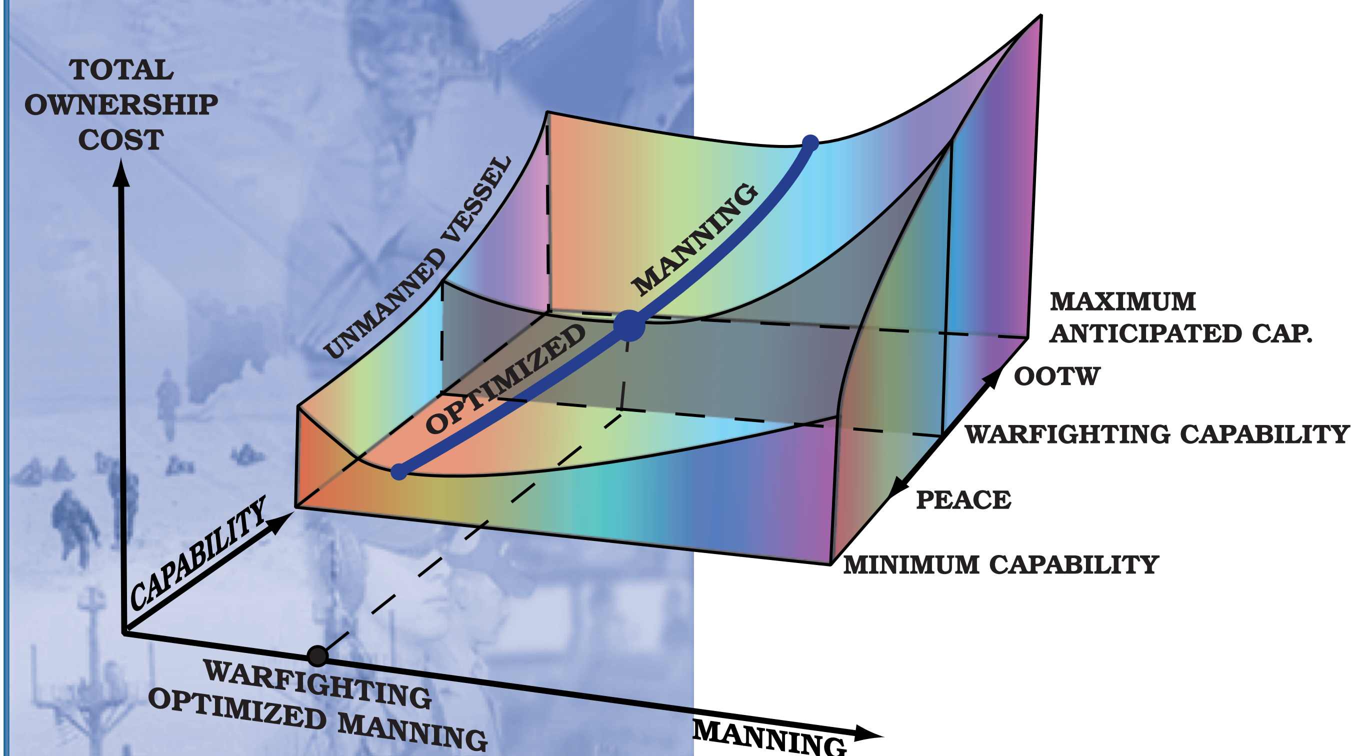
UNCLASSIFIED

Naval Research Advisory Committee Report

Optimized Surface Ship Manning

April 2000



Approved for Public Release: Distribution is Unlimited

OFFICE OF THE ASSISTANT SECRETARY OF THE NAVY (RESEARCH, DEVELOPMENT AND ACQUISITION)

NRAC 00-1

UNCLASSIFIED

COPY NO

This report is a product of the United States Naval Research Advisory Committee (NRAC) Panel on Optimized Surface Ship Manning. Statements, opinions, recommendations, and/or conclusions contained in this report are those of the NRAC Panel and do not necessarily represent the official position of the United States Navy and United States Marine Corps, or the Department of Defense.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 2000	Final, April 1999- April 2000

4. TITLE AND SUBTITLE
Optimized Surface Ship Manning

5. FUNDING NUMBERS

6. AUTHOR(S)
. Spindel, S. Laska. J. Cannon-Bowers, D. Cooper, K. Hegmann, R. Hogan,
. Hubbard, J. Johnson, D. Katz, E. Kohn, K. Roberts, T. Sheridan,
. Skalka, J. Smith

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Research Advisory Committee
800 North Quincy Street
Arlington, VA 22217-5660

8. PERFORMING ORGANIZATION REPORT NUMBER
NRAC-00-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Assistant Secretary of the Navy (Research, Development and Acquisition)
1000 Navy Pentagon
Washington, DC 20350-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release: Distribution is unlimited	A.

13. ABSTRACT (Maximum 200 words)
NRAC assessed Navy efforts to optimize manning on surface ships. This included a review of previous relevant studies, current programs in US and foreign navies, and relevant technology opportunities.

The panel reviewed system life cycle cost initiatives designed to produce savings for recapitalization and modernization. They found a growing cost database under development; however, they recommended continued expansion, cost methodology improvements and further identification of manpower cost components.

The Smart Ship demonstrated that technology insertion and process improvements can reduce manning, maintain capability and improve shipboard quality of life. The Navy has not diffused the Smart Ship lessons learned throughout the Fleet. This is attributed to a lack of top-down leadership and implementation strategy. This situation highlights the enormity of the problem the Navy faces to adapt the revolutionary changes anticipated in DD-21.

Recommendations: (1) CNO appoint a Flag Board responsible for strategy implementation to ensure technological, procedural and organizational changes are adopted throughout the Navy; (2) modify the ship design process to include human engineering to achieve optimal human/system performance; (3) align R&D efforts so that compatible processes and specifications are incorporated for ship components and subsystems for optimally manned ships; and (4) modify recruitment, training, compensation and career progression strategies to reflect changes in organization, skills, and expanded decision-making authority required on optimally manned ships.

14. SUBJECT TERMS:	15. NUMBER OF PAGES
Optimized manning; human systems engineering; life cycle cost reduction; total ownership cost (TOC) reduction; manning reductions; quality of life improvements; DD-21; human/system performance; R&D; recruitment; training; Operation and Support (O&S).	104
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI std 239-18
298-102

This page intentionally left blank

UNCLASSIFIED

Naval Research Advisory Committee Report

Optimized Surface Ship Manning

April 2000

Approved for Public Release: Distribution is Unlimited

OFFICE OF THE ASSISTANT SECRETARY OF THE NAVY
(RESEARCH, DEVELOPMENT AND ACQUISITION)

NRAC 99-2 UNCLASSIFIED COPY NO

This page intentionally left blank

TABLE OF CONTENTS

This page intentionally left blank

Optimizing Surface Ship Manning

Executive Summary

Purpose of Study

The panel was chartered to review and assess efforts to optimize manning on surface ships. This included the review of previous studies of the subject, current programs within the U.S. and foreign navies, and relevant technology efforts. The panel was also asked to identify technology opportunities and to recommend changes in procedures and policy that would hasten and improve efforts to optimize ship manning in the Navy.

Background

The Navy's total budget has declined by 40% since 1985, but Operation and Support (O&S) costs have remained almost constant. Unless the O&S portion of the budget can be decreased, funding that is essential to recapitalize and modernize the Fleet will be insufficient. Because personnel costs comprise over 50% of O&S costs, it is imperative to reduce the number of people necessary to fight ships of the future as well as the legacy ships of today's Fleet. There is also a realization that the Navy operates in a new political/military/social environment, and modern Sailors are very different from those in the past. Career alternatives, quality of life issues, and family responsibilities make recruiting and retention more difficult for the Navy. These factors all point to the importance of focusing on optimizing manning in our Surface Navy.

Recommendations

The panel reviewed several initiatives the Navy has undertaken to understand and manage ownership costs throughout the life cycle of systems to produce savings for recapitalization and modernization. New requirements to plan for Total Ownership Cost (TOC) in acquisition programs have caused a growing body of cost data to be developed. But continued efforts are required to expand this database, improve the cost methodology, and clearly identify the components of manpower costs.

Smart Ship has been a significant program to demonstrate how technology insertion and changes in procedure can reduce manning, maintain capability and improve shipboard quality of life. However, the Navy has encountered several obstacles in diffusing the lessons learned, adopting improvements in process, and extending technology innovations throughout the Surface Navy because it lacks top-down leadership and an articulated implementation strategy. This experience points to the enormity of the problem the Navy faces in adapting to the revolutionary changes anticipated in the Navy's Land Attack Destroyer DD 21 and other optimally manned ship development programs. In order to accomplish such revolutionary change the Navy must:

(1) Provide top-down leadership in the form of a Chief of Naval Operations (CNO) appointed Flag Board that is responsible for implementing strategies to ensure that required technological, procedural, and organizational changes are adopted throughout the Navy.

(2) Modify the ship design process to include Human Engineering so that optimal human/system performance is achieved with as few Sailors as possible.

(3) Align the execution of Research and Development (R&D) efforts so that ship components and subsystems for optimally manned ships incorporate the same kind of processes and specifications utilized for the platform.

(4) Modify recruitment, training, compensation and career progression strategies to reflect the changes in organization structure, skill mix, and expanded decision making required on more automated, optimally manned ships.

NRAC

Terms of Reference

Objectives

- Review and assess impact of previous studies to optimize ship manning, personnel effectiveness and quality of life
- Review current DON programs and plans
- Identify and recommend
  - Technology opportunities
  - Policy implications

To optimize manning to increase effectiveness of ship's personnel while maintaining readiness and mission capability

Naval Research Advisory Committee

Terms of Reference

Aggressive steps to reduce manning were undertaken in 1996 in the Smart Ship program, with the goal of demonstrating innovative methods for reducing manning and life cycle costs while retaining full mission readiness and safety. We now have three years of experience with Smart Ship and other similar initiatives, such as Smart Base, Smart Carrier, Smart Gator, and Smart Squadron. This study is aimed at examining the effectiveness of the technology, and extent of the process change that has been demonstrated, and to recommend further actions to optimize ship manning, especially in future ships.

The panel was asked to examine optimized manning experiences in current demonstration projects; e.g., Smart Ship, in foreign navies, the U.S. Coast Guard and commercial vessels.

Reduced manning levels can result in significant financial savings for the Navy, as well as enhanced quality of life for the Sailor, thus helping meet the Navy's challenges of more missions, less money, and increased competition for qualified people. The rapid development of automated systems coupled with human performance models of increasing fidelity should combine to enable ships to meet their missions with fewer people.

The study sponsor was Rear Admiral Michael G. Mullen, Director, Surface Warfare Division, N86, Office of the CNO.

The complete Terms of Reference are included in Appendix A.

Panel Membership

<u>Chairperson</u>	
Dr. Robert C. Spindel	University of Washington
<u>Vice Chairperson</u>	
Dr. Shirley Laska	University of New Orleans
<u>Panel Members</u>	
Dr. Jan A. Cannon-Bowers	Naval Air Warfare Center Training Systems Division
VADM Daniel L. Cooper, USN (Ret)	
Ms. Katherine C. Hegmann	Lockheed Martin Undersea Systems
CAPT Robert J. Hogan, USN (Ret)	
Dr. James E. Hubbard, Jr.	Boston University
Dr. Joseph A. Johnson	Florida A&M University
VADM Douglas J. Katz, USN (Ret)	
VADM Rudy Kohn, Jr., USN (Ret)	
Dr. Karlene A. Roberts	University of California, Berkeley
Dr. Thomas B. Sheridan	Massachusetts Institute of Technology
Dr. Anna Marie Skalka	Fox Chase Cancer Center
Dr. Jerome A. Smith	
CDR Gordon R. Graham, RN	British Defence Staff (Washington)
<u>Executive Secretary</u>	
LCDR Frank Novak, USN	Office of Naval Research
Ms. Jennifer McKneely	NAVSEA PMS 500 M/HSI

Naval Research Advisory Committee

Panel Membership

The panel consisted of a balanced group of individuals with backgrounds in industry, academia and the military. Three panel members had expertise in the psychology and sociology of organizational structure and change, several were experts in human factors engineering, and four retired naval officers had experience with Navy shipboard personnel reduction efforts already underway. Three members of the panel participated in the 1998 NRAC study on *Training Technologies*, and thus brought specific expertise related to recruitment, training and retention. Specific technical areas represented included oceanography and ocean science, psychology, sociology, photonics, engineering education, human factors engineering, automation, and industrial organization and modern business practices.

The panel was chaired by Dr. Robert C. Spindel. Dr. Shirley Laska served as Vice Chair, and LCDR Frank Novak, Office of Naval Research (ONR) and Ms. Jennifer McKneely, Deputy Manning/Human Systems Engineering Department, PMS 500, Naval Sea Systems Command (NAVSEA) served as Executive Secretaries.

This page intentionally left blank

Site Visits

- "Smart Ship", USS YORKTOWN CG-48
- Ex-USS SHADWELL
- Naval Research Laboratory
- Naval Air Warfare Center Training Systems Division
- Newport News Shipbuilding
- Naval Surface Warfare Center, Carderock Division, Philadelphia Detachment
- TNO Human Factors Research Institute, The Netherlands
- SPAWAR

Naval Research Advisory Committee

Site Visits

The panel visited various Navy shore facilities, ships and shipyards to gain a broad understanding of the complex issues involved in optimizing ship manning. Panel members visited Navy facilities in Norway and Sweden, as well as commercial shipyards and ship design centers in both these countries and in Germany. The British Royal Navy (RN) and the Royal Netherlands Navy (RNLN) have already had extensive experience in reduced manning designs, and the panel profited from detailed input concerning these efforts.

This page intentionally left blank

Representative Briefings

Optimized Manning for DD 21	NAVSEA PMS 500 M/HSI
Smart Ship	Smart Ship Program Office
Smart Squadron	Smart Squadron Project Office, N88
Smart Base	Smart Base Project Office
LPD 17 Manpower	NAVSEA PMS317L
Reduced Manning Technologies	ONR
The NAVMAC Connection	NAVMAC
Optimal Manning and Technological Change	CNA
Optimized Manning and Operations	US Navy MSC
Acquisition Reform	DSMC
SC 21 Manning Affordability Initiative	ONR/ NAVSEA PMS 500
Advanced Embedded Trainer/ShipMATE	NAWC TSD
Challenges of Reduced Manning: "What Cultures Need to Change?"	Naval Inspector General
Deepwater Project and Human Resources Challenges	USCG
US/UK Manning S&T Initiatives	ONR
Future Carriers Manpower	CVNX
Surface Training Vision	N869

Naval Research Advisory Committee

Representative Briefings

We received a variety of briefings on subjects related to reduced manning, including presentations on LPD 17, SC 21, DD 21, Smart Ship and CVNX programs. These programs all have strong influence on the way ships will be manned in the twenty-first century. Numerous other ship-manning perspectives were given by a variety of sources including the Office of Naval Research (ONR), the U.S. Coast Guard (USCG), the Naval Manpower and Material Analysis Center (NAVMAC), and the Inspector General.

This page intentionally left blank

Representative Studies

Life Cycle Cost Reduction, NRAC, 1995
Reduced Ship Manning, NRAC, 1995
Damage Control and Maintenance, 1996
Sailor 21, NPRDC, 1998
Recapitalizing the Navy, NSB, 1998
Training Technologies, NRAC, 1999
Optimal Manning and Technological Change, CNA, 1999
Trends in Manpower Reduction . . . , NATO, 1999

Naval Research Advisory Committee

Representative Studies

The panel also reviewed studies by previous NRAC panels as well as those of other organizations such as the Center for Naval Analyses (CNA), NATO, and the Naval Studies Board (NSB) of the National Research Council (NRC). These studies dealt directly or indirectly with the concept of reduced manning and provided insight into many of the components of TOC.

This page intentionally left blank

Study Scope

Focused mainly on surface ship manning issues
- LPD 17, DD 21, CVNX
- Foreign Navies - British, Dutch, German, Scandinavian
- Military Sealift Command
- Coast Guard

Did not consider how to optimize manning in:
- Specific ship subsystems
  - Operations and weapon systems (60% in DDG 51 and CG 47)
  - Helo detachment
- Submarines
- Shore establishment; e.g.,
  - Logistics tail
  - Base requirements
  - Repair

Naval Research Advisory Committee

Study Scope

The study focused mainly on issues pertaining to surface ships, largely because the Navy is beginning the production process on one new ship, LPD 17 and is in the early design phase of DD 21 and a new carrier, CVNX. DD 21 played an especially important role because it will represent the first Naval combatant designed with specific mandated manning levels. Unlike CVNX, which will evolve through two sequential designs and builds, the intent in DD 21 is a single design having all final desired attributes.

The study reviewed reduced manning programs and experiences of foreign navies, with emphasis on the British and Dutch Royal Navies, and new ship construction in Sweden and Germany. Briefings were obtained from the U.S. Military Sealift Command (MSC) and the USCG. The former operates most of its vessels according to commercial practice, with vastly reduced manning levels than a warship; the latter is in the early stages of redesigning its entire Fleet. The point of reviewing foreign navies and other U.S. maritime services, that perform vastly different functions than a U.S. warship, was simply to see what lessons had been learned, and what successful technology and procedural changes could be adopted by the U.S. Navy. The study addresses the potential negative impact of manning requirements in ship subsystems if the same rules and guidelines for reducing manning are not applied to them and comments in particular on legacy systems.

However, the panel did not consider specific subsystem manning requirements. This is an important issue because combat systems and operations alone account for roughly 60% of the total manning requirements of today's DDG-51 and CG-47 classes. We also did not study manning issues in submarines, nor did we address in any detail the so-called shoreside "tail" dealing with logistics, supply, basing, and repair.

Why Did We Do This Study Now?

- Recapitalization of the Fleet needed
  - Navy budget has decreased dramatically, while O&S dollars have remained constant
- New political/military/social environment
  - Engagement, peacekeeper, asymmetry, OOTW
  - Casualty concerns
- New sailor - expected life quality
  - “Home” is ashore, not at sea
  - Marriage and family common
  - Communications home expected - e-mail
  - Seafaring is becoming an unusual occupation in US
- Major new construction - LPD 17, DD 21, CVNX

Naval Research Advisory Committee

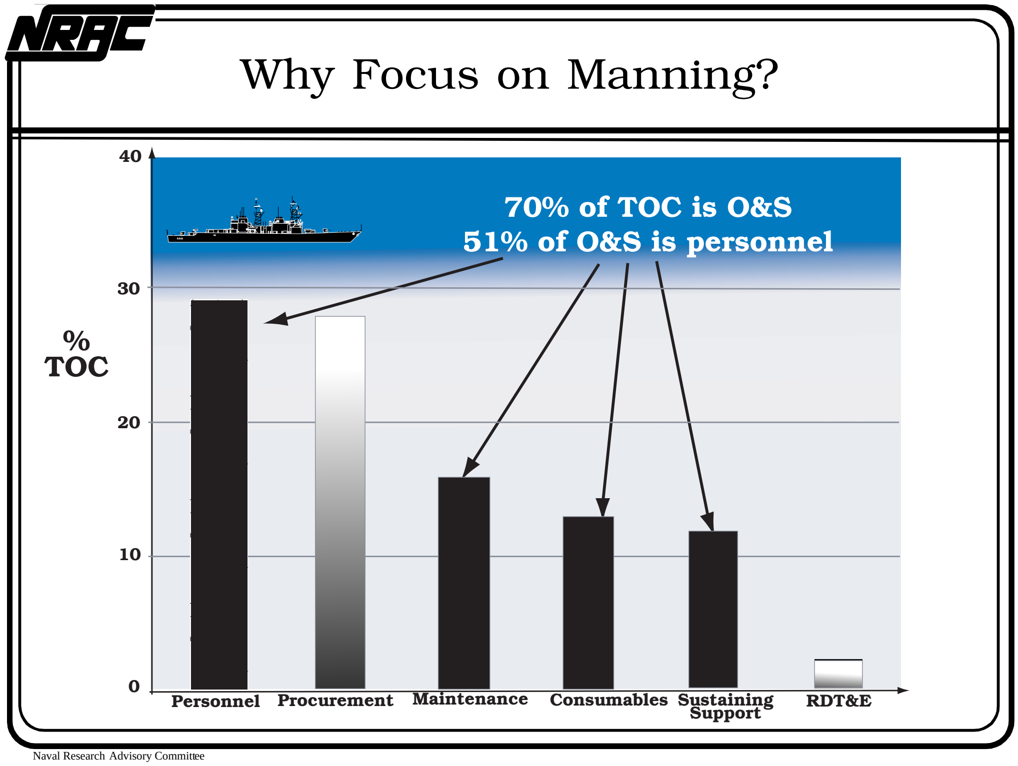
Why did we do this study now?

There have been dramatic changes in world politics, military missions, and U.S. social norms and expectations since the end of the Cold War.

One result is a vastly decreased Navy budget in the face of increased operating costs. From 1985 until today, the Navy’s Total Operating Authority (TOA) has declined by over 40% with procurement reduced by 50%. O&S costs, however, have remained almost constant during the same period--implying a smaller Fleet, or a same size, but less ready Fleet. (The Navy has chosen the smaller Fleet route.) TOC and readiness continue to be of paramount importance as the Fleet ages and needs to be recapitalized.

In addition to cost, the Navy is challenged with a new generation of potential Sailors; a generation that has grown up without knowledge of war, or conscription, or even a recognizable U.S. seafaring profession. In effect, there are no traditional role models for today’s Sailor. While yesterday's Sailor thought of his/her ship as home, today's is more apt to think of shore as home, and the ship as an assignment. Marriage and family are increasingly common among today's Sailors, and expectations for a career and life that account for family are much higher.

Finally, the Navy is in the beginning stages of building a Fleet to meet twenty-first century political and military missions. LPD 17 is about to start the production process; DD 21 is in early design, and CVNX is planned to evolve over the next 15 years through the design and deployment of two transition carriers.



Why Focus on Manning?

Seventy percent of the TOC of a ship is in O&S; i.e., personnel, maintenance, consumables, and sustaining support. Of that 70%, 51% is in personnel. Big accounts offer the potential for big savings, and manning is a big account.

This page intentionally left blank

Why Be Optimistic?

- Ready availability of new, low-cost technology
  - Information Technology
  - Sensors
- New understanding of
  - Human performance, cognition
  - Human/machine interaction
- Positive experience
  - Enthusiasm for required changes exists
  - Organizational changes occurring
  - YORKTOWN, GONZALEZ, M-class frigates (RNLN)
- Demographics
  - Growing, higher educated recruitment pool
- Military has demonstrated rapid cultural change in past

Naval Research Advisory Committee

Why be Optimistic?

Despite serious challenges, there are good reasons to be optimistic about the future. By almost every measure the rate of technology development is increasing over an already remarkable level, and promises to automate many human intensive tasks. These advances are rapidly finding their way into the Navy; one only need look at the speed with which information networking is being adopted for proof of this assertion. Current and near-term technology developments will enable dramatic improvements in future ship and weapons systems design; e.g., new sensors, control systems, robotic capabilities, and methods of perception such as virtual environments. New understanding of human performance, cognition, machine interaction, and the psychology of small groups will contribute to achieving effective mission performance with smaller crews.

The demographic picture is also positive. The pool of potential recruits is growing, following an early 1990s minimum, and the educational level of young people is rising. There will be more high school graduates and individuals with partial or full college education than there are today. The question, of course, is will they join the Navy?

Already there has been a significant, positive acceptance within the Navy of the organizational, cultural and procedural changes that the future demands. It should be emphasized, however, that what has so far occurred, measured against what is ultimately required, is only the beginning. The military, although by nature and necessity a conservative organization, has demonstrated an ability to make major, rapid changes in the past. Examples include the adoption of seaborne air power, nuclear propulsion and weapons systems. There is every reason to believe that a transition of similar magnitude can be made in the Navy for the next century, given an organization-wide will to do so.

NRAC

Take Away Messages

- A truly optimally manned ship is ***revolutionary***
  - Because the ultimate design goals of an optimally manned ship are so revolutionary, it is unlikely that all the ultimate design goals will be achieved in first of class, but insisting on modular, open systems design allows swift evolution toward the ultimate design goals.
- A systematic ***human engineering*** approach is needed
  - Incorporate scientific data on human capabilities and limitations into the design process is essential to achieve optimized manning
- The ***sailor*** is the key to achieving a fully ready, mission capable, optimally manned ship
- Revolutionary change requires ***top-down leadership***
  - Buy-in through all echelons of the organization and a clear vision and execution plan

Naval Research Advisory Committee

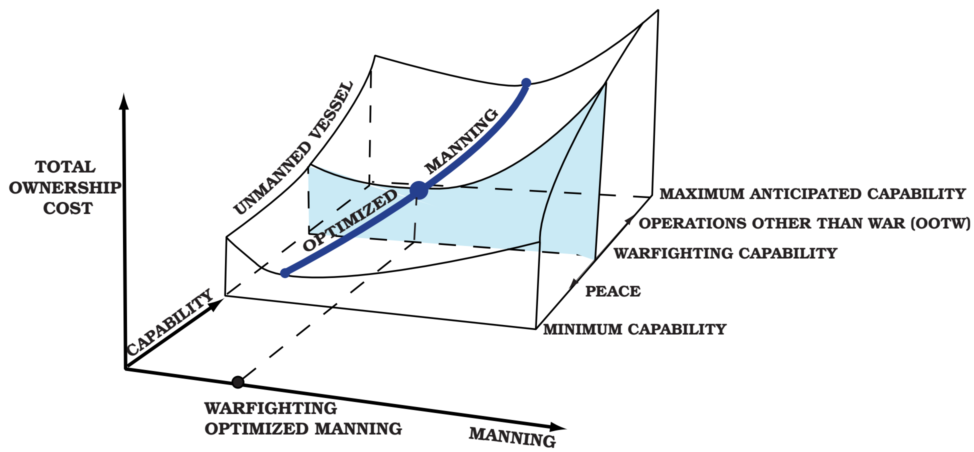
Take Away Messages

The report concludes with a number of specific recommendations and strategies to achieve optimized manning. The overarching main point is that optimized manning, if done correctly, will be a truly revolutionary change, and that change of this magnitude requires determined, persistent, and strong top-down leadership, with a clear vision and an articulated execution plan.

We believe Human Engineering--the hard quantitative science of incorporating data on human capabilities and limitations throughout the design process--is essential. We further believe that the right Sailor, with the right skill mix, with the right training, on-board at the right time and in the right place, is the key.

This page intentionally left blank

What Is “Optimized Manning”?



Optimized manning is the locus of minimum TOC points for various capabilities

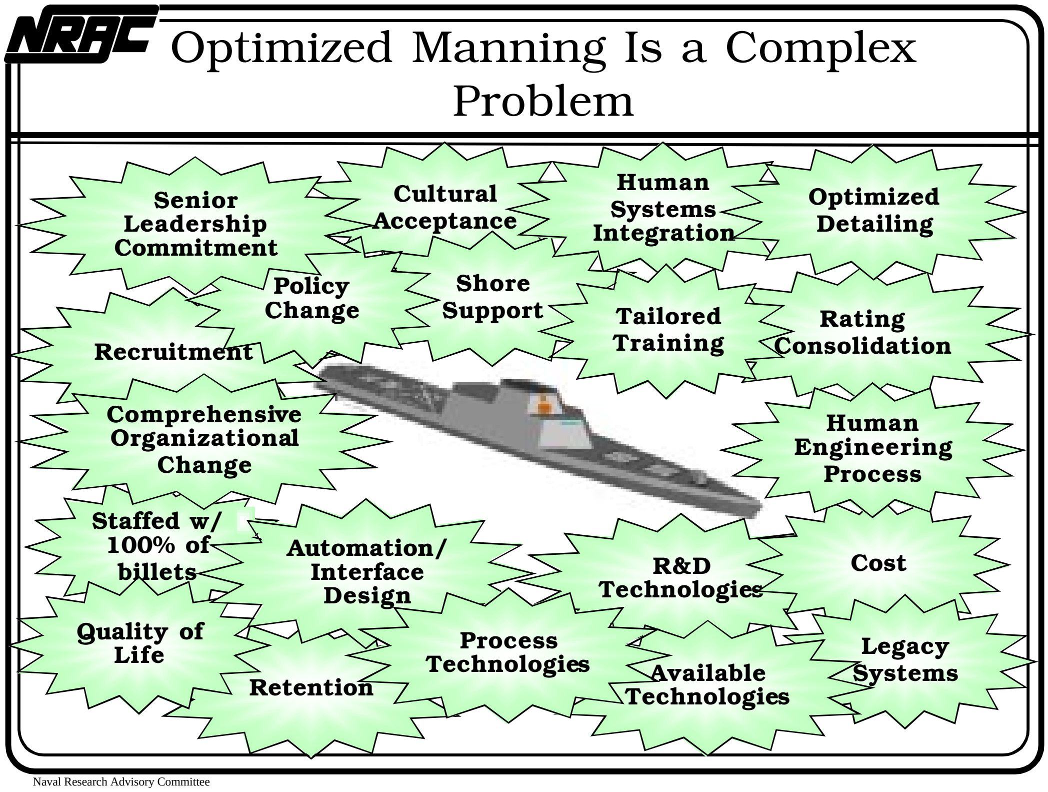
Naval Research Advisory Committee

What is Optimized Manning?

“Optimized manning” can be defined in terms of three key variables: TOC, manning level, and ship capability. Manning and TOC have single dimensions, number of people and dollars, respectively; while ship capability embodies a multiplicity of variables, as well as capabilities that change for different missions. A curve of TOC vs. manning can be constructed for any given capability. Costs are high at the low end of the manning axis (near the origin) because expensive automated systems are used to replace less costly people. Technology costs dominate. As automation is reduced, resulting in a larger crew, TOC goes down until a minimum is reached. Beyond this point, costs rise as more costly people replace less expensive equipment, or people are simply being added without need. Thus, there is a single point where TOC is a minimum and there is an associated manning level that is said to be “optimal” for that capability. The locus of all the minimum (optimum) points, considering all different mission capabilities, is a curved line along the surface, labeled “optimized manning” in the chart avove.

Note that if the ship is to be designed with a single value of crew size, compromise by parties representing various components of capability must be invoked. On the other hand, if the ship is designed to handle the largest “optimum” crew size, there will be some compromise on TOC.

The Navy has made some progress in developing TOC data for various classes of ships. This effort must continue because without such data for a ship class, manning cannot be optimized for the various capabilities; peace - operations other than war, war – that a particular ship class is required to have.



Optimized Manning is a complex problem

Reducing manpower on a ship is not simply a matter of more automation. There is a complex relationship between a host of factors entering into the total ship that can be loosely grouped into three main areas: ship design itself, crew capabilities and organizational support.

Technology, ranging from legacy systems to those associated with R&D programs undertaken during procurement, is the driving factor. In each case cost vs. capability decisions have to be made, and the level of required human interaction must be assessed.

A Sailor's effectiveness will be determined by, among other things, his or her training, the appropriateness of detailing, quality of life on board the ship, the design of human-machine interfaces, career progression, and so on.

The naval organization supporting an optimally manned ship is as important as the ship itself. Shore support facilities will generally need to be more extensive. There will be significant implications for recruitment, training and retention based on required skills and abilities. In turn, these changes will affect Navy policy and culture, and thus will need careful analysis at an early stage.

This page intentionally left blank

NRAC

Observations

Process

Technology

Crew

Organization

Conclusions and Recommendations

Naval Research Advisory Committee

Observations

This page intentionally left blank

NRAC

Observations: Existing Programs Smart Ship

- Successful program
  - 15% reduction in personnel--many important lessons
- Procedures as important as technology in workload reductions
- Core/flex watch standing is not yet institutionalized
- Tendency to return to old way; e.g., paper maintenance logs for inspection

Naval Research Advisory Committee

Observations: Existing Programs -- Smart Ship

The panel received briefings on the Smart Ship Program and went aboard USS YORKTOWN, CG-48, which is the demonstration platform for Smart Ship initiatives. It has been a successful program. In addition to reducing manning by 15% without reducing capability, CG-48 demonstrated new, more automated systems that can be used on other platforms, and served as a demonstration ship for new approaches to organizing work aboard ship.

Smart Ship is a particularly important initiative for demonstrating that changes in procedures can be as important to optimizing manning as the implementation of technology. To be sure, technology often enables procedure changes, but in some instances no technology insertion is necessary. An example is the introduction of the core-flex watch standing procedure on the ship. In essence, the manning for watch standing was greatly reduced by replacing the usual three or four section watch team by a smaller "core" team and several "flex" teams. The latter are called upon as required, thereby reducing the need for four section staffing.

The panel was impressed, again, by the difficulty in implementing major change. Many of the procedures demonstrated on CG 48 have yet to be institutionalized by the Surface Navy. For example, in the course of our briefings, we asked NAVMAC, LPD 17, and CVNX representatives if they were employing core-flex watch standing in their manning models. In each case we were given the answer that it was “not policy,” “the savings were not proven," etc. These responses fly in the face of the fact that in September, 1997, the Commander, Naval Surface Force, U.S. Atlantic Fleet requested the Office of the Chief of Naval Operations (OPNAV) make such policy and procedure changes in his Smart Ship Project Assessment report. Since then, the “core-flex” watch standing process has been demonstrated also on a squadron of destroyers. The Navy still has not instituted the procedure Fleet-wide.

Another example of lack of institutionalization of major change derived from the experience the USS YORKTOWN had when dealing with organizational stovepipes. Even though the ship had been approved for keeping paperless maintenance logs, it was forced to produce paper logs when operational inspections occurred. Similar difficulties were encountered in the ship supply function.

NRAC Observations: Existing Programs Foreign Navies

- Large manning reductions accomplished by top–down mandates and functional analysis
- Changes required in organizational structure and rating to achieve manning goals
- UK infrastructure took 5 years to adapt to demands of Type 23 Frigate

Naval Research Advisory Committee

Observations : Existing Programs -- Foreign Navies

Attempts by foreign navies to reduce manning levels have met with varying degrees of success. Challenges noted by foreign navies include lack of trust in automation, the need for manpower to enhance survivability, and the constraints of secondary tasks undertaken by the ship and by each Sailor.

Successful programs include the British Type 23 and the Dutch M-Class Frigates. Reductions of 30-40% have been achieved relative to the previous generation of ships. Adoption, for the first time, of a radical 'waterfall' approach to design was a major contributor. The process starts with a series of scenario models, followed by functional decomposition and analysis. Task allocation (to the human and machine) leads to system design specifications and human task descriptions. Experience suggests that these human task descriptions will lead to requirements for a novel skill mix within the crew, subsequently mandating Navy-wide changes in personnel structure.

A radical approach to accomplishing routine maintenance tasks, transferring a significant proportion of the effort ashore by contracting-out organizations, has been a significant source of manpower savings for foreign navies.

Both the changes in Sailor skill mix and ship support requirements have far reaching consequences for any Navy. The RN has learned that organizational implications need to be analyzed long before the first of class is commissioned if a seamless transition is to be achieved. The alternative is a shore organization attuned solely to the needs of legacy ships that is incapable of servicing early class ships.

Notably, in each Navy where success was achieved, the highest levels of the naval hierarchy had established and maintained clear and challenging goals for manpower reductions.

Observations: Existing Programs LPD 17 and CVNX

LPD 17
- Optimized manning not a primary design driver
- Appeared to be working toward high end of manning range vice minimum
- Maintaining manpower cushion

CVNX
- TOC (manning) reductions a primary focus of effort
- Major opportunity to impact manning
  - One third of afloat personnel are aboard carriers
- Smart Carrier implementing Smart Ship technologies
- Additional opportunity for major savings in procurement and manning by further integrating NAVSEA and NAVAIR design efforts

Naval Research Advisory Committee

Observations: Existing Programs -- LPD 17 and CVNX

The panel received briefings from both the LPD 17 and CVNX programs. Each was focused on O&S cost reduction for platforms that will involve a great deal of new design.

In the case of LPD 17 the objective is an O&S cost reduction of $4 billion. While manning costs have been shown to be the single largest component of O&S costs, the program appears to be relatively conservative in any effort to reduce manning. In instances where assumptions were questioned, they appear to be working toward the high end of the manning range. Also, in addition to the conservative manning assumptions, LPD 17 is maintaining a cushion or contingency allowance in the manning budget for the ship.

The Program Executive Officer (PEO) Aircraft Carriers is clearly focused on TOC reductions by incremented changes in manning in the CVN 77 and CVNX programs. The briefing demonstrated both knowledge of the derivation of existing O&S costs, and an understanding of the importance of the problem. Since fully one third of afloat personnel in the Navy are aboard the Carrier Fleet, this represents a major opportunity to impact manning in the Surface Navy.

The CVNX program described many opportunities for TOC reductions by design changes in the ship, and they identified launch operations and "own unit support" functions as drivers in ship manning. However, the current assumption is that the aircraft, its weapons, and its associated manning and support systems are legacy systems, are predetermined, and are therefore not subject to optimization. Both the briefer and the panel recognized that there is another major opportunity to reduce both procurement costs and manning requirements by bringing the NAVSEA and Naval Air Systems Command (NAVAIR) design efforts closer together. We believe there are opportunities to reduce the amount of "yellow gear" and to acquire the appropriate ship systems to support air operations, reducing the number of maintenance and logistics personnel in the process.

The panel also received a briefing on a cost model for existing carriers that had been developed by a contractor. The architecture of the cost model, its ability to be used in "what-if" or design trade-offs, and the real world validation of the data are noteworthy. It is an approach that should be emulated for other ship classes.

Observations: Existing Programs DD 21

- Fundamental change in ship acquisition.
  - Contractor design vs Navy design
  - New acquisition regulations
- Program office is advocate for optimized manning.
- The Panel believes R&D investment aimed at accomplishing optimal manning for DD-21 is insufficient. *

* NOTE: Since the Panel concluded and briefed its work, investment aimed at accomplishing optimal manning for DD-21 has been increased

Naval Research Advisory Committee

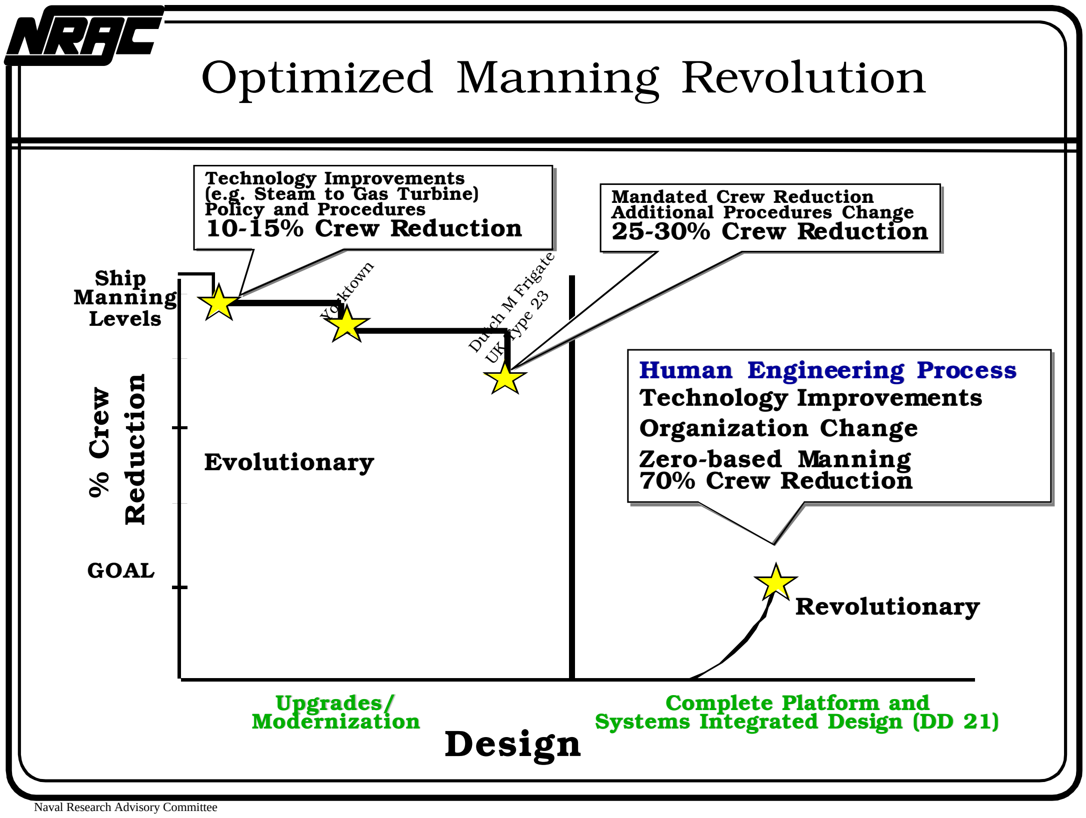
Observations : Existing Programs -- DD 21

The DD 21 program was a major focus of the panel's deliberations. This was due in part to the challenge posed by the aggressive goal to reduce manning by 70%. However, equally important to the challenge is the fact that this program represents a revolutionary change in the ship procurement process. Previous surface combatants were customer-designed, contractor-built. DD 21 will be contractor-designed, contractor-built under a new set of acquisition regulations.

The panel found the DD 21 program representatives to be undaunted by these challenges, as well as enthusiastic and knowledgeable advocates for optimal manning. They are concerned about the product as well as the development process and are committed to this revolution in manning.

The panel recognizes that all of the R&D efforts relevant to the success of DD 21 are not under the control of the Program Office. Although not unusual, it does have special importance for this program since the magnitude of the changes is so dramatic. We return to this point later.

This page intentionally left blank



Optimized Manning Revolution

Current trends among NATO nations in crew reductions indicate that over several decades, evolutionary approaches through upgrades and modernization have yielded approximately 10-15% reduction. The majority of the improvement came from conversion of steam propulsion to gas turbine, or minor technology improvements, and some changes to policy and procedure. Examples such as the Dutch M-Frigate, USS YORKTOWN and UK Type 23 Frigate yielded 15-30% reductions with additional technology improvements, policy and procedure changes and some key organization changes. Still, this evolutionary process has only demonstrated relatively small reductions in manning and will not, in itself, result in the aggressive reductions being sought (70% for DD 21).

These require a revolutionary change in the ship design process, beginning with a zero-based manning starting point, and including Human Engineering as an essential component of the systems design process.

Integrating a Human Engineering process into the systems engineering design process provides a complete platform integrated design that can achieve performance, risk and TOC objectives. In this disciplined approach, the design team starts with zero-based manning, and through an iterative process allocates tasks to hardware, software, and people.

This page intentionally left blank

Observations

Process

Technology

Crew

Organization

Conclusions and Recommendations

Naval Research Advisory Committee

Process

This page intentionally left blank

What Is the Human Engineering Process?

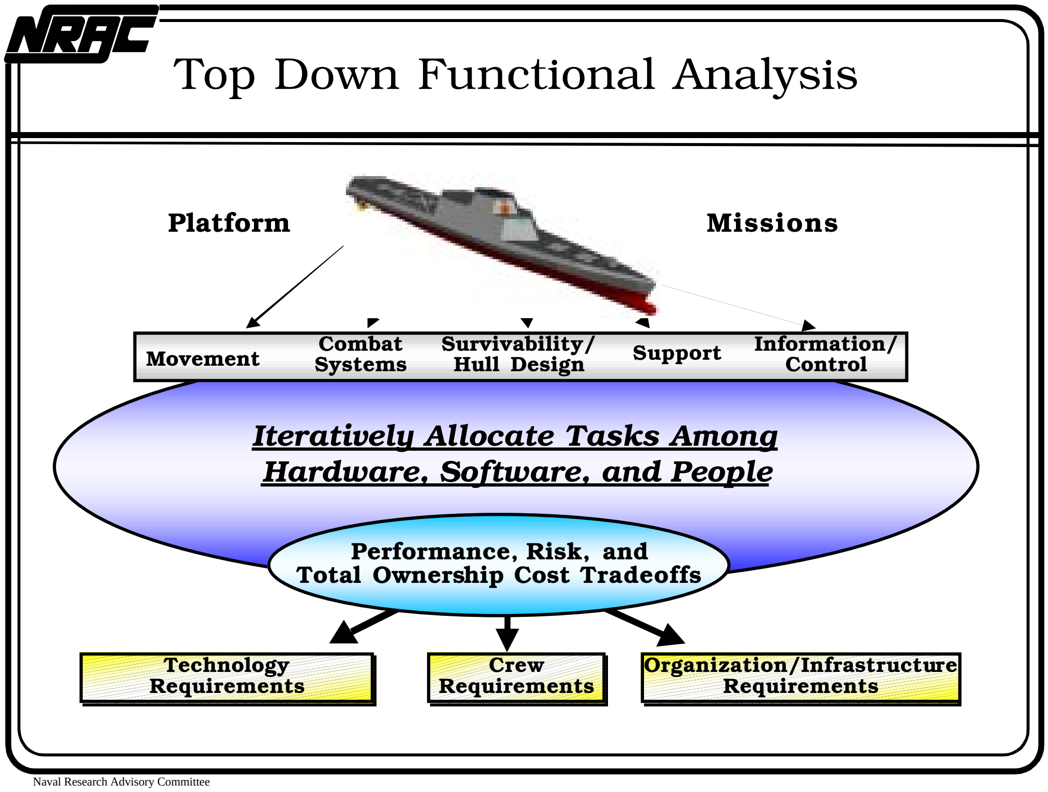
- A part of the system engineering process that incorporates scientific data on human capabilities and limitations fully and explicitly in design
- It includes:
  - Mission analysis
  - ***Top-down functional analysis***
  - Function allocation (to people, machines, or both)
  - Human-machine modeling
  - Design of displays, controls and procedures
  - Human-in-the-loop simulation for evaluation

Naval Research Advisory Committee

What is the Human Engineering Process?

Human Engineering is the process that incorporates information about human capabilities and limitations directly and explicitly into the system design process. Human Engineering can be applied to both existing and future platform design. On current ships, personnel utilization should be assessed by analysis of the tasks being performed, and level of workload for each crew member. While limitations due to legacy systems are inevitable, some reduction in manning may be possible by improving human-system interfaces, upgrading decision support strategies, and enhancing training. For future ships, a detailed top-down functional analysis should be conducted. This will determine what information and resources are required for each function, how a team can be best structured to cope with needed information, how to complete required functions, and how functions change across the range of missions to be performed.

Based on the results of the top-down functional analysis, specific functions can then be allocated to people or machines, or more precisely, some combination of the two. Degrees of automation can be accomplished ranging from: (1) none (human acting independently of automation); (2) human acting with computer-based decision support; (3) automation acting as a back-up to human action; (4) automation performing action with human in role of a supervisor, failure detector and back-up; to (5) automation performing the function independently of the human. The selection of a particular automation strategy must be specific to the nature of the task and the context in which it occurs. For example, an ambiguous engagement decision should most often be left to the human (supported by automation). However, in extreme cases (e.g. exceptionally short timeframes) completely automating the engagement process may be the right choice.



Top-Down Functional Analysis

To achieve a human centered design, top-down functional analysis is applied to the systems engineering design process. Mission analysis is performed, utilizing inputs from the Operational Requirements Document and the Design Reference Mission. Through an iterative process, tasks are allocated among hardware, software and people to meet performance and TOC objectives at an acceptable risk. Output from the functional analysis will be technology requirements, the ship and its weapon systems, crew requirements, their skills and training, and the organization and infrastructure requirements needed to support the crew and fight the ship.

This page intentionally left blank

Ignoring Human Engineering Process

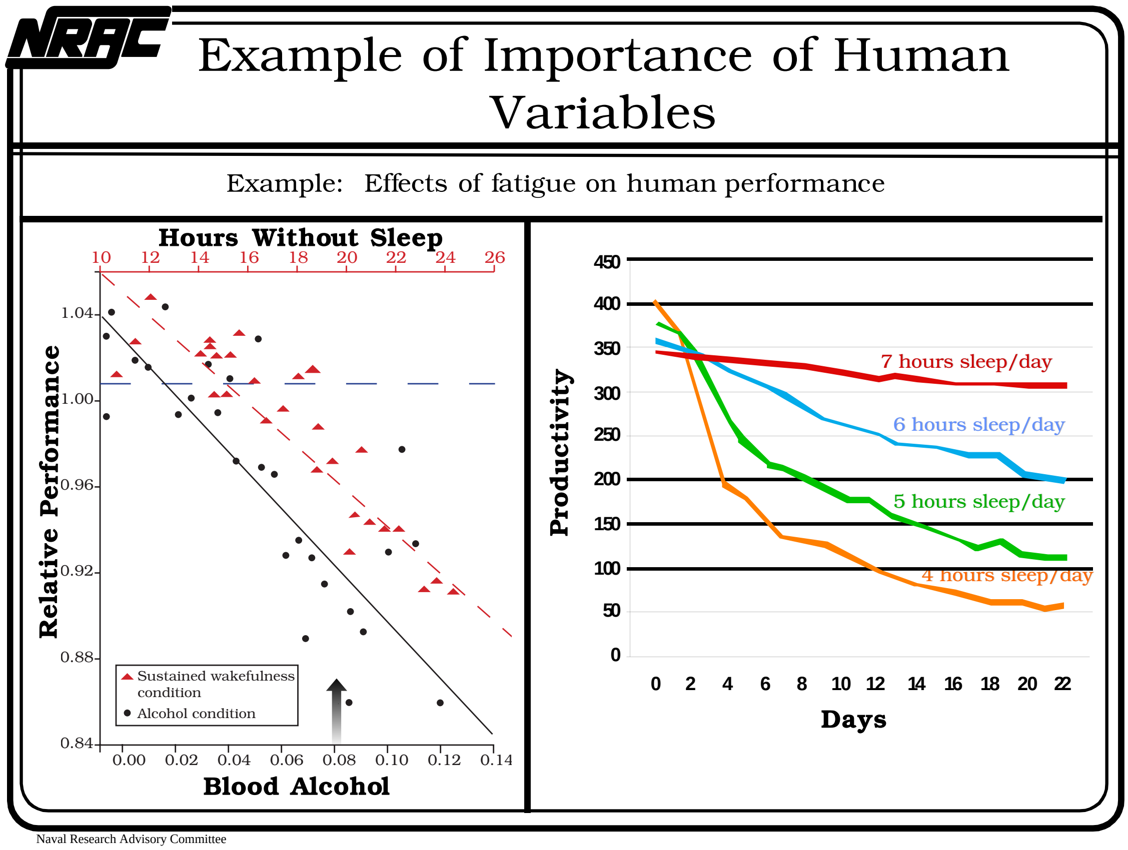
- Poorly implemented automation is dangerous, typical problems include:
  - Automation that is ***unpredictable*** and ***difficult*** to interpret
  - Display symbology that is easily ***misinterpreted***
  - Procedures that are ***complex*** and tend to be ***confused***
  - Automation that is ***over*** or ***under trusted***
  - Excessive information that causes ***operator overload***

Naval Research Advisory Committee

Ignoring Human Engineering Process

Many system designs fail because they ignore the Human Engineering process. For example, the Three Mile Island accident, USS VINCENNES incident, and American Airlines crash in Cali, Columbia were, at least in part, attributable to poor human/systems integration. History indicates repeatedly that confusion over display symbology, forgetting the mode to which automation was set, and overtrusting the automation's capability have all led to fatal air crashes. Excessive detail on computer displays or too many alarms on control panels overload operators and cause breakdowns. Human limitations such as color blindness and inability to reach controls are often ignored. Infrequently used procedures are confused with well-learned procedures. Human error (that leads to system error) is to be expected if such human factors are not taken seriously. A comprehensive Human Engineering process ensures that such concerns are considered fully.

This page intentionally left blank



Example of Importance of Human Variables

Source: Dawson & Reid, 1997

Source: Department of Behavioral Biology at Walter Reed Army Medical Center

A simple, easily understood, but often overlooked, example of the importance of human variables is provided by the results of two studies aimed at determining the effects of fatigue on performance. It is generally understood that poor quality of sleep and inadequate recovery leads to fatigue and consequent impaired performance; however, the risks associated with fatigue are not well quantified.

On the left, a group of subjects was kept awake for 28 hours, and periodically subjected to a variety of cognitive psychomotor tests. A second group, subjected to the same periodic tests, was asked to consume 10-15 grams of alcohol every 30 minutes until their mean blood alcohol level reached 0.1%. The correlation between the performance of the two groups makes it clear that the effects of moderate sleep loss on performance are similar to moderate intoxication. Another way of stating this is that after 18-20 hours of sleeplessness, subjects were performing at a level equivalent to what is considered legally drunk in most states.

The experiment on the right illustrates the accumulated effects of chronic sleep loss over an extended period. Subjects were allowed to sleep between four and seven hours/day. The group receiving seven daily hours of sleep was performing nearly as well at the end of the three-week test as at the beginning. On the other hand, the group receiving only four hours of sleep per night was performing at only 15% of its starting capacity.

Process
Human Engineering

Findings

- Integrating human engineering into the systems engineering process is key
  - Processes, tools, and technologies need maturing
- Top down functional analysis identifies priorities for technology investment
- US Army MANPRINT acquisition policy is a good example

Strategy

- Invest R&D to enhance human engineering process tools and technologies; e.g.,
  - Human cognitive and behavior models
  - Automated tool data bases for system engineering and human factors integration
- Prioritize available R&D funding to support ultimate new ship design and requirements
- Implement Human Systems Integration, as defined in DOD 5000

Naval Research Advisory Committee

Process -- Human Engineering

The Human Engineering process applied to ship design is key to achieving optimal manning and TOC objectives. While many of the tools exist to accomplish this, many require further development. Two key areas that require investment are human cognitive and behavior models, and automated tool databases for system engineering and human factor integration. The panel noted excellent work in these and other Human Engineering areas being supported by ONR at the Naval Research Laboratory and the Naval Air Warfare Center, Training Systems Division (NAWC TSD) in Orlando.

The Human Engineering top-down functional analysis process will result in optimal allocation of tasks to technology and crew, and will suggest the organizational infrastructure to support them. To achieve the benefits of this design process, R&D funding needs to be prioritized to support new ship design requirements.

This page intentionally left blank

Process
Use of Legacy Systems

Findings

- Legacy Systems may be used to meet a requirement (Tomahawk, etc.)
  - Legacy systems are burdened with legacy manning
  - Combat systems/operations comprise 60% of manning on current ships

Strategy

- Require modular, flexible, open systems new ship design to allow future technology insertions to achieve revolutionary results
- Utilize human engineering process to identify
  - Technology (and R&D) opportunities for workload intensive legacy systems

Naval Research Advisory Committee

Process -- Use of Legacy Systems

Achieving revolutionary manning reductions and TOC objectives requires a bottom-up, zero-based approach to the design of the ship as well as its subsystems, and there is neither the time nor the dollars to do it all immediately. As a result, we could wind up using some legacy systems which are burdened with legacy manning to meet a requirement. Some of the manning associated with legacy systems may be reduced if integrated into the ship using an optimized manning approach.

This calls for a modular, flexible, open system to ensure that the platform is ready for the rapid insertion of new technology as it becomes available. It is important to design for the required functions of the new technology, and not for the available space. The German MEKO class frigate is a good example of modular construction; an open systems hardware approach. The New Attack Submarine (NAS) combat system is a good example of open systems software design.

This page intentionally left blank

Process
R&D Programs

Findings

- Some candidate subsystems in development are not subject to same process and design requirements
  - Will impact manning objectives and TOC

Strategy

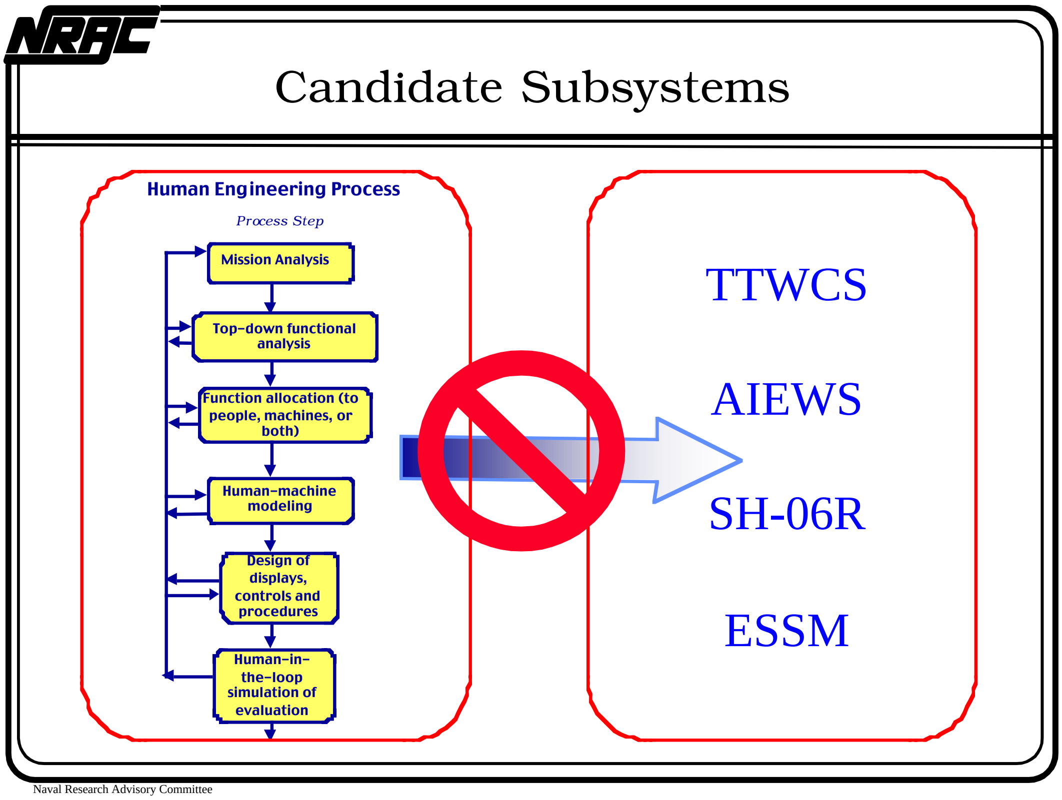
- Subject subsystems in development to same human engineering process and design

Naval Research Advisory Committee

Process -- R&D Programs

The second legacy system issue arises in the case of systems currently under development that are candidates for use on future platforms, but that have not been subject to the same manning requirements as the platform itself.

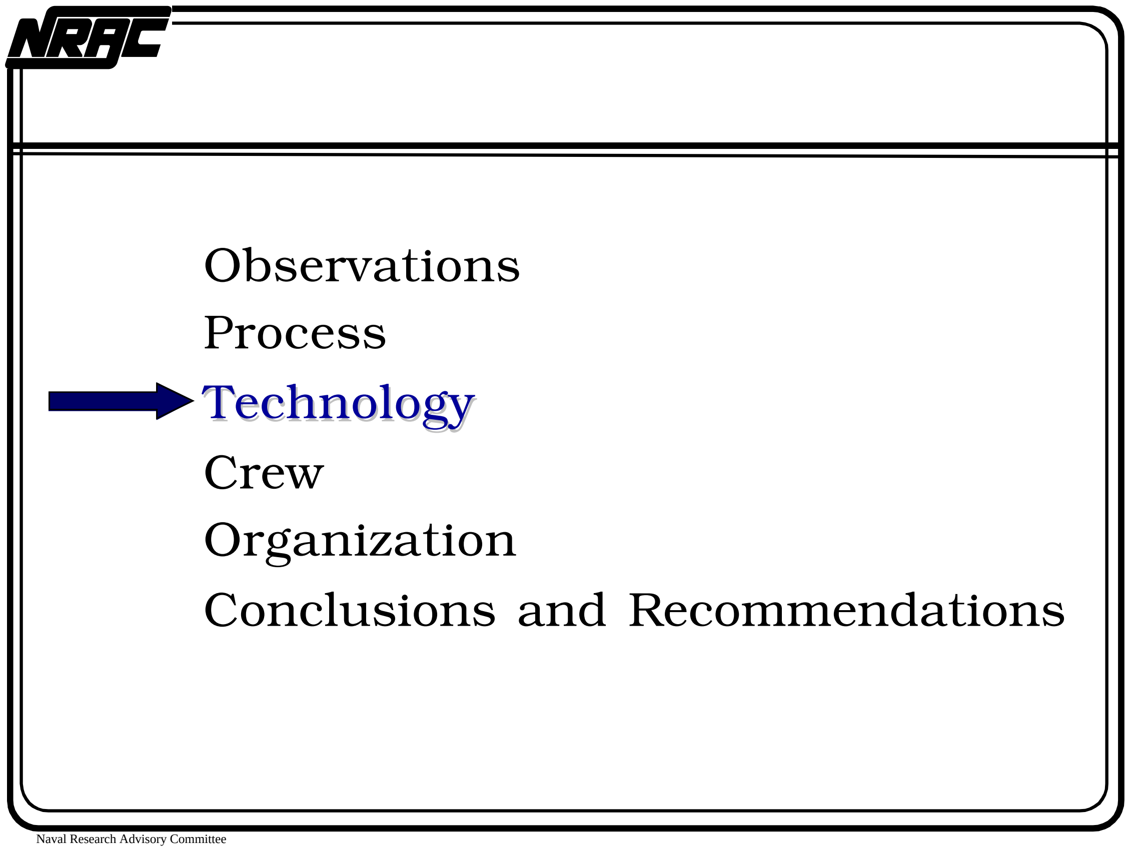
This page intentionally left blank



Candidate Subsystems

Some of these systems under development are subject to strict manpower reduction requirements; others are not. To achieve optimized manning, they all need to use the same Human Engineering process and design requirements as the ship itself.

This page intentionally left blank


Observations
Process
Technology
Crew
Organization
Conclusions and Recommendations
Naval Research Advisory Committee

Technology

This page intentionally left blank

Technologies

- Enablers of optimized manning
  - Eliminate or replace people
  - Support those left on board
- Have successfully demonstrated several key technologies on Smart Ship; e.g.,
  - Integrated Condition Assessment (ICAS)
  - Wireless Internal Communications
  - Machinery Control System (MCS)
- Technologies in the pipeline, e.g.
  - MFR, VR, RSVP, Advanced Gun System, Electric Drive, Mobile Robotics, Personal Readiness Monitors
- Subject to Human Engineering process
- Include trade-offs for new ship design
- Develop rapid insertion process--possibly using Smart Ship--for concept validation

Naval Research Advisory Committee

Technologies

Technology is the enabler, and it is available. The challenge is to ensure that it is properly engineered and tested, including subjecting it to Human Engineering analysis.

Technology eliminates or replaces people and, equally importantly, supports those left on-board. The Integrated Condition Assessment System (ICAS), Integrated Bridge System (IBS) and Wireless Internal Communications are examples that were demonstrated successfully on the USS YORKTOWN. (These were not subject to a Human Engineering process, and it is interesting to speculate how much more successful they might be if they had been.)

Available and near-term technologies need to be included in trade-offs for new ship designs.

It is also important to develop a rapid insertion process for concept validation to ensure a smooth transition to operational platforms.

This page intentionally left blank

Observations

Process

Technology

Crew

Organization

Conclusions and Recommendations

Naval Research Advisory Committee

Crew

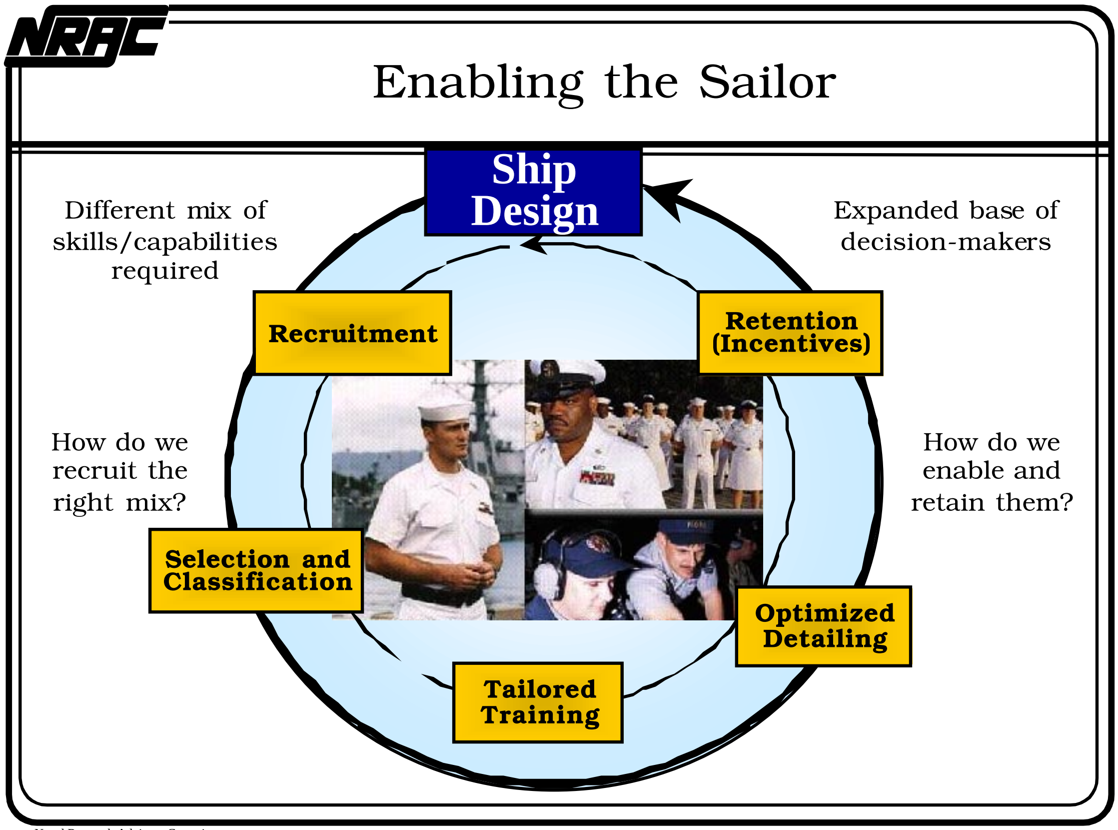
This page intentionally left blank

The Sailor is Key

Optimized Manning involves making trade-offs between life-cycle cost, mission capabilities, and crew size. Reduced manning requirements, advanced technology in naval hardware, and an increase in the complexity of naval roles and missions, all call for a life-cycle focus.

For today's Navy, reduced budgets are a reality and provide hard constraints on TOC. The key to maintaining capability, for a given state-of-the art technology advance, lies in a well-trained, highly motivated crew. Sailors are the key!

This page intentionally left blank



Naval Research Advisory Committee

Enabling the Sailor

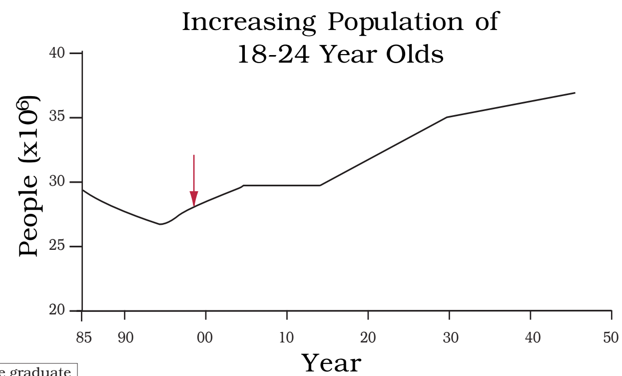
Recruitment, training, detailing, and retention are all interrelated issues in ship design that enable Sailors. For example, opportunities for advanced training, going to sea, and incentives designed to enhance retention, are important motivators for recruitment. Tailored training and optimized detailing will ensure that crews with the right skill mix are deployed to the right ship at the right time. A new mix of skills and capabilities will be required in the future, and crew reductions will result in an expanded base of decision-makers. These changes present new challenges to ship designers who must aim at maximizing mission capabilities while satisfying the Sailor's personal and professional aspirations.

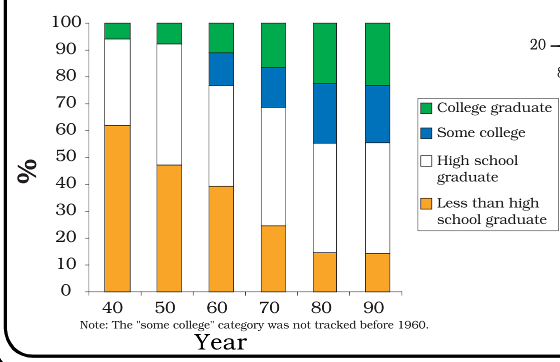
This page intentionally left blank

Recruitment

Findings

- A serious gap now exists between what the Navy *needs* and what it *gets*
- Recruitment pools are projected to be larger, well-qualified, but highly sought after





Strategy

- Focus on the expanded pool with strategies targeted to needs

Naval Research Advisory Committee

Recruitment

The youth population in the U.S., including high school graduates, began an upward trend in the 1990s[1]**.** Using current indices, today's graduates are as intelligent and academically prepared as students were in the past, and from other countries. An increasing percentage of this population has some post-high school education or college degrees. This implies that the Navy will have access to a larger and well-qualified recruitment pool in the foreseeable future. On the other hand, the competition from industry for this population will be stiff. Therefore, the Navy will have to define its required skill mix clearly, and recruit the necessary individuals aggressively.

The future Navy work force is predicted to include a *reduced* unskilled labor component, but a *significantly increased* number of skilled technicians. Targeting individuals with some post-high school education may offer special advantages for the Navy, if the potential for enhanced career development with market-competitive compensation is embedded in the recruitment strategy. As the effects of recruitment success or failure impact all Navy capabilities and performance, this critical issue will have to be addressed.

[1] Martha E. Koopman and Heidi L.W. Golding, (July 1999). Optimal Manning and Technical Change. Alexandria, VA: Center For Naval Analyses

This page intentionally left blank

Selection and Classification

Findings

- Poor selection (choosing the wrong person) leads to early attrition, disciplinary problems, and staff shortages
- Poor classification (putting the Sailor on the wrong track) leads to poor job performance and low retention, job dissatisfaction, and low morale

Strategy

- Develop better, more complete predictors of job success
- Invest R&D to better understand how to optimize the Sailor-job fit

Naval Research Advisory Committee

Selection and Classification

Lessons learned from industry and the military indicate that poor selection practices lead to a number of costly problems including early attrition, disciplinary problems and, eventually, staff shortages. Once selected, the process of classification (putting the Sailor into a career track that fits his/her unique capabilities and interests) is equally important. Poor Sailor-job fit leads to retention problems, attrition in training, inadequate job performance, low job satisfaction and low morale. Deficiencies in selection and classification ultimately degrade readiness.

In order to improve the selection/classification challenge of the future, the Navy must develop better and more complete predictors of training and job successes including, psychomotor abilities, cognitive abilities, spatial abilities, and interests. R&D is required to better understand how to optimize the fit between the Sailor and the job. The result will be a more efficient and effective process for ensuring that the right Sailor is selected and placed on the right career path.

This page intentionally left blank

Tailored Training

Findings

- Profound changes in the Navy are driven by
  - Increasing weapons capabilities
  - Time lines of war
  - Reduced crew size
- Sailors will be required to
  - Perform more tasks
  - Be technically sophisticated
  - Operate independently and in teams
  - Make critical decisions

Strategy

- Provide a continuous learning environment
- Be just in time and with just enough training
- Exploit emerging training technology innovations

Naval Research Advisory Committee

Tailored Training

The Navy of the future will encounter new ways of doing battle in addition to multiple missions and threats. Increasing weapons capabilities, shorter timelines of war, and greatly reduced crew size will drive profound change in shipboard operations. Optimized manning and an associated reduction in crew size imply that each Sailor will have increased responsibilities and decision-making opportunities. Smaller crew sizes result in less time for traditional shipboard training methods such as on-the-job training. New training methods and technologies that support a reduction in training time and manning requirements are essential to achieving efficient and effective shipboard operations.

Training should be customized to address the individual career needs of the Sailor, in harmony and unified with the Navy mission. New methods of training must be instituted to empower the individual Sailor to perform more tasks, be more technically sophisticated, and make critical decisions. Equipped appropriately, he or she will be able to operate effectively, both independently and in teams. When implemented properly, tailored training will provide a continuous learning environment, be just the right training, offered just in time, and effectively exploit emerging technology innovations.

“A smaller number of people must work smarter and perform better than ever before--therefore there must be a greater investment in the people, with the learner as the principle focus in all training technologies.” [2]

---

[2] (Feb.,1999). Training Technologies, NRAC Committee Report

Optimized Detailing

Findings

- There will be significantly different detailing requirements for legacy and new ships

Strategy

- New ship classes should be closed loop-detailed
- For all detailing:
  - Identify the right skill mix
  - Ensure tailored training
  - Prevent billet gaps

Naval Research Advisory Committee

Optimized Detailing

The context for detailing in the *Navy of the Future* will be that of fewer people, greater complexity, a larger number of tasks, rapid turnover, sophisticated technologies, and greater training challenges. There is a well-established need to continue to provide each Sailor with assignments that contribute to satisfactory career development and promote efficient ship operations. The Navy will continue to have a mixture of ships that are currently at sea and new ships that will be platforms for new technologies. Training and detailing must accommodate both.

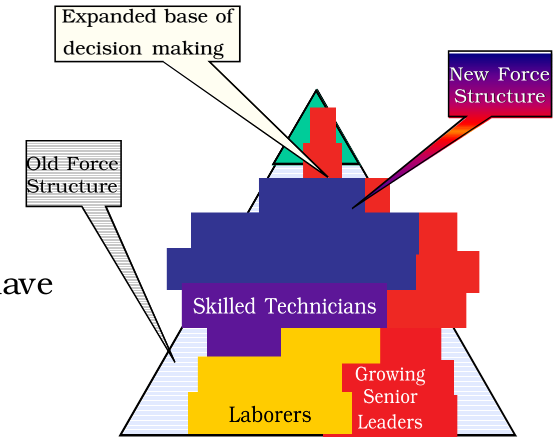
Efficient ship operations require that a Sailor be prepared to contribute productively immediately upon reporting on board. In closed-loop-detailing, a Sailor’s assignment always builds on his or her technical expertise, thus benefiting the ship--a Sailor arrives ready to work in his or her area of competence, and benefiting the Sailor--who can progress in technical experience.

Billet gaps are a problem. In the British Royal Navy maintaining a small pool of appropriately trained Sailors who are available to ensure a full complement for each ship class has precluded billet gaps. Detailing if done correctly, optimally, will allow each ship to have Sailors in adequate numbers and ready to go to work without the need for a reserve Sailor pool.

This page intentionally left blank

Retention

Findings
- The pyramidal work force structure may soon be outdated
- Pay and promotion scales must be competitive with marketplace standards
- Productive career lengths have increased



Strategy
- Consider changing to a system of skill-based pay
- Flexible retirement options

Naval Research Advisory Committee

Retention

The current Navy work force structure uses a manpower pyramid with career paths from entry-level to leadership, a promote-from-within ladder, and an up-or-out promotion system. The future work force will be driven by the need for skilled laborers (performance based on strength and vigor), skilled technicians (needed in almost every field), and senior leaders (with a knowledge of Navy operations, procedures, and personnel). This implies an end to the manpower pyramid, with more laborers serving single enlistments, lateral entry points for skilled technicians, and new potential opportunities for decision making in the lower officer and enlisted personnel ranks.

Changing to a system of skill- and performance-based pay can increase retention.[3] In this construct, a Sailor would receive increasing pay with increasing competency in a given skill function, whether or not he or she is promoted. It should also be possible, through additional education or training, to advance to a higher skill function level and enjoy the benefits of increased pay associated with this new competency. The RN has experienced success in initial implementation of such a model, which has been approved as military policy for the next fiscal year. Industry has seen the benefits of this course of action. In the best, most successful high technology industries--and the *Navy of the Future* is certainly a high technology enterprise--one need not switch to management to achieve pay and status success. Equal remuneration and stature are awarded to those who choose to remain in technical tracks.

Finally, a change in retirement policy to allow an active career beyond 20 years is needed to make a Navy career more attractive. Up or out for a 20-year commander with valuable technical skills simply doesn't make sense. A more attractive (and tolerant) system will accommodate a longer, useful navy lifetime for Sailors with technical skills, and a greater opportunity for the Navy to recoup its investment.

---

[3] Martha E. Koopman and Heidi L.W. Golding, (July 1999). Optimal Manning and Technical Change. Alexandria, VA: Center For Naval Analyses

Observations

Process

Technology

Crew

→ Organization

Conclusions and Recommendations

Naval Research Advisory Committee

Organization

This page intentionally left blank

NRAC

Organizational Change

- Optimized manning requires *substantial* organizational change
- Proven organizational change success factors include
  - Senior leadership commitment
  - "Buy-in" by entire organization
  - Preparation for the organizational impacts
  - Incentives

Naval Research Advisory Committee

Organizational Change

Optimized manning requires substantial Navy-wide organizational change. It will affect virtually every naval function from acquisition and system design, to warfighting, training, recruiting, maintenance procedures, and shore support. Change of this magnitude is difficult. People are resistant because they know and are comfortable with what the current organization expects of them, and are apprehensive about how the change will affect them.

Experience and organizational research have revealed the basic tenets for successful change. First and foremost is senior leadership. It must commit to the change, and initiate actions to ensure that the change can take place. It must deploy appropriate resources, assign responsibility, support champions of the change, and explicitly and visibly articulate the benefits of change to the entire organization.

Second, the entire organization must "buy-in" to change and demonstrate this by its actions. "Walking the talk" throughout the organization is important.

A third necessary component of change is identifying the activities that will be affected, and preparing them for the change and for possible modification.

Finally, there needs to be an incentive structure (both positive and negative) that is consistent with what the organization wants to achieve.

Commitment and Action

Findings

- Senior Navy leadership recognizes the need for optimized manning as a mechanism to reduce TOC
- Smart Ship had empowered and committed Naval leaders
- There is no *Navy-wide* strategy for optimizing manning in legacy or future ships

Strategy

- Create a Flag Board composed of DASN (Ships), N1, N7, N8, NAVSEA, and Fleet representatives
  - Oversee development of optimized manning planning strategies with specific action items and time lines
  - Report directly to ASN(RD&A) and CNO

Naval Research Advisory Committee

Commitment and Action

When one maps these general themes of successful organizational change against what is observed in the Navy today, the score is mixed. Senior Navy leadership certainly recognizes the role of personnel reduction in TOC, and support for reductions in manning is growing. The USS YORKTOWN and its empowered leaders bear witness. A dramatic demonstration of this order can only occur with strong senior level endorsement. Such strong advocates are key to effecting organizational change.

However, the essential need for an optimized manning strategy has not yet penetrated the full Navy. The concept has to be absorbed by the Navy's psyche in the sense that Total Quality Leadership has been. There is still no *Navy-wide* optimizing strategy for either legacy or future ships.

A senior management board is an effective means for creating and implementing such a strategy. A Flag Board composed of operational elements, N1, N7, N8, NAVSEA, and Fleet representatives, reporting directly to the CNO and the Assistant Secretary of the Navy (Research, Development and Acquisition) (ASN(RD&A)), and charged to articulate a robust plan with specific action items and time lines would be an effective mechanism.

This page intentionally left blank

"Buy-In"

Findings

- Smart Ship illustrates that reduced manning can be successful
- The British Royal Navy concluded that providing flex capacity to support special missions lessens concern about reduced manning
- The Royal Netherlands Navy found user/designer interface in ship building encourages overall support

Strategy

- Implement Smart Ship reduced manning successes throughout the Navy
- Publicize manning reduction innovations
- Get users involved in design process
- Ensure buy-in occurs at all levels and across stovepipes

Naval Research Advisory Committee

Buy-In

Successful organizational change requires buy-in at all levels of the organization, and experience shows this is accomplished by demonstrating successes so that people see their benefits, lessening concerns about change, and creating ownership in change.

The Smart Ship experience is an example of how manning reductions can be successfully implemented. A powerful demonstration of Smart Ship's success would be an implementation of its procedural and technological changes across the entire Surface Navy.

People are often uncertain about their ability to cope with major changes, and lessening their concern is essential for success. In the case of reduced manning, this might translate into allaying fears that warfighting capability will be hampered due to the lack of people. A solution here is to publicize the extent of the effort being made to ensure that optimal manning will result in a more, rather than less, effective platform. The British Royal Navy is doing this by reassuring its operators that flex capacity will exist to accommodate special missions on future optimally manned platforms.

Buy-in also requires that users feel "ownership" in the change. They need to feel they are important components of the change, not that change is being imposed on them. In the Royal Netherlands Navy this was accomplished by tight coupling between the users and designers. Users themselves became advocates of the change.

Finally, it is important to ensure that buy-in occurs at all levels in the organization; an easy statement to make, but a difficult task in an organization as complex as the Navy. It requires a broad spectrum of participation by all affected elements and this will range widely, and include acquisition, training, recruiting, detailing, shore support, and so on.

Impacts

Findings

- While optimized manning in DD 21 is anticipated to have Navy-wide impacts, a systematic assessment of them has not been undertaken

Strategy

- CNO undertake an assessment of impacts for DD 21
  - Determine needed changes
  - Implement as early as possible
- Institutionalize similar assessments for all future ships

Naval Research Advisory Committee

Impacts

Successful organizational change, especially that of the size and scope of optimal manning in the Navy, requires analysis of its impact across all affected organizational units. Anticipating the impact allows for early steps to be taken to align the policies, procedures, practices, regulations, traditions, etc. that might hinder adoption of the change. A specific example might be the impact of optimal manning efforts on recruiting practices, which will have to be suitably changed to acquire the different crew skill mix required by optimally manned platforms. Early planning for this will encourage a smoother and more rapid transition to an optimally manned Fleet. A past example is the experience with the FFG 7, which demonstrated the impact of poorly implemented shore support.

In the case of DD 21, there is still time to undertake a comprehensive assessment of how manning goals will impact various aspects of the Navy, and to plan appropriately before the ship is completed. Such assessments should be part of all future ship designs.

This page intentionally left blank

Incentives

Findings

- The British Royal Navy and MSC prohibit new systems that increase TOC or manning
- In Smart Ship, the crew was motivated by advanced systems, empowerment, reduced workload and streamlined reporting responsibility
- Smart Ship personnel were allowed to take acceptable risks
- It appeared that support structure did not have incentives to encourage Smart Ship success

Strategy

- Build incentives to promote optimized manning
- Provide environment for reasonable risk taking

Naval Research Advisory Committee

Incentives

People do things best when they are rewarded, or at a minimum, not punished. Incentives that are clearly connected to organizational goals are the key; but unfortunately, organizations often fail to provide them. An example of a direct, clear, successful incentive to achieve the goal of optimized manning is the British Royal Navy's requirement that no modernizing systems can be added to legacy ships if the changes bring additional costs or manning.

Clear incentives were part of the Smart Ship project. The crew was motivated by the enjoyment of working with new, sophisticated technology, and by their reduced workload and streamlined responsibilities. They were encouraged to take risks without fear of reprisal.

Incentives must be provided to the entire organization. In the case of Smart Ship, for example, incentives did not extend to many support activities. For example, inspectors held to the traditional way of inspecting, i.e., with a paper report rather than an electronic one.

This page intentionally left blank

Observations

Process

Technology

Crew

Organization

Conclusions and Recommendations

Naval Research Advisory Committee

Conclusions and Recommendations

This page intentionally left blank

Conclusions

- A truly optimally manned ship is a ***revolutionary*** change that is unlikely to be achieved in first of class
  - *–Must design a revolutionary ship that will accommodate and facilitate future systems and alternative missions*
- ***Human engineering*** is key to optimized ship manning
  - *–Must incorporate into systems engineering process by making it a part of acquisition policy*
  - *–Must invest in R&D to enhance human engineering tools and methods*
- The ***sailor*** is key
  - *–Must provide optimized personnel system to attract, select, train, and retain*
- ***Top down leadership*** and a clear execution plan are required to achieve revolutionary change
  - *–Must continuously articulate proven tenets for successful change*

Naval Research Advisory Committee

Conclusions

A truly optimally manned ship is a revolutionary change that is unlikely to be achieved in the first of class. The application of technology early in the design will ensure proper systems integration. However, if the required technology is not available for the lead ship, the design must accommodate the rapid insertion of the technology when it becomes available. A "plug and play" approach, (modular, flexible, open system) is required for software *and* hardware.

Top-down leadership and a clear execution plan are required to achieve revolutionary change. The change must be managed by senior leaders who have a compelling belief in, and a clear vision for the change, and have a plan to deal with the obstacles and impediments that will stand in their way. As a start we recommend a Flag Board comprised of N1, N7, N8, and NAVSEA as well as flag-level Fleet members who must develop the vision, plan for change, and maintain oversight in change implementation.

The key to the most effective technology for replacing and assisting people is proper Human Engineering. It must become an integral part of the system design process, and the tools and methods of this relatively new science need to be enhanced.

This page intentionally left blank

Recommendations

ASN(RD&A)

- Enforce May 98 policy for ***TOC reduction plans in acquisition process***
- Incorporate ***Human Engineering in all acquisition*** as a key performance parameter
- Institutionalize ***Human Engineering*** in the systems design methodology to achieve significant reductions in TOC
- Develop ***rapid technology insertion*** process using open systems architecture/COTS/modularity
- Establish ***consistent performance specifications*** for subsystems

CNO

- Create ***Flag Board*** to insure development, promulgation and enforcement of optimized manning policies
- Promulgate and ***institutionalize Smart Ship*** lessons Fleet-wide

Naval Research Advisory Committee

Recommendations

In May, 1998, ASN(RD&A) issued a policy that requires TOC reduction plans be a consideration in all acquisitions. This is an essential first step to achieving the cost reductions required to recapitalize the Fleet. The panel urges promulgation of and vigorous adherence to this policy. A second, but no less essential step is to include Human Engineering principals in the design process, backed by policy authority in the acquisition like the U.S. Army's Manpower and Personnel Integration (MANPRINT) program. Enforced policy ensures practice.

We have stressed throughout this report that Human Engineering is an essential element towards achieving the manning reductions and optimality of human/machine synergism that will make the Navy of the next century the Navy we need. It should be a guiding principle throughout, absorbed by the organization in the same spirit as Total Quality Leadership has become part of the Navy ethos.

Human Engineering needs to become an essential component of the systems design process if the manning and consequent TOC reductions expected for DD 21and future ship construction are to be realized. The traditional design flow, from mission and task analysis, through function allocation, to hardware embodiment must incorporate at all stages the capabilities and limitations of the most versatile, intelligent, and important component of the system--the human. The panel was impressed with the Human Engineering research being conducted by ONR, and urges that results be transitioned swiftly.

The Panel believes achieving the desired manning goals on DD-21 is very challenging and unlikely if legacy systems are used in place of the necessary new systems, designed under strict optimal manning guidelines. Thus, it is essential that a technology insertion process involving open architectures and modularity be developed to allow rapid and low-cost replacement of old systems as new ones are developed. The German MEKO Class hull provides a hardware example. The combat system architecture of the New Attack Submarine provides a software example.

The magnitude of the change required to achieve optimally manned ships, an essential component of a re-engineered Naval force, is enormous, and will occur with the kind of strong, consistent, and determined leadership that only the CNO can provide. The process of change needs to begin immediately, and needs to be driven first at the highest levels. It must ultimately and swiftly engage all echelons of the Navy.

The case for optimized ship manning, although recognized by senior leaders, is being made most strongly by lower level support elements who lack the authority to effect Navy-wide change. Thus, the panel suggests the creation of a Flag Board to oversee the development and enforcement of optimal manning policies.

It is the panel's observation that manning reductions achieved so far are confined to specific programs (mostly to SMART SHIP), and few of the successes have found their way into the rest of the Navy. It would seem a simple matter to institutionalize successes, such as core-flex watchstanding, or paperless maintenance logs, Fleet-wide.

Recommendations

CNR

- Review S&T investments to enhance ***human engineering methodologies***, tools, and data and report to ASN(RD&A)
- Incorporate optimized ***manning requirements*** that support new ship designs in investment spikes
- Develop and deliver tools to CNP to optimize detailing

CNP

- Once tools are delivered, optimize ***detailing process*** to capitalize on sailor's skills and allow career-long specialties with concomitant pay and benefit rewards

CNET

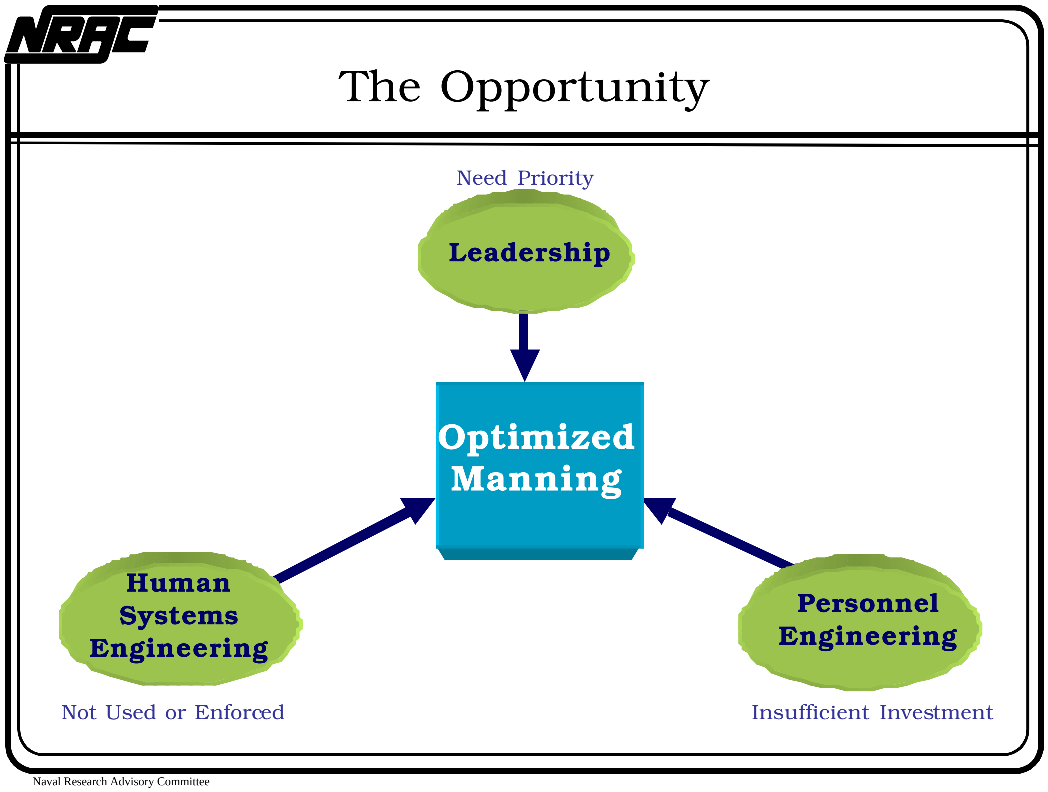
- Develop ***tailored training*** process to support future ship manpower requirements

Naval Research Advisory Committee

Recommendations

There is a large and fairly well developed set of Human Engineering methodologies and technologies that can be adapted to ship design. There are also opportunities that require the development of new methods, such as personnel alertness monitoring techniques, or virtual environments, where significant efficiencies may be found. Both adapting existing tools and developing new ones is a Navy-unique requirement, which is unlikely to be undertaken by the commercial sector alone. Thus, the Chief of Naval Research (CNR) must continue to invest in Human Engineering R&D, and incorporate optimal manning requirements into the higher categories of its investment 'spikes' to support new ship designs.

We have also argued that the Sailor is the key, and that ships with small crew complements will require Sailors with a different mix of skills and decision-making abilities than today's Sailor. While the pool of potential Sailors will be larger, and the average educational level will be higher, the competition for them will be stiff. The Navy needs to sharpen its recruitment efforts to focus on the appropriate segment of the pool, and it needs to tailor its training to provide the skills to support future ship manpower requirements. The former implies targeting a higher educational level recruit. The latter suggests 'just right' training to enable a Sailor to immediately undertake full responsibilities upon joining a ship. There is a well-recognized need to provide assignments that translate into satisfactory career development while promoting efficient ship operations. Optimizing the detailing function, by developing and providing appropriate tools to the Chief of Naval Personnel (CNP), together with 'just right' training, will allow each ship to have Sailors in adequate numbers, on board and on time ready to go to work.



The Opportunity

The ultimate objective is to achieve an optimally manned Naval force, paced by new construction ships. We have outlined a prescription for achieving this goal that includes Human Engineering, the hard, quantitative science of understanding human physical and cognitive capabilities, as a focal point. The prescription includes technology development and stresses that open systems architectures and modularity will be absolutely essential to achieving desired manning goals. It focuses on the life style needs of the Sailor, including career and family aspirations, as well as the needs of the Navy for qualified, skilled technical experts. It also embodies the principals of organizational change that are essential for successfully achieving an optimally manned ship.

The diagram above emphasizes that technology alone, although an essential ingredient does not provide the solution. People do, through leadership, which needs priority, through Human Engineering, which needs to be a component of the systems design process, and through satisfied Sailors, which will require a redesigned recruitment, training, detailing and retirement system.

The prescription suggests a beginning, a necessary component of the larger Navy re-engineering process required to meet national defense needs of the next century, within the constraints of fiscal prudence and political reality. It augurs a revolutionary change for the entire Navy.

This page intentionally left blank

Appendix A

Terms of Reference

Naval Research Advisory Committee
Panel on Optimizing Surface Ship Manning

OBJECTIVES: Review and assess the impact of previous studies to optimize ship manning, personnel effectiveness, and life quality, and review the status of current Department of the Navy (DON) programs and plans. Identify technology opportunities and policy implications for increasing the effectiveness of ship's personnel without sacrificing readiness or mission capability.

BACKGROUND: Reduced manning levels can result in significant financial savings for the Navy, as well as enhanced quality of life for the Sailor, thus helping meet the Navy's challenges of more missions, less money, and increased competition for qualified people. The rapid development of automated systems, coupled with human performance models of increasing fidelity, should combine to enable ships to meet their missions with fewer people provided the Navy's culture, policy and shore infrastructure are properly inclined.

Aggressive steps to reduce manning were undertaken in 1996 in the Smart Ship program, with the goal of demonstrating innovative methods for reducing manning and life cycle costs without jeopardizing mission readiness or safety. We now have three years of experience with Smart Ship and other similar initiatives. The present study is aimed at examining the effectiveness of the technology, and extent of the process change that has been demonstrated, and to recommend further actions to optimize ship manning, especially in future ships.

SPECIFIC TASKING:

- Review and assess past and present programs for engineering process change and technology development to optimize manning, and enhance personnel effectiveness and retention. Examples include:

  --Smart Ship;
  --Foreign Navies;
  --U.S. Coast Guard;
  --Commercial vessels.

- Survey emerging technological opportunities and organizational changes that have the potential to regain or improve overall fighting effectiveness while optimizing crew size. Assess the impact on:

  --The use of personnel and technology in ship operation and maintenance including fighting and damage control;

--Personnel recruiting, assignment, career development and retention;
--Shore and ship-based training, including innovative technologies.

- Recommend changes to policies, procedures and doctrines that block cultural change and thus the adoption of technologies and processes that would retain or improve overall fighting effectiveness, while optimizing manning levels, improving training, and improving quality of life. Consider for example:

  --DD 21 and other ship design and construction efforts;
  --On-ship training and personnel development;
  --Use of personnel and work groups on ship.

POINTS OF CONTACT: Rear Admiral Michael G. Mullen, USN
Director, Surface Warfare Division, N86 Office of the Chief of Naval Operations
Captain Lloyd Swift, USN
Head, Readiness, Training and Manpower Branch, N869
703/604-7646

Appendix B

Acronyms

ASN(RD&A)	Assistant Secretary of the Navy (Research, Development and Acquisition)
CG 47	USS TICONDEROGA
CNA	Center for Naval Analyses
CNET	Chief of Naval Education and Training
CNO	Chief of Naval Operations
CNR	Chief of Naval Research
CNP	Chief of Naval Personnel
COTS	Commercial Off the Shelf
CVNX	Aircraft Carrier of the Future
DASN (Ships)	Deputy Assistant Secretary of the Navy (Ships)
DD 21	Land Attack Destroyer of the Future
DDG 51	USS ARLEIGH BURKE
DON	Department of the Navy
DSMC	Defense Systems Management College
IBS	Integrated Bridge System
ICAS	Integrated Condition Assessment System
LCDR	Lieutenant Commander
LPD 17	USS SAN ANTONIO
MANPRINT	Manpower and Personnel Integration
MCS	Machinery Control System
MFR	Multi-Function Radar
MSC	Military Sealift Command
N1	Deputy Chief of Naval Operations (Manpower and Personnel)
N7	Director of Naval Training
N8	Deputy Chief of Naval Operations (Resources, Warfare Requirements and Assessments)
NAS	New Attack Submarine
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVMAC	Naval Manpower and Material Analysis Center
NAVSEA	Naval Sea Systems Command
NAWC TSD	Naval Air Warfare Center, Training Systems Division
NPRDC	Naval Personnel Research and Development Center
NRC	National Research Council
NSB	Naval Studies Board

O&S	Operation and Support
OOTW	Operations Other than War
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
PEO	Program Executive Officer
PMS	Program Manager Surface
R&D	Research and Development
RN	(British) Royal Navy
RNLN	Royal Netherlands Navy
RSVP	Reduced Ship Crew by Virtual Presence
SC 21	Surface Combatant of the 21st Century
SPAWAR	Space and Naval Warfare Systems Commend
S&T	Science and Technology
TOA	Total Operating Authority
TOC	Total Ownership Cost
U.S.	United States
USCG	United States Coast Guard
USW	Undersea Warfare
VR	Virtual Reality