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Bausch, Dan O.; Brown, Gerald G.; Hundley, Danny; Rapp, Stephen; Rosenthal, Richard E.

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Mobilizing Marine Corps Officers

Dan O. Bausch — *Insight, Incorporated, Bend, Oregon 97709-1609*

Gerald G. Brown — *Operations Research Department, Naval Postgraduate School, Monterey, California 93943*

Danny R. Hundley — *United States Marine Corps, Washington, DC 20380*

Stephen H. Rapp — *United States Marine Corps, Naval Postgraduate School*

Richard E. Rosenthal — *Operations Research Department, Naval Postgraduate School*

The ability to rapidly mobilize the Marine Corps in times of crisis is a cornerstone of United States defense strategy. To mobilize rapidly, the marines need an efficient system for assigning officers to mobilization billets. The system we designed and built is based on a network optimization algorithm that works in conjunction with carefully designed and scrupulously maintained Marine Corps data bases. It takes less than 10 minutes on a 386-based personal computer to complete a mobilization involving 40,000 officers and 27,000 billets and to produce output suitable for generating orders to report via *MAILGRAM*. Prior to our work, the Marine Corps had a mainframe-based system that took two to four days to complete a mobilization. The new system is not only much faster than the old system, but it also produces significantly better assignments with respect to all measures of effectiveness considered.

You'll find us rough, sir, but you'll find us ready.—Charles Dickens, *David Copperfield*

Almost all of the United States' contingency plans for responding with force to international crises involve rapid deployment of the marines in the earliest phases of action. The marines may be called upon to seize and hold a strategic geographic location or to negate a specific enemy asset. The exact mission will depend on the nature of the crisis, but in any case, it is essential for national security

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MILITARY APPLICATIONS—MANPOWER
OPTIMIZATION—NETWORKS

that the Marine Corps be able to rapidly mobilize its personnel from peacetime to wartime duties. We designed and built a system to assign marine officers appropriate duty assignments—or billets—during a crisis mobilization.

The officer assignment branch at Marine Corps headquarters is responsible for providing officers to billets if a mobilization occurs. The branch spends most of its time assigning officers' peacetime billets, but it occasionally engages in mobilization assignment exercises. In these exercises, a hypothetical crisis scenario is assumed, and the branch is supposed to go as far as printing (but not sending) *MAILGRAM* orders to report for officers to fill the required mobilization billets. The branch studies the time it takes to finish the exercise and evaluates the quality of the resulting officer assignments. The branch concluded from past performance that improvements were needed.

Problem Objectives

Since the officer assignment branch spends most of its time on peacetime billets and we are concerned here with mobilization billets, we will explain the differences between the two.

First of all, problem size and urgency differ greatly. In peacetime, active-duty marine officers receive new assignments about once every three years; whereas, during mobilization, all active-duty, reserve, and retired officers are eligible for immediate reassignment. In the words of the branch chief, mobilization requires "years' worth of work in a matter of days."

Secondly, the peacetime and mobilization assignment problems have different measures of effectiveness. In peacetime, the officer's career development and professional desires are major considerations. Each officer should amass a collection of skills and experiences that enhance the Marine Corps' long-term effectiveness. During mobilization, the marines' purpose is much more straightforward: just fill the required billets with the best possible officers. In the urgency of mobilization, we can ignore officer development considerations. But we must carefully examine the skills officers currently possess and determine how and where they can best be deployed in the present crisis.

We address the officer mobilization problem with an optimization model that combines three objectives:

(1) Maximize fill, that is, maximize the number of billets filled by officers with acceptable (or better) qualifications.

(2) Maximize fit, that is, attempt to fill billets with officers whose qualifications are not merely acceptable but come as close as possible to fitting the billets perfectly.

(3) Minimize turbulence, that is, try to keep officers assigned to the same unit they were assigned to before mobilization, or, failing that, try to have them reassigned to a nearby unit.

Our ability to model and measure these criteria varies. The *fill* criterion is defined simply as the percentage of billets filled, so it is easily measured. The *fit* criterion is subjective and requires an approximate model based on several criteria for matching officers to billets, including grade, sex, special training, and status (active, reserve, or retired). Turbulence is a lower priority criterion than fit or fill but is still very important. We define *turbulence* as the percentage of assigned officers whose mobilization billet requires them to report to a unit more than 100 miles away from their current assignment.

Previous Mobilization Methods

Prior to our work, the only tool the marines had to help with mobilization assignment was the officer staffing goal model (OSGM) [Decision Systems Associates 1983]. OSGM was designed to provide peacetime staffing targets. When it was created, it was not intended to provide mobilization assignments. Even so, the marines relied on it in mobilization exercises for many years.

The marines had several reasons for wanting a better mobilization system than OSGM:

(1) Solution quality: OSGM focuses on peacetime factors that are irrelevant for mobilization and ignores things that are important, such as turbulence. Optimization (with a focus on mobilization issues) should produce better solutions.

(2) Timeliness: At the time our project was undertaken, it took two to four days to complete a mobilization assignment exercise with OSGM. This was largely due to the fact that OSGM has to be run on a remote, leased computer. Undoubtedly, the marines would like to be able to try several model runs before committing to action, so fast turn-around is important.

(3) Cost: The marines spend a great deal for external execution and maintenance of OSGM. Because the OSGM is written in machine-specific code for a 1970s vintage Cyber computer, it is very expensive to maintain and not transportable to more modern computers. Our in-house model residing on a personal computer is much cheaper to execute and maintain, and it has already been transported effortlessly between computing platforms.

(4) Reliability: A mobilization system must work on the first try.

The marines asked the Naval Postgraduate School to develop an improved system, first as a masters' thesis [Rapp 1987] and then as a faculty research project (Brown and Rosenthal). We decided to take advantage of the 386-based personal computers that we had recently demonstrated to be capable of large-scale optimization and to exploit the suite of optimization software that was installed in the 80386 environment for this purpose [Bausch and Brown 1988].

The military has made use of optimization modeling for manpower planning in other instances, [Gass et al. 1988; Grinold and Marshall 1977; Klingman, Mead, and Phillips 1984; Klingman and Phillips 1984; Liang and Buclatin 1988; and Liang and Thompson 1987]. As far as we know, we are the first to specifically address officer assignment during mobilization.

Data and Terminology

Two files are crucial for our work. The wartime officer slate file (WOSF) contains detailed information on every officer. The wartime authorized strength report (WASR) describes every wartime billet for a mobilization scenario. Several versions of WASR are maintained for various war plans. The quick-response mobilization system crucially depends upon the Marine Corps's commitment to sustained, in-house maintenance of the WOSF and WASR data bases (Tables 1 and 2).

We explain special terms below:

A *monitor command code* (MCC) designates the unit of a particular officer billet.

A *military occupational specialty* (MOS) is a four-digit code representing an area of expertise that requires specialized qualification and training. Some officers have earned a *primary MOS* (PMOS) plus one or two *additional MOS*'s (AMOS).

A few of the MOS's in WOSF are catch-all codes for officers whose specialties are outdated. Similarly, some of the billets do not require special expertise and are coded with an imprecise MOS. We refer to these unspecialized billets as *generalized billets* and the others as *regular billets*. Some generalized billets are partially specialized in that they are restricted to ground officers or aviators.

The *staffing priority level* (SPL) of a wartime billet indicates its priority. The higher the SPL, the more crucial it is to fill the billet with an officer of the right fit.

The grades included in WOSF and WASR are warrant officers through colonels. Generals are omitted because their billets are preassigned.

Conceptual Network Model

Figure 1 shows a network model in which each officer in WOSF is represented by a node on the left-hand side and each billet in WASR is represented by a node on the right-hand side. In this conceptual network, the officer nodes have a supply of one and the billet nodes have a demand equal to the number of officers required.

If an officer is eligible for a billet, a directed arc connects the corresponding officer and billet nodes. Eligibility depends on the input data (Tables 1 and 2) and on numerous Marine Corps rules and policies (for example, no retired officers wanted in combat billets, no grade substitutions wanted in high-priority billets). The cost of an arc is a weighted sum of a measure of

Officer Supply Data

For each officer
(a) Social security number
(b) Grade
(c) Current monitor command code (MCC)
(d) Primary military occupational specialty (PMOS)
(e) First additional MOS (AMOS1)
(f) Second additional MOS (AMOS2)
(g) Officer type: regular, reserve, or retired
(h) Sex
(i) LDO (limited duty officer) status

Table 1: The wartime officer slate file (WOSF) is a data base that contains current records on all active, reserve, and retired marine officers. Our mobilization system uses WOSF as input and extracts the listed attributes for all officers who are eligible for mobilization. Officers with matching attributes are temporarily aggregated into "officer supply nodes" for a network optimization model. The WOSF contains as many as 40,000 eligible officers, from whom aggregation yields about 10,000 to 15,000 supply nodes.

Billet Demand Data

For each billet:
(a) Staffing priority level (SPL)
(b) Monitor command code (MCC)
(c) Grade
(d) Required MOS
(e) Number of officers needed
(f) Female officer allowed (yes or no)
(g) Limited duty officer allowed (yes or no)

Table 2: The wartime authorized strength report (WASR) is a Marine Corps file that contains every required wartime billet for a specific mobilization scenario. The marines maintain several versions of WASR for different war plans. Our system reads the listed billet attributes and temporarily aggregates matching billets into "billet demand nodes." A WASR file can contain as many as 25,000 billets, which are typically reduced about three-fold by aggregation.

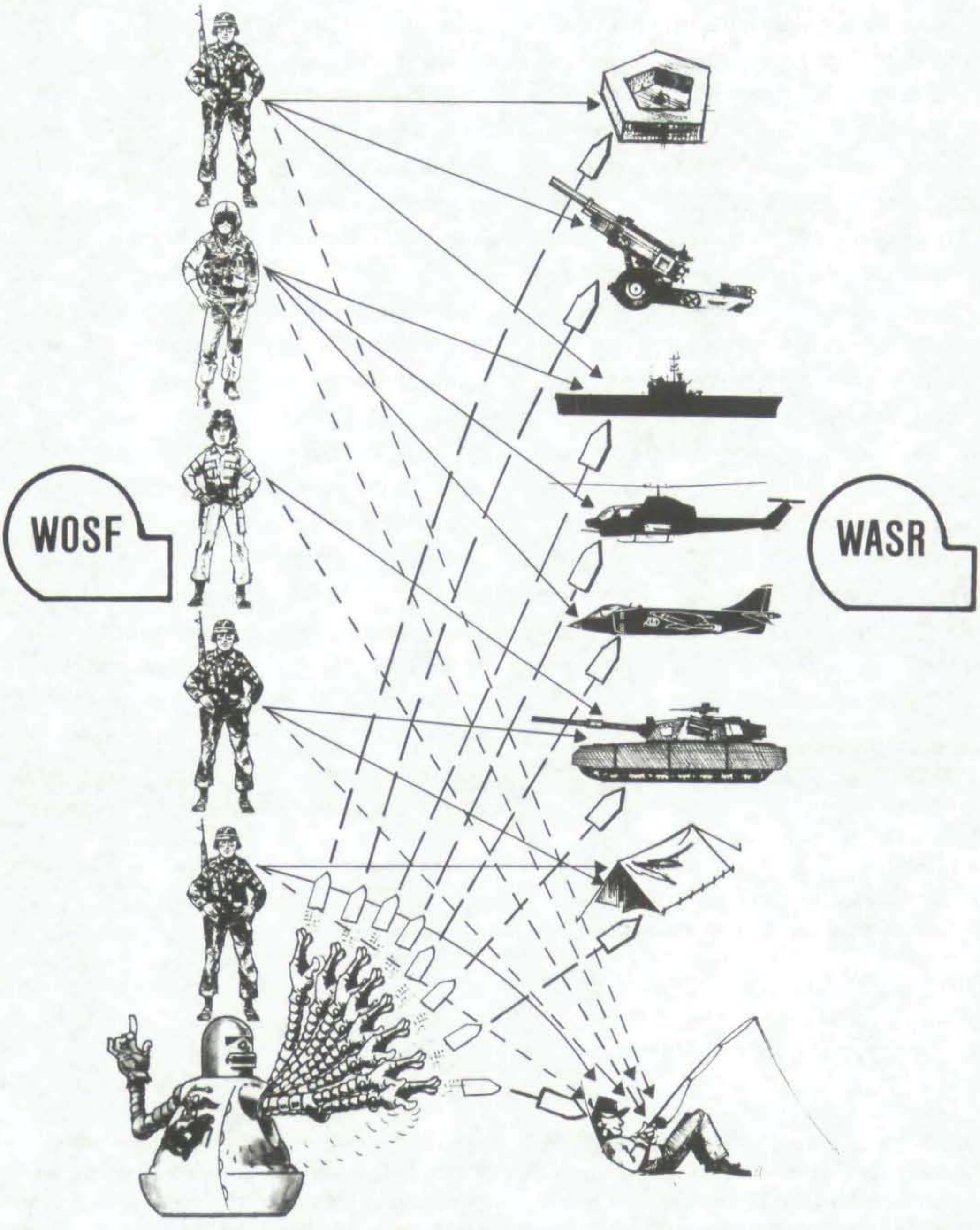

Figure 1: A conceptual network model of the Marine Corps mobilization problem depicts each officer as a supply node and each billet as a demand node. The "clonemaker" node at the lower left accounts for the possibility that some billets will remain unfilled due to a shortage of eligible officers. Conversely, the "unused" node at the lower right accounts for available officers who are not eligible for any unfilled billets. A literal implementation of the conceptual model would be computationally impractical, so our mobilization system employs several important refinements.

the quality of the officer-billet fit and the distance between the officer's current MCC and the billet's MCC (appendix).

There is a high probability that some billets will remain unfilled in any given mobilization because of a shortage of eligible officers. To account for this eventuality, the conceptual network has an extra node, called *clonemaker*, that represents a fictitious large supply of officers who can fill any billet at a very high cost. The conceptual model has an arc connecting the clonemaker node to all billet nodes.

There is also a very good chance that some officers (particularly retired officers) will not be eligible for any unfilled billets and, hence, will remain unassigned. To account for this possibility, an extra billet node called *unused* is added to the conceptual model, with explicit arcs connecting all officers' nodes to this node. The clonemaker and unused additions to the conceptual model guarantee network feasibility.

One of us (Rapp) implemented a prototypic version of the conceptual model using the NETSOLVE package [Jarvis and Shier 1988]. This prototype gave encouraging results, but NETSOLVE could handle only a very small number of officers and billets compared to the needs of a real mobilization problem.

Our next implementation of the conceptual model [Rapp 1987] used the GNET network optimizer [Bradley, Brown, and Graves 1977]. This implementation, dubbed MCMAM, yielded concrete improvement in solution quality over OSGM, for example, about six percent greater fill. MCMAM did not stand alone, it relied on the Statistical Analysis System [SAS Institute 1985] for reading, sorting, and error-checking the WOSF and WASR data bases. On an IBM 3033-AP mainframe, it took five minutes of SAS time and 30 minutes of MCMAM time to generate and solve a 27,000-officer, 10,000-billet problem. We deemed this computational performance inadequate to warrant converting the system to a personal computer or installing it at Marine Corps headquarters. Accordingly, we engaged in further research to improve performance.

Practical Refinements to the Conceptual Model

The conceptual model has some inherent computational impracticalities, so the model we built for the marines differs from it in a number of important ways. The differences have to do with making the network smaller, reducing the work required to generate it and reducing the time required to solve it. The key changes to the conceptual model are summarized below:

(1) Node Aggregation: The number of nodes is substantially reduced by a temporary node aggregation. Officers who match one another with respect to grade, sex, limited-duty status, type, occupational specialties, and MCC are merged into a single *officer-supply node*. Similarly, billets with matching data attributes are merged into *billet-demand nodes*. These aggregations can yield three-fold reductions in the number of nodes yet sacrifice nothing in terms of solution quality.

(2) Arc Screening: A realistic scenario exhibits as many as 40,000 available officers and 25,000 required billets. A literal implementation of the conceptual model would require eligibility tests for 1,000,000,000 officer-billet pairs. Fortunately, in practice

most pairs are ineligible, so we do not have to worry about solving billion-arc networks, but it is vital to be able to pick out the eligible pairs as efficiently as possible. We expended a great deal of effort in data structure design and programming for the arc generation routine to ensure that most of the ineligible officer-billet pairs are not considered explicitly.

Mobilization requires years' worth of work in a matter of days.

(3) Priority Separation: The problem can be optionally separated into subproblems based on billet priority. The first subproblem assigns only the highest priority billets, subject to very tight officer-billet fit restrictions. Subsequent subproblems successively admit lower priority billets and less stringent fit criteria. This approach reflects the preferences of the Marine Corps and does not detract from our results. (Originally, this option was mandatory. We allowed it to be bypassed in a later modification.)

(4) Generalized Billet Heuristic: Because so many officers are eligible for generalized billets, they are very easy to fill. Yet, for the same reason, they necessitate the generation of a burdensome number of arcs in the conceptual network. We chose, therefore, to treat the generalized billets differently from the regular billets, using a simple greedy heuristic rather than the network optimization model.

(5) ENET Solver: By using an elastic network program, ENET, we omitted the explicit arcs representing unused officers and "clonemaker-filled" billets and handled them implicitly. This results in a substantial reduction in the number of arcs. This is possible because the ENET algorithm treats networks as inequality-constrained linear programs, in which a dynamic subset of the flow conservation constraints are binding at any given iteration. ENET also employs automatic basis aggregation, as described for the XNET variant of GNET in Bradley, Brown, and Graves, [1977, p. 28].

The preceding refinements, individually and collectively, result in the generation of much smaller networks than the conceptual model. By using judiciously chosen data structures, we generate these networks extremely rapidly. The next refinement is an algorithmic device, which might be referred to as a type of linear programming pricing strategy, and which greatly reduces network optimization times.

(6) Successive Restrictions: When solving one of our network subproblems, we initially consider all the arcs representing perfect officer-to-billet fits eligible and all other explicit arcs temporarily ineligible. ENET optimizes first over this restricted set. Although the resulting solution is suboptimal in the network at hand, it is found extremely rapidly and furnishes ENET with a good starting point for solving another less restricted version of the original subproblem. In the second restriction, ENET optimizes over all arcs with penalty costs up to one-third the maximum arc penalty cost. ENET then starts from the solution to the second restriction and performs a final optimization in which all arcs are eligible. As you would expect, the perfect arcs are preferred, and large numbers of increasingly imperfect arcs have dimin-

ishing influence on the decreasingly restricted solutions. This modest refinement renders speed improvements of between three- and 20-fold.

The computational benefit of all these refinements is shown in Table 3.

Implementation

Application of the preceding ideas leads to an efficient mobilization system. We developed research versions of the system on an IBM 3033-AP mainframe computer under CMS in VS FORTRAN (Table 3). We then implemented the system in NDP FORTRAN-386 [MicroWay 1988]. (See Bausch and Brown [1988] for a complete description of this PC programming environment.) About 18 months later, we switched to the SVS FORTRAN 77 compiler [Silicon Valley Software, 1990], which sped up the program by a factor of two. The marines originally ran the mobilization system on a Compaq desktop personal computer with a 25-megahertz 80386 processor, 80387 coprocessor, and nine megabytes of memory. It now runs on a 80486 PC as well. A run of the system proceeds as follows:

Step 1: Data input and node aggregation: We read three input files: WOSF, WASR and a small file containing policy parameters that define the cost function and the eligibility rules. The WOSF and WASR files are read once and carefully checked for errors. Good records are aggregated and stored in a binary file. Bad records are excluded from the model and reported in exception files. Step 1 takes almost half of the total time of a complete run of the system, but if there are multiple runs (for example, with different values for the policy parameters), it needs to be performed only once. The binary file contains pointers that are used later for disaggregation.

Step 2: Network generation and solution for high-priority regular billets: We generate an elastic network model that is restricted to the high priority regular billets and to the officers who can fill them. Then we call ENET as a subroutine and obtain an optimal solution. The optimal assignments are stored on another binary file, while officer availabilities and billet demands are updated accordingly.

Step 3: High-priority generalized billet assignment: Each high-priority generalized billet is assigned to the closest available

Version Date	Refinements Added	Network Generation and Optimization (Mainframe CPU Time)
9/87	Node aggregation Priority separation Arc screening	30 minutes
11/87	Generalized billet heuristic ENET solver	3.5 minutes
4/88	Specialized data structures Successive restrictions	9 seconds

Table 3: Our refinements to the conceptual model were added in stages in research versions of the mobilization assignment system. This table shows the effects of the refinements on computation time for one subproblem containing 27,003 officers and 10,441 billets. The research versions of the system were implemented on an IBM 3033-AP mainframe, whereas the version currently used by the marines resides on a personal computer.

Officer Mobilization Assignments

	Priority High	Priority Medium	Priority Low	TOTAL
Number of billets	13,625	12,186	938	26,749
Percentage of billets filled	94.9	91.1	94.0	93.2
Percentage of filled billets in which assignment uses:				
—perfect grade fit	84.4	79.6	91.3	82.4
—perfect MOS fit	92.8	87.6	72.0	89.7
—no turbulence	58.3	42.0	14.5	49.3
—active-duty officers	65.9	50.9	19.3	57.4
—reserve officers	19.6	25.1	9.9	21.8
—retired officers	9.4	15.1	64.9	14.0

Table 4: The marines are concerned about several measures of effectiveness in officer mobilization. The primary objective is to maximize the number of billets filled with suitably qualified officers. The second objective is to maximize the quality of officer-to-billet fit. Fit is evaluated with respect to several criteria, including grade fit, MOS (military occupational specialty) fit, and preference for active-duty officers and reserves over retired officers. The third objective is to minimize turbulence, defined as the percentage of assigned officers whose mobilization billet requires them to report to a unit more than 100 miles away from their current assignment. Results of our mobilization system for a full-scale marine mobilization scenario are reported. This example is too large to run on the marines' old system; but, on smaller problems where comparisons could be made, the new system always produced significantly better results with respect to all measures of effectiveness.

officer of the right grade, subject to sex, limited-duty and air/ground restrictions. These assignments are added to the binary output file and appropriate updates are made.

Step 4: Medium-priority subproblem generation and solution: We repeat Steps 2 and 3, for regular and generalized billets, except now we restrict attention to medium-priority billets and any high-priority billets that remain unfilled.

Step 5: Low-priority subproblem generation and solution: We repeat Steps 2 and 3 for regular and generalized billets, except now we consider low-priority billets and any higher-priority billets that remain unfilled. After ENET solves the last subproblem, we produce a summary report on cumulative solution quality (similar to Table 4).

Step 6: Node disaggregation and solution reporting: If the user desires, we create detailed reports on filled and unfilled billets. The optimal assignments are disaggregated to an individual officer-to-billet level, and are placed in a file which can be used as input to a *MAILGRAM* printing program.

Early Results

The outputs from many versions of our system have been carefully scrutinized with the view of revealing data deficiencies, modeling oversights, and programming errors. Preliminary criticisms have enabled us to identify previously unelucidated institutional policies (a frequent unadvertised benefit of applied operations research).

The approved solutions exhibit the qualities summarized in Table 4. Total computing time on the marines' 80386-based personal computer is under 10 minutes, with the time divided among tasks as reported in Table 5.

The model run reported in Tables 4 and 5 uses a full-scale marine mobilization scenario. That problem could not be run on the old system used for mobilization, OSGM, because of its large size, but we have compared results on smaller problems. In every case, the new system achieves better quality solutions with respect to every measure of effectiveness considered.

Computing Effort as Percentage of Total Time	
Data input and node aggregation	48%
Network generation Network optimization Generalized billet assignments	33%
Node disaggregation and report writing	19%
	100%

Table 5: Our mobilization system provides the marines with sufficiently rapid response to be used in wartime. On a personal computer, it takes under 10 minutes for full-scale Marine Corps mobilization, with computational effort distributed as shown. The system can be run in two ways. In one option, separate networks are generated and solved for each priority level. Alternatively, the system can solve a single network encompassing all billets. Using the first option, the largest subproblem to date had about 21,000 nodes and 120,000 arcs. The largest problem encountered to date using the second option had the same number of nodes and over 1 million arcs.

Subsequent Results

In the first 18 months that our system resided at Marine Corps headquarters, it was used extensively, and it underwent some significant changes. Among other things, the system was named and renamed. First it was called *OMAM,* for officer mobilization assignment model, and then it became *MARS,* for manpower assignment recommendation system.

As often happens with the installation of an optimization-based system, the most significant outcome in the early applications was the discovery of errors in the input data. (Optimizers tend to hone right in on bad data, unlike simulations and statistical analyses, which tend to wash out their effects.) Dan Bausch was assigned to fix the errors while on temporary active duty as a reserve marine officer. He redesigned the input files so they are now much easier to understand, verify, and modify.

Bausch also added new information to the input files that enables MARS's network generator to comprehend and obey more complex eligibility rules than before. This results in better fit. For example, the billet file now specifies grade and MOS substitution policies for each billet individually, yielding new flexibility. Also, there are now matching "compatibility fields" in the officer and billet files, so, for instance, if a billet requires an officer with top-secret clearance, MARS enforces this restriction. Not all of the compatibility fields are currently used, so there is room to accommodate future considerations. In general, the input file structure and the eligibility logic are now sufficiently flexible to allow MARS to be used for peacetime as well as mobilization assignment. MARS has been tested on a limited basis in peacetime scenarios.

Bausch also added a great deal of reporting capability, which is another common occurrence in the early period of adoption of an optimization-based system. As the users learn more from and about the system, they tend to request new ways to summarize and present the results.

Two criticisms of the system emerged in the early going. One has been permanently rectified, the other may now be circumvented at the user's discretion.

The system originally aggregated monitor command codes into geographic regions, which made the node aggregations more effective. However, because of this geographic aggregation, our early system was criticized for inaccurately measuring the travel distance between an officer's current location and his mobilization billet, (particularly if he was moving within the same region). As a result, we dispensed with the geographic aggregation and use more accurate MCC-to-MCC distances in the evaluation of all potential assignments. Solution quality has improved as a result of this change but at the cost of a small increase in computing time. The officer node aggregation is now such that if two officers belong to the same node, the only difference between them in the WOSF data base is their social security number.

The second area of criticism involves priority separation. Strictly speaking, the critics are right in saying that this procedure potentially sacrifices some optimality. (Some Marine Corps manpower planners have a surprisingly devout attitude toward optimization.) In our view, the objective function of the optimization model is not meaningful per se, but rather is a compilation of many policies and preferences, among the most important of which is to fill the top priority billets first. In other words, priority separation is not only a computational convenience but also an accurate reflection of Marine Corps official policy. Though we still believe in this justification, we heard the criticism enough times to do something about it.

MARS now offers the option of omitting priority separation, thus optimizing all billet assignments in one very large problem. A recent instance of such a problem, involving 16,739 officers and 16,411 billets (a peacetime scenario), had the following performance characteristics:

A realistic scenario exhibits as many as 40,000 available officers and 25,000 required billets.

Number of nodes = 20,942;
Number of arcs = 1,059,607;
Network generation time = 1.06 minutes; and
Network optimization time = 8.71 minutes on a Compaq 486/33. In contrast, the same problem with priority separation takes one-sixth the time and requires much less computer memory. The solution obtained without priority separation has greater total fill but it sacrifices quality of fit in the high priority billets.

Whether or not priority separation is appropriate, we expect the option of circumventing it to be exercised frequently. It was quite comforting, therefore, to discover that our system can generate and solve problems with over a million variables in under 10 minutes on a personal computer.

Conclusions

United States' defense plans rely upon our ability to mobilize the Marine Corps on extremely short notice. The marines have invested heavily in prepositioning strategic stockpiles of ammunition and equipment to prepare for contingent crises. But without getting the people to the stockpiles in time, in the worst situation, our prepositioned assets could be captured by an enemy and used against us. Therefore, the problem we addressed is one of great significance to our national defense. With our officer assignment system and a firm commitment to maintaining the WOSF and WASR data bases, the Marine Corps is ready to mobilize its officers quickly in war.

APPENDIX: Guidelines for Assignment Eligibility and Cost

Our mobilization system uses the following Marine Corps policies and preferences to decide whether an assignment arc should exist between particular officer-billet pairs and to decide how much existing arcs should cost. A nonretired officer who matches a billet perfectly with respect to grade, MOS, MCC, sex, and limited-duty status costs zero to assign. All other allowable assignments have positive cost.

—Active-duty officers are preferred to reserve officers for some high-priority billets.

—Active-duty and reserve officers are preferred to retired officers in high-priority billets and, to a lesser extent, in other billets.

—Females and limited-duty officers can never be assigned to billets from which they are restricted.

—Grade substitution is most undesirable in high-priority billets (with the exception of some warrant officers who can fill lieutenant billets).

—Grade substitutions are permissible in medium- and low-priority regular billets under the following guidelines. These general guidelines are ignored, however, if specific guidelines are given for an individual MOS.

Any officer can be assigned a billet that is one grade above his or her grade.

Active-duty aviation officers, reserve officers, and retired officers can be assigned billets that are one grade below their grades.

A retired officer can be assigned a billet that is two grades below.

—Grade substitutions are permissible in low-priority generalized billets under the preceding guidelines.

—Grade substitutions are prohibited when MOS substitutions take place.

—In technical billets, MOS substitutions are worse than grade substitutions. In nontechnical billets, the reverse is true.

—It is preferable to assign an officer to a billet requiring his or her PMOS rather than one of his or her AMOSs.

—MOS substitution is permissible only for certain specified MOS pairs.

—Billets in certain specified MCCs that are involved in the earliest mobilization actions have the highest priority.

—Some reserve officers carry "hip-pocket orders" to report to specific MCCs in case of emergency. These officers should be assigned billets in the specified MCC.

—High-priority billets should not be assigned to officers more than a specified number of miles away. Medium-priority billets have a similar, but less stringent, restriction.

—Officers who are enrolled in the early weeks of certain basic MOS schools should not be given mobilization assignments. (They are screened out in the WOSF input step.)

—Retired officers cannot be used unless they retired less than a specified number of years ago. (This policy is also enforced through screening the WOSF on input.)

Several of these guidelines require specification of policy parameters. Our mobilization system stores default values in a small file that the user can edit at any time.

References

Bausch, D. and Brown, G. 1988, "NDP FORTRAN and Phar Lap Tools: A PC environment for large-scale programming," *OR/MS Today*, (June).

Bradley, G.; Brown, G.; and Graves, G. 1977, "Design and implementation of large-scale primal transshipment algorithms," *Management Science*, Vol. 24, No. 1, pp. 1–34.

Decision Systems Associates, Inc. 1983, *Officer Staffing Goal Model User's Guide: Enhanced OSGM*, Rockville, Maryland.

Gass, S.; Collins, R. W.; Meinhardt, C. W.; Lemon, D. M.; and Gillette, M. D. 1988, "The army manpower long-range planning system," *Operations Research*, Vol. 36, No. 1, pp. 5–17.

Grinold, R. and Marshall, K. 1977, *Manpower Planning Models*, North-Holland, Amsterdam, The Netherlands.

Jarvis, J. and Shier, D. 1988, *User's Guide to NETSOLVE*, URI, Six Mile, South Carolina.

Klingman, D.; Mead, M.; and Phillips, N. 1984, "Network optimization models for military manpower planning," in *Operational Research '84*, ed. J. P. Brans, Elsevier Science Publishers, Amsterdam, The Netherlands, pp. 786–800.

Klingman, D. and Phillips, N. 1984, "Topological and computational aspects of preemptive multicriteria military personnel assignment problems," *Management Science*, Vol. 30, No. 11, pp. 1362–1375.

Liang, T. and Buclatin, B. 1988, "Improving the utilization of training resources through optimal personnel assignment in the US Navy," *European Journal of Operations Research*, Vol. 33, No. 2, pp. 183–190.

Liang, T. and Thompson, T. 1987, "A large-scale personnel assignment model for the navy," *Decision Sciences*, Vol. 18, No. 2, pp. 234–249.

MicroWay, Inc. 1988, *NDP FORTRAN-386 User's Guide and Reference Manual*, Kingston, Massachusetts.

Rapp, S. 1987, "Design and implementation of a network optimizer for officer assignment during mobilization," MS thesis, Naval Postgraduate School, Monterey, California.

SAS Institute, Inc. 1985, *SAS User's Guide: Basics, Version 5*, Cary, North Carolina.

Silicon Valley Software 1990, *SVS FORTRAN 77 User's Guide and Reference Manual*, San Mateo, California.

Brigadier General John J. Sheehan, USMC Director, Personnel Management Division Headquarters, US Marine Corps, writes "Tests have revealed that this system far exceeds the capabilities of our previous one. As a result of the increased capability, we now have the ability to quickly and efficiently determine appropriate placement of qualified officers to wartime billets. This means that during an all-out mobilization, our new system could provide the edge we need. As a result, it could effect the saving of lives and increase our probability of winning the war."

"Constraints of time, distance, and individual billet requirements could not be handled very well prior to the development of the officer mobilization assignment model. Since these constraints were primary considerations at every point of the development of our new system, we now have a tool that makes something, which used to be impossible, almost easy."

"We intend to use the knowledge that has been gained through this development to enhance our peace-time capabilities. We must ensure that our peace-time functions and ways of doing business do not interfere with or hamper any transition to wartime functions."

"If we must mobilize, we will be ready."