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Inside the Black Box: Assessing the Navy's Manpower Requirements Process

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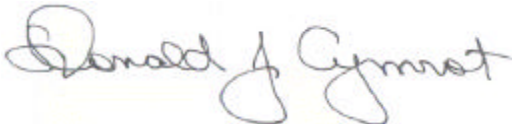

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Summary

> Our Navy starts with the Fleet. [To ensure fleet readiness,] we must accurately define and continuously validate our requirements.
>
> —*Admiral Vern Clark, CNO*[1]

The Navy's assessment of its manpower needs is critical to fleet readiness. If too few people are on board, the ship's capability, readiness, and performance will suffer. Overstating manpower requirements, however, draws funds away from other important resources.

This study describes, challenges, and evaluates the methods by which the Navy determines enlisted shipboard manpower requirements.[2] We focus on existing ships—legacy platforms—as opposed to designs for the future. The Navy Manpower Analysis Center (NAVMAC) determines requirements and publishes them in Ship Manpower Documents (SMDs) and Activity Manpower Documents (AMDs).

Findings

This work yields several insights into manpower determination and the direction of system improvements.

The manpower requirements process successfully meets the goals that the Navy has set out for it. It accomplishes the stated goals of establishing a credible basis for ship manning, assisting in the management of readiness and personnel, and validating workload—independent of

1. *Fight and Win! CNO's Guidance for 2002* (http://www.chinfo.navy.mil/navpalib/cno/clark-guidance2002.html).
2. Enlisted strength also includes (a) aviation manpower in squadrons, carrier air wings, sea operational detachments, and afloat intermediate maintenance departments and (b) shore personnel and the Individuals Account (IA)—transients, patients, prisoners and holdees (TPPH), students, trainees, cadets, and midshipmen.

warfare sponsors and costs. It does so through extensive data collection, feedback from the fleets, compliance with policies and instructions, reference to equipment manuals, and a rigorous computer model (the Navy Manpower Requirements System (NMRS)) that computes numbers and types of billets based on projected workload. In general, the Navy has been responsive to the concerns of outside agencies and has improved its methodology in response to criticism.

The process does not adequately consider manning alternatives. In setting requirements, NAVMAC takes technology as given and uses decades-old assumptions about average hours of work and the paygrade mix of the crew. Were these allowed to vary, the optimal solution might differ from the billets listed in the requirements document.

Of course, the long life of ships limits the range of alternatives; today's manpower planners must work with design decisions that may have been made decades ago. Still, part of the problem rests with business practices of today: an absence of incentives, organizational stovepiping that separates technology and manpower decisions, and incomplete metrics of how manpower affects safety, readiness, and other variables.

Navy instructions explicitly rule out considerations of cost and personnel availability in developing manpower documents. In the private sector, we found companies continually assessing the way they allocated resources based on costs, technology, and available labor. We were unable to find requirements processes in which manpower decisions were institutionally separated from other decisions.

Reductions in workload (person-hours needed to get the job done) do not readily lead to reductions in the number of billets. This is a crucial point; new technologies may fail to deliver reductions that may be expected at first glance. The reasons lie in the mechanics of the NMRS billet-generation algorithm.

Some of the manpower drivers in the NMRS merit revalidation. Although the model offers a consistent, accountable way to compute requirements from workload, this decision-support tool is only as good as the assumptions that go into it. The Navy Standard Workweek, paygrade tables, and workload allowances date from the 1960s and 1970s. As a

result, they may be incompatible with today's technology, personnel policies, workforce, and business practices. For example, today's more highly skilled sailors may require less direct supervision than those of the past. Taken together and across the fleet, NMRS drivers have significant effects on billet requirements and manpower costs.

Recommendations

The Navy can significantly improve its manpower requirements process for legacy platforms by taking steps to:

1. Make the costs (and benefits) of billets more visible, and integrate them into the process.
2. Shift the focus from workload validation toward innovation and improvement.
3. Charge an agent or organization with identifying areas for manpower savings, through methodological, technological, or organizational changes.

Recommendations 1 and 2 go together; to the extent that the Navy pursues one, it supports the other. As the experience of the private sector shows, *innovation* is the key to reducing costs and enhancing performance. The term refers to identifying manning alternatives and implementing those that work best. It encompasses any effort to reduce manpower costs, improve sailor productivity, or enhance quality of life through changes in technology and organization.

Recommendation 3 stems from our observation that no one party is charged with coordinating manpower and technology decisions. Creation of such an agent would improve the ability of the Navy to merge cost incentives and innovation into its manpower requirements.

Cost visibility

To make the cost of a given requirement (and the assumptions behind it) explicit and visible to leadership, task NAVMAC to:

- Compute the cost of various manning configurations using the Cost of Manpower Estimation Tool (COMET) or another cost assessment system.

- Report the cost of important NMRS assumptions (e.g., standard workweek, productivity allowance, and paygrade matrix) and their effects on requirements.
- Redesign manpower documents to more clearly show what the requirements are and how much they cost. For example, cost and summary tables by paygrade and rating could be added.

If billet costs are visible, the system will be more easily scrutinized by policymakers and stakeholders. Ultimately, costs should be incorporated directly into incentives. This doesn't mean compromising operations by putting dollars ahead of other criteria. Rather, it means weighing the costs of manning alternatives against the benefits. For example, at one manufacturer we visited, management requires that the costs of capital improvements be directly offset by labor savings, enhanced safety, or improved product quality.[3]

Innovation

The Navy can promote innovation (either technological or organizational) on legacy platforms in a number of ways. We discuss seven methods here.

Seek out and publicize innovations. The fleet is a source of good ideas and presents natural experimental conditions in which to test their workability. Innovations, such as core-flex and Blue-Gold schedules on ships, arise in the fleet. The Navy should seek out such innovations and encourage dialogue among innovators, other ships in the fleet, and manpower planners. It may be useful to conduct field studies to test the ideas, ensuring that observations are well documented.

Create a Navy-wide award for manpower innovation. Awards could be for improvements in process, organization, or technology, and the criteria could include manpower reductions, improved quality of service, or greater readiness. Any group could be eligible—ships' crews, commanding officers, engineers, or manpower planners at NAVMAC.

Establish a "tiger team" that looks for efficiencies. The tiger team, which would report to N12, would take a critical look at the workload that is

3. See the appendix for a description of the companies interviewed.

performed on established platforms and would try to find opportunities for reducing manning. This would address a long-standing criticism that, although methods improvement studies are not part of the requirements process, they should be [1]. The team could perform formal methods improvement studies or simply look for opportunities to use manpower more efficiently.

Task NAVMAC with reporting on the status of manpower innovations—both adopted and rejected—that result from tiger team assessments, awards, and fleet experiments. Have NAVMAC function as a clearing-house, not only uncovering and documenting innovations but using web surveys or site visits to keep track of their adoption.

Develop and use objective performance metrics to evaluate changes in productivity, efficiency, readiness, safety, or any other valued result. Private companies depend on performance metrics to gauge the appropriateness of their current staffing levels. The Navy would develop its own metrics, which might include readiness, accident rates, material condition, or personnel retention. Some of the data could be collected through electronic sensors, but others, such as data pertaining to administrative tasks, would need more observation. Metrics would create a further "check" on manpower levels, allowing leadership to monitor the relationship between manning and safety or manning and readiness.

Reassess NMRS inputs. It would be difficult for the Navy to establish consistent, repeatable requirements without a model like NMRS. However, several NMRS inputs need to be reassessed. The paygrade matrix is an excellent place to start. It has not changed since 1972, but the "ideal" seniority distribution has probably been affected by changes in mission, on-board training, sailor quality, and technology. Similarly, technologies installed over the past few decades may have changed some allowances, such as the fatigue and delay allowance.

Make the requirements determination process less opaque. Although it is analytically useful, the NMRS is unnecessarily difficult for policymakers, fleet commanders, and the public to understand. NAVMAC's recent proposal to web-enable NMRS is a good way to expand access and, with it, knowledge of the system. Once they learn how to use NMRS, the resource sponsors, type commanders, and government

contractors could simulate the impact of different scenarios, including changes in the ROC/POE, variations in onboard training, and changes in the paygrade distribution. Because NMRS documentation and working papers are currently accessible to only a small cadre of manpower experts, broader access could be provided by making NMRS's processes more user friendly. An alternative is to distribute one of several existing simulation tools that are similar to NMRS but more oriented toward prediction and simulation.

Background

The process the Navy uses to determine the number of sailors it needs on board ships is complex and demanding. To those not directly involved, it is a black box. Decision-makers can see the billet requirements listed in SMDs and AMDs. But lacking precise information about the source of those requirements or the factors driving them, many are concerned about their accuracy.

Issues

Interviews with Navy officials and our reading of the literature uncovered two main questions, and a third related question, about ship manpower requirements.

Is the methodology sound?

A 1986 General Accounting Office (GAO) report criticized the SMD program and suggested that it overstates billet requirements [1]. The report listed numerous methodological problems, including inappropriate application of industrial engineering concepts, lack of rigor in validating workload, and insufficient data. NAVMAC subsequently addressed several of the issues raised,[4] but in some cases it did not concur with the GAO's recommendations, so no changes were made.

4. Improvements made in response to the GAO's criticisms include better feedback mechanisms among NAVMAC, N-12, and the fleet, as well as the use of (a) surveys on multiple hulls to identify and document own-unit support (OUS), (b) onsite validation, (c) preventive maintenance (PM) data from multiple hulls, and (d) corrective maintenance data across the class. NAVMAC is testing a database system that it hopes will replace the corrective maintenance (CM) ratio in July 2002. In addition, the Navy has funded studies to validate the Navy Standard Workweek (see [2]) and to map sailors' occupational competencies.

Does the process result in an optimal crew?

Throughout this paper, we define an optimal crew as one that meets objectives—strategic, tactical, operational, or managerial—most cost-effectively. Some objectives may compete, whereas other may complement each other. Navy leadership sets the priorities.

The stated goal of today's manpower requirements process is to determine the *minimal* crew needed to achieve an assigned capability [3]. This suggests that it is impossible for the Navy to reduce crew sizes from current levels while maintaining performance, readiness, and safety. Yet, an influential 1995 study by the Naval Research Advisory Committee concluded that the Navy could achieve significant manning reductions on today's operational ships [4]. The report influenced Navy leadership to undertake the Smart Ship project; its successful implementation on USS *Yorktown* (CG-48) confirms that such changes are feasible not just years into the future, but in the near term.

Spearheaded by leadership, the *Yorktown* manning reductions were achieved far outside the Navy's standard requirements process. This raises concerns that the standard process may be overly affected by culture or hindered by outdated policies and business practices, an idea that is backed up by some experts [5, 6].

A related question is, "What does each billet contribute?" In their published form, today's SMDs and AMDs do not link billets with either ROC/POE tasks or performance outcomes. As a result, when deciding whether to increase (or decrease) personnel spending, planners can't predict the impact on capability, safety, or readiness.

Study objectives

The two major questions can be broken down into a series of smaller questions (shown in bold italics), which we address by describing and assessing the evidence.

Is it possible to reduce shipboard manning while maintaining operational standards? We discuss avenues for substituting technology and using more highly skilled crews.

What can a requirements process achieve? To what extent do Navy business practices support or undermine those functions? The creation of an SMD is only one step leading to Navy requirements. The demand side of the Navy's labor market is populated by NAVMAC, ship designers and engineers, and resource sponsors. Do their interactions allocate human resources in a cost-effective manner? Are there mechanisms or institutions to ensure that innovation takes place?

What are the main drivers of manpower requirements? Do those drivers make sense? One of NAVMAC's most important tools is the Navy Manpower Requirements System (NMRS), a computer model that optimizes requirements given certain assumptions, parameters, and data inputs. Its inputs include assumptions about hours of work (the Navy Standard Workweek), paygrades (Staffing Standards), and working conditions (workload allowances). Essentially, the NMRS computes billets from expected workload.

How sound are these inputs, parameters, and assumptions? Do they conform to industry standards? We identify alternative modeling approaches and predict their effects on costs and manpower. To do so, we use the Manpower Analysis Prediction System (MAPS), a simulation tool developed at Naval Surface Warfare Center, Carderock, in partnership with NAVMAC.

How do private companies determine requirements? Might these practices be of value to the Navy? We learned about the methods that private firms use to determine staffing, and how those methods fit in with an organization's objectives. Our approach was to interview private-sector company managers from various industries. The Navy's specialized mission guarantees that many of its staffing issues will be unique and not all lessons will apply.[5] The experience of private firms, however, can offer lessons because the profit motive provides a constant incentive to minimize costs through efficient labor utilization. Of course, profits are not an issue with the Navy, but this does not mean that business goals are irrelevant. Dollars that pay for manpower can't

5. Foreign navies offer the most natural comparison, but they still differ from the U.S. Navy in terms of weapons, mission, and personnel management, all of which are likely to affect requirements.

be used to modernize equipment, purchase spare parts, or add bunks to ships. Because the Navy has competing uses for its dollars, it makes sense to optimize the use of manpower and all other resources.

Because Navy personnel perform such a wide range of functions, we interviewed the following organizations from the manufacturing, shipping, and service industries:

- The Trex Company, a Virginia-based manufacturer of non-wood decking products. In 2000, *Forbes* magazine voted Trex the #1 Best Small Company in America.
- Riggs Bank N.A., based in Washington, DC, has branches in over 50 locations.
- Sylvan Learning Centers, an education provider with 90 corporate and 797 franchise sites across North America and Asia. Recently, Sylvan was named by *Success* magazine as the top franchise in America.
- The Military Sealift Command (MSC), which operates supply ships that were once part of the Navy's fleet and continue to perform many of the same duties.
- Britain's Royal Fleet Auxiliary (RFA), whose ships perform duties similar to the MSC but also carry defensive weapons.

Overview of requirements determination

The core product of the ship manpower requirements process is the Ship Manpower Document (SMD), which states the numbers and types of billets needed to man a particular ship class once the acquisition phase is complete. The SMDs form the basis for the Activity Manpower Documents (AMDs), which are more detailed requirements lists for each ship. The Navy Manpower Analysis Center (NAVMAC) produces the SMDs and AMDs and conducts the data-gathering and analysis that go into creating and maintaining them.[6] NAVSEA plays a role in determining preventive maintenance estimates. Today, the SMD program supports approximately 124,500 enlisted ship billets, which cover 9 million person-hours of workload per week.

What manpower documents don't do

In current practice, an SMD is not a vehicle to reduce costs, increase crew productivity, improve work efficiency, reduce manning, or make it easier for sailors to do their jobs.[7] No recommendations are made for reorganizing work or for adding technology, materials, or equipment. In 1986, the GAO noted that NAVMAC "analysts perform no methods-improvement studies to identify inefficiencies in the

6. Following the practice of previous analysts, we find it convenient to use the terms *SMD process* and *SMD methodology* to apply to the overall ship requirements program that includes AMDs.

7. Apparently, this has not always been the case. In the 1960s the Fleet Work Study Program performed work measurement, methods improvement, and human factors studies in an effort to optimize use of people. A parallel effort, the Manpower Survey Program, provided manning and workload documentation. The two organizations merged in 1970, forming the forerunner to NAVMAC. However, NAVMAC in its current form has not been formally tasked to make similar judgments.

way...work is performed [1]." This observation remains true today. For example, NAVMAC validates much of the Navy's workload through interviews with crew members and site visits. The approach has the advantage of keeping analysts in touch with the real worklife on board ship, but methods improvement requires a critical stance.

Purpose of manpower documents

An SMD does, however, fill a number of important roles. It represents an assessment of requirements by an honest broker [e.g., 7], it establishes a credible basis for ship manning, and it assists in the management of personnel and readiness.

Represent the honest broker

As part of the DCNO (M&P), NAVMAC is the Navy's honest broker, tasked to determine and validate requirements when changes are made to the ROC/POE or at the request of claimants. However, NAVMAC does not depend on its claimants for funding or direction. The organization's independence from resource sponsors and claimants is a crucial part of its identity, meant to safeguard SMD and AMD development from institutional pressure.

Establish a credible basis for ship manning

Title 10, Section 115a, of the United States Code (U.S.C.) requires the Secretary of Defense to submit an annual manpower requirements report to Congress. DoD policy tasks the Secretary of the Navy with developing, maintaining, and submitting wartime requirements data [8]. DoD also requires that the services use the least number of people possible to "accomplish missions with a minimum number of personnel" [9].

Navy instructions suggest that the purpose of today's ship requirements process is to establish an accountable, credible basis for ship manning. According to [10], the first SMD was developed in 1966 for a class of destroyers. The methodology became fully operational in 1970 when, after repeated testing, it proved "effective in justifying requirements to reviewing authorities (e.g., OSD and OMB)."

Assist in management of personnel and readiness

By stating the numbers and types of skills needed in the fleet, the SMD guides the Navy's recruiting goal, its training curriculum, and its strategy for retaining and retiring personnel [11].

Finally, the SMD process assists in meeting the DoD's legal obligation (Section 113 of Title 10, U.S.C.) to establish and maintain a readiness reporting system to measure the capability of units to conduct their wartime missions. By policy of the Secretary of the Navy, the M+1 requirement forms the basis for measuring personnel readiness in the Navy's readiness reporting system [12].

Development of manpower documents

When a class of ships is under development, NAVMAC creates a Preliminary Ship Manpower Document (PSMD) listing the billets needed for the envisioned mission with the systems expected to be on board. By the time the new class is ready for the fleet, NAVMAC has created the SMD. This initial statement of manpower requirements will change with changes in the ROC/POE or substantial equipment upgrades. The SMD forms the baseline for the AMDs, which are tailored to each ship in the class. The fleets (and other claimants) can request changes in AMDs, and NAVMAC investigates the options.

There are three main steps in developing manpower documents:[8]

- Validate primary workload through site visits, fleet feedback, and review of policies, technical manuals, and ROC/POEs.
- Apply factors and allowances to account for working conditions and productivity constraints.
- Compute the minimum number of billets that will be needed to execute the workload, including the allowances.

To create an SMD, NAVMAC first estimates the amount of workload that will be required by virtue of the platform ROC/POE and the equipment on board. The link to the ROC/POE is critical because it

8. We base this description on discussions with NAVMAC staff [3 and 13].

means that ships must be manned for capability in *all* of its assigned missions and tasks, not just for average daily workload. The situation is similar to that of electric utilities, which must maintain peak-load (surge) capacity but which work below that capacity most of the time.

There are five workload categories: operational manning (OM), or watch-standing; own-unit support (OUS); preventive maintenance (PM); corrective maintenance (CM); and facilities maintenance (FM), which includes painting and cleaning the ship.[9] These categories are types of *primary workload*.

NAVMAC analysts determine watch-standing workload by interpreting the ROC/POE and systems installed on the ship. The estimation of other workload relies more heavily on data-gathering. OUS comprises administrative, medical, food service, shopkeeping, and all other service functions aboard ship, as well as evolutions like underway replenishment. Only underway workload is included in OUS. NAVMAC uses operational audits—interviews with crew members about their work—to estimate OUS workload. NAVMAC bases estimates of maintenance workload on manufacturers' equipment documentation and reviews of expected equipment maintenance actions.

Added to the primary workload estimates are a number of factors and allowances:

- A 20-percent productivity allowance (PA) applied to observed workload for the OUS, CM, and FM workload categories, but not to OM
- A 30-percent make-ready put-away allowance (MRPA) applied to PM only.

Finally, crew members are expected to engage in service diversion and training. Service diversion is a catchall category that includes quarters, inspections, sick call, ceremonies, and other activities that are not directly productive but are nevertheless necessary. Training

9. NAVSEA determines engineering estimates for preventive maintenance. A sixth category, customer support (CS), is used for submarine tenders. It affects a small number of people and is usually treated as a special case.

includes “scheduled events (e.g., general drills, engineering casualty damage control) for all hands.” It does not include deductions from productivity that result from skill deficits.

Table 1 shows the Navy-wide workload for all active ships. Following the usual practice, workload is expressed in person-hours per week. Altogether, Navy ships require over 9 million person-hours of work per week. The biggest component of workload is operational manning, or watch-standing. Own-unit support makes up another 22 percent of the workload.

Table 1. Shipboard workload: all active vessels[a]

Category	Person-hours per week[b]	As percentage of total
Operational manning	3,429,104	38
Own-unit support	1,961,703	22
Preventive maintenance	360,485	4
Facilities maintenance	551,005	6
Corrective maintenance	265,400	3
Customer support[c]	69,589	1
Make-ready put-away allowance	154,494	2
Productivity allowance	555,640	6
All productive workload	7,347,420	80
Training	873,187	10
Service diversion	873,187	10
Total workload	9,093,794	100

a. Based on SMDs of 307 ships.
b. Computed as workload for each class times the number of ships in the class.
c. AS submarine tender only.

The second, and most complex, phase of the manpower determination process involves converting the workload estimate into manpower requirements or billets. The Navy Manpower Requirements System (NMRS) translates workload into billets via an interactive optimization program. To do this, the Navy assumes that crew members will average 67 hours of productive work per week. This planning factor, called the Navy Standard Workweek (NSWW), is currently under evaluation [2].

First, NMRS determines the number of billets needed for the OM workload. They consider the requirement under Condition I (general quarters, or battle conditions) and Condition III (wartime steaming/forward deployed/increased tension), and take the greater of the two. NAVMAC does *not* write requirements for periods in port or for time under way but not deployed; those periods do not define the ship's missions and tasks as assigned in the ROC/POE.

Condition III is usually more manpower-intensive than Condition I, so most billets are based on Condition III. Assuming a 3-section watchbill implies that each person will stand 56 hours of watch per 7-day workweek. With 67 hours available, each watch-stander can work an additional 11 hours per week to execute other types of workload.

Roughly speaking, the system allocates 11 hours per watch-stander to this extra workload, until each billet is "assigned" 67 hours of workload per week. Workload that cannot be allocated to watch-standers generates additional billets. In practice, the additional 11 hours attributed to each person is sufficient to absorb most of the workload aboard ship. *Thus, most of the non-watch-standing workload is absorbed by billets that exist to fulfill watch-standing requirements* [3]:[10]

- On the CG-47 class, OM accounts for only 37 percent of the workload but 92 percent of the billets. (That is, only 8 percent of the billets exist just to support maintenance, own-unit support, the workload allowances, training, and service diversion.)
- On the DDG-51 class, OM accounts for 35 percent of the workload but 85 percent of the billets. Only 15 percent of the billets exist to execute workload other than OM.
- For the CVN-68 class, OM accounts for 39 percent of the workload but 61 percent of the billets. Thirty-nine percent of the billets exist to execute non-OM workload.

The workload is parceled out in accordance with department, division, and rating boundaries. The Navy's *Standard Organization and Regulations Manual* (SORM) prescribes the departments and divisions that will be on each ship [14]. NAVMAC analysts determine the ratings based on the skills, or Occupational Standards, involved.

10. These numbers were valid as of February 2001.

The NMRS computes the numbers in each paygrade using Staffing Tables, which are matrices that relate the percentage in each paygrade to the number of people. There are different Staffing Tables for each rating, and for certain offices and work centers, but they are the same for each ship class. In practice, the NMRS may override parts of the paygrade matrix to accommodate NECs, which raise the level of seniority. Table 2 displays a typical paygrade matrix (in somewhat consolidated form). The distribution is centered on a mid-level paygrade. If only one person is needed, he or she will be an E-5. The system generates more junior requirements as group sizes increase. Applying the percentages in table 2, a group of five will consist of one each of E-3, E-5, and E-6, and two E-4s. Nondesignated personnel are presumably E-2s or GENDETs striking for the rating in question.

Table 2. Paygrade matrix for ratings CT, ET, EW, FC, FT, GM, MN and MT (percentage in paygrade by number of people in rating)[a]

	Percentage in paygrade							
Number in rating	Non-desig.	E3	E4	E5	E6	E7	E8 & E9	All
1	0	0	0	100	0	0	0	100
5	0	20	40	20	20	0	0	100
10	20	10	30	20	10	10	0	100
20	25	10	30	15	15	0	5	100
30	27	10	27	13	13	7	3	100
50	22	8	32	16	12	6	4	100
70	24	7	31	16	11	7	2	100
90	26	8	31	16	11	7	2	100
110	25	7	32	15	11	6	3	100
130	26	7	30	16	12	7	3	100
150	25	7	31	16	11	7	2	100

a. Source: Navy Manpower Analysis Center.

This procedure doesn't apply to "directed" requirements, which the CNO orders and which are not tied to primary workload. Directed requirements include Command Master Chiefs, religious specialists (RPs), medical personnel, and career counselors.

Manpower choices

The Smart Ship program (exemplified by CG-48, USS *Yorktown*) suggests that it is possible to reduce manpower requirements on active ships while maintaining standards of operational effectiveness. The solution is to choose appropriate technology and adapt crew skills accordingly. There have been no empirical studies of the ship's readiness or performance, but *Yorktown* recently won the Golden Anchor Award for Personnel Retention and last year received the Battle 'E' Award for material condition. While the *Yorktown* M+1 requirement is 337 sailors, the average ship in the CG-47 class requires 358.

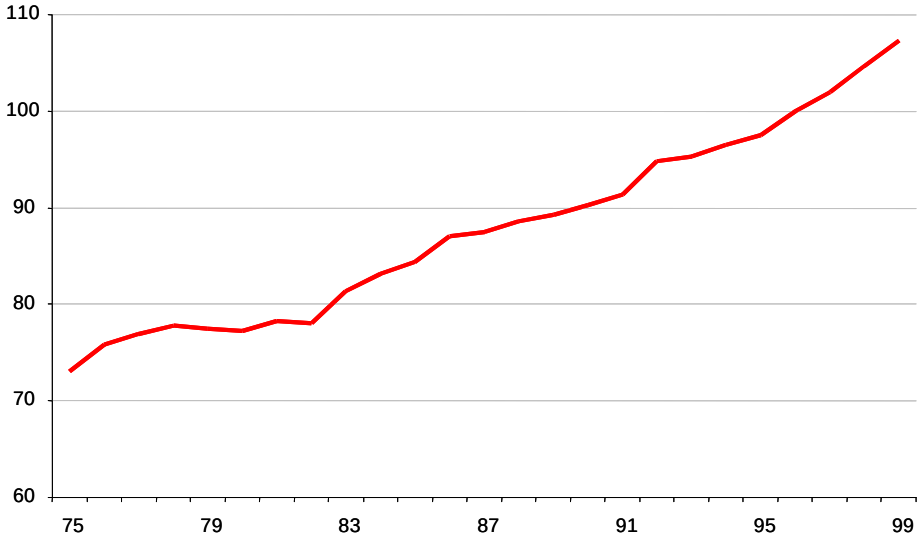
Private-sector practices

Labor productivity on the rise

In the private sector, labor productivity grows consistently (figure 1). Productivity growth translates into more (or better) goods and services produced with a given number of people working a given number of hours. Alternatively, it means the same level of production with fewer people, or fewer hours. Growth reflects firms' continual efforts to optimize the use of resources and is driven by investments in capital equipment, managerial innovations, and an increasingly skilled and knowledgeable workforce.[11] During the 1990s, labor productivity growth was driven by investments in information technology [16].

11. Reference [15] argues that the educational attainment and achievement of youth show an increasing trend. For example, 50 percent of the high school class of 1967 had not attended college within a year of graduation, compared to 33 percent of the class of 1996. The percentage of students who used computers in school and had taken selected science and math courses increased between 1982 and 1994.

Figure 1. Labor productivity index, U.S. private non-farm business, 1975-1999 (1996=100)[a]



a. Source: Bureau of Labor Statistics, output per hour of all persons, private nonagricultural businesses. Productivity is indexed relative to 1996.

Capitalizing on technology

In our discussions with private-sector firms, we found that companies were quick to capitalize on new technologies, economies of scale, and enhanced production techniques. For example, at the Trex Company, the purchase of equipment that automatically opened plastic bales eliminated workers required for that task. Similarly, a new saw that cut boards more accurately reduced the need for workers at that stage of the manufacturing process. These labor savings did not require layoffs because personnel were absorbed into ongoing operation expansions. The company plans to move toward the automatic bundling and packaging of its product, which would also reduce labor needs, and is creating a centralized equipment monitoring system that will automatically collect and analyze maintenance data, generate reports, and alert personnel about needed repairs.

Reducing crews

For the Navy to reduce crew sizes without sacrificing readiness, it must substitute other resources to do the work or to use labor more efficiently. Choices include:

- Workload-reducing technology
- Using more highly skilled and experienced people
- Using crew members more efficiently by eliminating unnecessary work, manipulating work schedules, cross-training, or other means.

All the options are feasible: the Navy has had access to the same (or better) labor-saving technologies as civilian firms. And like the civilian labor market, it **has** benefited from a steady increase in the quality of personnel.[12]

A combination of changes is best

We have seen how the mathematics of billet creation limits the realization of billet savings from workload reductions, whether the change in workload comes from technology or from some other source. However, some barriers are practical in nature. An organization can inhibit labor-savings by attempting to introduce technology without making complementary adjustments to other resources and practices.

Experts emphasize that no *single* ingredient ensures manning reductions. To take full advantage of the manpower-reducing effect of technology, it may be necessary to reorganize work or employ more skilled people. For example, Sims [18] concluded that reorganizing work schedules and cutting watch-standing requirements would entail

12. Between 1973 and 1982, only about 71 percent of Navy accessions had high-school degrees. Starting in 1983, that percentage ranged from 85 to 95 percent. Similarly, one-half of the recruits who entered the Navy between 1984 and 1989 had high school degrees *and* tested in the top 50 percent of the AFQT, compared to about 60 percent between 1990 and 1999 [17].

greater manning reductions than installing information technology. "However, new technology may indirectly affect manning by providing a rationale for watch-standing reductions that could have been made anyway." According to [19], new technology helps only "when viewed as part of a larger re-thinking of the organization." And one of the lessons learned from reduced manning experiments in the Navy is the value of cross-trained crews—who are fully skilled in more than one area—as well as general problem-solving ability [15]. Finally, some authors have discussed workload-reducing strategies, such as an integrated bridge, that were not adopted because they were inconsistent with traditional ways of performing work in the Navy [5, 6].

Workload-reducing technology

The Navy has access to many types of workload-reducing technology.[13] One study identified three uses of technology that have also led to reduced manning on Navy ships [19]:

- Situation assessment—better tools for tracking and communicating the big picture allowed for more efficient, smaller teams
- Use of remote specialists—for instance, a core of maintainers could be on a ship with more experienced experts standing by in other locations
- Centralized monitoring systems.

For example, the Integrated Condition Assessment System (ICAS), which is installed on *Yorktown*, allows crew members to monitor the condition of equipment. By removing the need for many repairs in the preventive maintenance schedule, ICAS has the potential to reduce the number of engineering department billets by 5 on the CG-47 class, by 7 on the LSD-41 class, and by 12 on the LHD-1 class [21].

The Navy has the communication technology to make greater use of remote specialists, but we found some additional applications in the U.S. Military Sealift Command (MSC) and Britain's Royal Fleet Auxiliary (RFA). In the MSC, shore-based Customer Service Unit staff manage MSC personnel, handling such issues as leave and discipline.

13. Extensive discussions are available in [15] and [20].

This reduces the need for administrative personnel aboard MSC ships. The RFA uses remote specialists by moving some functions to shore and consolidating workloads. One yeoman ashore may coordinate activities and perform administrative tasks for two or three RFA ships. The Navy could investigate the potential effectiveness of reducing shipboard requirements by increasing the use of detachments to perform specialized work.

Skill and experience

Statistical evidence

Research has found that manning as a percentage of the M+1 requirement has a positive effect on a ship's readiness—not just personnel readiness, but material condition as well [21, 22]. This is consistent with the general validity of the M+1 requirement: the closer the size of a ship's crew to the requirement, the greater the readiness in most resource categories, including equipment, supply, and training.

Readiness studies also point to the importance of the skill and experience of the crew. For a given manning rate, the quality of enlisted personnel (defined in terms of education, test scores, and seniority) is an important driver of inspection results [23, 24] and of equipment, supply, and training readiness [21, 25]. This suggests that the Navy can substitute smaller, more experienced crews for larger, less experienced ones and achieve the same readiness.

It is not only length of service that matters, but the time that sailors serve in particular billets. Enlisted turnover (percentage of crew that arrived on board in the past 3 to 6 months) reduces ship readiness. More turnover decreases the percentage of time free of CASREPs and slows down the repair rate [22]. This could imply that labor savings are achievable by keeping people at sea longer. Of course, tours that are too long eventually harm morale and performance. Linking readiness evidence with insights from human factors and human systems engineering will help identify the optimal tour length.

The Navy is currently exploring a method called SkillsNet that will catalogue sailors' knowledge, skills, abilities, and tools. The results may suggest other ways to make substitutions among personnel.

Case study evidence: MSC and RFA

Staff at the MSC and RFA told us that their experienced workforces—combined with labor-saving ways of organizing work—have enabled them to keep crews relatively small. The majority of MSC and RFA personnel are civilianized, but many have prior military experience and are older than their Navy counterparts.[14] As a result, they need less supervision and training than Navy crews, which frees labor for productive tasks.

A comparison of MSC and Navy manning aboard the AOE-6 (Navy) and T-AOE-6 (MSC) shows that the MSC ship is able to operate with 3 more officers but 379 fewer enlisted personnel (table 3).

Table 3. MSC and Navy manning differences aboard the AOE-6 and T-AOE-6

	MSC manning[a]		Navy manning		Navy-MSC difference	
Department	Licensed/ officers	Unlicensed/ enlisted	Licensed/ officers	Unlicensed/ enlisted	Licensed/ officers	Unlicensed/ enlisted
Weapons/operations	0	0	3	37	3	37
Deck	8	72	4	214	-4	142
Communications	1	14	3	28	2	14
Electronic repair	0	5	0	8	0	3
Purser	1	1	3	17	2	16
Medical	1	0	2	7	1	7
Engineering	11	29	5	150	-6	121
Deck machine repair	1	5	2	12	1	7
Supply	4	7	5	34	1	27
Food preparation	1	9	1	17	0	8
Food service	0	33	0	20	0	-13
Laundry	0	1	0	11	0	10
Total	28	176	28	555	-3	379

a. Source: Military Sealift Command. Includes military detachments.

14. RFA personnel were 39 years old on average in 2001, roughly comparable to the average MSC mariner age of 46. This is significantly older than an active-duty Navy crewmember, who is 28 on average, or a new Navy enlisted recruit, whose average age is 19. MSC mariners average about 13 years of government service, compared to about 9 years for their naval counterparts [26].

Crew experience is not the only factor explaining the difference, but it is an important one. In addition, the AOE needed personnel to man and maintain the weapon systems. The Navy's combat mission is a contributing factor, but not a driving force. The AOE-6 employed only 40 people in weapons/operations; 342 billets remain unexplained. The vast majority of the manning difference of 379 occurs not in the combat departments, but in deck and engineering. These are departments in which great labor-saving possibilities exist, but some requirements planners believe them to be unsafe for use in the Navy [6].

Cross-training

One way of creating a more skilled labor force is to provide extensive cross-training. Managers from commercial firms, the MSC, and the RFA told us that cross-training reduces manpower requirements because the same person can transition into multiple roles. According to managers at Riggs Bank and Trex, cross-training can even foster corporate commitment because the employees come to see the organization as a dynamic whole.

The current Navy model is specialized schoolhouse training in a rating combined with low-skilled labor. When sailors work "out of rate," it usually means they are painting and cleaning. Although the Navy does offer some cross-training opportunities (for example, sailors may have watch station duties in addition to their primary duties, and assume collateral duties as needed), Navy personnel do not typically rotate to a large class of jobs outside their ratings.

Goals for a requirements process

Exploring alternatives

Overall, the Navy's SMD program provides an independent assessment of manpower requirements for readiness reporting and staffing the fleet. These functions are important, but they are not all the Navy needs. Organizations are confronted with innumerable manpower choices. Some choices better support the organization's mission, make better use of resources, and are more feasible than others. Therefore, any organization needs a requirements process that assists in making those choices. Such a process needs to be able to:

- Recognize staffing alternatives
- Determine how to use resources cost-effectively for the benefit of customers and employees
- Investigate ways to make use of technology and follow through with appropriate innovations.

We found that private-sector companies reassess manpower requirements frequently, once they find a way that works. When the Trex Company opened its Winchester, Virginia, plant in 1993, it based its manning on historical counts at an established plant. As new lines became operational, the same number of personnel (typically five per line) would be added to the Winchester staff. This process was not formally assessed until 1997, when an engineering intern decided to reexamine the plant's manning determinations. Trex first reviewed and revised all of its Winchester plant job descriptions. Workload was then measured through the use of extensive time / motion studies and employee surveys. Since the initial reassessment was completed, the number of required workers per line has dropped from 5 to 4.2 as the company has continued to take advantage of economies of scale, enhanced process techniques, and technological improvements. Assessments are now done on an annual basis to adapt manning to the constantly changing work environment, or more frequently if new

lines, equipment, or manufacturing sites are added. The company seeks improvement by encouraging employee feedback, and it has expanded its internship program, which gives it access to people with new ideas at low cost.

Navy's barriers to reaching these goals

As we have seen, the Navy's manpower determination process serves a specific set of purposes, and is not tailored to the goals laid out above. This is not a problem as long as other channels exist. However, several characteristics of the Navy's overall requirements process constrain its functioning. These are:

- Limited cost incentives
- Separation of technology and manpower decisions
- Inaccessibility of tools and analysis that go into requirements
- Limited information about what works.

Limited cost incentives

Although DoD policy holds that the services must keep requirements to a minimum, the process of SMD (or AMD) development lacks incentives to locate and implement opportunities for reducing workload. The Navy employs a "zero-base concept," which is so important that it appears in the first two sentences of the Navy's requirements directive [13]:

> The zero-base concept is basic to determining manpower requirements. Under this concept, the Navy determines multi-year requirements without consideration of funds, availability of personnel, or organization.

Reference [13] continues:

> Specifically excluded from the computations are allowances for personnel in a transient/leave status, hospital patients, and inadequately trained personnel. Also not included are fiscal and habitability constraints and abnormal operational demands resulting from military contingencies and emergencies.

The zero-base concept means that decisions with economic implications can be made without regard for economic conditions. For example, a private-sector manager might respond to an increase in the wages of workers with special training by substituting workers with less specialized skills. This decision would be weighed against the productivity difference between specialized and unspecialized workers. Such optimization is ruled out when developing an SMD or AMD. Yet, because a manpower document only presents one solution, there is an appearance of optimality.

Another outcome of the zero-base concept is a lack of complementarity between requirements and other business systems. Private firms strive to integrate various systems that the Navy separates. Requirements planners distinguish between manpower (requirements, or billets) and personnel (inventory, or "bodies"). The distinction is useful in theory but may be overly strict in practice. In reality, the distribution system can be slow in delivering sailors to gapped billets, and certain skills may be in short supply. Under these conditions, what would be the best manning configuration for the fleet? Today's requirements process does not provide an answer.

A manpower document has value beyond the workings of the Navy's labor market. The existence of a technical solution that can endure fluctuations in budget, costs, or available personnel is useful. Even so, we did not find a similar approach in the private sector, where requirements are inextricably linked with business objectives.

How much latitude does the Navy actually have in this matter? The zero-base concept is not required by law; it supports the Navy's interpretation of the law. Title 10 requires only a statement of requirements and a readiness reporting system.[15]

15. Indeed, the only reference to cost that we found in the law governing requirements was Section 129a of Title 10, General Personnel Policy, which states that "the Secretary of Defense shall use the least costly form of personnel consistent with military requirements and other needs of the department." The law refers to the decision to employ military, civil servant, or contractor labor.

Resource sponsors can't buy billets that are not in a manpower document [16]. If efficiency is not a criterion in manpower document development, the ability to compensate downstream is limited.

Cost considerations are more explicit in acquisition and design than in SMD production and billet authorization. Life-cycle cost goals are stated in Operational Requirements Documents (ORDs), which specify ships and systems the Navy wants to acquire. But unless officials put manning (not just cost) in an ORD, there is no reason to expect designers to achieve reductions. It is exceedingly rare for manning to be a Key Performance Parameter (KPP) in an ORD; the DD-21 offers one of the few examples. Recently, Navy leadership has been interested in making manning a KPP in *all* ship and system programs.[16]

Separation of technology and manning decisions

Operating without the intervention of senior guidance, requirements organizations will not work to reduce manning, or even conserve it. As one observer put it, "manning reduction is an organizational orphan, beyond the reach of even the most diligent, skillful manager" [6]. Smart Ship was initiated by the Chief of Naval Operations in response to a Naval Research Advisory Committee study. Recently, NAVMAC set up a branch specifically to keep abreast with smart technology and manning innovations. Still, a significant chasm remains between "smart" and "normal" requirements processes.

NAVMAC staff told us that their role is to observe technological changes as they occur; trip wires are in place to signal when a reassessment is due. Ordinarily, technology is the domain of the Naval Sea Systems Command (NAVSEA) and the fleets, whereas the current workforce is determined by NAVMAC. Manpower determinations

16. Military acquisition regulations ask that ORD KPPs be limited to eight or fewer [27]. They suggest the following guidelines for choosing KPPs:

    1. Is it essential for defining system or required capabilities?
    2. Is it warfighting-oriented or does it contribute to the improvement in warfighting capabilities?
    3. Is it achievable/testable?
    4. Can the numbers/percentages be explained by analysis?
    5. If not met, are you willing to look at canceling the program?

follow decisions about equipment, technology, and materials. Smart programs better resemble the private sector in that they rely on the joint determination of manning and technology, materials, and equipment.

Inaccessibility of tools and analysis

An accessible system is well documented and easy to understand with a small investment of time. On the whole, the Navy's requirements process is well documented but difficult to understand. This creates a barrier to innovation because engineers and analysts are unable to get a realistic sense of how a workload reduction will affect billet requirements.

Manuals describing the NMRS model and showing how to use it in SMD creation are readily available from the contractor that manages the system (contractors have documented NMRS since 1986). NAVMAC uses watch-section analysis sheets (OPNAV Form 1000/24) to report the basis for the watch-standing manpower requirement. Furthermore, NMRS produces "working papers" that contain OM information. All of these sources are helpful, but understanding them requires prior working knowledge of manpower procedures.

Where the documentation falls short is in describing analyst input. Although NAVMAC's role is essentially that of an observer, the SMDs and AMDs reflect the judgments of its analysts. Analyst experience is a critical ingredient for translating the ROC/POE into a set of requirements. According to one staff member, "Lessons learned, engagement in the process and experience are the core skills to ensure the ROC/POE is properly reviewed and interpreted." Unfortunately, the analyst's contribution is not written down, which makes it unnecessarily difficult for outsiders to replicate a manpower document and to perform what-if, quick-response analysis.

Once NMRS produces a draft SMD, NAVMAC analysts apply "quality controls" [3], or analyst judgment. Again, the adjustments are not recorded. Even though analyst adjustment has a small impact, it would be worth documenting because such decisions help reveal the way the process works. In one case, an analyst shifted 17 hours of workload from one division to another to avoid adding another billet

requirement. What's interesting is that (a) 17 hours of workload is enough to add a billet in NMRS and (b) analyst judgment can result in manpower savings.

Additional documentation problems involve justifying some of the assumptions embedded in the NMRS model, determining OUS workload, and determining the size of divisions and departments. Documentation may once have existed but is no longer recoverable.

Limited information about what works

Quantitative measures of effectiveness

To the commercial companies we interviewed, performance metrics are indispensable. All developed metrics to quantify such variables as safety, amount of output, quality of products and services, and workforce performance. At Riggs Bank, the value of performance metrics became obvious when the company abandoned its computer-based staffing model several years ago. The software was unable to integrate the company's varied data systems, so Riggs switched to a more hands-on process that depends on performance metrics. The company plans to adopt a newer, computer-based staffing model that is intended to complement—not replace—the performance metrics.

In contrast, the Navy doesn't routinely measure the effectiveness of particular billets, skills, watch-standing schedules, or uses of technology. Units collect data on accidents, repairs, readiness, and material condition that could form manpower performance metrics. However, the effort is not designed to be used in the requirements process.

Measures of safety and risk

Assessment of safety and risk is critical to Navy staffing decisions, but measurements are not part of the requirements process. Safety and risk are instead implicitly defined by the ROC/POE. According to NAVMAC [3]:

> When writing a ROC/POE, a certain amount of risk is assigned. However, onboard a ship, when the Commanding Officer decides not to stand a particular watch station, he is assuming risk. The level of risk that a Commanding Officer can assume is greater than the level of risk that he should be assigned.

This says that it is not the role of NAVMAC to assign risk to a CO by limiting the number of watch-standing billet requirements. This position seems reasonable in the context of the current system. If NAVMAC is not tasked to find improvements, it is not going to make changes that could increase risk.

The problem is that the risk factor is unknown. How much is the "certain amount of risk" assigned when writing a ROC/POE? Can the Navy articulate and quantify these risks? If there are no measures of risk, there is no way to know how much risk a CO is assigned in an SMD or how much extra risk he would take on with fewer watch-standing billets. There are likely to be diminishing returns to adding people; after a point, additional people may not only fail to alleviate risk, they may actually increase it.

Qualitative information

The private-sector managers we spoke to also emphasized the importance of soliciting qualitative information about what works. This fact is relevant to the Navy because ship's crews and COs are responsible for such innovations as core-flex and Blue-Gold manning on surface ships, and making them work.

Often, private-sector firms organize their workforces so as to facilitate employee innovation and to transmit that knowledge throughout the organization. At the Trex Company, process improvements suggested by employees save the company an estimated $100,000 to $200,000 annually. The hands-on manpower determination process used at Sylvan Learning Centers, Riggs Bank, and the MSC and RFA also provides a feedback mechanism because people who use and manage staff have a direct role in the process.

For an organization as large as the Navy, transmitting information in this way poses a tremendous challenge, but information technology allows for a virtual clearing-house that gathers and disseminates lessons learned.

Assumptions behind manpower requirements

So far, we have described the basics of Navy SMD creation. To better understand and evaluate the system, we examine the roles of (1) productivity allowances, (2) the Navy Standard Workweek, (3) the Staffing Table, or paygrade matrix, and (4) starting points. We discuss the rationale behind each of these and describe how they affect billets and costs.

Deriving relationships between workload and billets

Estimating the contribution of assumptions to billets and costs is complex; straightforward extrapolations are not possible. As we have seen, it is surprisingly difficult to reduce billets by cutting workload. The reason is simple: eliminating a billet requires the elimination of 67 hours of workload.

The following simplified example illustrates the principle. Suppose that it becomes possible to eliminate a workload related to a specialized NEC aboard a ship, and that 2 people hold that NEC. Does this mean that 2 billets will be eliminated? Only if the NEC workload is 134 hours a week (=67*2) or more, but this is unlikely. NEC workload typically accounts for a small fraction of the workload expected to be performed by the person who holds it. The more likely outcome is that billet requirements will remain unchanged.

The Manpower Analysis Prediction System

Because of the complexity of the calculations, we use the Manpower Analysis Prediction System (MAPS) to test the effect of NMRS assumptions. MAPS is a simulation model developed at the Naval Surface Warfare Center, Carderock. It mimics the NMRS (using NMRS inputs as a baseline) but is simpler to use and provides valuable quick-response capability. It reproduces the NMRS requirements with a high degree of fidelity and, even if not thorough enough for SMD

production, is appropriate for analysis.[17] Unlike NMRS, MAPS contains a billet-cost component, making it possible to predict costs. The costs in MAPS include all MPN and OMN cost of personnel—salaries, recruiting, training, housing and medical expenses. It also creates linkages between the ROC/POE and manpower requirements, which could prove useful to policymakers.

Using MAPS, we performed simulations for three ship classes: DDG-51, LHD-1 and CVN-68. The 42 ships in this class encompass 46,500 M+1 enlisted billets, 37 percent of the Navy total.

Allowances

Rationale

The productivity allowance makes up 6 percent of the total workload on Navy ships. The make-ready put-away allowance, which applies to maintenance, makes up another 2 percent.

According to Navy instructions [10], "The productive allowance factor is a percentage allowance applied to basic productive work requirements to reflect those delays arising from fatigue, environmental effects, personal needs, and unavoidable interruptions which serve to increase the time required for work accomplishment."

NAVMAC staff told us Navy explored productivity allowances between 1966 and 1970. The resulting PA factor is a composite of the 15 percent personal and fatigue allowance and the 5 percent delay allowance for a total value of 20 percent. This value is based on industrial standards and on activity sampling on operational Navy ships [10], but record of the study is no longer available.

The PA allowance

According to industrial engineering experts, a PA is typically the sum of three allowances: personal, fatigue, and delay.

17. A test run compared the results of NMRS and MAPS simulations. They were very close.

Personal allowance

According to a standard textbook on workplace design, a personal allowance is for "such things as blowing your nose, going to the toilet, getting a drink of water, smoking and so forth," and the average value in industry is 5 to 7 percent [28].

Fatigue allowance

A fatigue allowance is meant to compensate for time lost as a result of physical or mental fatigue. Fatigue allowances may exist for monotonous work, restrictive clothing, awkward postures, visual demand, long hours, noise, the need for exact timing, or a range of other conditions.

There is no consensus as to the appropriate size of a fatigue allowance for given conditions [28]. The appropriate allowance depends on job design and assignment policies. Jobs that are designed with the endurance of crews in mind may require smaller fatigue allowances, as may better matching sailors to jobs. According to [29], "The major fatigue factor in today's industry is not physical but psychological. However, with scientific selection programs, putting the right people in the right jobs appears to substantially reduce fatigue."

Delay allowance

Delay allowances compensate for short delays beyond the control of operators. Examples include machine breakdowns, interrupted material flow, conversations with supervisors and machine maintenance and cleaning. The make-ready put-away allowance is a type of delay allowance, applied to preventive maintenance workload only.

There is no industry standard; delay allowances are best based on activity sampling and time studies. Experts say that delay allowances should be reviewed and changed periodically, say every 2 years, to reflect organizational learning and technical change [28].

Is the PA allowance fixed?

Given the strenuous nature of shipboard work, there is nothing especially odd about a PA of 20 percent or an MRPA of 30 percent. However, the lack of professional consensus regarding fatigue and delay

allowances, and the urgings of experts to subject these to investigation, suggest that the Navy should invest in methods and time studies.

For example, anecdotal evidence suggests that sailors "multitask" in response to delays, performing alternate activities based upon situational priorities and opportunities. Technological change aboard ships may facilitate multitasking.

The Navy may reduce fatigue with alternative schedules and human systems integration. For instance, USS *Lake Erie* (CG-70) follows a "Blue-Gold" manning schedule in which two teams trade off 12-hour shifts. Shifts start at noon or midnight, with the teams trading off start times once a month. According to the ship's website, the "off" team is truly off-duty; the "on" team handles all watch and non-watch work short of General Quarters. It is possible that such arrangements as Blue-Gold manning enhance productivity by reducing fatigue and delays. For instance, in *Lake Erie's* combat systems department, "No Blue person was ever called to relieve a Gold person other than at the normal midnight or noon turnover. All watch reliefs during the on-duty Team's 12 hours were by an already-awake person with sufficient situational awareness that big-picture information need not be rehashed" [30]. It is likely that the benefits would also apply to maintenance and OUS work.

How much can the Navy save if studies indicate that allowances could be reduced? According to MAPS, the gains from cutting the PA allowance from today's baseline—or even from eliminating it altogether—are small (table 4). Again, we see that a relatively large change in a workload factor has a small effect on the number of billets. On a CVN-68 class carrier, reducing the PA from the baseline of 20 percent to 10 percent would save 32 billets, which together have a value of $2.5 million per year. Revising the allowances is one source of manning reductions, but not the driver of change.

However, the savings become significant in the aggregate and over time. Reducing the PA from 20 percent to 10 percent for each of the ships in these three classes would save $42 million worth of billets per year (table 5). The savings reported are upper bounds: they assume that ships are fully manned now.

Table 4. Billets and costs per ship with alternative productivity allowances[a]

PA	DDG-51		LHD-1		CVN-68	
(%)	Billets	Cost ($M)	Billets	Cost ($M)	Billets	Cost ($M)
0	325	29.86	1,174	101.47	3,290	282.55
5	327	30.02	1,180	101.92	3,302	283.57
10	328	30.10	1,185	102.28	3,316	284.65
15	330	30.25	1,194	102.96	3,328	285.56
20	333	30.50	1,202	103.62	3,348	287.14
25	344	31.45	1,233	105.30	3,400	291.38

a. From the Manpower Analysis Prediction System (MAPS). Costs are expressed in FY01 dollars and include all MPN and OMN spending on personnel. Baseline is 20 percent.

Table 5. Total cost impact of PA on CVN-68, LHD-1 and DDG-51 ships[a]

PA (%)	Cost ($M)	Change in cost rel. to baseline ($M)
0	4,029.66	-72.93
5	4,046.15	-56.44
10	4,060.52	-42.06
15	4,077.38	-25.21
20	4,102.59	0
25	4,177.32	74.73

a. From MAPS. Costs are in FY01 dollars and include all MPN and OMN spending on personnel. Baseline is 20 percent.

We also used MAPS to simulate the effects of changing the MRPA. Once again, we estimated the combined effect on billets and costs of changing the MRPA on each ship in the DDG-51, LHD-1 and CVN-68 classes. In aggregate, reducing the MRPA from 30 to 20 percent would cut billets by 74 and save $5.8 million per year. If research suggested an increase was necessary, costs could increase. For example, increasing the MRPA to 40 percent would add 197 billets valued at $15.5 million per year.

Navy Standard Workweek

Rationale

The at-sea workweek is based on a mix of human factors, policy, and operational considerations (see table 6). Some parts of it, such as the 56 hours allocated to sleep, are fairly transparent. Others, such as the 67-hour productive workweek, are less so: what lies behind the expectation that sailors work 11 hours of non-watch duty? There have been several changes to the standard workweek, but we can only speculate about the reasons. Perhaps they were clear at the time, but informative documentation no longer exists.

Table 6. Navy Standard Workweek for military personnel afloat[a]

Activity	Hours
Sleep	56
Messing	14
Personal needs	14
Sunday free time	3
Productive work	67
Training	14
Service diversion	14
Total hours per week	168

a. Different NSWWs exist for squadron and shore personnel.

The workweek in its current form dates from 1986. An ongoing CNA study is revalidating the NSWW by interviewing sailors about their schedules. The study found that the average sailor spent 74 hours in productive work, defined as watch, evolutions, and others ship's work. At the level of the department, undermanning relative to the M+1 requirement has only a weak effect on hours of work. When necessary, COs adapt by assigning people to areas that are undermanned.

Savings potential

We used MAPS to estimate the impact of the NSWW on requirements and costs (table 7). All changes to the NSWW affect billets via additions to, or subtractions from, productive work time. For instance, reducing the standard for service diversion from 7 to 5 would affect the number of billets only if the 2 hours were added to productive time. If the reduced service diversion went to personal needs, that would be a benefit to sailors but would not affect the number of billets. Therefore, our MAPS simulations focused on changes in the productive workweek, which could arise because of changes in any other element of the workweek.

Table 7. Billets and costs per ship with alternative working hours per week[a]

	DDG-51		LHD-1		CVN-68	
Hours	Billets	Cost ($M)	Billets	Cost ($M)	Billets	Cost ($M)
59	356	32.45	1,280	109.80	3,516	300.74
63	348	31.78	1,238	106.49	3,432	293.91
67	333	30.50	1,202	103.62	3,348	287.14
71	326	29.93	1,170	101.16	3,308	284.01
75	321	29.52	1,150	99.64	3,286	282.27

a. From the Manpower Analysis Prediction System. Costs are expressed in FY01 dollars and include all MPN and OMN spending on personnel. Baseline is 67.

In aggregate, if the NSWW were to be 71 instead of 67, the Navy would reduce required billets on these ship classes by 766. Together, those billets have an annual value of $61 million.

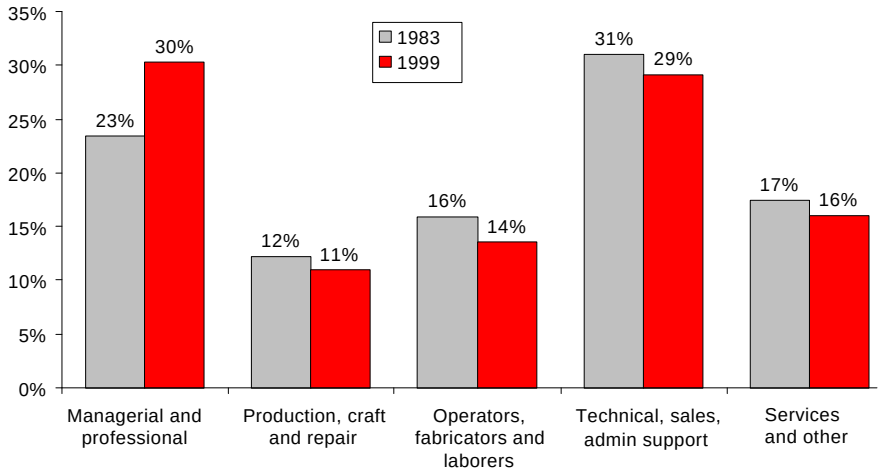
The paygrade matrix

According to NAVMAC, the matrices, or Staffing Tables, that lie behind NMRS's paygrade distribution date from 1972 and are based on at-sea observations of 75 ships. The Navy began a revalidation study in 1982, but the project has never been completed. In 1986, the GAO noted that NAVMAC had adjusted the staffing tables over time but had not documented the changes. This is also the case for any adjustments that have been made since 1986.[18]

18. NAVMAC has recently requested that the Staffing Tables be reviewed.

The fixity of the Navy's paygrade Staffing Tables contrasts with the changes that have occurred elsewhere. Figure 2 shows the occupational distribution of the civilian labor force in 1983 and 1999. Roughly speaking, managerial and professional occupations correspond to high paygrades. The percentage of workers employed in these occupations has increased from 23 percent in 1983 to 30 percent in 1999. The percentages employed in all other categories has declined. It is possible that technological change and the changing quality of Navy crews is exerting similar pressure on the Navy's paygrade structure.

Figure 2. Occupational employment as percentage of civilian employment, 1983 and 1999



Starting points

The GAO noted that the Navy's requirements process tends to reproduce the status quo and allows inefficiencies to perpetuate. The reliance on operational audits, as well as a lack of rigor in assessing watchstanding requirements, means that the current manning configuration exerts too great an impact on requirements determination [1].

The SMDs are baselines for the more tailored and recent AMDs. If the past requirement is the baseline, today's requirements may be inflated.

The MSC and the RFA start with a bare minimum crew and work up. Each begins with the minimum number of personnel deemed necessary to meet its country's Coast Guard's safety standards and the Standard for Training, Crewing, and Watchkeeping (STCW), the international manning standard. Each country's Coast Guard determines required safe manning levels (based on such factors as size of ship, routes, and horsepower), certifies ships, and mandates the certifications required to hold each position on a ship. Once they determine the basic crew, the MSC and the RFA assess the need for additional people.

Appendix: Descriptions of private-sector companies interviewed

We spoke with representatives from several private-sector companies, the U.S. Military Sealift Command (MSC), and Britain's Royal Fleet Auxiliary (RFA). A short description of each organization, and our reasons for selecting it for our study, follow.

Riggs Bank N.A.

Riggs Bank N.A. is a publicly traded company that has branches at more than 50 locations in the Washington, DC, metropolitan area. Founded in 1836, Riggs offers a variety of personal banking services including personal accounts, borrowing, private banking, and online and ATM services.

We chose to study the manpower determination processes at Riggs Bank for several reasons. First, it is a well-regarded local company in the services sector. Because we also examined the manpower determination processes in a manufacturing environment, we thought a service-sector company would provide an alternative view of the manpower determination process under different operating conditions. Second, the nature of work done within branch banks is somewhat similar to that performed in the administrative departments of a ship. Finally, because the corporation is responsible for determining manning across a series of small operations (the branch banks), the process shares some similarities with the process of manning individual entities (ships) within the Navy.

Sylvan Learning Centers

Sylvan Learning Group is a business unit of Sylvan Learning Systems, Inc., a publicly traded company headquartered in Baltimore, MD. Sylvan Learning Group consists of three separate divisions:

1. Sylvan Learning Centers—a for-profit division providing personalized instructional and test preparation services to students of all ages and skill levels.
2. Sylvan Education Solutions—a division providing tutoring and other direct services to students. The division also offers professional development support and certification to teachers in both public and private schools.
3. Wall Street Institute (WSI)—a division offering English language instruction.

The Sylvan Learning Centers division consists of 90 corporate and 797 franchise sites across North America and Asia (Hong Kong and Guam). Founded in 1979 (and first franchised in 1980), it offers a variety of educational services to children, primarily in grades K–12. *Success* magazine recently named Sylvan Learning Centers the top franchise in America. In the fourth quarter of 2001, the division expects to realize revenues of $25 million to $27 million, with operating margins of about 15 percent.

We focus on this division of Sylvan for several reasons. First, it is part of a well-regarded local company in the services sector. Second, we thought that this division could potentially offer us some insights because the Navy also provides educational services. Finally, because most of the learning centers are franchised, we are able to draw some parallels between the manning of individual franchise operations and the manning of individual entities (ships) within the Navy.

The Trex Company

The Trex Company is the nation's largest manufacturer of non-wood decking products. Made from recycled plastic and wood, Trex® offers the durability and appearance of wood without wood's associated maintenance requirements.

In 2000, Trex was selected by *Forbes* magazine as the #1 Best Small Company in America and also won *Industry Week's* Growing Companies 25 Award. In 2001, it was named one of *Business Week's* "Top 100 Hot Growth Companies." Net sales of Trex® increased 52 percent between 1999 and 2000, and the company has plans to add lines at its existing Winchester, VA, and Fernley, NV, plants, with development of a third manufacturing site in Knox County, TN, under consideration.

We chose to study the Trex Company for several reasons. First, it is a well-regarded local company in the manufacturing sector—a sector that has traditionally recognized labor / capital tradeoffs and has been systematic in optimizing labor requirements. Second, because the company is relatively young (formed in 1996), we were able to speak to people who were familiar with the Winchester plant's development and growth over time. Finally, the operating environment at the Trex Company's plants is similar in several ways to that of a Navy ship. Like the Navy, the Trex Company uses preemployment testing and requires a high school degree or GED as a prerequisite for employment. Also, because it operates 24 hours a day, 7 days a week, the Winchester plant requires the same continuous staffing requirements as a Navy ship. In fact, several of the tasks performed at the plant (preventive and corrective maintenance of equipment, emergency fire fighting) have direct Navy counterparts.

The Military Sealift Command

Since World War II, the MSC has been the single managing agency for the Department of Defense's sealift and ocean transportation services. Its mission is to provide ocean transportation of equipment, fuel, supplies, and ammunition during both peacetime and wartime. In fact, the MSC delivered over 12 million tons of equipment and supplies to U.S. troops during the Persian Gulf War.

As of FY00, the MSC had 115 active, noncombatant ships and 99 inactive ships at its disposal. Most MSC crew members are civilians—federal employees and private contractors. The MSC began operating the first Naval Fleet Auxiliary Force (NFAF) ship in 1972, and now operates almost 30 other NFAF ships.

We chose to study the MSC because it operates ships that were once part of the Navy's fleet with far smaller crews. MSC vessels continue to perform many of the same duties they did when in service to the Navy. And because they operate 24 hours a day, 7 days a week, they have the same continuous staffing requirements as Navy ships.

Royal Fleet Auxiliary

Since 1905, the RFA has provided the Royal Navy with ocean transportation of equipment, troops, fuel, supplies, and ammunition during both peacetime and wartime. Owned by the Minister of Defense, the RFA recently has participated in operations in the Gulf War, disaster relief in Mozambique, and support of the Royal Navy, Royal Marines, and British Army in Sierra Leone.

As of 2001, the RFA had 22 active ships at its disposal (including 1 aviation training and primary casualty reception ship, 2 fleet support stores ships, 3 small fleet tankers, 2 strategic lift RO-ROs, 6 fleet support tankers, 2 combined fleet support tanker and stores ships, 5 landing ship logistics, and 1 fast fleet tanker). All RFA crew members are civilians—federal employees and private contractors—and, as in the MSC, most are unionized. The RFA did not take over operation of existing ships from the Royal Navy. Rather, it operates its own shipbuilding program.

We chose to study the RFA because it shares several similarities with the MSC's Naval Fleet Auxiliary Force, but is linked to another country's Navy. RFA vessels have the same continuous staffing requirements as Navy and MSC ships because they also operate 24 hours a day, 7 days a week. Finally, unlike MSC ships, RFA ships maintain defensive weapons—a difference that could potentially be significant.

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