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This report describes the development of a system for automating billet projection, personnel projection, and personnel allocation for Navy officers. Heuristic modeling techniques are used to develop personnel allocations by grade, skill type, and according to CNO manning priorities. The prototype officer distribution projection (ODPROJ) system produces detailed 10-14 month officer and billet projections. It is the first module in the development of an integrated officer distribution system.

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OFFICER DISTRIBUTION PROJECTION SYSTEM:
PROTOTYPE DEVELOPMENT.

**NAVY PERSONNEL RESEARCH
AND
DEVELOPMENT CENTER.
San Diego, California 92152**

OFFICER DISTRIBUTION PROJECTION SYSTEM: PROTOTYPE DEVELOPMENT

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FOREWORD

This research and development effort was conducted in support of Navy decision coordinating paper Z0011-PN (Personnel Assignment Systems) under the sponsorship of the Deputy Chief of Naval Operations (Manpower, Personnel, and Training) (DCNO (MPT)). The objective of this project is to develop computer systems to distribute persons to jobs more accurately and efficiently.

This report describes the development of an officer distribution projection (ODPROJ) system prototype. ODPROJ produces detailed 10 to 14 month officer personnel and billet projections. It then allocates projected personnel to projected billets by job type and by activity composite. ODPROJ is the first module in the development of an integrated officer distribution system.

Appreciation is expressed to CDR George Anastasi (NMPC-454), Officer Allocation Branch Head, for his support and cooperation, and especially for coordinating our efforts with ongoing Air Force and Army officer distribution system developments. Acknowledgements are also due to LTCOL Norm O'Meara and MAJ Howard Carpenter of the Distribution Development Branch of the Army Military Personnel Center for providing an overview of the Army Officer Distribution system and for assistance in understanding the computer programs within the system.

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Technical Director

SUMMARY

Problem

When Navy officers are reassigned to new billets (jobs), reassignment must allow for each officer's career needs and preferences, while meeting overall Navy manning goals and readiness requirements. Individual assignment decisions are difficult to coordinate with Navy manning plans because there is no method to translate long-range targets into policy guidelines for short-term assignment decisions. Short-term assignment decisions made with incomplete information may not attain long-term goals.

Objective

The objective of this research was to develop a prototype officer distribution projection (ODPROJ) computer model to project and allocate officers by grade, skill type, and CNO manning priorities, thereby improving the match of officer skills to billet requirements.

Model Description

The model uses attrition, promotion, and accession rates to project available officers in a distribution planning period. Personnel allocation is performed in two stages. To allocate officers, ODPROJ first converts a multiskill officer inventory into a single-skill inventory. Then ODPROJ allocates the single-skill inventory to groups of Navy activities (composites) according to relative manning priorities.

Conclusions and Future Plans

The ODPROJ system is a first step in the development of an automated officer distribution management system (ODMS). ODPROJ is designed to provide essential distribution planning information, including billet projections, officer inventory projections, and an aggregate allocation of officer skill groups to billet composites. Naval Military Personnel Command testing of the ODPROJ prototype will initiate necessary model refinements and modifications. A companion monitoring system will provide assignment information updates to ODPROJ and track achievement of allocation goals.
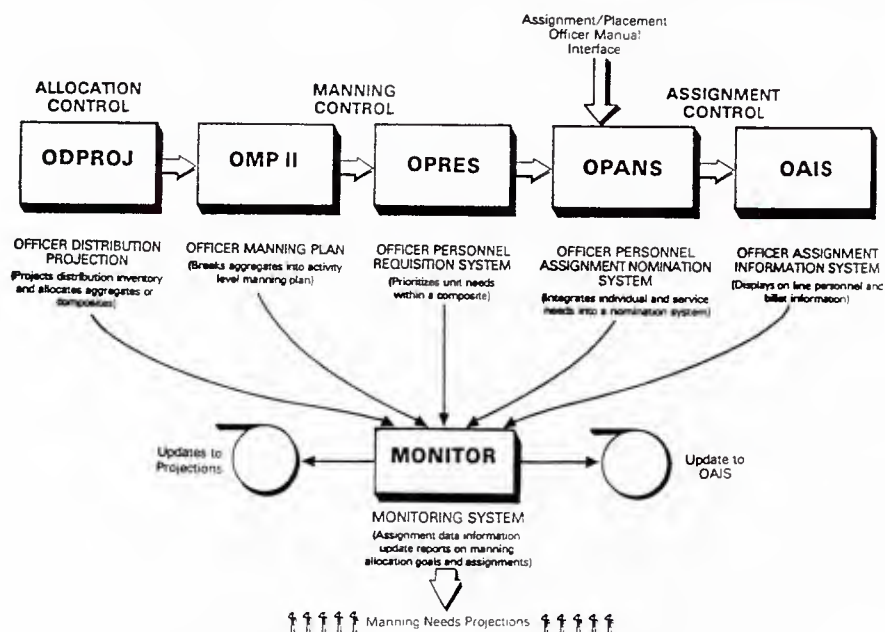
Figure 1. Officer distribution management system.

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INTRODUCTION

Problem

The distribution of Navy officers to jobs must be viewed in two ways. On the one hand, Navy manpower planners must allocate officer skills to best match the skill requirements of the jobs, thus increasing Navy efficiency and readiness. Assignment officers, on the other hand, must allow for each officer's career needs and preferences in making assignments. Individual assignment decisions are difficult to coordinate with Navy manning plans because there is no method to translate long-range targets into policy guidelines for short-term assignment decisions. Assignment decisions made with incomplete information may not attain long-term goals.

Background

Among other tasks, the Naval Military Personnel Command (NMPC) distributes officer resources to fill authorized billets (jobs). Officer distribution decisions are made at both the planning and operational levels. Navy distribution planners must develop manning goals consistent with available personnel and Chief of Naval Operations (CNO) manning priorities for billets as well as ensure that long-term aggregate distribution policies are followed.

Each assignment officer works with a small portion of the Navy's officers and billets and has little information about how this subset must relate to the Navy-wide plan. Without an exchange of information between the planning and assignment levels, Navy manning plans cannot be attained. The distribution information most important to both the planning and assignment levels concerns timing and skill mix. It is necessary to have advance knowledge when officers are due for rotation to a new job assignment, as well as when billets (i.e., jobs) will become vacant. Assignment officers can then begin negotiations for each officer's reassignment well in advance of the scheduled rotation date and make the transition to the new billet as smooth and timely as possible. Distribution planners also need this information to determine how fast manning levels can be changed within the constraints of normal rotation patterns.

The skill mix of officers and jobs is also critical. A good match of officer skills with billet skill requirements is essential both to Navy readiness and to the welfare and morale of individual officers. The qualifiers used to define billet skill requirements are based on a number of officer attributes. A major qualification is the officer's designator, which is a numerical code showing his or her major area of specialty (e.g., pilot, surface warfare officer). Another is the officer grade, which indicates both the officer's rank and level of experience. Also important to both the assignment and planning functions are such qualifiers as subspecialties and additional qualification designators (AQDs). Subspecialties reflect additional training in areas outside of the officer's designator field, and include computer, management, intelligence, and strategic planning expertise. AQDs identify additional skills and knowledge beyond those identified by the designator, such as qualification to fly a particular type of aircraft, command experience, and warfare training.

The major response to the officer allocation plan requirement was the officer manning plan (OMP) (Cass, Charnes, & Cooper, 1975), which compares total billets to personnel by designator and grade. Personnel shortages are "fair-shared" across activities according to activity priority. Manpower claimants are then asked to identify the billets that will absorb shortages. The designated billets are called gapped billets.

1

The OMP has some major deficiencies. Its transportation algorithm, used to optimize force distribution, causes two problems. First, the values summed in the objective functions must represent policies not easily quantified. For example, officer-job pairings that do not match exactly by designator or grade receive a value arbitrarily smaller than those for perfect matches. Second, the transportation model formulation lacks flexibility. The model's objective function and constraints cannot straightforwardly include changes in distribution policy.

OMP ignores other important distribution factors. Officer rotation is ignored, producing an idealized distribution of job fills and shortages that fails to allow for the time necessary to implement an allocation plan. In addition, officers are characterized only by grade and designator; skill categories are insufficiently detailed in relation to job requirements. Furthermore, the OMP does not accept assignment feedback.

The NMPC Distribution Development Group (1979) set forth additional distribution guidelines. In 1983 and 1984 the Navy Personnel Research Development Center (NAVPERSRANDCEN) investigated the problem and developed a concept design for an officer distribution projection system (Cass, 1984). This design described the personnel distribution approaches taken by the Air Force and the Army, specified officer allocation plan data requirements and proposed skill and manning categories. The design also outlined a set of system modules that parallel the Navy enlisted personnel allocation system.

Objective

The objective of this research was to develop a prototype officer distribution projection (ODPROJ) computer model to project and allocate officers by grade, skill type, and CNO manning priorities, thereby improving the match of officer skills to billet requirements.

MODEL DESCRIPTION

The ODPROJ model performs two major functions: projection and allocation. The projection function forecasts the availability of officers and billet vacancies 10 to 14 months ahead. The allocation function includes two subfunctions: (1) distributing officers to skill categories, and (2) sharing these skill assets among groups of Navy activities. Because individual officer skills provide essential information for distributing manpower, the number and type of skill categories are major design factors for ODPROJ. ODPROJ is the first module in the development of an integrated distribution management system (see Appendix A).

Projection

The model assembles its manning data base from elements found in the officer master file (OMF) personnel data and the officer special extract of the billet file, extracting data for active-duty unrestricted line (URL) officers, ensign through captain. These files are merged at the activity/billet level of detail. The resulting file reflects the current distribution of officers across billets and activities. ODPROJ uses this information to forecast the distribution of officers for the period 10-14 months ahead.

The forecast of billets in this distribution window is determined by applying billet phase dates. The phase date indicates the effective date of an authorized billet and, when

viewed in conjunction with other billet file data, indicates whether a new billet is to be authorized or an old one disestablished.

Estimating officer availability is a more complicated process. Essentially, ODPROJ must project changes in the officer population over the planning period. To do this, the model combines OP-130 (Navy Officer Plans and Community Management) planning data on attrition, promotion, and accession with individual officer data from the OMF.[1] First losses, then promotions, are applied to its current manning data base. Officers are randomly selected for attrition or promotion. Officers with pending orders are transferred to their new activities. Finally, accessions (including lateral gains) are added to the data base.

Next, composite labels are attached to data records on the basis of activity unit identification code (UIC). A composite is any collection of Navy billets that are treated similarly for manpower distribution purposes; for example, ships, shore staffs, or instructional personnel. In the prototype, selected composites correspond directly with Chief of Naval Operations manning priority groups, although composite definitions could be changed without impacting the effectiveness of the allocation algorithms. Each billet is identified with a job skill category, and each officer is identified with a pair of job skills, based on billet or officer designator, AQD, and subspecialty.

The model attaches skill categories to officer billet and personnel data records by first distinguishing among rotating and nonrotating officers. It examines the projected rotation date (PRD) field in the OMF. An officer who has a PRD in the distribution window is categorized as rotating. Otherwise, the officer is categorized as nonrotating, or "stabilized," in the composite. In the prototype all accessions are treated as rotating officers.

Billet vacancies are computed by subtracting nonrotating officers from authorized billets. Vacancies are detailed by skill category and by composite. Rotating officers available to fill these billets are in the ODPROJ data base, identified by skill pairs.

Allocation to Skill Category

The allocation process begins with the distribution of each officer to a skill category that must indicate a match between the characteristics of the officer and the characteristics of the billets the officer may potentially fill. The criteria for classifying an officer or a billet to a skill category are the same. The logic differs: Billets fall into general skill categories and officers into specific skill categories. Officers generally have several AQDs and one or more subspecialties, but only a fraction of billets are tagged with such specific requirements. For example, an A-7 pilot can fill an A-7 squadron billet, a general aviation billet (designator 130x), a general warfare billet (designator 105x), and a general URL billet (designator 100x). If the pilot has a subspecialty, he or she is an asset in that skill category as well. Similarly, certain billet vacancies may only be filled from the A-7 pilot community, while other vacancies may be filled from several officer communities. Figure 1 shows this complex relationship.

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[1]OP-130's structured accession planning model for officers (STRAP-O) gives estimated losses, promotions, and accessions for separate officer communities by grade and length of service.
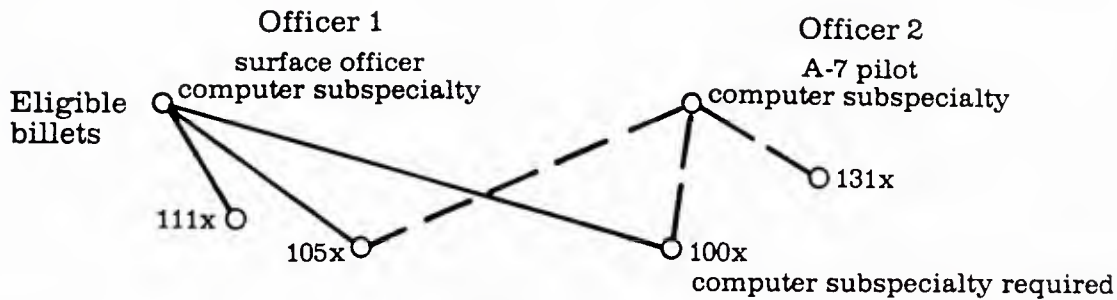
Figure 1. Officer eligibility for billets, two examples.

To cope with the multidimensionality of skill assignment, skill categories are assigned to billets based on an AQD or subspecialty requirement, or based on the billet designator. Skill pairs are assigned to officers; each skill exactly matches one of the billet skill categories. One skill is assigned based on the officer's set of AQDs. The other is based on the officer's subspecialty.[2] Although it is possible to assign more than two skills to each officer, very few officers were found to have more than two AQD or subspecialty skills. While officers can also fill billets with more general skill requirements, this is handled in the allocation model by a process called skill substitution. Table 1 lists the officer skill categories used in the ODPROJ prototype. They are based on the skill groups proposed in Cass (1983).

Skill category refinement is expected. The level of skill detail may change for the major officer communities. Additional AQDs, such as weapons system acquisition management (WSAM) qualifiers or previous-command indicators, may be added to the list of skills. When several potential skills are present in an officer's record, the method for tagging AQD or subspecialty skill categories can be modified.

ODPROJ assesses the pool of officer skills in relation to existing billet vacancies. The algorithm which performs skill allocation is a modification of the Army's asset utilization program (Carpenter, 1984), hereafter referred to as the Navy asset utilization program (NAUP). The two-skill officer inventory is converted into an "optimized" single-skill inventory based on projected billet vacancies. NAUP is an heuristic algorithm that matches the personnel inventory to authorized billets by grade and by skill. The aim is to allocate assets so that all billet skill categories have the same manning percentage unless a different skill level goal has been specified by the user.

Even though NAUP receives a two-skill inventory, the distribution of the personnel can occur over a wider set of skill categories. The program uses skill substitution matrices to allow the broader inventory distribution to occur. For example, a general 1120 requirement can be filled by more specific skill category assets, such as submarine-nuclear engineering, submarine-weapons, or submarine-navigation. This substitution occurs only when the substituting skill's billets are already at their minimum fill level. Skill substitution is especially important for the 1000 and 1050 skill groups because these billets can draw on officer assets from most skill categories.

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[2] If the officer has no AQD, the primary skill is his or her warfare designator. Likewise, the designator is used as a secondary skill if the officer has an AQD but no subspecialty. If the officer designator is used as the primary skill and there is no subspecialty, the secondary skill becomes 1000 or 1050, depending upon the officer's warfare status.

Table 1

Prototype Officer Skill Categories

Officer Designator	Skill Title
110x	General URL officer
111x	Surface warfare officer
112x	Submarine officer
112x	Sub--nuclear engineering
112x	Sub--weapons
112x	Sub--navigation
113x	Special warfare officer
114x	Special operations officer
116x	Surface warfare trainee
117x	Submarine warfare trainee
118x	Special warfare trainee
119x	Special operations trainee
130x	General aviation
131x	Pilot
131x	Jet light attack pilot
131x	Jet medium attack pilot
131x	Jet fighter pilot
131x	Jet electronic warfare pilot
131x	Jet antisubmarine warfare pilot
131x	Jet transport pilot
131x	Jet reconnaissance pilot
131x	Prop electronic warfare pilot
131x	Prop air early warning pilot
131x	Prop antisubmarine warfare pilot
131x	Prop utility pilot
131x	Helo antisubmarine warfare pilot
131x	Helo combat pilot
132x	Naval flight officer
132x	Jet medium attack NFO
132x	Jet fighter NFO
132x	Jet electronic warfare NFO
132x	Jet antisubmarine warfare NFO
132x	Jet reconnaissance NFO
132x	Prop electronic warfare NFO
132x	Prop air early warning NFO
132x	Prop antisubmarine warfare NFO
Any	Public affairs
Any	Intelligence
Any	Strategic planning
Any	Management
Any	Applied logic
Any	Operations systems technology
Any	Environmental science
Any	Systems engineering
Any	Weapons engineering
Any	Aeronautical engineering
Any	Communications
Any	Computer technology

Table 2 shows a sample NAUP distribution for the commander grade and shore staffs composite. For this subset of skills, the user did not request skill substitution or skill priority overrides. Table 2 includes four designator-defined skills and two subspecialty skill categories. Note that both assets columns (available and unused) contain some double counts of officers. An officer who has two of the skills shown in the table may be counted as an asset for each. For instance, he or she may be both a surface warfare officer (designator 111x) and a management subspecialist. In most cases, the fill in the subspecialty is constrained by either the authorized billets or the available assets. However, in the management subspecialty category, neither situation is the case and a tradeoff has been made. The 207th officer in the sample run is a submarine warfare officer, and as the fill in that skill category is very low, the officer is distributed to the 1120 category and not the management category. Because the use of a personnel asset in one skill disallows the use of that asset in any other skill group, the unused assets column is not the difference between the total authorizations and available assets. Instead, it contains the double counts of assets remaining after all possible skill group fills are made. Table 3 shows the results of including in the sample data base the 1000/1050 authorized billets that are filled primarily from other skill populations. This example shows NAUP's skill substitution capabilities. As shown in Table 3, all previously unused assets have been distributed. Furthermore, the 1000 billets are filled almost entirely with officers from other skill categories. Although the contributing skill categories are still well manned, a skill priority override could be used to keep assets from flowing from a given category into the general skill group. A category that has not reached the desired minimum fill is not allowed to give up assets for skill substitution purposes. For example, 1120 skill assets may not be used to fill 1000/1050 billets. The major allocation questions that should be posed, given the billet-officer scenario in Table 3, are: (1) Could assets from one of the other skill categories be substituted into this poorly manned skill? or (2) Could upward grade substitution ameliorate the apparent shortage?

Table 2

NAUP Sample Run Without Skill Substitution
(Commander, Shore Staffs)

Skill	Total Authori- zations	Avail. Assets	Total Fill	Unused Assets	Billet Fill %
1110	201	376	201	82	100
1120	81	15	15	0	19
1310	53	158	53	105	100
1320	5	44	5	39	100
Management	272	207	206	0	76
Computer	44	47	44	1	100
Total	656	750	524	226	80

Table 3

NAUP Sample Run Allowing Skill Substitution
(Commander, Shore Staffs)

Skill	Total Authori- zations	Avail. Assets	Total Fill	Unused Assets	Billet Fill %
1000	265	19	208	0	78
1050	65	66	56	0	86
1110	201	376	185	0	92
1120	81	15	15	0	19
1310	53	158	51	0	96
1320	5	44	5	0	100
Management	272	207	190	0	70
Computer	44	47	40	0	91
Total	986	750	750	0	76

Besides skill substitution capability and skill priority overrides, NAUP permits the user to allow upward grade substitution, to fill authorizations with "unused" assets from the grade below. The higher grade billet vacancies are filled from lower grade unused assets first, then the higher grade skill assets are distributed.[3]

NAUP can be readily adapted to a variety of relatively simple improvements. Skill substitution matrices and priorities can be varied for each grade. The junior officer grades can be combined. Special treatment of training designators in the algorithm can also be designed. Appendix B gives an in-depth mathematical description of the NAUP.

Allocation to Composite

NAUP produces a personnel inventory by grade and skill category. Next, this one-skill inventory is distributed to composites (see Table 4).

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[3] NAUP also accepts specifically designated types of billets and personnel categories, such as transients, patients, students, and detainees (TPS&D) inventory and excepted billets, which are billets by grade and skill category that must be filled regardless of fill goal considerations (e.g., commanding officer billets). TPS&D, a nondistributable inventory, cannot be assessed with respect to the fill goal, but must be included in inventory totals passed through the system.

Table 4

Prototype Composites

Composite	Description
Ships	Amphibious, cruiser/destroyer, carrier, and submarine forces, special warfare, special operations.
Instruction	Aviation and nuclear power instruction, recruiting, USNA/ROTC/OCS, and JCS/OSD/international staffs.
Squadrons	Jet, prop, and helicopter squadrons.
Afloat staffs	Afloat staffs.
Shore staffs	OPNAV/SECNAV, joint staffs, defense agencies, fleet CINCS/TYCOMS, MAAGS/missions, material command, NMPC, selected functional training staffs, and War College/Post-graduate School.
Other activities	CONUS staffs, reserve support, base operating support, etc.

The algorithm that performs this distribution is the Navy personnel allocation model (NPAM). Like NAUP, it is based on a distribution procedure used by the Army (Reeves, 1980). Officers are distributed to composites based on the number of authorized billets, nonrotating inventory (inventory on-board), and priority classification of each composite (see Figure 2.).
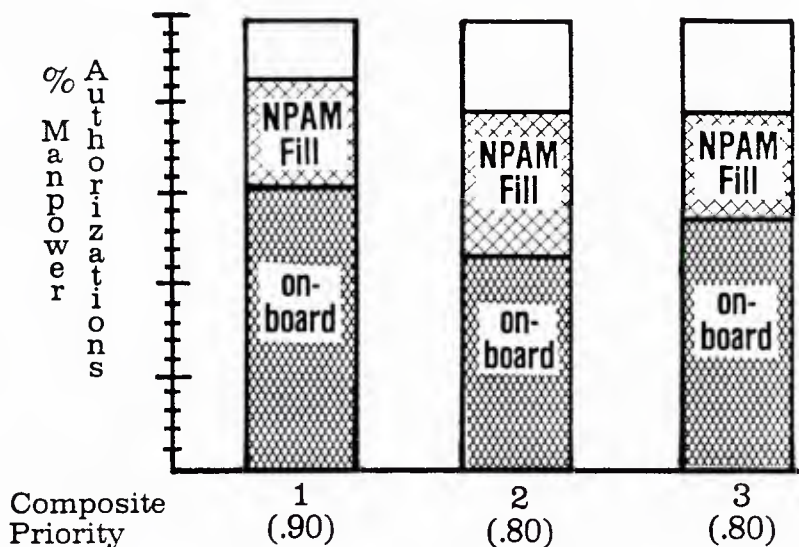

Figure 2. Illustration of the Navy personnel allocation model (NPAM).

The model distributes officers by grade and skill category and by CNO manning priority weights. The officer distribution is bound below by the officer levels projected to be already on-board in each composite, and above by the number of composite billets. (In the prototype, each composite is identified with a CNO manning priority.)

The officer share allocated to each composite is proportional to the CNO manning priority weight times the number of authorized composite billets. This share represents the importance of each composite's billets in relation to total authorized billets. The number of officers distributed to a composite is computed by multiplying this fraction by the total officer inventory. Thus,

$$IA(i) = \frac{Pri(i) * Auth(i)}{Pri(1)*Auth(1)+...+Pri(n)*Auth(n)} * Total\ Inventory$$

where
- $IA(i)$ is the inventory allocated to composite i,
- $Pri(i)$ is the priority weight of composite i, and
- $Auth(i)$ is the number of authorized billets in composite i.
- n is the number of composites.

Table 5, taken from Cass (1984), gives the percentage manning attained by five priority defined composites of equal size; these percentages are derived from the NPAM formula. Table 6 illustrates a sample NPAM allocation for the surface warfare (1110) skill community.

Table 5

Sample NPAM Prioritized Manning Percentages
(Inventory/Billets)

Overall Force Manning %	Priority Levels and Weights				
	1 1.00	2 0.95	3 0.90	4 0.85	5 0.80
100	100	100	100	100	100
95	100	100	97	92	86
90	100	95	90	85	80
85	94	89	85	80	75
80	90	86	81	76	71
75	83	79	75	71	66

Table 6

Sample NPAM Personnel Allocation
(Surface Warfare, All Grades)

| Grade | Ships | Composite | | | | |
		Instruction	Squadrons	Afloat Staffs	Shore Staffs	Other
ENS	905	0	0	1	0	9
LTJG	1358	9	0	10	7	39
LT	778	268	0	81	181	212
LCDR	375	57	0	108	229	142
CDR	320	30	0	53	201	83
CAPT	39	18	0	61	72	22
Total	3775	382	0	314	690	507
Weight	(1.00)	(1.00)	(0.97)	(0.96)	(0.90)	(0.71)

Weights correspond to the CNO manning priorities for each of the selected composites. The CNO manning priority for ships is 105 percent. Since NPAM cannot distribute personnel to a composite at a level exceeding the number of authorized billets, the ships composite's billets were overstated by 5 percent to compensate.

As shown in Table 7, NPAM achieves its allocation goals by using the authorized billets upper bound, the on-board inventory lower bound, and NPAM personnel allocations, in this case, for the captains in the data sample. The CNO manning priority weight is shown in Table 7, along with the manning percentages computed from the model distribution.

If the inventory allocated is less than the on-board inventory constraint for a composite, then the composite must be removed from NPAM distribution evaluation. The composite will be allocated its on-board inventory, and officer distribution levels to the other composites will be recalculated, using the officers not already absorbed into the "over-manned" composite.

NPAM can also allocate personnel excesses across grades. For example, if the number of ensigns or lieutenants junior grade exceeds total authorized billets for that grade-skill combination, the user may prompt the model to look at total authorized billets across all grades and to distribute grade excesses according to each composite's share of skill resources. Appendix C explains the allocation of personnel excesses and the method for adapting the NPAM formula to meet on-board and total billet constraints.

NPAM is the final step of the entire projection-allocation process. The result is an officer allocation plan by grade and skill for each composite.

Table 7

Sample NPAM Personnel Distribution
Surface Warfare, Captains

	Composite					
	Ships	Instruction	Squadrons	Afloat Staffs	Shore Staffs	Other
Weight	1.00	1.00	0.97	0.96	0.90	0.71
Billet authorization	39	19	0	66	84	32
NPAM distribution	39	18	0	61	72	22
On-board personnel	39	13	0	49	43	18
Manning (%)	100	95	--	92	86	69

In the prototype, the composites correspond to manning priority categories. When the composites chosen for use in the model cut across CNO priority lines, NPAM still allocates inventory by these priority weights. Under these circumstances, additional accounting measures must be built into ODPROJ, so that activities that fall within the same composites but that have different priorities can be combined.

CONCLUSIONS AND FUTURE PLANS

The ODPROJ model will be a first step towards the development of an automated officer distribution management system (ODMS--see Appendix A). ODPROJ methodologies are designed to provide NMPC with essential distribution planning information, including billet projections, officer inventory projections, and an aggregate allocation of available officers to billet vacancies.

Final development and implementation will be made in conjunction with NMPC users. NMPC testing of the ODPROJ prototype will initiate necessary model refinements and modifications. Testing should identify required changes to skill category or composite definitions, or to the composite weights that affect the officer allocations.

A companion allocation monitoring system is also planned to provide assignment information updates to ODPROJ and track the achievement of allocation goals.

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APPENDIX A

THE OFFICER DISTRIBUTION MANAGEMENT SYSTEM

The proposed automated officer distribution management system (ODMS) would support the major distribution functions of allocation control, manning control, and assignment control. Allocation control distributes projected officer resources into groups of Navy units called composites,[4] ranked according to CNO priorities. Manning control determines the skill, grade, and quantity of personnel to be distributed to individual units according to billet priorities. While allocation control and manning control functions involve the distribution of aggregate groups of officer resources, assignment control nominates individual officers to specific billets.

Figure A-1 summarizes a six-module officer distribution system that parallels the current and planned enlisted system. The ODPROJ module supports the allocation control function. It projects officer inventory and billets for a target distribution window (i.e., 10-14 months) and allocates rotating officers to composites according to skill, grade, and CNO manning priorities.

The projected inventory, now distributed by composite, is input to the officer manning plan (OMP II) module. OMP II further distributes composite personnel to the unit level. The officer control authorities (OCAs)[5] give priorities to billets at the unit level and, therefore, control the detailed personnel distribution.

The allocation plan produced by OMP II is input to the officer personnel requisition system (OPRES) module along with near-term, deterministic (i.e., 3 month) projections of available officers and authorized billets. From this information, OPRES computes job vacancies or "postings" that need to be filled by the available inventory. Postings feed into the officer personnel allocation and nomination system (OPANS) which nominates distributable officers to billets. Postings also feed into the officer assignment information system (OAIS), which allows assignment and placement officers access to the full range of distribution planning information.

The Monitor module, also shown in Figure A-1, provides an important feedback and report writing link to the distribution system. As officer assignments are made, Monitor collects transaction data from OAIS. It prepares multilevel reports and directs updated assignment information back into ODPROJ. Thus, sequential iterations of allocation plan development take account of assignments. If assignments are made that do not conform to the plan, subsequent plans are revised based on updated manning information.

Aside from OAIS, which is already operational in several URL communities, the development of an automated officer distribution system depends most heavily on the officer projection-allocation function performed in ODPROJ.

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[4] In the prototype, composites are aggregates of units with the same CNO manning priority. These are ships, instruction, squadrons, afloat staffs, shore staffs, and other activities (see Table 4 in the body of this report).

[5] The six officer control authorities are CINCPACFLT, CINCLANTFLT, NAVMAT, NMPC, CNET, and NAVRES.
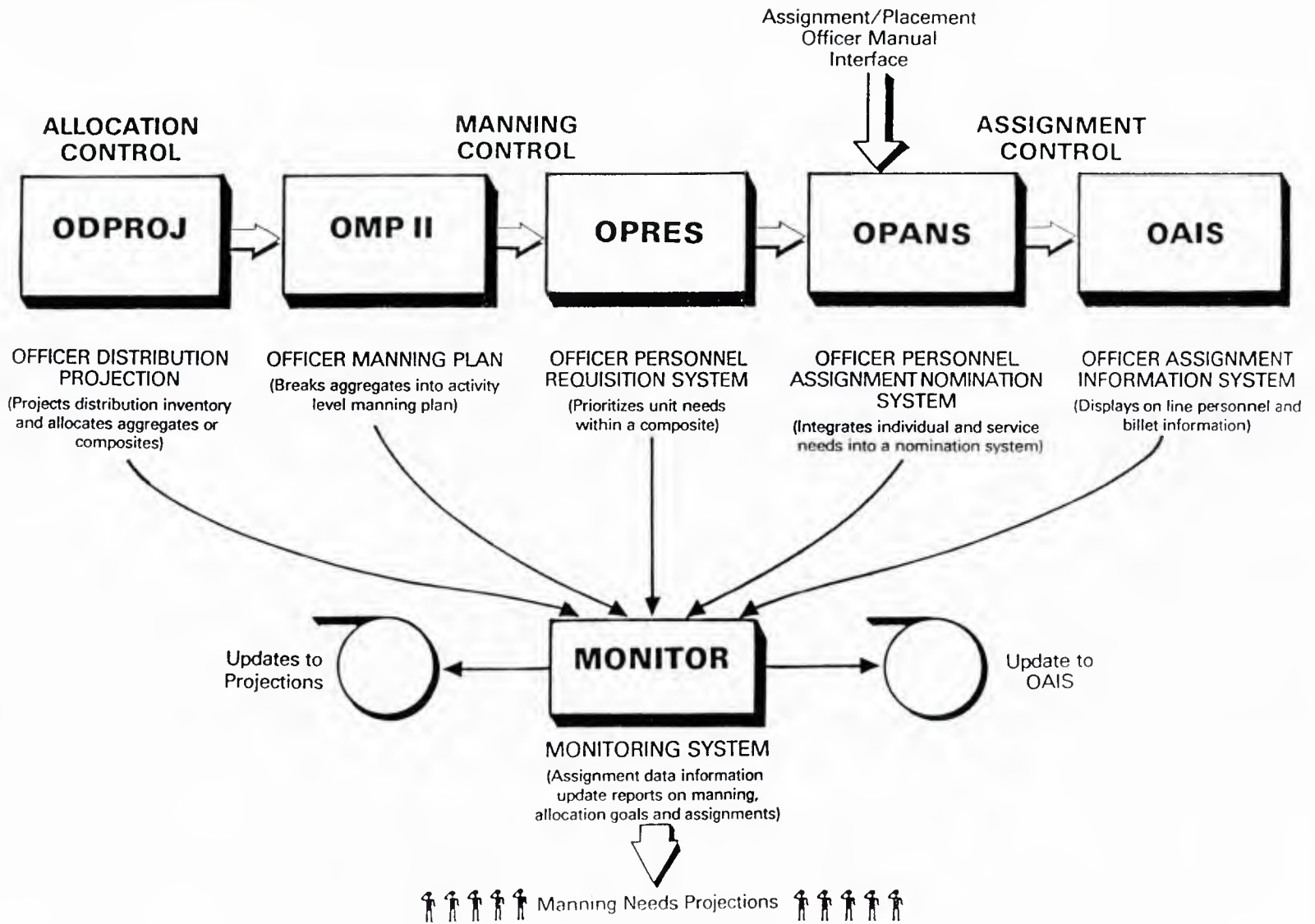
Assignment/Placement
Officer Manual
Interface

**ALLOCATION
CONTROL**

**MANNING
CONTROL**

**ASSIGNMENT
CONTROL**

ODPROJ	OMP II	OPRES	OPANS	OAIS

OFFICER DISTRIBUTION
PROJECTION

(Projects distribution inventory
and allocates aggregates or
composites)

OFFICER MANNING PLAN

(Breaks aggregates into activity
level manning plan)

OFFICER PERSONNEL
REQUISITION SYSTEM

(Prioritizes unit needs
within a composite)

OFFICER PERSONNEL
ASSIGNMENT NOMINATION
SYSTEM

(Integrates individual and service
needs into a nomination system)

OFFICER ASSIGNMENT
INFORMATION SYSTEM

(Displays on line personnel and
billet information)

Updates to
Projections

MONITOR

Update to
OAIS

MONITORING SYSTEM

(Assignment data information
update reports on manning,
allocation goals and assignments)

↟↟↟↟↟ Manning Needs Projections ↟↟↟↟↟

Figure A-1. Officer distribution management system.

APPENDIX B

THE NAVY ASSET UTILIZATION PROGRAM (NAUP)

The Navy asset utilization program (NAUP) is a mathematical procedure used to allocate multiskilled officers to the single skill category where they are most needed to fill billets. In lieu of being used in his or her primary or secondary skill, an officer may also be used to fill a billet with less specific skill requirements by a process called substitution. Drawing from billet vacancy data, the available two-skill officer inventory, and the rules for allowable substitutions, NAUP performs an allocation of officers to billet skills.

Data Requirements

Inventory are allocated to skills for one pay grade at a time, with the option of allocating for all grades in succession from ensign (0-1) to captain (0-6). For each grade, the algorithm uses the following input files:

1. Inventory of avails (officers available for reallocation) arrayed by primary and secondary skill.

2. Total officer billets arrayed by skill.

3. Vacant officer billets arrayed by skill.

4. Minimal manning percentages--a user-specified minimum percentage of billets to be filled in each skill. Default value is 50 percent for each skill.

5. Table of substitutable skills--a user-specified table showing the officer skills that can be used to fill each billet skill.

6. Grade substitution parameter--when the model produces allocations for all six grades in succession, there is an option to allow excess inventory in a specified grade to fill positions in the grade above. To do so, the user sets the substitution parameter for the higher grade equal to 1.

Skill Matching Procedure

Before matching the population of rotating officers to vacant billets, it is necessary to account for the officers who are currently assigned to a billet and will not rotate during the period under consideration. These nonrotating officers are treated as having only one skill, that of the billet which they now occupy. The nonrotating population is computed for each skill by subtracting vacant billets from total billets. The step of the program that allocates this population is called nondiscretionary fill.

After the nondiscretionary fill, the program passes to the normal fill stage. A criticality factor is used to determine which skill requires personnel. The factor is calculated for each skill from three measures: (1) the number of billets already filled in the skill (Fill), (2) the total number of billets for the skill (Billet), and (3) the remaining unallocated inventory in the skill (Invrem). The formula is

$$\text{Criticality} = \text{Invrem} \times \text{Fill} / (\text{Billet} - \text{Fill})^2$$

NAUP calculates the criticality factor for all skills and allocates personnel to the skill with the smallest factor. We can get a better idea of how the criticality formula works by rewriting it as

$$\text{Criticality} = \frac{\text{Invrem}}{(\text{Billet} - \text{Fill})} \text{ X } \frac{\text{Fill}}{(\text{Billet} - \text{Fill})}$$

The term to the immediate right of the equal sign is the ratio of remaining inventory to remaining vacancies. As this gets smaller, the criticality factor gets smaller, reflecting the fact that it will be more difficult to fill the remaining vacancies with a relatively small number of remaining personnel. The term on the far right will be small, yielding a small criticality factor, whenever Fill is small relative to Billet.

When an officer is allocated to a skill, the officer's other skill can not be used, and the Invrem of both skills decreases by one. Therefore, each skill's criticality depends on the fill it has received and on the amount of inventory it has lost to other skills. To analyze this aspect of the criticality factor, we look at the variables as fractions of Billet. We define

M = Maximum Potential Fill

= (Invrem + Fill) / (Billet)

and

p = fraction of billets filled

= Fill / Billet

The criticality factor can now be written

$$\text{Criticality} = (Mp - p^2) / (1 - p)^2$$

This function is graphed in Figure B-1 as a function of p for several fixed values of M.

As the algorithm operates, when a skill gets a fill, its value of p increases while M remains constant, resulting in a move to the right along the appropriate criticality curve. When the skill loses inventory to another skill, M decreases and p remains constant, resulting in a downward vertical move to a new curve with a lower M value. Hence, losing inventory always causes a skill's criticality to decrease, while getting a fill generally (except when Invrem is nearly exhausted) causes the factor to increase.

When Invrem equals 0 for some skill A, criticality also equals 0. However, a fill cannot be made at this point because skill A has no remaining inventory. If no skills can substitute for skill A, then it has reached its maximum fill and is ignored in the remainder of the algorithm. If substitutable inventory exists, a surrogate criticality factor for skill A is calculated in place of the one defined above. The same formula is used, but the values for Invrem, Fill, and Billet are the sum of these values for skill A and all of its possible substitutes. The surrogate criticality factor is compared with criticality factors for other skills and, if it is the smallest, a skill A billet is filled by substitution.

To fill billets in the most critical skill (e.g., skill A), an officer must be selected from some skill pair. If Invrem > 0 in skill A, a search is made for the least critical other skill B which is paired with it, and up to three officers (fewer if the inventory is insufficient) are assigned from pair (A, B) to billet skill A.

FIG B−1: NAUP CRITICALITY FUNCTION
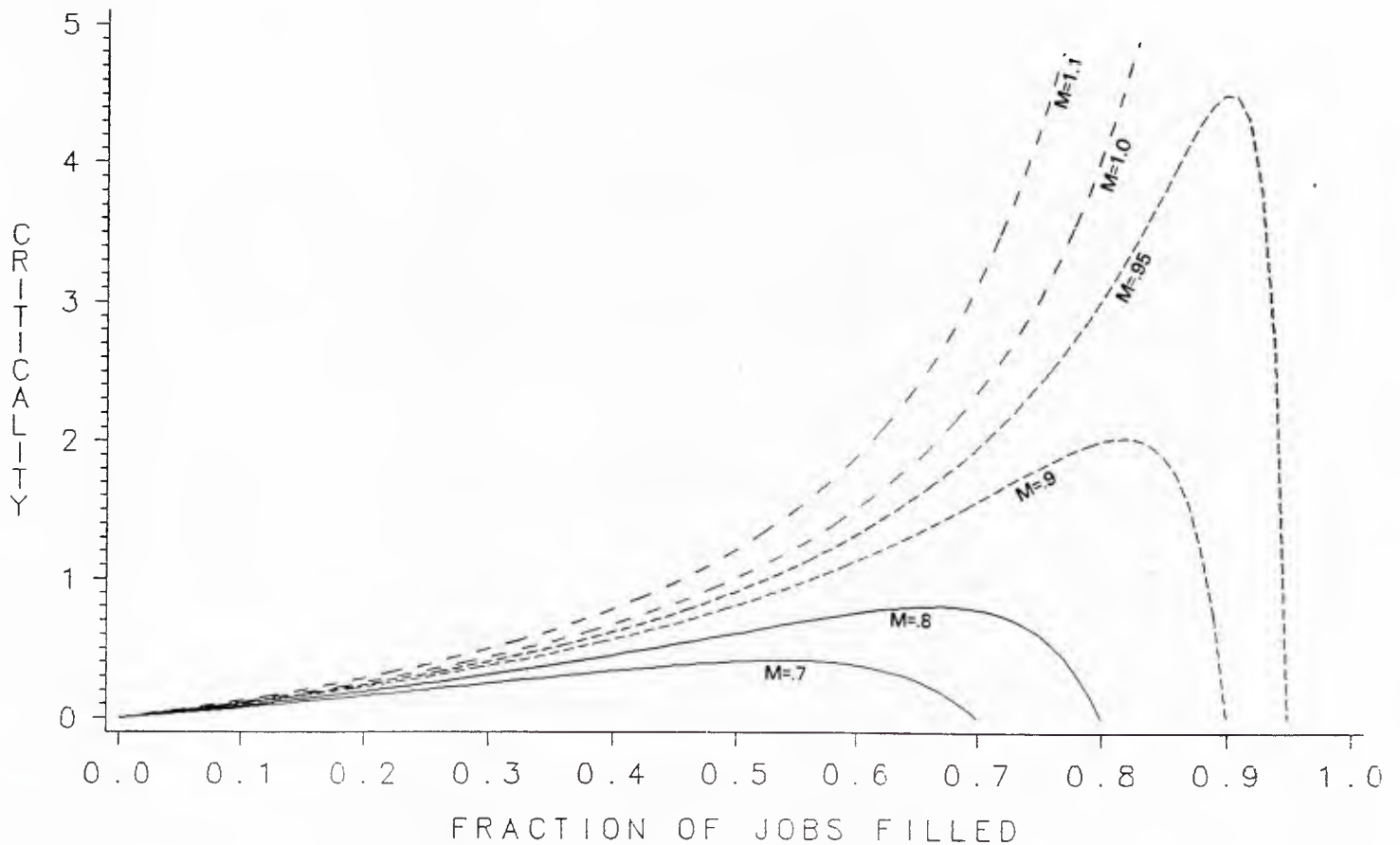
M=MAXIMUM POTENTIAL FILL

Figure B-1. NAUP criticality function.

When Invrem = 0 for skill A, substitution must be used to fill the billet. The least critical substitutable skill, say skill B, is used to make the fill. To get an inventory skill pair, a search is made for the least critical skill paired with skill B (e.g., skill C). Up to three people are then allocated into skill A billets from inventory pair (B, C).

The normal fill procedure fills each skill to roughly the same percentage as the ratio of grade inventory to grade billets, the grade average. However, the user may specify that certain important skills attain a minimum percentage fill higher than the grade average. To attain the user-specified minima while still driving the other skills toward the grade fill, the normal fill stage of the NAUP performs a three-step fill procedure:

Step 1. The most critical skills below the minimum manning target are filled.

Step 2. When no further fills can be made in Step 1, the most critical skills of those below grade average are filled.

Step 3. After all possible Step 2 fills are made, any remaining officers are placed into the most critical skills.

The three-step process is designed to avoid filling skills already manned above a fill target at the expense of those below it.

After the three steps of normal fill are completed, all personnel who can be matched to a job will have been allocated. A final program stage, called convergence fill, works to smooth the level of manning across skills. The algorithm searches for the most poorly manned skill, say skill X. If an officer with skills X and Y was assigned in the normal fill to a billet of type Y, and Y is manned at a high level, then the officer is reassigned and used in skill X. The convergence fill is the last stage in the NAUP allocation of officers to a single skill category.

Model Output

NAUP writes three reports which contain statistics on officer skill utilization:

(1) The fill synopsis report summarizes the total number of billets filled and each skill's fill percentage. The report is written after each allocation step (nondiscretionary fill, the three normal fill steps, and convergence fill).

(2) The authorizations and assets report contains statistics on the final allocation for each skill, including total billets, initial inventory, minimum fill requirement, billets filled and unused inventory.

(3) The asset utilization report is a matrix showing the number of rotating officers with each skill, broken down by the billet skills in which they were utilized. The number of officers with skill type A used to fill billets of skill type B is found at the intersection of the A row and B column of the report matrix.

APPENDIX C

THE NAVY PERSONNEL ALLOCATION MODEL (NPAM)

The Navy personnel allocation model (NPAM) is used to allocate officer personnel to groups of billets called composites. The composites are mutually exclusive groups made up of all billets which share a common fill priority, represented by a priority factor or weight. The algorithm allocates officer inventory by grade and skill category to billets specified by grade, skill, and priority. Both composite priorities and nonrotating composite inventory (onboard manning) constrain the model allocation.

Data Requirements

In order to perform an allocation, the NPAM uses the following information about billets, inventory, and priorities:

1. The total number of officers by grade and skill. This is generally obtained from NAUP.

2. The number of on-board (i.e., nonrotating) officers, by grade, skill, and billet priority category (composite).

3. Total number of authorized billets, by grade, skill, and priority category (composite).

4. Priority factors or weights. One nonnegative weight is assigned to each priority category. This weight represents the level of fill desired in each category relative to other categories. The following section explains how the model uses these weights.

Allocation Methodology

The algorithm works on one skill at a time and one grade at a time within that skill. When the number of priority categories is N, then NPAM allocates the skill-grade inventory to billets in composite k using the following formula:
(allocation of skill/grade inventory to priority k billets) =

$$\frac{\text{Inventory} * \text{Weight}(k) * \text{Billet}(k)}{\text{Weight}(1) * \text{Billet}(1) + \ldots + \text{Weight}(N) * \text{Billet}(N)}$$

where Billet(i) is the number of composite i billets for that skill/grade,
Weight(i) > 0 is the priority weight for composite i, and
Inventory is the total skill/grade inventory.

The meaning of the weights is better understood by examining a simple example. If composite 1 has a priority weight of 0.9, and composite 2 has a weight of 0.8, then the NPAM formula allocates inventory so that the percentage of billets filled in composite 1 is always nine eighths of the percentage fill in composite 2. Thus, depending on the amount of inventory available, the percentage fill levels might be 90 percent and 80 percent, or 99 percent and 88 percent, or some other values in the ratio of nine to eight.

This formula is a starting point in determining an allocation of officers, but there are instances when the formula allocation is not feasible. For example, it is possible for the formula to allocate more people to a composite than the number of authorized billets in that composite. In this case, NPAM must adjust the allocation so that it is no larger than the number of billets. Also, nonrotating personnel must be allocated to their current

composite. Formula allocations that fall short of onboard manning must be adjusted upward to equal or exceed these levels.

Sometimes, the officer inventory in a skill-grade category may exceed billets (especially in junior grades). In this case, NPAM can allocate inventory to each composite at or above its authorized level, using a special procedure to determine an allocation for the "excess" officers.

NPAM Fill Algorithm

To make the allocations feasible, the model uses a more complex algorithm that produces trial allocations from the basic formula and gradually modifies them to conform to allocation constraints. Each modified allocation is produced by fixing values for certain composites and applying the formula to the remaining composites. This process of successive formula recalculations is described below, beginning with the more usual case in which inventory of personnel in the grade or skill is less than the number of corresponding billets.

A modified NPAM process prevents allocations to a composite from exceeding authorized billets. Before beginning this procedure, the composites must be reordered according to their priority weights, with composite 1 having the largest weight. To start, the model applies the basic formula, and if each composite receives a calculated allocation less than its authorized billets, then the allocation is feasible. Suppose, however, that the first k composites (i.e., the k highest priority composites) each receive a formula fill exceeding the total number of composite authorized billets. NPAM then recalculates the allocation by (a) setting allocations equal to the total number of billets in composites 1, 2, ...k; and (b) using the formula to compute an additional allocation of the remaining inventory to composites k + 1, ...N. The additional allocation may in turn cause composites k + 1, k + 2, etc. to have an allocation greater than their authorized billets so that the modified process must be repeated for the subset of composites k + 1, k + 2, ...N. This process is illustrated below for an example with k = 2 and N = 5. The formula allocates more officers to composites 1 and 2 than there are billets to fill, so their allocation is cut to total authorized billets. The number of officers released by the cut are reallocated to composites 3, 4, and 5, using only the weights and billets of those three composites in the NPAM formula. Figure C-1 shows the results of the initial allocation and the reallocation step. Note that composite 3 is now manned above its billet total, and so a third allocation must be done, setting composite 3 fill to total authorized billets and reallocating the released officers to composites 4 and 5.
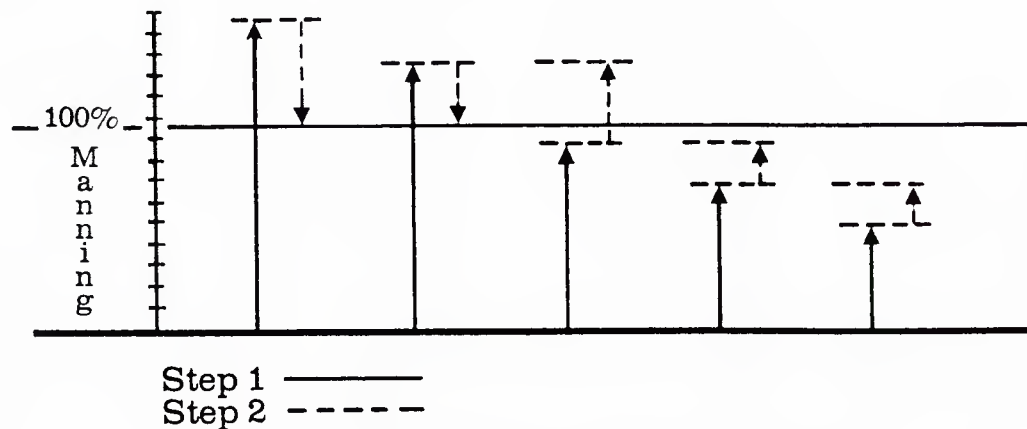

Figure C-1. Reallocation to avoid overmanning.

Using this procedure, officers are allocated so that all composites are manned at or below total authorized billets and many of the properties of the original NPAM formula are still in force. For example, for any two composites manned below the total billet level, the ratio of their manning percentages is equal to the ratio of their priority weights.

NPAM officer allocations must always equal or exceed projected on-board manning levels. So, while executing the procedure described above, all composite allocations are compared to their respective on-board manning levels. When a composite allocation is less than the on-board manning level, the allocation to the composite is permanently set equal to its on-board manning. This composite, say composite j, is permanently removed from the formula, and the inventory in j is subtracted from the inventory to be allocated. The procedure is then restarted from the beginning with one less composite then before. If another allocation is below the on-board manning level, another composite is removed and the algorithm starts again. Using this iterative process, a final allocation is obtained for each skill and grade, with all manning levels bounded between on-board levels and authorized billets. Any two composites having (on-boards < allocation < total authorized billets) will have manning percentage ratios equal to the ratio of their priority weights.

When the skill-grade inventory exceeds the number of corresponding authorized billets, NPAM temporarily allocates enough officers to fill all billets in each composite and holds back the "excess" inventory. It allocates officers to the remaining grades in that skill before resolving the allocation of the excesses.

When all grades have been allocated and there is excess inventory for one or more grades, NPAM calculates a total allocation for the entire skill (i.e., for inventory and billets combined across all grades). Each composite's total allocation must equal or exceed the sum of allocations previously made to individual grades. NPAM subtracts the previous grade level allocations from the total allocation to get the number of excess officers to be allocated to each composite. Each composite's allocation of excesses is shared fairly across grade. If composite 1 is allocated 25 percent of the excesses, NPAM gives it 25 percent of the 0-1 excesses, 25 percent of the 0-2 excesses, etc. (see Table C-1).

In Table C-1, there is excess inventory in the ensign grade. In Step 1, NPAM allocates officers to grades not in excess (0-2 through 0-6) and fills total authorized billets in the excess grade (0-1). Then, using authorized billets and inventory for the entire skill the model computes the total allocation (Step 2). For each composite, NPAM constrains the total allocation to equal or exceed the Step 1 personnel distribution. NPAM determines the distribution of the excess ensigns by subtracting the Step 1 allocation from the Step 2 total allocation.

Table C-1

NPAM Distribution of Inventory that Exceeds Authorizations

Grade	Composite				
	1	2	3	Total	
ENS	(7)	(5)	(3)	15	--> grade excess = 5
LTJG	10	10	10	30	
LT	10	15	5	30	
LCDR	10	5	10	25	Step 1
CDR	5	10	5	20	
CAPT	5	5	5	15	
Dist. from 0-1 through 0-6	47	50	38	135	
NPAM Dist. over entire skill	50	50	40	140	Step 2
Dist. of ENS excess	3	0	2	5	Step 3 (Step 2 - Step 1)

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