*) (619) 225-2971 22c. OFFICE SYMBOL (Code 61)

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

FOREWORD

This development was conducted within advanced development subproject Z1770-002 (Fleet Demand for Base Operating Support Manpower) under the mission sponsorship of the Chief of Naval Operations (OPNAV) (OP-01). The objective of this subproject is to develop long-range aggregate planning models to forecast Navy requirements for officer, enlisted, and civilian manpower.

This report describes the development of an interactive model to estimate long-range total Navy military and civilian manpower, given the number and type of ships and aircraft. The model can be used by the OPNAV staff to evaluate the long-range support manpower required for alternative fleet configurations.

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SUMMARY

Problem

An essential element of planning for the Navy of the future involves estimating the manpower consequences of alternative force levels. At present, the Navy lacks quick methods for assessing the impact of alternative fleet sizes and configurations on long-range support manpower requirements. This deficiency is highlighted as the Navy seeks to achieve a force strength of 15 battle groups and 600 ships. Improved analytic methods are needed to project support manpower requirements for 17 years when the extended planning annex (EPA) is prepared. In addition, there is a need to verify quickly the manpower authorizations programmed during the Department of the Navy five-year defense plan (FYDP) and program objectives memorandum (POM) process, a 2-7 year planning horizon. Because the planning, programming, and budgeting system (PPBS) process is so long, involves so many commands, and is so data-intensive, minor changes, such as procuring 10 guided missile destroyers instead of 10 guided missile frigates over the next 5 years, require a long and detailed revision to estimate resource requirements. A quick and easy means to estimate the force size and required support structure for these changes would allow realistic projections of total life-cycle manpower "costs-of-ownership" associated with new major weapons systems to be considered in the PPBS.

Objective

The primary objective of this effort was to develop a quick-response computer model to estimate the total long-range Navy military and civilian manpower implications of specific force structures.

Approach

The Navy's active ships, aircraft squadrons, and support activities were categorized into homogeneous groupings. Then the Navy cost information system was used to match past manpower levels to ship and aircraft inventories so that manpower planning factors could be obtained by ship type, aircraft type, and support manpower category. These planning factors were verified, validated, and used to project the manpower implications for a 600-ship, 15-battle-group Navy. A manpower projection model (MAPRO) was developed to automate these projections.

Results

The results verified the ability of MAPRO to develop simple planning factors to estimate force end strength, given the number of ships and aircraft. The validation demonstrated that MAPRO can estimate the support end strength for FY72-76, given force end strength. Manpower projections for the 600-ship, 15-battle-group Navy showed the need to increase total Navy military end strength by 10.4 percent and total Navy civilian end strength by 10.3 percent from FY82 to FY90. MAPRO has been installed at the Argonne National Laboratory computer facility but can be made accessible on other computers.

Future Directions

MAPRO provides a quick-response method for estimating support manpower based on the size and configuration of the fleet.

Future plans include division and further analysis of the indirect support category. For these new categories, additional aggregate workload measures, such as the size of research, development, test and evaluation budget account or student work load, will be used to develop manpower estimating relationships.

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INTRODUCTION

Problem

An essential element of planning for the Navy of the future involves estimating the manpower consequences of alternative force levels. At present, the Navy lacks quick methods for assessing the impact of alternative fleet sizes and configurations on long-range support manpower requirements. This deficiency is highlighted as the Navy seeks to achieve a force strength of 15 battle groups and 600 ships. Improved analytic methods are needed to project support manpower requirements for 17 years when the extended planning annex (EPA) is prepared. In addition, there is a need to verify quickly the manpower authorizations programmed during the Department of the Navy five-year defense plan (FYDP) and program objectives memorandum (POM) process, a 2-7 year planning horizon. Because the planning, programming, and budgeting system (PPBS) process is so long, involves so many commands, and is so data-intensive, minor changes, such as procuring 10 guided missile destroyers instead of 10 guided missile frigates over the next 5 years, require a long and detailed revision to estimate resource requirements. A quick and easy means to estimate the force size and required support structure for these changes would allow realistic projections of total life-cycle manpower "costs-of-ownership" associated with new major weapons systems to be considered in the PPBS.

Objective

The objective of this effort was to develop a quick-response computer model to estimate the long-range total manpower implications of specific sets of ship and aircraft platforms. To be useful in the PPBS, the support manpower projections should be organized in some aggregation of current budget program categories, such as program elements (PEs) or defense planning and programming categories (DPPCs).

Background

The current procedures used for long-range manpower planning, the EPA, and Navy manpower planning system (NAMPS), concentrate on ship and aircraft platforms and their operational manpower requirements. At present, both procedures prorate support manpower requirements in the out years. During the POM process, questions such as, "What is the impact on total support manpower requirements if four FFGs instead of 2 DDGs are procured for FY88 and FY89 commissioning?" are generally not answered analytically. The systems presently in use for estimating manpower requirements--either the Navy resource model (NARM) or shore requirements standards and manpower planning system (SHORSTAMPS)--are too slow and too detailed to provide answers quickly. In addition, SHORSTAMPS cannot provide a complete answer because it does not include the entire shore establishment.

APPROACH

Scope of the Model

To develop the manpower projection model (MAPRO), all officer, enlisted, and civilian manpower were included. Military manpower was defined as:

1. All active duty officer and enlisted personnel.

2. Student and trainee military personnel.

3. Training and administration of reserve (TAR) personnel historically paid from military pay Navy (MPN) appropriations.

Civilian manpower included direct hire U.S. and foreign civilians. All manpower was categorized based on mission and program categories into five major categories: (1) Operating Forces, (2) Other Forces, (3) Direct Support, (4) Indirect Support, and (5) Overhead. These categories broadly encompass all Navy manpower in non-overlapping homogeneous groups.

Data Base

The data base selected for model development was the Navy cost information system (NCIS). It was chosen because the Navy uses it for the FYDP, and because it contains data for 20 years (FY62-81) for end-of-year personnel on board (end strength).[1] End strength is approximately equal to authorizations, that is, the manpower approved by Department of Defense, Congress, and Navy program sponsors in each budget category. End strength figures also account for overhaul, deployment, and home port manning patterns. Projections based on past end strength amounts can be validated. "True requirements," the staffing that would fully meet all demands placed on each activity in accomplishment of its mission, have almost never been realized, and thus, any forecasts based on true requirements could not be validated. The NCIS also identifies the active ships and squadrons and force levels, so that ship and squadron on-board manpower can be matched to the official ship and aircraft inventories, thus allowing manpower forecasts to be based on the official budget projection of force inventories.

In 1982, researchers at the Navy Personnel Research and Development Center grouped the NCIS budget categories, PEs, and activity unit identification codes (UICs) into an aggregate structure based on budget program categories (see Figure 1). Wherever possible, the groups included whole program elements. The major exception was in Program II, General Purpose Forces, which contains ship and aircraft force units with their directly related force support components, such as naval stations. To separate support from forces, program elements in Program II were divided among aggregate structure Groups 1 and 2: Group 1, Navy Forces, contains all ship and aircraft forces and weapon and missile force units, as well as electronic, communication, and operational headquarter activities performing direct support; Group 2, Force-Related Support Activities, contains the maintenance, supply, base operations, and force support training activities. Support activities with functions less directly related to force units are in Groups 3-5.

Ship and aircraft data were taken from the official active inventories in past Navy budgets. Only active ships and aircraft squadrons were used because these are the primary forces affected by the MAPRO categories of Direct and Indirect Support. The combined Navy and Marine Corps aircraft inventory was used instead of Navy aircraft alone because the combined figures were more readily available in the long-range planning systems.

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[1]End strength is defined as the personnel reported on board each activity on the last day of each fiscal year. End strength does not include temporary civilian employees.

Group 1.	Navy Forces
	Ship forces
	Aviation forces
	Other forces
Group 2.	Force-Related Support Activities
	Maintenance
	Supply
	Base operations
	Force support training
Group 3.	Central Support Activities
	Communications
	Intelligence
	Central and logistic support activities
Group 4.	Personnel Activities
	Training
	Personnel and medical support
Group 5.	Other Support
	Geophysical, research and development
	Management headquarters
	Federal agency support, individual, miscellaneous

Figure 1. Aggregate structure based on major budget and planning groups.

Model Development

Simple homogeneous groups and simple planning factors or ratios were developed so that the total force structure could be estimated quickly, based on any configuration of ships and aircraft. No assumptions were made about technology and productivity changes. As Figure 2 demonstrates, the proportions of Navy military manpower distribution to forces, support, and overhead have changed little between 1972 and 1980. Therefore, this distribution was assumed to be constant in developing MAPRO planning factors for forecasting total manpower requirements.

Table 1 presents FY81 end strength for the five major MAPRO categories and their subcategories. To develop planning factors for forecasting force levels, ship and aircraft squadron types from aggregate structure Group 1 were combined as much as possible. Ships were combined by similar size and mission characteristics, aircraft squadrons according to their major aircraft type. The active ship and aircraft squadron groups used in the model development and included in MAPRO as Operating Forces are presented in Table 2. Naval forces from aggregate structure Group 1 that were not active ships and squadrons were defined as Other Forces (see Table 1). Since this category is primarily composed of reserve ships and squadrons, the pipeline of ships that have manpower

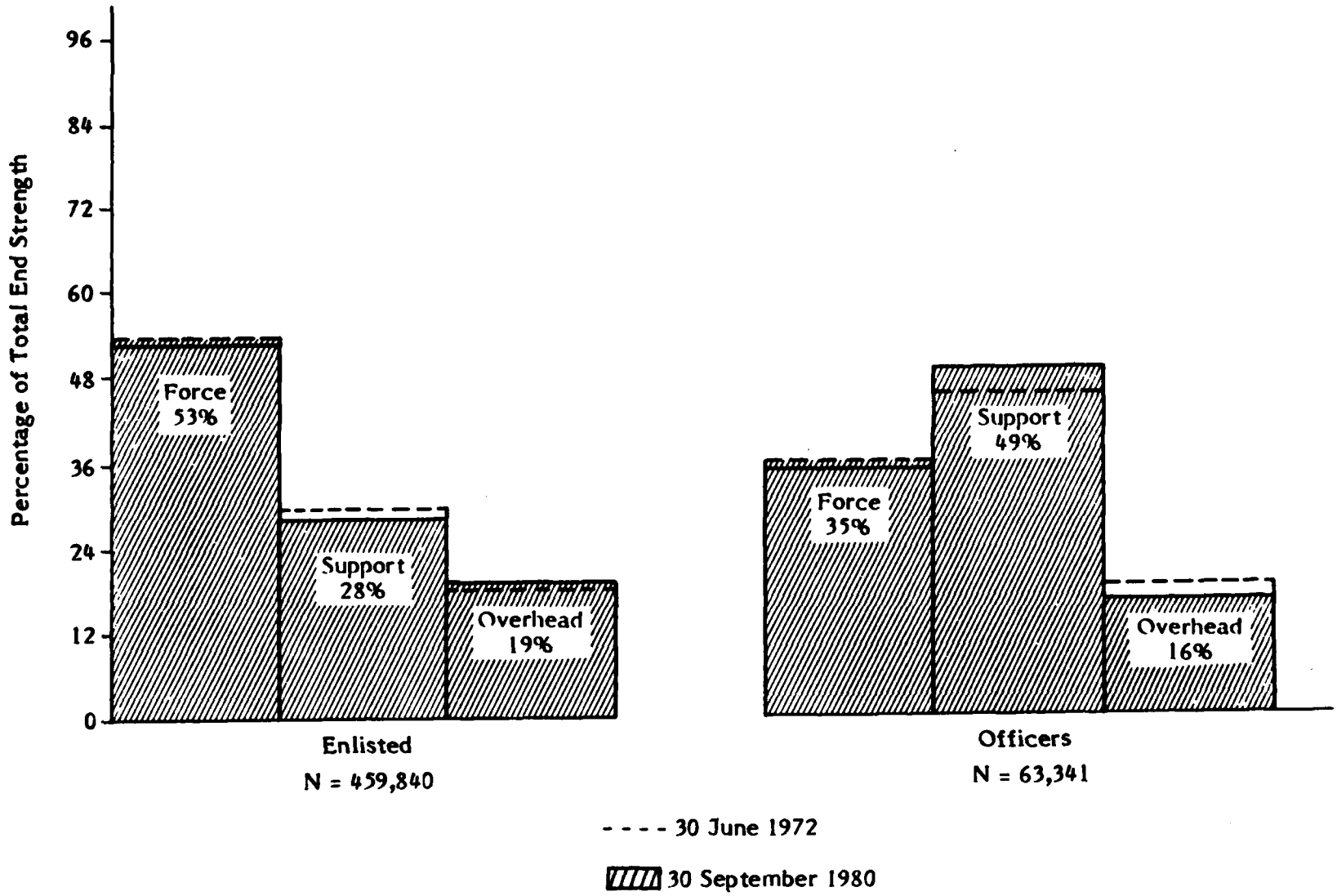

Figure 2. Military end strength distribution, 1972 and 1980.

Table 1

FY81 End Strength by MAPRO Category

	Military N	Civilian N
Operating Forces		
Active ships	173,169	0
Active squadrons	56,448	0
Total	229,617	0
Other Forces		
Reserve and other non-active ships and aircraft units	27,206	1,861
Sealift ships and operations	261	5,902
Weapons and missile forces	592	182
Electronic and communications systems	2,115	299
Operational headquarters	6,402	203
Naval construction forces	7,622	100
Naval personnel attached to Marine Corps units	1,913	0
Total	46,110	8,547
Direct Support		
Ship and aircraft maintenance activities	8,686	108,761
Supply, procurement, and inventory control point operations	1,581	21,517
Base operating support	50,670	61,885
Force support training	1,427	24
Total	62,364	192,187
Indirect Support		
Communications activities	5,842	1,490
Intelligence and cryptologic activities	7,044	1,095
Logistics and central support activities	7,567	36,881
Training activities	20,977	4,223
Recruiting and personnel support activities	7,694	1,311
Medical activities	21,550	6,628
Weather and oceanography activities	1,722	1,046
Research and development activities	4,729	30,468
Management headquarters	8,435	8,635
Federal agency support, international activities	1,073	484
Miscellaneous	5,191	302
Total	91,824	92,563
Overhead		
Transients	27,256	0
Patients, prisoners, holders	6,832	0
Students, trainees	71,642	0
Total	105,730	0
Grand Total	535,646	293,297

Table 2

Ship and Aircraft Squadron Groups
(MAPRO Operating Forces)

Abbreviation	Description
	Ships
FBM	Ballistic missile submarines.
CAR	Aircraft carriers.
CRU	Cruisers, battleships, and command ships (cruiser type).
DES	Destroyers.
MIN	Patrol craft and mine warfare ships.
FFG	Frigates and destroyer escorts.
SUB	Attack and auxiliary submarines.
AMP	Amphibious ships and command ships (amphibious type).
AUX	Mobile logistics and support ships.
	Aircraft
ATK	Attack and tactical electronic warfare squadrons.
FTG	Fighter, light photographic, fighter-attack, and air test and evaluation squadrons.
WRN	Airborne early warning and reconnaissance squadrons.
CRG	Air transport, fleet tactical support, and antarctic air development squadrons.
PTL	Patrol and oceanographic air development squadrons.
ASW	Air antisubmarine squadrons.
HEL	Helicopter squadrons.
TRN	Training squadrons.
MISC	Fleet composite, ferry, and observation squadrons.

reported but are as yet uncommissioned, sealift ships, and operational headquarters, it was assumed to be directly related to ship and aircraft forces. One MAPRO category, Direct Support, was designed to include all of aggregate structure Group 2, those activities directly supporting the force units and, thus, directly related to the size of the forces they support. Another model category, Indirect Support, was designed to include all the other support activities, such as training, personnel, medical, R&D, intelligence, and management headquarters activities (Groups 3-5), that indirectly impact the effective operation of the force units. Since most Indirect Support activities provide overall Navy support, it was assumed that Indirect Support was related to the total Navy manpower in

Direct Support, Operating Forces, and Other Forces. The MAPRO Overhead budget categories were assumed to be a fixed percentage of the total military manpower in the Navy.

Increment and Decrement Factors

Planning factors were developed for the support manpower categories of MAPRO from the average ratios over the 5-year period FY77-81 (see Table 3). Initially, the planning factors were average end strength for each group. However, after test and evaluation of MAPRO, the research team decided that more accurate force projections and, therefore, more accurate support projections, could be obtained if the ship planning factors were changed to increments and decrements based on the average end strength for the ships to be commissioned and decommissioned in the future. For ship decrements (see Table 4), the average end strength for the last 5 years was calculated for the ship type in each group most likely to be deleted from the fleet. For increments, the average end strength for the newest ship class in each group was calculated from the last 5 years' data. If sufficient data were not available, the end strength of the newest class ship was estimated based on the authorizations in the current FYDP. For aircraft forces (see Table 5), the planning factors used were the average manpower per aircraft among all the squadrons. It was assumed that the Navy would add or subtract manpower in the squadron groups in proportion to the aircraft added or subtracted. It was also assumed the proportion of aircraft that would be added to the Marine Corps and to the repair pipeline in the future would be the same as at present.

Table 3

Support Manpower Planning Factors

Factor	Officer	Enlisted	Civilian	Total
Other forces	.022308	.166217	.035157	.223683
Direct support	.021967	.188135	.640634	.850735
Indirect support	.040900	.131245	.186725	.358879
Overhead	.232677	.237745	N/A	.237133

Note. Factors were developed from average ratios over the period FY77 to FY81.

Table 4

Manpower Planning Factors for Ships

Ship		Average Military Personnel	
Group	Class	Officers	Enlisted
	Decrements		
FBM	SSBN 616	26.56	261.42
CAR	CV 41	122.20	2320.40
CRU	CG 16	23.67	363.04
DES	DD 931	18.78	284.04
MIN	MSO 422	5.87	66.53
FFG	FF 1037	14.20	192.40
SUB	SSN 585	12.68	103.68
AMP	LSD 28	18.63	296.72
AUX	AVG AUX[a]	19.25	399.84
	Increments		
FBM	SSBN 726	28.85	258.57
CAR	CVN 68	150.60	2639.70
CRU	CG 47	19.76	277.72
DES	DD 963	18.77	263.78
MIN	MCM 1	4.89	61.71
FFG	FFG 7	8.86	149.10
SUB	SSN 688	12.53	116.07
AMP	LSD 41	17.77	308.38
AUX	AVG AUX[a]	19.25	399.84

Note. Ship categories are explained in Table 2.

[a]Averages were used in AUX because end strength varies greatly in this group, from submarine tenders (end strength = 1372) to salvage ships (end strength = 85).

Table 5

Manpower Planning Factors for Aircraft

Aircraft Group	Officer	Enlisted
PTL	4.217	20.533
WRN	5.603	31.647
ASW	3.544	19.974
ATK	1.203	10.716
FTG	1.403	11.062
CRG	1.302	7.238
TRN	0.727	3.085
HEL	0.853	4.872
OTH	0.994	6.267

Implementation

MAPRO was implemented in APL in a user-friendly interactive environment at the Argonne National Laboratory computer facility, but it can be accessible to other computers, as well. It has color-graphics capability to plot force-level assumptions and manpower forecasts (see Figures 3-5). When the ship and aircraft figures derived for the MAPRO model were entered into the computer, projections were obtained in less than 10 minutes. Modifications to assess the impact of alternative force structures took even less time. This rapid display of results provides a powerful decision-support system for the user, who has options to change the planning factors as new ship classes are added to the fleet and to save force scenarios for future changes and tests of assumptions on fleet configuration.

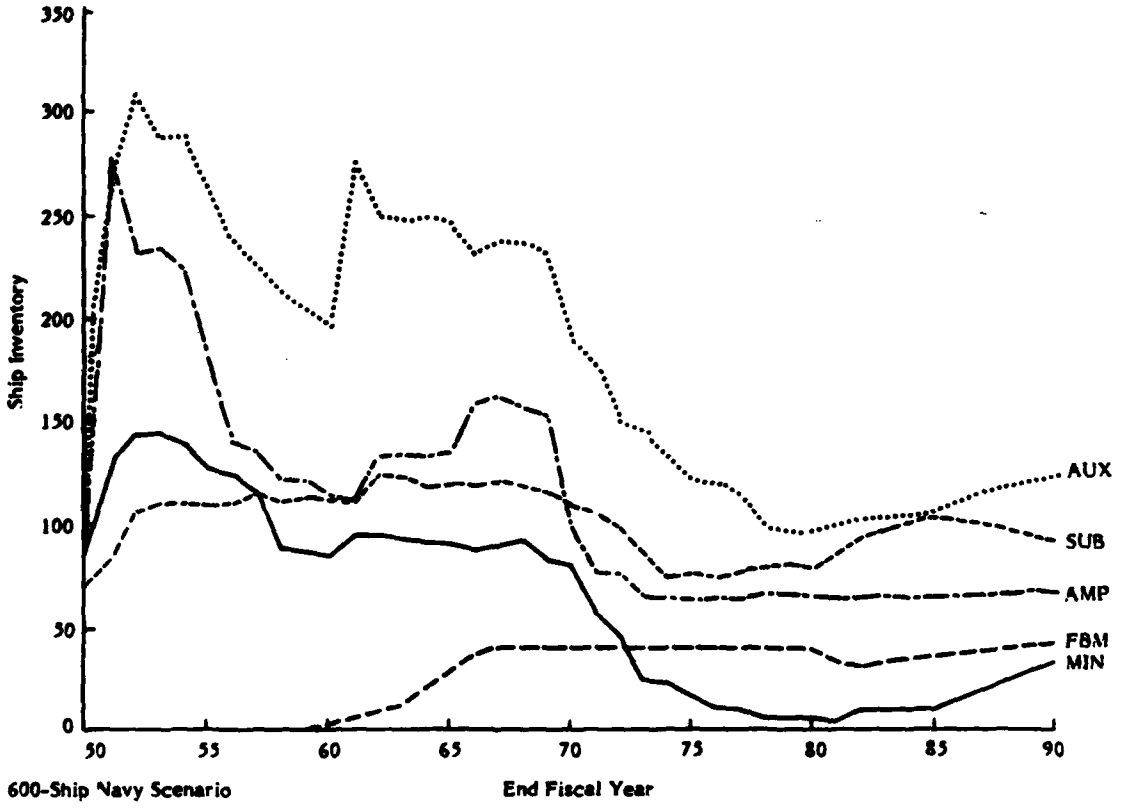

Figure 3a. AUX, SUB, AMP, FBM, MIN.

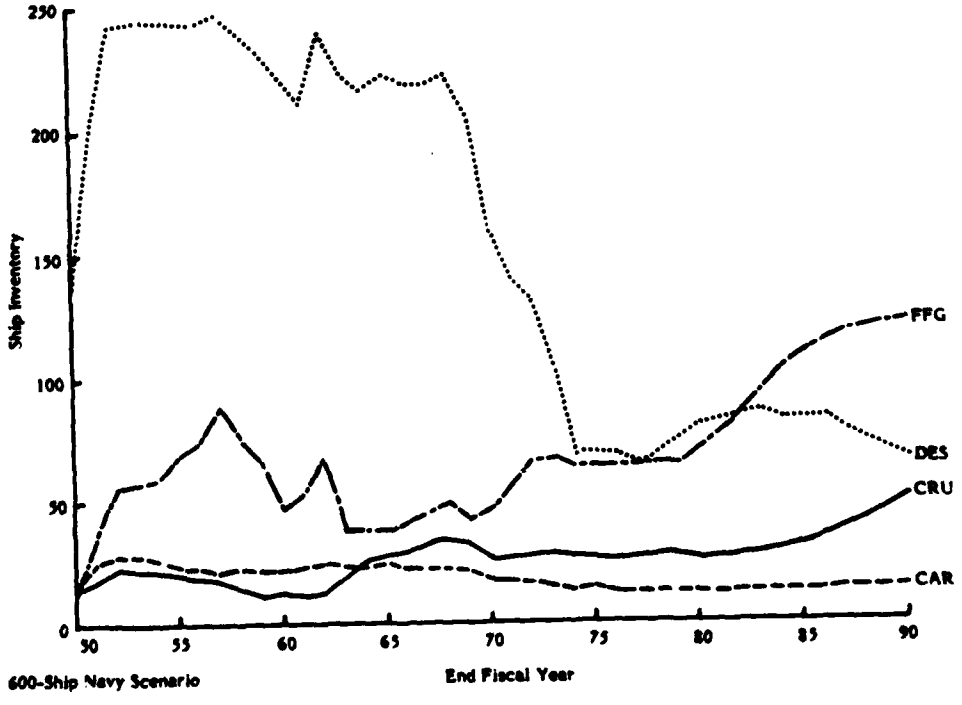

Figure 3b. FFG, DES, CRU, CAR.

Figure 3. Ship inventories from 1950 through 1989.

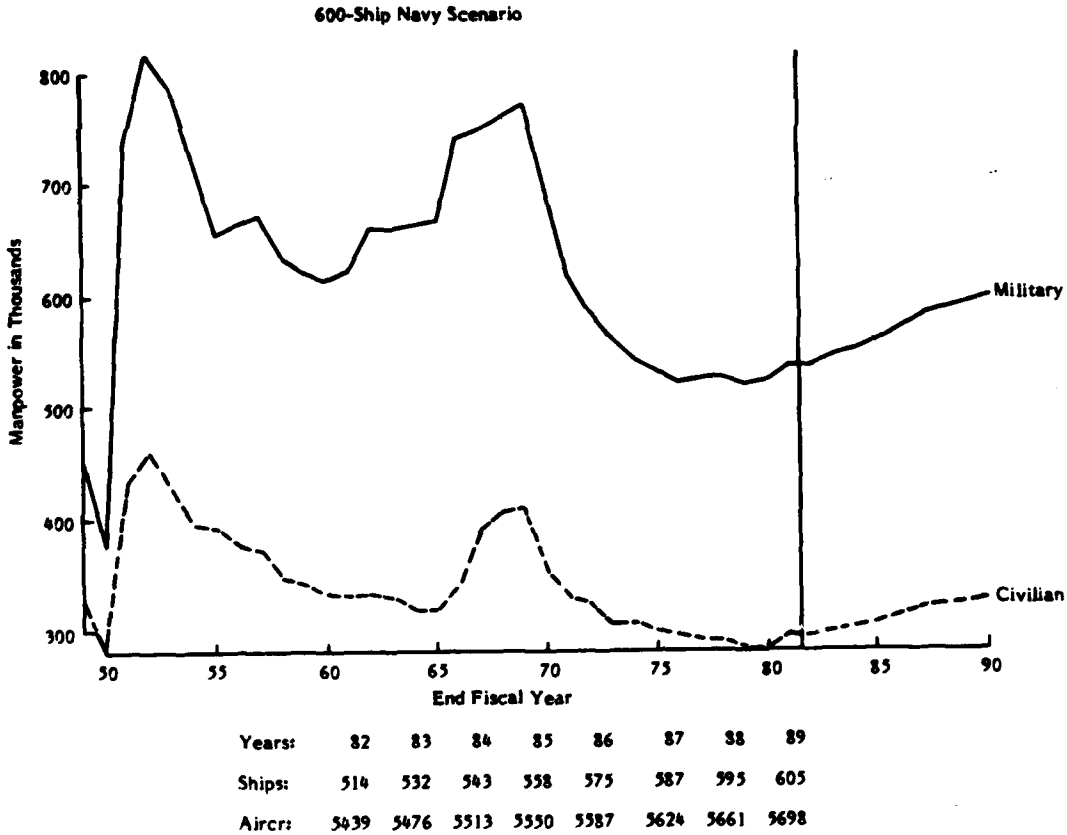

Figure 4. Total manpower from 1950 through 1989.

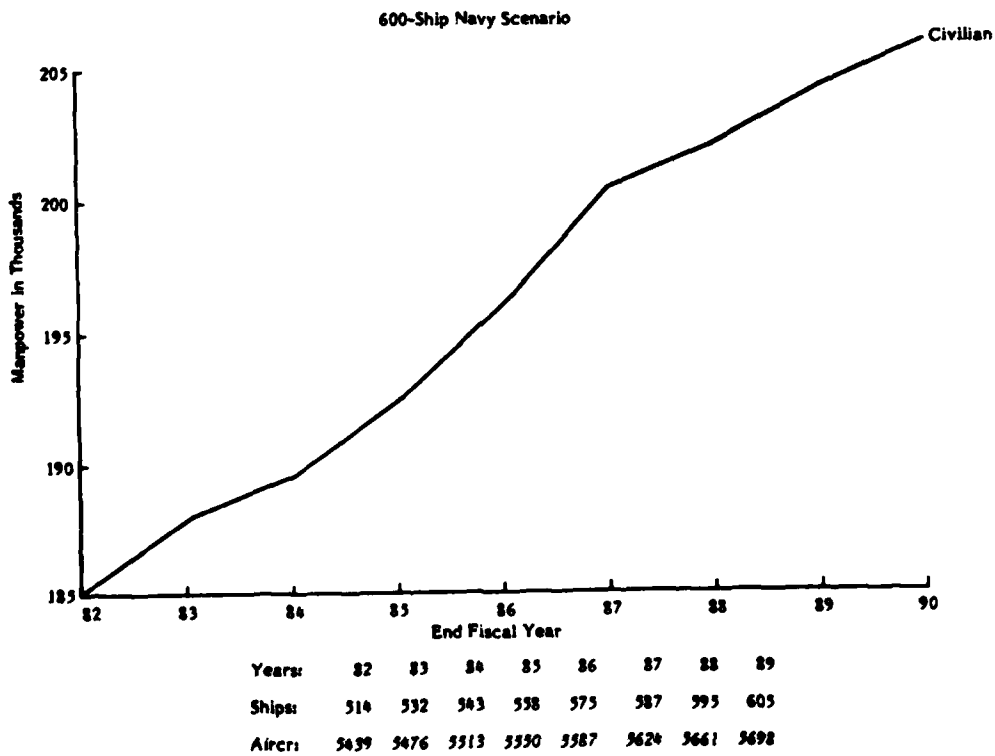

Figure 5. Direct civilian support from 1982 through 1989.

RESULTS

Model Application

MAPRO was tested on a 600-ship, 15-battle-group scenario for FY89. Table 6 presents ship and aircraft changes assumed for this scenario. Figures 3-5 present ship inventories, manpower requirements, and civilian support since 1950, ending with this scenario. As shown in Figure 4, a 23.2 percent increase in ships and a 5.5 percent increase in aircraft results in a 10.4 percent increase in total military manpower requirements and a 10.3 percent increase in civilian requirements. As shown in Figure 5, based on the data presented in Tables 1 and 3, civilian direct support requirements increase by 11.3 percent from FY82 to FY89.

Table 6

Net Changes in Force for 600-Ship Navy Scenario

Group	1981 Inventory	Change N	Change %	1989 Inventory
		Ships		
FBM[a]	34	8	25.0	42
CAR	12	2	16.7	14
CRU	27	19	70.4	46
DES	83	-13	-15.7	70
MIN	4	25	625.0	29
FFG	78	43	55.1	121
SUB	87	7	8.0	94
AMP	65	3	4.6	68
AUX	101	20	19.8	121
Total	491	114	23.2	605
		Aircraft		
PTL[a]	410	0	0.0	410
WRN	126	16	12.7	142
ASW	149	0	0.0	149
ATK	1205	160	13.3	1365
FTG	824	-56	-6.8	768
CRG	172	-56	-32.6	116
TRN	1034	80	7.7	1114
HEL	1279	200	15.6	1479
MISC	203	-48	-23.6	155
Total	5402	296	5.48	5698

[a]Ship and aircraft groups are explained in Table 2.

Effectiveness of MAPRO Planning Factors

To assess the effectiveness of the planning factors developed for MAPRO, residuals (observed end strength minus predicted) were analyzed in two ways for the 5 years used in development of the planning factors. First, the average end strength of the ship and aircraft groupings was used to develop the predicted figures, and support planning factors were applied. The results shown in Table 7 verify the ability of MAPRO to estimate the force structure, given ship and aircraft inventory. Second, ship manpower was estimated by reversing the factors presented in Table 3; the ships that have been added to the fleet since 1977 were decremented and the ships deleted from the fleet since then were incremented. Then the aircraft and support planning factors were applied. The results shown in Table 8 verify the ability of MAPRO to estimate support manpower, given ship and squadron manpower.

Table 7

MAPRO Residual Analysis for Total Manpower, Using
Average Ship and Squadron End Strength
1977-81

FY	Error (Observed End Strength - Predicted)	%
77	-5,224	-.6
78	10,217	1.3
79	-8,477	-1.1
80	-8,352	-1.0
81	11,867	1.4

Table 8

MAPRO Residual Analysis for Total Manpower, Using Increment
and Decrement Planning Factors
1977-81

FY	Error (Observed - Predicted) N	%
77	-10,066	-1.24
78	-17,643	-2.16
79	-2,859	-.36
80	-8,206	1.02
81	22,366	2.70

Validation of the Model

Table 9 presents the results of two validations of the ability of MAPRO to estimate total Navy manpower requirements for FY72 and FY76. In the first validation, ship manpower estimates were based on the average end strength in each group, and then the aircraft and support planning factors were applied. In the second validation attempt, ship manpower was estimated, using the same method as described for Table 8. This second validation compared the impact of the average ship and aircraft planning factors used in the first validation to the impact of accurate increment and decrement factors.

Table 9

MAPRO Validation for Total Officer, Enlisted, and Civilian Manpower
1972-76

	Validation 1 Ship and Air Forces Estimated Using Average End Strength		Validation 2 Ship and Air Forces Estimated Using Increment and Decrement Factors	
	Error (Observed - Predicted)		Error (Observed - Predicted)	
FY	N	%	N	%
72	-147,038	-16.2	-20,237	-2.2
73	-124,073	-14.3	-54,543	-6.3
74	-36,372	-4.3	475	.1
75	-33,891	-4.1	873	.1
76	-20,480	-2.1	-8,913	-1.1

As shown in Table 9, in the first validation the error increases as the analysis proceeds into the past. In FY72 no CV 68s, DD 963s, FFG 7s, or SSN 688s, newer ship classes that have a greater end strength than their predecessors, existed in the fleet. With average values for ship and aircraft end strength, MAPRO overpredicts these earlier fiscal years. The category contributing most to the error is Other Forces, because today's values for ships in the pipeline, which are included in this category, are not appropriate for the early 1970s when proportionally fewer new ships were being built. As seen in validation 2, when ship and aircraft forces are not estimated, the error is much less in total manpower. The FY72-73 errors result from the Navy's rapid downturn in forces and manpower during that period; Other Forces and Overhead were proportionally smaller than the other categories. Today there is a greater pipeline of new ships and students and trainees. As shown by the data in Table 9, MAPRO can estimate the support end strength for fiscal years 1972-76, given ship and aircraft inventory.

FUTURE DIRECTIONS

MAPRO currently provides a quick-response method to estimate support manpower end strength based on the size and configuration of the fleet. Separation of support manpower categories into several categories and development of manpower estimating relationships based on other aggregate workload measures, such as the size of the research, development, test and evaluation budget or student workload for the functions less related to force levels, would provide greater accuracy with little loss in the speed of displaying projections.

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