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A MANPOWER COMPARISON OF THREE U. S. NAVIES: THE CURRENT FLEET, A PROJECTED 313 SHIP FLEET, AND A MORE DISTRIBUTED BIMODAL ALTERNATIVE

by

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September 2009

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A study conducted by the faculty at Naval Postgraduate School entitled "The New Navy Fighting Machine" (NNFM) proposes a new fleet design with 677 ships. The study speculates that the manning would not be greatly different from the present Navy of 280 ships or the planned fleet of 313 ships. The purpose of this thesis is to determine whether the study's conjecture is true, by comparing the manpower requirements of the three fleets as rigorously as data and statistical methods will permit.

Manpower estimates of existing ships, ships being designed and procured for the planned future Navy, and non-existent ships proposed for the NNFM were developed through various methodologies.

A manpower baseline of 134,708 was calculated for the current ship inventory. Although the 313 Ship Navy has more ships, the manpower afloat decreased to 130,810. The NNFM design required an even lower manpower number of 121,318 for even more ships. Manpower is also more widely distributed. Fifty-six percent of its total afloat manpower is designated to blue water missions, 21 percent are allocated to green water vessels, and 7 percent to the submarine force. This long-term manpower information can provide valuable insight for future U.S. Navy fleet composition, size, requirements, and limitations.

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A MANPOWER COMPARISON OF THREE U. S. NAVIES: THE CURRENT FLEET, A PROJECTED 313 SHIP FLEET, AND A MORE DISTRIBUTED BIMODAL ALTERNATIVE

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EXECUTIVE SUMMARY

A study conducted by the faculty of the Naval Postgraduate School (NPS) entitled "The New Navy Fighting Machine" was published in August 2009[1]. It propounds an affordable new fleet design with significantly more ships than at present, including many vessels suited for widely distributed offshore patrol and coastal combat operations. The study speculates that the manning its many more vessels would not be greatly different from the present Navy of 280 ships or the planned fleet of 313 ships. The NPS study expects that the manning numbers would be similar because there are fewer large, multipurpose ships and many smaller and less costly vessels designed for more focused missions and tasks.

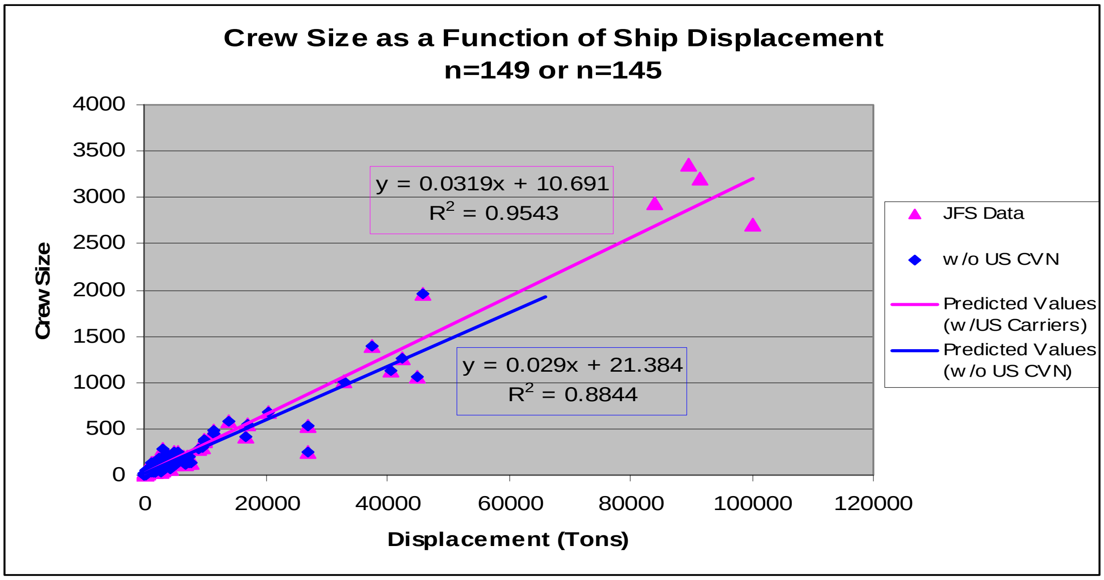
The purpose of this thesis is to determine whether the study's conjecture is true, by comparing the manning of the three fleets as rigorously as data and statistical methods will permit. The comparison includes uniformed personnel in ships' companies and air crews and civilian seamen in the non-combatants, but not Marines or staffs that might be embarked. It includes afloat personnel in support ships, but not the manpower for support or training ashore at either overseas or domestic sites, in either temporary or permanent installations.

The methodology, described in detail in Chapter I, determines the manning of existing ships, ships being designed and procured for the planned future Navy, and non-existent ships proposed for the "new navy fighting machine" (NNFM). The analysis itself is described in detail in the succeeding chapters and appendices.

Crew size estimates for the NNFM ships were particularly challenging. Because many of the ships proposed do not exist in the U. S. Navy, there were no examples in which to develop a crew size. The assumption that displacement is an adequate proxy for estimating capability and crew size was tested and shown to be statistically sound. In general, the larger the combatant and the greater its capabilities, the more manpower is

[1] "The New Navy Fighting Machine: A Study of the Connections Between Contemporary Policy, Strategy, Sea Power, Naval Operations, and the Composition of the United States Fleet," Wayne P. Hughes, Jr., CAPT, USN (Ret.), Principal Investigator, August 2009.

required[2]. To show the relationship, a sample of 149 U. S. and foreign ships was developed. We show that a strong correlation exists between crew size and ship tonnage, as can be seen in the figure below.



Crew Size as a Function of Displacement on Warships

The summarized results are provided in the following table:

	Number of Ships	Total Civilian Crew	Total Air Crew	Total Ship Crew	Total Manpower
Current Ship Inventory	280	3953	34930	95825	134708
313 Ship Navy	313	5272	41158	84380	130810
New Navy Fighting Machine	677	7101	25954	88263	121318

Summary of Manpower Estimates

The resultant 134,708 total manpower baseline for the current ship inventory is sound. For example, the total military afloat manpower requirement was calculated at 130,810. This estimate is approximately 11% higher than the average afloat USN and USMC personnel onboard from 2005 to 2009, the period that the U.S. Navy has fluctuated around 280 warships. This is well within the "readiness gaps" normally

[2] This assumption is only applied to warships. Logistics supply ships do not exhibit the same displacement/crew relationship.

incurred by the difference in declared manpower requirements and current-onboard numbers. Of particular interest is that the 11 aircraft carriers (4% of the Navy's warships) constitute 46.5% of the manpower afloat.

Although the 313 Ship Navy has more ships (an increase of approximately 12%) the manpower afloat decreased to 130,810 (a decrease of nearly 3%). This reduction is credible if current technological advances and optimal manning initiatives successfully shape future crew sizes as proposed. The fleet is still blue water-centric with nearly 58% of the manpower afloat aboard aircraft carriers, cruisers, and destroyers.

The result of the NNFM design is an even lower manpower requirement of 121,318 (a reduction of 7% over the 313 Ship Navy and nearly 10% less than the Current Fleet Inventory) for even more ships (116% more ships than 313 and 141% more than the current inventory). Manpower seems more widely distributed throughout the Navy's missions. There is still a large percent of manpower (43%) aboard aircraft carriers, although there are now 24 of them. Sixteen of the carriers with only 34% of the manpower afloat are allocated for blue water operations. The total number of manpower required aboard the 165 blue water ships decreased slightly to 56%. The remaining eight light carriers are allotted to the green water mission. With a total of 248 ships and 400 inshore patrol craft, the green water manpower personnel increased dramatically, from 1.2% in the current inventory and 3% in the 313 Ship Navy design, to 21% in the NNFM.

This information can provide valuable insight for future U.S. Navy fleet composition, size, requirements, and limitations. Estimations on recruiting numbers, training resources, retention rates, and overall personnel costs can be made from the long-term manpower projections developed in this work.

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I. INTRODUCTION

A. BACKGROUND

1. Fleet Size

Change in the size and composition of the U.S. Navy fleet is inevitable. During the Reagan era, 1980 to 1988, the Navy increased from 480 warships to a maximum of 594 in 1987. Shipbuilding plans were to have "14 deployable carrier battle groups…and a total of 582 deployable ships" ("Manpower for a 600-Ship Navy: Costs and Policy Alternatives," 1983, p. 1) by 1988. To meet the continuing Cold War threat, long term goals of the administration were to have 15 carrier battle groups and a total of 610 warships. Ship numbers began to fall in 1990 after the end of the Cold War and continued to decline for the next 18 years to the current inventory of 280[3] ships. Warship numbers in Figure 1 are were taken from The Naval History and Heritage Command website. More data is provided in Appendix B.

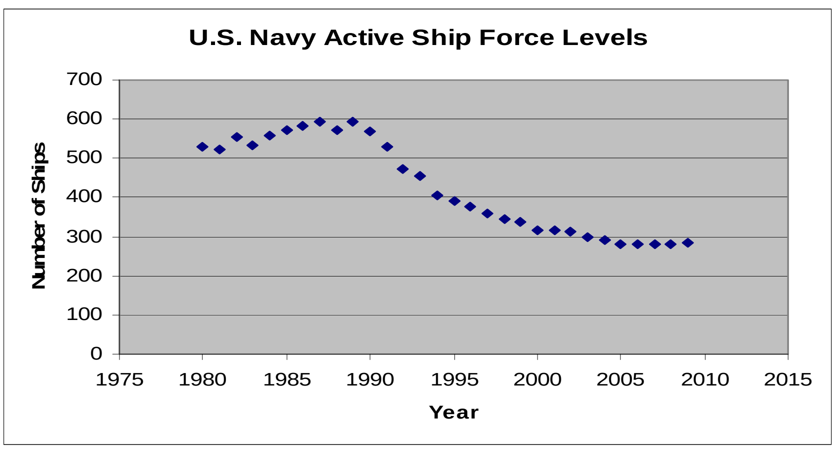

Figure 1. U.S. Navy Ship Levels

[3] There were 280 ships at the time of this study. Ship numbers have fluctuated between 279 and 283 for the last several years, as some ships are retired and others are commissioned.

A shipbuilding plan to reach 313 ships by 2035 was proposed in 2005. The plan retains the carrier strike group as the dominant naval force structure. With 11/12 aircraft carriers, this arrangement appears to be a power projection-heavy fleet "optimized to pound land targets with aviation and guided missile strikes." (Work, 2006, p. 10) Many critics say that the proposed 313 Ship Navy cannot be afforded in today's current economic climate. "Indeed, CBO projects that average shipbuilding costs between FYs 07 and 35 may approach $20 billion annually." (Work, 2006, p. 4) This is well above the estimated $13.4 billion baseline shipbuilding budget. Others observe that it is too heavy in power projection, a residual of the Cold War Navy that was meant to confront the Soviets. The plan "exemplifies the Defense Department's fixation on preserving legacy systems designed for a kind of war that the U.S. is likely never to fight again." (Arquilla, 2008) Now, small irregular wars and China dominate our national strategy.

Professor Hughes and others have presented their ideas of a "New Navy Fighting Machine[4]" (NNFM) which proposes alternative ship designs believed to be consistent with national goals, and a maritime strategy to accommodate the goals, threats, and responses indicated for the Twenty-first Century. (Hughes, 2009, p 1) It attempts to do this within the $13.4 billion budget proposed for the 313 Ship Navy[5]. The NNFM offers a "wider mix of ships in a more numerous fleet with better focused capabilities" (Hughes, 2009, p. vii) to meet a range of traditional "blue water" scenarios as well as asymmetric, unconventional threats often times found in the littorals and "green water." With smaller, less expensive, and more distributable ships, the NNFM may better respond to small and "hybrid" wars while simultaneously freeing the high end warships for more demanding operations. A count of 677 ships and an additional 400 small inshore patrol craft is put forward.

[4] "The New Navy Fighting Machine: A Study of the Connections Between Contemporary Policy, Strategy, Sea Power, Naval Operations, and the Composition of the United States Fleet," Wayne P. Hughes, Jr., CAPT, USN (Ret.), Principal Investigator, August 2009.

[5] FY05$ 13.4 billion adjusts to FY09$ 14.7 billion after a 1.1005 inflation factor is applied. The NNFM study projects a $15.0 billion per year SCN budget, with 10%, or $1.5 billion set aside for strategic deterrence.

The idea of an alternative fleet design with smaller more numerous warships better suited to face the Navy's current strategic vision of engagement in littorals is not unique. In an April 2009 speech at the U.S. Naval War College, Defense Secretary Robert M. Gates said:

> You don't necessarily need a billion-dollar ship to chase down a bunch of teenaged pirates…To carry out the missions we may face in the future—whether dealing with non-state actors at sea or near shore, or swarming speedboats—we will need numbers, speed and ability to operate in shallow waters.[6]

2. Manpower Concerns

A discussion of manpower requirements is conspicuously absent from both plans. As a Navy Human Resources Officer, the author understands that an accurate assessment of manpower needs is critical to the fleet. (Moore et al., 2002, p. 1) If the manpower number is too low, ships' capability and performance suffer, ultimately resulting in reduction of overall Navy readiness. However, "The cost of a ship's crew is the single largest incurred over the ship's life cycle." (GAO–03–520, 2003, p. 1) Funds that could be used for other vital programs are wasted if the manpower numbers are too high.

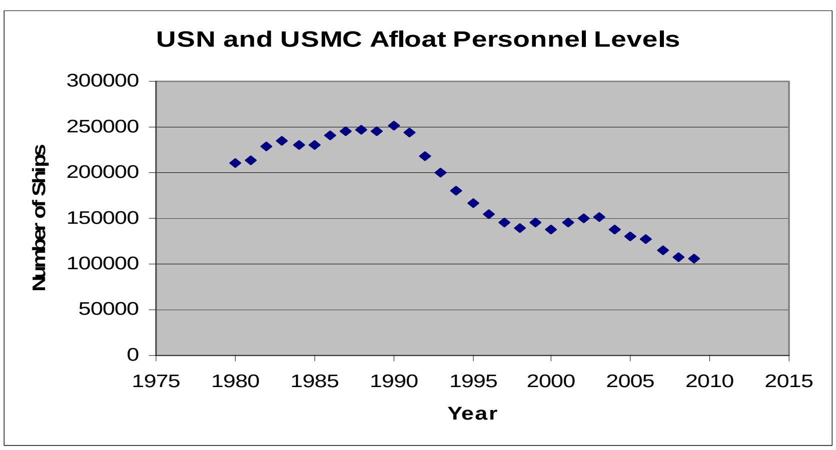

Figure 2. U.S. Afloat Personnel Levels

[6] Secretary Gates' quote is taken from the article "Fleets Turn to Small Ships for New Conflicts," Paul McLeary, Aviation Week Defense Technology International, June 30, 2009

Figure 2 above provides the numbers USN and USMC personnel afloat since 1980. Active Duty personnel numbers were taken from DoD PERSONNEL & PROCUREMENT STATISTICS files. The numbers generally follow the number of warships ships in the fleet. The normalized data in Figure 3 more clearly shows this trend for nearly the last three decades. Generally speaking, "A larger fleet will require more manpower." ("Manpower for a 600-Ship Navy: Costs and Policy Alternatives," 1983, p. 1) This should be a real concern if the Navy plans to increase its number of ships, as personnel costs continue to escalate.

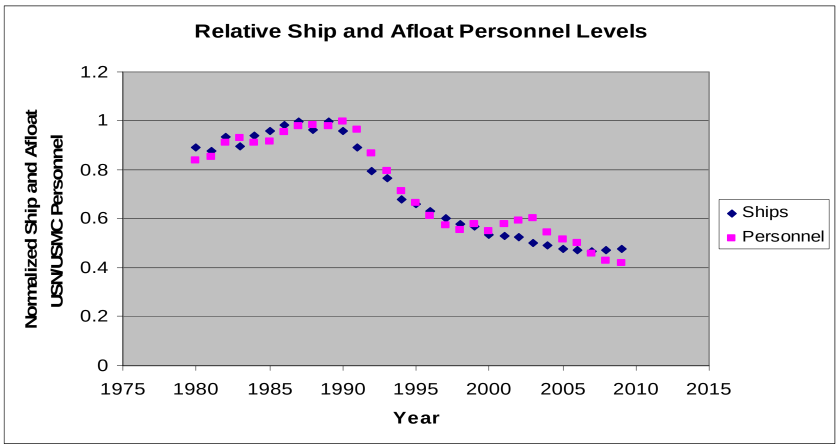

Figure 3. Normalized Ship and Personnel Levels

If the historic trend line for the number of ships vs. afloat personnel shown in Figure 4 holds into the future, then the personnel required for 313 ships would be approximately 137,000 and 677 ships would require approximately 284,000[7]. (Current USN and USMC personnel afloat is at 105,480, an all-time low for the last 20 years) Not only does it appear that the 313 Ship Navy will not remain within its budget, it may prove to be even more expensive if the number of personnel must also rise with the increased number of ships. With 677 ships, any budgetary advantage gained by the NNFM with smaller, less expensive ships may be lost due to the additional manpower required to operate the more numerous ships.

[7] 402.95 * 313 + 11039 = 137162, 402.95 * 677 + 11039 = 283836.

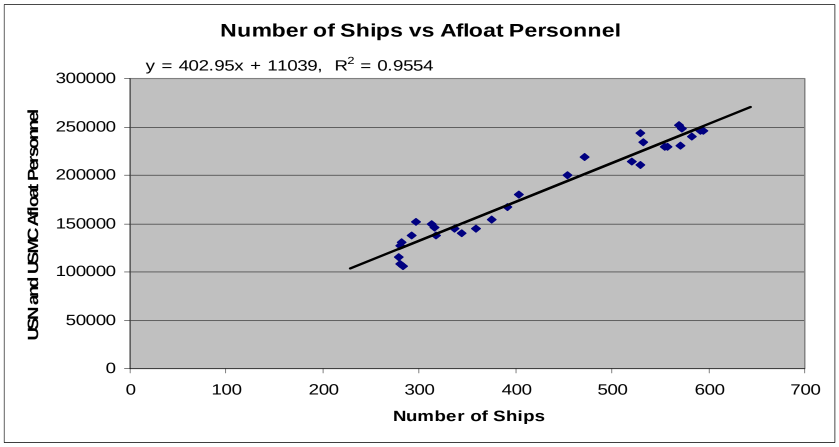

Figure 4. Afloat Personnel versus Number of Ships

This research will examine the afloat manpower numbers of the current U.S. Navy Fleet of 280 ships and then develop projected manpower requirements for both the 313 Ship Fleet serving as the Navy's target force and the proposed bimodal NNFM. The manpower requirements include uniformed personnel in the ship's company, uniformed aviation personnel, and civilian seamen in the Military Sealift Command (MSC). Only afloat personnel were examined.

The Navy is a closed personnel system; that is, nearly all of its personnel enter as raw recruits and gain experience while in the service. The Navy must have a plan to recruit, house, train, and develop personnel well in advance to ensure that it will have the required mix of experience when needed. Estimations on recruiting numbers, training resources, retention rates, and overall personnel costs can be made from the long-term manpower projections developed in this work. This information can provide valuable insight for future U.S. Navy fleet composition, size, requirements, and limitations.

We will learn in this study that the straight-line projection based solely on the number of ships in the fleet can be very misleading. The composition of the fleet, from small single-mission vessels to large multi-mission capital ships, greatly affects overall manpower requirements. Technology and manpower reduction initiatives likewise affect final numbers. Manpower estimates entail a more thorough and detailed process. This study is but one approach to estimating these requirements.

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II. METHODOLOGY AND DATA

A. DATA

Initially crew data was to be gathered primarily using U.S. Navy Ship Manpower Documents (SMD). SMDs provide the most current manpower requirements for each class of USN warship. A requirement is "the minimum number of people required to accomplish 100% of a mission." However, there are many "X" class ships in the 313 Ship Navy, and the majority of NNFM ships simply do not exist in the current USN fleet. SMDs for these proposed classes of ships, therefore, do not exist. Foreign ships of particular sizes and similar capabilities would need to be considered in the development of crew size estimates. A single source of ship type, country, class, displacement, crew size, aircrew, and approximate number of aircraft data was desired for consistent comparisons.

Ship data was therefore extracted from Jane's Fighting Ships (JFS) whenever possible (http://jfs.janes.com/public/jfs/index.shtml). Although JFS data collection methodology is not transparent to the user, it appears to be based on ship manpower requirements, as reported to it by each country's Navy. Whatever the source, it is assumed that the JFS methodology is relatively consistent across ship types and that errors in numbers are likewise consistent.

There were a few occasions for USN ships when JFS data was out of date and more current data was significantly different. For example, Arleigh Burke class destroyers had two phases, Flight I and Flight II. JFS provided data of 346 (FLI) and 352 (FLII) based on the initial crew sizes. The SMD provided more current numbers of 271, 276, or 278, depending on flight. Such differences were significant enough to warrant consideration. On these occasions SMD were used to supplement the JFS data. Differences are explained where applicable.

A total sample of 149 ship classes was collected and is provided in Appendix C.

B. METHOD FOR DETERMINING CREW SIZES

Different methodologies were used to determine crew sizes, depending on which fleet architecture was being analyzed. In general, crew size refers to the ships crew which is required to operate the ship. Aircrew numbers consist of pilots and maintenance crew in the aviation detachment. Flag staff personnel and Marine military lift troops have not been included in this study. Detailed explanations of crew size estimates are provided in each section of the analysis.

Technology tends to reduce the manpower needs as is reflected in the RAND graph shown in Figure 5. Efforts will be made to capture reductions in manpower resulting from improved technology and the implementation of Optimum Manning (OM) initiatives. Other assumptions and limitations are discussed in each applicable section.

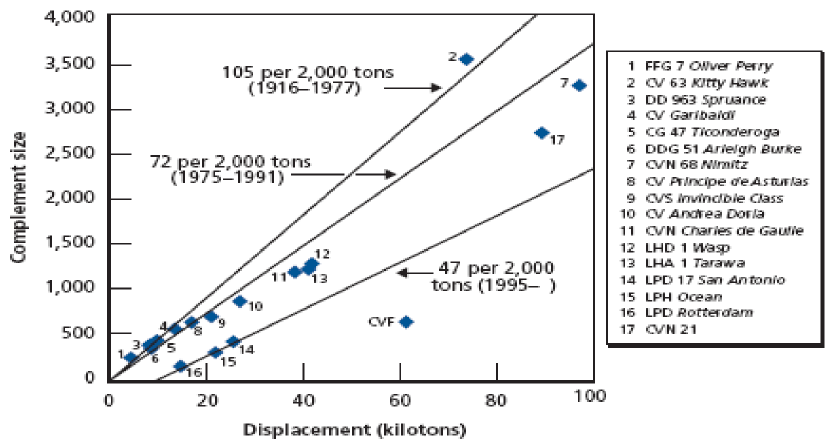

Figure 5. Technology Effects on Manpower Needs (From Schank et al., 2005, p. 71)

1. Current Inventory

Crew size data for ships in the current inventory are easily available. Although SMD crew data for current USN warships could have been used, it was determined that comparisons with foreign ships would be required to develop manpower estimates for many of the ships in the 313 Ship and NNFM fleets. Ship data from JFS would provide a consistent source. Aircrew sizes for some ships were estimated by examining analogous ships with similar aircraft capabilities. Reductions in manpower through implementation of OM initiatives were captured by supplementing SMD data when JFS data was significantly out-dated. Any differences are discussed in their respective sections.

2. 313 Ship Navy

Ship and crew size data was extracted from JFS whenever possible. However, many ships in the 313 Ship Navy are proposed "X" class ships. Documentation exists from a variety of sources on their projected ship capabilities, size, armament, etc. Getting consistent data on crew sizes, however, was difficult. Current USN warships were used as analogies. Ship builder web pages, PEO briefs, reports to Congress, and other presentations provided the bulk of context for these proposed ships. Historical numbers and trends were used when possible to help develop crew estimates for new ("X" class) ships.

3. New Navy Fighting Machine

The majority of analysis was done in this section. Because most ships in the NNFM do not exist, there is no JFS data available. Because many of them are novel concepts for the current U.S. Navy, there were no specific U.S. ships to use as direct analogies. When the development of crew size estimates was required, an assumption was made that displacement of warships is an adequate proxy for capability and, by extension, could be used as a basis for estimating crew size. For example, the larger a ship is, the greater the capability, and therefore, more manpower required to operate it. Further discussion on the assumption crew sizes as a function of displacement is provided in the following section. By performing regressions on foreign and USN ships of similar size and capability, potential crew sizes could be estimated. Standard regression statistics were applied to determining if the postulated relationship between ship tonnage and ship crew size indeed existed. In general, a significance of F of less than 10% and an adjusted R^2 value of greater than 80% is desired[8]. With a crew size relationship determined, crew size estimates could be developed once ship displacement was determined.

[8] See Appendix A for a brief description of adjusted $R^{2,}$ significance of F, and other statistics terms.

C. DISPLACEMENT AS A PROXY FOR CAPABILITY

This work uses a supposition that the size of a warship, specifically its tonnage, is indicative of the crew size required to operate it. The assumption employs a ship's displacement as a proxy for its capability, and by extension, the manpower required to operate it. If the assumption is valid, then crew sizes of proposed ships can be predicted by utilizing an estimated ship displacement based on ship size and desired capabilities.

The sample collected from JFS of 149 USN and Foreign warships in Appendix C was examined. There is a strong correlation of 0.9769 between displacement and crew size, indicating that as one increases, so does the other. A regression was performed with a resulting equation of: $y = 0.0319 * x + 10.691$, where y is the estimated crew size and x is the ship displacement in tons. The trend line is shown in Figure 6. The significance of F is 2.1750E–100, signifying that regression equation is better than the mean of the data. The adjusted R2 value is high at 0.9540, signifying that nearly all of the variation of the data is explained by the regression model.

There were several outliers that caused some concern. The four U.S. Carriers in particular may be acting as influencers to the regression. If these data points are omitted, the regression produces an equation of $y = 0.029 * x + 21.384$, predicting estimates very similar to the first model. The F-score significance is 6.9981E–69 and the adjusted R2 value is 0.8836, suggesting that this is an acceptable model as well. Even better statistical results are obtained if all eight outliers are omitted from the regression.

From the statistics it can be determined that the regression is a good model of the data and that there is in fact a relationship between a ship's displacement and its crew size. Additional regression statistics are available in Appendix D.

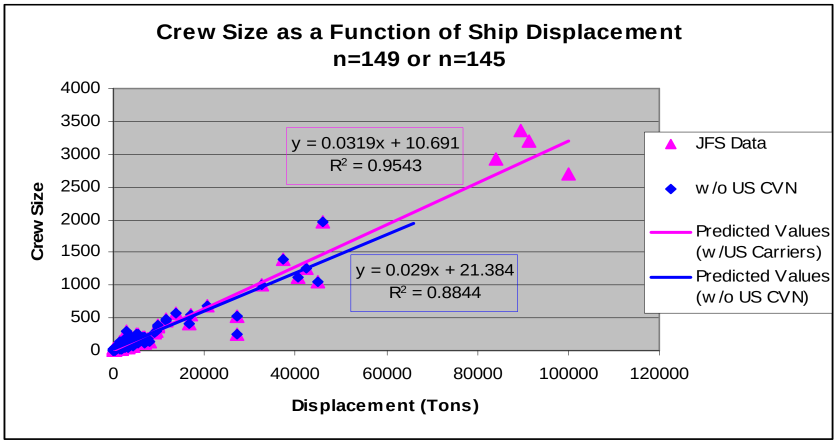

Figure 6. Warship Crew Sizes as a Function of Tonnage

Because different ship types are sure to have different relationships with respect to crew size, separate regressions were conducted on ships of similar type and size – approximately 10 in all. Neither the MSC combat logistics support ships nor the MPF(F) ships exhibit the same displacement/crew relationship that warships demonstrate[9]. Crew size estimations for these ships were performed separately, using MSC web page data and MPF(F) presentations. Explanations are given in their respective sections.

D. MANPOWER TERMINOLOGY

This work estimates Manpower Requirements that are necessary to operate a ship or air wing detachment. The manpower data provided in JFS is assumed to be the Manpower Requirements as reported by each country's navy. The U.S. Navy's wartime requirements are set in Ship and Squadron Manpower Documents (SMD/SQMD). These documents record Fleet requirements for minimum number of people required to accomplish 100% of a wartime mission. The Billets Authorized are those billets approved by the CNO for the current operating conditions, typically some amount less than the determined requirements. This number is tied to the End Strength set by Congress and has typically been 90% of the determined Manpower Requirements. The Personnel Assigned are all the officers and enlisted personnel attached to that ship or

[9] Regression produced an adjusted R^2 value of 0.0319. See Appendix F for additional regression statistics.

squadron, usually less than the Billets Authorized. Finally, the Current-Onboard numbers are the actual personnel onboard ready for operations. This number is usually less than the Personnel Assigned due to training, illness, transfers, holdees, etc. The difference between The Manpower Requirements and the Current-Onboard is called the "Personnel Readiness Gap," illustrated in Figure 7.

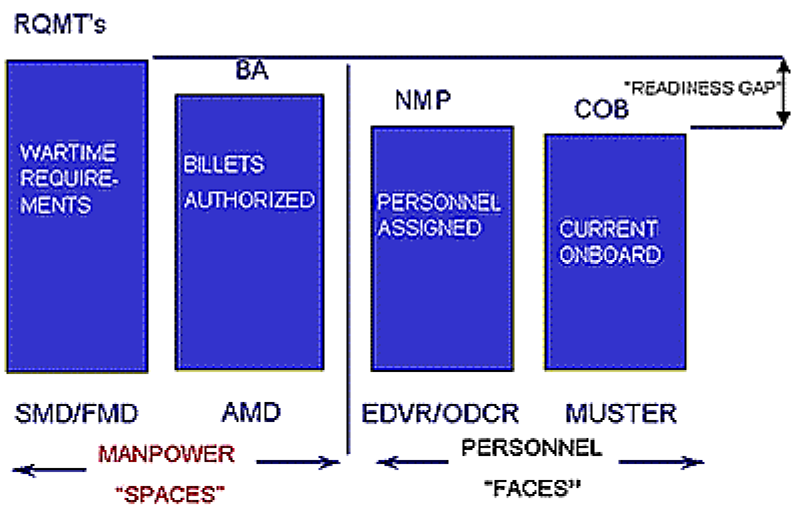

Figure 7. Personnel Readiness Gap (from http://web.nps.navy.mil/~kishore/mpt/mpt.overall.process.htm)

The following definitions were taken from OPNAVINST 1000.16K: Navy Total Force Manpower Policies Procedure:

ACTIVE DUTY (ACDU): Full-time duty in the military service of the U. S. (other than active duty for training purposes)

ACTIVITY (ACTY): A unit, organization or installation performing a specific mission or function and established under a commanding officer, officer in charge, etc. (e.g., Naval Air Station, Naval Shipyard, Naval Station, a specific air squadron, ship, etc.).

AUTHORIZATION (AUTH): A billet for which funding has been provided (manpower space) and for which the quality has been authorized by CNO as a requirement to perform the billet functions.

END STRENGTH: The number of officer and enlisted requirements that can be authorized (funding) based on approved budgets. End strength is set forth for each activity in the FYDP.

MANNING: The specific inventory of personnel at an activity, in terms of numbers, grades, and occupational groups.

MANPOWER MANAGEMENT: The methodical process of determining, validating, and using manpower requirements as a basis for budget decisions; determining manpower authorization priorities based on available funding and personnel inventory; and the ability to link all these factors together.

MANPOWER REQUIREMENT: The minimum quantitative and qualitative resource needed to perform a specific mission, function, or task.

MANPOWER RESOURCES: Human resources available that can be applied against manpower requirements.

PERSONNEL ASSIGNED: A tabulation of all officer and enlisted personnel charged to an activity.

REQUIREMENT: A specific manpower space that is assigned qualifiers that define the duties, tasks, and functions to be performed and the specific skills and skill level required to perform the delineated functions. Also referred to as “BILLET.”

SHIP MANPOWER DOCUMENT (SMD): Quantitative and qualitative manpower requirements for an individual ship or class of ships and the rational for determination of the requirements. Requirements are predicated upon a ROC/POE, ship configuration, specified operating profile, computed workload, and established doctrinal constraints such as standard workweeks, leave policy, etc.

SQUADRON MANPOWER DOCUMENT (SQMD): Quantitative and qualitative manpower requirements for an individual aviation squadron or a class of squadrons and the rationale for the determination of the manpower requirements. Manpower requirements are predicated upon statements of ROC/POE, aircraft configuration, specified operating profile, computed workload, and established doctrinal constraints.

SUPPORT MANPOWER: Shore manpower associated with shore activities. Support manpower is all manpower associated with units included in categories not included in combat manpower.

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III. ANALYSIS

A. CURRENT INVENTORY BASELINE

The U.S. Navy currently has 280 battle force ships consisting of 11 aircraft carriers, 22 cruisers, 52 destroyers, 30 frigates, 1 littoral combat ships, 14 mine warfare ships, 8 patrol craft, 53 attack submarines, 14 strategic ballistic missile submarines; 4 guided missile submarines, 32 amphibious ships, and 39 combat logistics support ships.

Most ship crew sizes in this research were determined using Jane's Fighting Ships (JFS) whenever possible (http://jfs.janes.com/public/jfs/index.shtml). U.S. Navy Ship Manpower Documents (SMD) were used on occasion when JFS data was out of date and more current data was significantly different. Differences are explained where applicable.

The U.S. Navy first reached 282 ships in 2005 with 130,026 USN and USMC personnel afloat. ("DoD Active Duty Military Personnel Strengths by Regional area and by Country," 2005) It has since fluctuated between 279 and 283 for several years with an average of 117,240 active duty personnel afloat. There has been some observable pressure to reduce personnel numbers in the last two years (as was observed previously in Table 3). With 283 ships in 2009, there is one more ship than in 2005, but nearly 25,000 less personnel. It is unclear whether this reduction is due to transient current-onboard numbers, relatively temporary changes in Billet Authorizations as directed annually by Congress, or more permanent reductions due to changes in manpower requirements[10]. Because the numbers available change throughout the year, it is assumed to be current-onboard data.

The resultant baseline for total manpower afloat, including Active Duty ship's crew and aircrew and civilian crew is estimated at 134,708. This estimate for the current ship inventory is sound. For example, the total military afloat manpower requirement was calculated at approximately 130,800. This estimate is approximately 11% higher

[10] See the Manpower Terminology section for a brief discussion on this.

than the average afloat USN and USMC personnel onboard from 2005 to 2009. This is well within the "readiness gaps" normally incurred by the differences in declared manpower requirements and current-onboard numbers. "Currently, the U.S. Navy 'authorises' ship manpower at approximately 90 percent of the requirement." (J. F. Schank et. al., p. 75)

Table 5 on page 28 summarizes the final numbers based on the discussions below.

1. Aircraft Carriers

Particular attention is given to CVN manpower because these ships take about 47% of the total personnel afloat. Only 11 aircraft carriers remain after the decommissioning of USS John F. Kennedy in 2007—1 CVN 65 and 10 CVN 68 class ships. Both classes have similar capability for carrying a mix of approximately 52 aircraft. The JFS aircrew estimate will be used in the model.

a. CVN 65 Aircraft Carrier

JFS states a ship's crew size of 3350. This is significantly different from the 3524 listed in Part II of the CVN 65 SMD. It should also be noted, however, that this number differs from the actual count of 3627 billets in Part III of the SMD. Although the SMD number may be more accurate, the JFS number will be used as the estimate for consistency when comparing crew sizes to foreign ships. The JFS aircrew estimate 2480 will be used for CVN 65.

b. CVN 68 Aircraft Carrier

There is also a discrepancy between JFS and CVN 68 SMD numbers, 3200 and 3332 respectively. Again, it should be noted that this also differs from the actual count of 3465 billets in Part III. The JFS number will again be used as the estimate for consistency. The JFS aircrew estimate 2480 will again be used for CVN 68.

2. Cruisers, Destroyers, and Frigates

Cruisers, destroyers, and frigates are large, heavily armed, multi-mission surface combatants. They carry out a wide range of missions from surface and anti-submarine warfare to operations against enemy aircraft and land targets. There are 22 cruisers, 52 destroyers and 30 frigates. They all have the capability to carry helicopters ,and therefore, aircrew must be added to the overall manpower number. Any aviation maintenance detachment personnel are assumed to be incorporated within the ship's crew and aircrew totals. See Section 7 below for a discussion of aircrew.

a. CG 47 Cruiser

JFS lists a crew size of 358. However, Ticonderoga class cruisers are to undergo SmartShip modernization, which is a program to apply technology to reduce workload and manpower requirements. According to JFS, modernization began in 2006 and is to be completed on all Ticonderoga class ships by 2017. Other initiatives have also reduced manpower requirements. It is important to capture effects of optimal manning initiatives on future ships. For this reason, SMD data will be used vice JFS to develop a crew size estimate for cruisers. CG 47 SMD lists crew size without SmartShip at 339. Crew size for CG 47 with SmartShip is listed as 326 (a difference of 13 billets). An average of crew size with and without SmartShip (333) will be used to estimate current cruiser manpower. Ticonderoga class cruisers carry two SH-60B Seahawk LAMPS III helicopters. An aircrew estimate of 19 requirements will be included; see section 7 below for further detail.

SmartShip reduction in cruiser manpower will be used later as a baseline to derive CG (X) manpower numbers for the 313 Ship Navy.

b. DDG 51 Destroyer

The Arleigh Burke destroyer class had two phases, Flight I and Flight II. JFS provided crew size of 346 for Flight I and 352 for Flight II based the initial crew data. The DDG 51 SMD provides more current numbers of 271, 276, or 278, depending on flight, after modernization and manpower reduction initiatives. A weighted average[11], of manpower requirements was taken to develop the crew size estimate of 274 for current destroyers.

52%*271 (DDG 51–78) + 11.5%*278 (DDG 79–84) + 35.5%*276 (DDG 85–104)

DDG 51 class destroyers have the capacity for two SH-60 Seahawk helicopters but usually only carry one. An aircrew estimate of 10 will be included. See Section 7 below for further detail on aircrew estimation.

Similar to the cruisers above, it is important to reflect manpower reduction and adjustment effects on crew size to forecast future requirements. These will be captured by using the most current destroyer data of 276 (DDG 85–90 Flight II SMD) as the baseline for future DDG(X) manpower numbers.

c. FFG 7 Frigate

Ship's crew of 200 and air crew of 19 were taken directly from JFS. FFG 7 SMD states a ship's crew of 205.

3. Littoral Vessels

Littoral vessels provide theater security for ports and shore areas. There are currently one littoral combat ship, 14 mine warfare ships and 8 patrol craft that operate in littoral environments.

a. LCS 1 Littoral Combat Ship

The Littoral Combat Ship (LCS) is still a new program, consisting of two variants, so there are some discrepancies on the final number of LCS crew. JFS states a crew size of 50 for LCS 1 class ships and a crew size of 40 for LCS 2 class ships. These numbers are both supported by available literature. A proceedings presentation in May05 (Etnyre, 2005) states a crew of 40 while the LCS Flight 0 Pre ACAT ("Littoral Combat

[11] Weighted by number of ships in each flight phase in the current inventory.

Ship Flight 0," 2003, p. 4) states threshold level of 50 core crew members. An average estimate of 45 billets for LCS is used. LCS carries 2 MH-60 or 1 MH-60 and 3 UAV's; an aircrew of 19 will be included.

b. MCM 1 Mine Sweeper

Ship's crew of 84 was taken directly from JFS. MCM 1 SMD states a ship's crew of 87.

c. PC 1 Patrol Craft

Ship's crew of 39 was taken directly from JFS. This study did not include the 9 SEALs or law enforcement detachment that could be deployed. PC 1 SMD states a ship's crew of 28.

4. Submarines

All U.S. submarines are nuclear powered. There are 53 fast attack submarines, 14 strategic missile submarines, and four cruise missile submarines. Attack submarines are multi-mission, conducting surveillance and special operations and well as tradition roles of surface and anti-submarine warfare. Cruise missile submarines also conduct surveillance and special operations as well as having a tremendous strike capability. Strategic missile submarines typically have a single mission: strategic deterrence.

a. SSN 688 Fast Attack Submarine (Los Angeles)

Ship's crew of 134 was taken directly from JFS. SSN 688 SMD states a ship's crew of 149. This is a large difference for the size of the crew. It is unclear what causes the difference between the two documents. The JFS number will be used as the estimate to be consistent when comparing crew sizes to foreign ships.

b. SSN 21 Fast Attack Submarine (Seawolf)

There is again a relatively large difference between JFS data and SSN 21 SMD data; crew sizes of 140 and 151 respectively. Again JFS numbers will be used to provide consistency across foreign classes.

c. SSN 774 Fast Attack Submarine (Virginia)

Ship's crew of 134 was taken directly from JFS. SSN 774 SMD data was not available at the time of this study.

d. SSBN 730 Strategic Missile Submarines

Ship's crew of 155 was taken directly from JFS. SSN 730 SMD states a ship's crew of 159.

e. SSGN 726 Cruise Missile Submarines

Ship's crew of 155 was taken directly from JFS. SSN 726 SMD data was not available at the time of this study. It is assumed that crew size and structure would be closely analogous to the SSBN crew.

f. AS 39 Sub Tenders

Ship's crew of 1268 was taken directly from JFS.

5. Amphibious Ships

Amphibious ships support Marine Corps operations from the sea. "They must be able to sail in harm's way and provide a rapid buildup of combat power ashore in the face of opposition." ("Amphibious Assault Ships—LHA/LHD/LHA(R)," 2009) Amphibious ships often have large decks and have the capability to carry helicopters. Two classes have flight decks that can also launch and receive airplanes. Aircrew must be added to the overall manpower number. As before, any aviation maintenance detachment personnel are assumed to be incorporated into the ship's crew and aircrew totals. See Section 7 below for a discussion of aircrew.

a. LHA 1 Tarawa Class Amphibious Assault Ship

There is a large discrepancy for crew size between JFS and LHA 1 SMD data. JFS lists 964 while SMD lists 1230. Table 1 lists the specifications of the preceding and succeeding classes of ships, and normalizes the crew size to ship displacement.

	Year	Ship Class	Tons	Crew	Crew/Tons	ln(#)	ln(ratio)
1	1961	Iwo Jima Class	18,474	667	0.0361	0	-3.321
2	1976	Tarawa Class(SMD)	39,967	1230	0.0308	0.693	-3.481
2	1976	Tarawa Class(JFS)	39,967	964	0.0241	0.693	-3.724
3	1989	Wasp Class	40,650	1123	0.0276	1.098	-3.589
4	2009	Makin Island	41,661	1123	0.0270	1.386	-3.613
5	2012	America Class	44,850	1059	0.0236	1.609	-3.746

Table 1. Crew Size Normalized to Ship Displacement

By examining the normalized data, a "learning curve" with respect to crew size over ship successions can be seen, $y = 0.0363 * x^{-0.2453}$, as shown in Figure 8. The learning curve has a slope of approximately 84%.

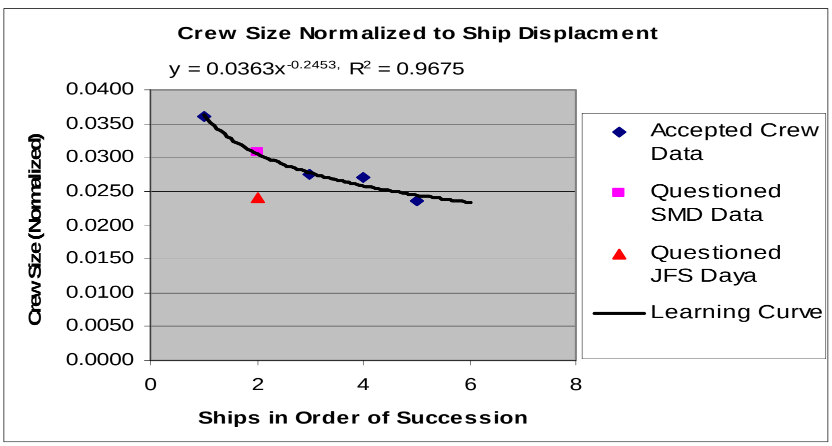

Figure 8. Crew Size Learning Curve for Amphibious Assault Ships

A logarithmic transformation of the data was done to perform a linear regression of the model and obtain statistical analysis. The resulting trend line shown in

Figure 9 is y = -0.2453 * x – 3.3164. The F-score significance is 0.0164 and the adjusted R^2 is 0.9513. Additional regression statistics can be found in Appendix D.

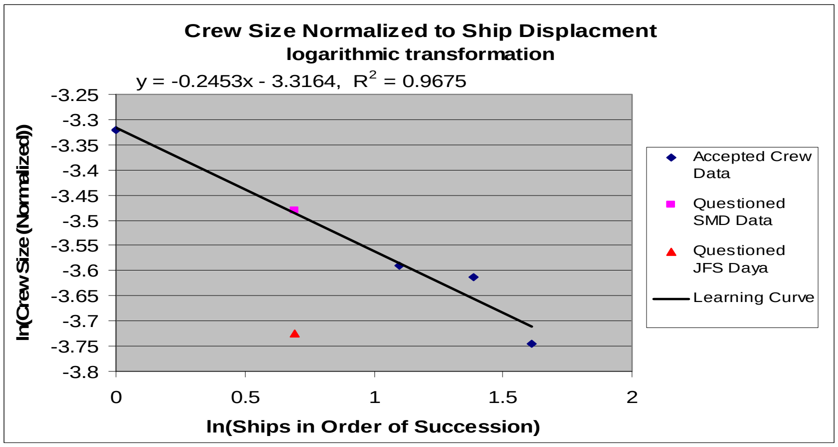

Figure 9. Logarithmic Transformation of Crew Size

When the JFS data is included, the statistics of the regression worsen, with an F-score significance of 0.1246 and an adjusted R2 value of 0.4651. On the other hand, when the SMD data is used, the statistics improve with an F-score significance of 0.0023 and an adjusted R2 of 0.9590. The LHA 1 SMD data fits the curve better and so will be used as the estimate for crew size for of this class. Learning curves such as this will become important when predicting crew sizes of future amphibious assault ships.

Tarawa class amphibious assault ships can carry nine CH-53D Sea Stallion, or twelve CH-46D/E Sea Knight helicopters, or any mix of these. An estimate of 263 will be used to model aircrew for this class.

This study does not consider the 1700 marines of the military lift detachment.

b. LHD 1 Wasp Class Amphibious Assault Ship

Ship's crew of 1123 was taken directly from JFS. LHD 1 SMD states a ship's crew of 1075. "A typical complement of aircraft is a mix of 25 helicopters and six to eight Harriers (AV-8B). In the secondary role as a sea control ship the most likely mix is 20 AV-8B Harriers and four to six SH-60B Seahawk helicopters." (Jane's Fighting Ships, 2009) An estimate of 511 aircrew requirements will be used. See Section 7 below for further discussion on aircrew estimates. This study does not consider the 1690 marines of the military lift detachment.

c. LCC 19 Amphibious Command Ship

JFS data provides crew size of 786. This is likely initial crew size as of 1970 commissioning date. LCC 19 SMD lists a crew size of 600 after several rounds of crew decreases. The lower number of 600 will be used to estimate LCC 19 crew size to help capture crew reduction initiatives in the fleet. There is only one ship of this class, so it should not have a large impact on current fleet numbers, but it will serve as the basis for predicting future command ship manpower. Flag staff personnel have not been included in this study—up to 637 staff personnel may also be deployed on the ship. Nor does this study consider the 700 marines of the military lift detachment.

LCC 19 carries one SH-3H Sea King helicopter. A 10 man aircrew estimate is included in the model.

d. LCC 20 Amphibious Command Ship

LCC 20 also saw substantial crew size reductions. In addition to conventional manpower reductions, LCC 20 also utilized civilian crew members to reduce manpower costs. An "analysis found that using a mix of military and civilian personnel rather than all military personnel would reduce personnel costs by nearly a third." (GAO–03–520, 2003, p. 17)

JFS states a military crew of 157 and a civilian crew of 146 for a total ship's crew of 303, which will be used for this analysis. (LCC 20 SMD states 159 ship's crew but it gives no data on the civilian crew.) Neither the Flag staff personnel of up to 562 nor the military lift detachment of 700 marines are considered in this study.

LCC 20 also carries an SH-3H Sea King helicopter. A 10 man aircrew estimate is included in the model.

e. LPD 4 Amphibious Transport Dock

Ship's crew for Austin class ships of 420 was taken directly from JFS. LPD 4 SMD lists a ship crew of 413. An LPD 4 can carry up to six CH-46D/E Sea Knight helicopters, although a typical operational load might include one SH-60, two CH-46, two UH-1, and AH-1 helicopters (Jane's Fighting Ships, 2009). An estimate of 105 is used to model the aircrew for this class.

Flag staff personnel of up to 90 and military lift troops of 930 are not included.

f. LPD 17 Amphibious Transport Dock

The next 5 LPD ordered are of the San Antonio class. Both JFS and a LPD17 Fact Sheet ("USS San Antonio LPD 17 Fact Sheet," 2006) state crew size of 360. Three Marine liaison officers were not included in the count. This number will also be used for future LPD estimates. San Antonio class ships have the capacity for 1 CH-53E Sea Stallion, 2 CH-46E Sea Knights, or 1 MV-22 Osprey. Aircrew requirements will be estimated at 35. The 720 troops in the military lift are not included in this study.

g. LSD 41 Amphibious Landing

JFS data provides crew size of 413. This is likely the initial crew size as of its 1985 commissioning date. LSD 41 SMD lists a crew size of 323 after several rounds of crew decreases. Similar to the LCC 19 above, the lower number of 323 will be used to estimate LSD 41 crew size to help capture crew reduction initiatives in the fleet. LSD 41 can carry two CH-53 Sea Stallions. An aircrew of 70 is used for this class. The military lift troops of 402 marines are not included in this study.

6. Naval Fleet Auxiliary Force

Naval Fleet Auxiliary Force (NFAF) ships provide combat logistics services to U.S. Navy ships at sea. Some of the ships also have NFAF ships, such as the T-AOE, T-AE, T-AKE, T-AFS, T-AO, and T-ARS, are government owned and use a mixed complement of Merchant Marines or Military Sealift Command (MSC) personnel and a "small contingent of Navy personnel aboard for operations support, supply coordination and helicopter operations." ("Naval Fleet Auxiliary Force," 2009) This "generally results in a smaller crew because these organizations employ more experienced seamen, have reduced watchstanding requirements, and use a different maintenance and training philosophy." (GAO–03–520, 2003, p. 13) Large MSC supply/support ships do not generally have the displacement/crew relationship that warships exhibit. JFS crew data, listed in Table 2, generally agrees with MSC webpage data (http://www.msc.navy.mil/) and will be used for consistency of data. Navy divers on salvage ships are not considered in this study. Air crew of 35 on the T-AE 32 is taken directly from JFS. Air crews on other NFAS are discussed in Section 7 below.

Class	Type	Civilian Crew	Military Crew	Aircraft	Aircrew
T-AOE 6	Fast Combat Support	160	28	2 MH-60	19
T-AE 32	Ammo ships	133	4	2 CH-46	35
T-AKE 1	Cargo and Ammo	113	11	2 MH-60	19
T-AFS 5	Combat Stores	127	22	2 MH-60	19
T-AO 187	Oiler	89	5	N/A	0
T-ARS 50	Salvage ship	26	4	N/A	0

Table 2. Naval Fleet Auxiliary Force

7. Aircrew

Embarked aircrew numbers for smaller ships (roughly from 1000 to 6000 tons) carrying smaller aircraft (typically SH-60 helicopters) were difficult to find. JFS had only limited information available. Estimates are based on the Oliver Hazard Perry class frigate (FFG 7), which carries two SH-60B Seahawks and has an air crew of 19 (Jane's Fighting Ships, 2009) as an analogous model.

According to JFS, Ticonderoga class cruisers (CG 47) carry two SH-60B Seahawks. Similarly, T-AOE 6 class, T-AKE 1 class, and T-AFS 5 class ships each carry two MH-60 variants of the Seahawk helicopters. These can be considered to be analogous systems. The air crew for each of these current inventory ships will be estimated at nineteen. Arleigh Burke class destroyers (DDG 51) also have the capacity for two similar helicopters, although they typically only carry one. Its aircrew will be estimated at 10 as explained in Table 3.

The assumption is validated when ships of this size with available aircraft and aircrew data are examined. The data in Table 3 does not lend itself well to regression techniques (the best R^2 score was 0.0394). Instead, average number of ships and aircrew were calculated to develop a crew/craft ratio of 9.7. Using this ratio, 1 aircraft requires an aircrew of 10; 2 aircraft requires 19. This ratio will be used for ships carrying only one helicopter (such as LCC 19 and 20) and for appropriate future ships.

Country	Ship	Tonnage	Crew	Aircraft	Aircrew
Canada	Halifax	4770	198	1	17
Germany	Sachsen	5600	255	2	13
U.S.	Oliver Hazard Perry	4100	200	2	19
UK	Type 22	4900	250	2	10
France	Floreal	2950	90	1	11
Turkey	Barbaros	3380	187	1	9
Greece	Hydra	3350	199	1	13
Singapore	Formidable	3200	71	1	15
			Average:	1.375	13.375

Table 3. 1000 to 6000 Ton ships with aircraft

Aircrew sizes for amphibious ships (roughly from 16000 to 45000 tons) carrying a mix of aircraft (typically helicopters and harriers) were also difficult to find. JFS had only limited information available; however, it did provide information for the aircraft and aircrew on the T-AE 32. The T-AE 32 carries two CH-46 Sea Knight helicopters. These helicopters can provide the basis for converting known quantities of aircraft aboard ships to estimated aircrew numbers. The two CH-46 helicopters have an aircrew of 35 personnel.

JFS states that LPD 17 can carry either one CH-53 Sea Stallion, or two CH-46 Sea Knights, or one MV-22 Osprey. This information provides a conversion method for aircrew of other aircraft.

Rough estimates are 10 aircrew personnel for smaller helicopters like the SH-60, 17 for medium helicopters like the CH-46 and 35 aircrew personnel for large helicopters like the CH-53. An estimate of 20 aircrew per Harrier is also made. Table 4 provides the resulting aircrew estimates for the ships listed.

Class	Aircraft	Estimates	Aircrew
T-AE 32	2 CH-46 Sea Knight		35
LPD 17	1 CH-53 Sea Stallion, or 2 CH-46 Sea Knight	2 CH-46 Sea Knight = 35 1 CH-53 Sea Stallion = 35	35
LSD 41	2 CH-53 Sea Stallion	1 CH-53 = 35, 2 CH-53 = 2*35 = 70	70
LPD 4	Up to 6 CH-46	estimate at 6 / 2 * 35 = 105	105
LHA 1	9 CH-53 Sea Stallion or 12 CH-46 Sea Knight	estimate between : 12 / 2 * 35 = 210 and 9 * 35 = 315	263 (avg)
LHD 1	25 helos and 6 Harriers or 20 Harriers and 6 SH-60	estimate between: (10 SH-60, 10 CH-60, 5 CH-53, and 6 Harriers) 10 / 2 * 19 + 10 / 2 * 35 + 5 * 35 + 6 * 20 = 565 Or 20 * 20 + 6 / 2 * 19 = 457	511 (avg)

Table 4. Aircrew estimates based on 2 CH-46 aircrew

Current Ship Inventory	Number of Ships	Civilian Crew	Air Crew	Ship Crew	Total Civilian Crew	Total Air Crew	Total Ship Crew	Total Manpower
CVN 68 Aircraft Carrier	10	0	2480	3200	0	24800	32000	56800
CVN 65 Aircraft Carrier	1	0	2480	3350	0	2480	3350	5830
CG 51 Cruiser	22	0	19	333	0	418	7326	7744
DDG 51 Destroyer	52	0	10	274	0	520	14248	14768
FFG 7 Frigate	30	0	19	200	0	570	6000	6570
LCS 1 Littoral Combat Ship	1	0	19	45	0	19	45	64
MCM 1 Mine Warfare	14	0	0	84	0	0	1176	1176
PC 1 Patrol craft	8	0	0	39	0	0	312	312
LHA 1 Amphibious Assault Ship	2	0	263	1230	0	526	2460	2986
LHD 1 Amphibious Assault Ship	7	0	511	1123	0	3577	7861	11438
LCC 19 Amphib Command Ship	1	0	10	600	0	10	600	610
LCC 20 Amphib Command Ship	1	146	10	157	146	10	157	313
LPD 4 Amphib Transport Dock	6	0	105	420	0	630	2520	3150
LPD 17 Amphib Transport Dock	3	0	35	360	0	105	1080	1185
LSD 41 Amphib Landing Dock	12	0	70	323	0	840	3876	4716
SSN 688 Fast Attack Submarine	45	0	0	134	0	0	6030	6030
SSN 21 Fast Attack Submarine	3	0	0	140	0	0	420	420
SSN 774 Fast Attack Submarine	5	0	0	134	0	0	670	670
SSBN 730 Strategic Missile Submarine	14	0	0	155	0	0	2170	2170
SSGN 726 Cruise Missile Submarine	4	0	0	155	0	0	620	620
AS 39 Sub Tender	2	0	0	1268	0	0	2536	2536
T-AOE 6 Fast Combat Support	4	160	19	28	640	76	112	828
T-AE 32 Ammo Ship	4	133	35	4	532	140	16	688
T-AKE 1 Cargo and Ammo	8	113	19	11	904	152	88	1144
T-AFS 5 Combat Stores	3	127	19	22	381	57	66	504
T-AO 187 Oiler	14	89	0	5	1246	0	70	1316
T-ARS 50 Salvage Ship	4	26	0	4	104	0	16	120
	280				3953	34930	95825	134708

Table 5. Model of Current Ship Inventory Manpower

B. 313 SHIP NAVY

The proposed 313-ship fleet outlined in 2006 is likely to consist of 11 aircraft carriers, 19 CG (X) cruisers, 7 Arleigh Burke class destroyers, 7 DD 1000 destroyers, 55 DDG (X) destroyers, 55 littoral combat ships, 48 attack submarines, 14 strategic ballistic missile submarines; 4 guided missile submarines, 31 amphibious ships, a future maritime prepositioning force of 12 ships, and 50 NFAF combat logistics ships.

This is a projection of the proposed fleet to around 2035. Many studies such as the CBO report "Resource Implications of the Navy's 313-Ship Plan," Dec 16, 2005, estimate that the policy "achieve a 313-ship fleet in 2035" based on a 30-year ship-building program. Ship building plans like those in a CRS Report for Congress suggest that by 2035, most of the "X" classes of ships should be well into construction and utilization.

Existing ships' crews were again taken from JFS (and SMD as necessary) whenever possible. Because many of these, such as CG(X)/DDG(X), LHA/D(X), LSD(X), and MPF(F) ships, are in the design or initial construction phases, they were not listed in JFS and SMD data does not exist. Ship builder web pages, PEO briefs, reports to Congress, and other presentations provided the bulk of context for these proposed ships. Historical numbers and trends were used when possible to help develop new crew estimates. Attempts were made to capture the benefits of optimal manning initiatives to shape future crew sizes.

Table 10 on page 40 summarizes the final numbers based on the discussion below.

1. Aircraft Carriers

The mix of aircraft carrier classes that will exist in 2035 must be determined to credibly forecast required carrier personnel. The commission dates of the CVN 68 class carriers can be seen in Table 6, with a rough average of one carrier every four years. Decommissioning dates are estimated at 45 years after commission. The CVN 21 (formerly CVN (X)) program is the next generation of aircraft carrier, with CVN 78 as the lead ship. JFS projects CVN 78 to be commissioned in 2015, CVN 79 commissioned in 2019, and CVN 80 in 2023, one every four years. If this trend is continued out to 2035, three more carriers will be delivered: CVN 81–83. This is confirmed in a CBO report that "over the 2006–2035 period, a total of six CVN-21s would be purchased." ("Resource Implications of the Navy's 313-Ship Plan," 2005, p. 4) By that time, it is assumed that six CVN 68 will be retired, for a mix of five CVN 68 and six CVN 78.

Hull #	Ship	Commission	Decommission
CVN 68	USS Nimitz	1975	2020
CVN 69	USS Dwight D. Eisenhower	1977	2022
CVN 70	USS Carl Vinson	1982	2027
CVN 71	USS Theodore Roosevelt	1986	2031
CVN 72	USS Abraham Lincoln	1989	2034
CVN 73	USS George Washington	1992	2037
CVN 74	USS John C. Stennis	1995	2040
CVN 75	USS Harry S. Truman	1998	2043
CVN 76	USS Ronald Reagan	2003	2048
CVN 77	USS George H.W. Bush	2009	2054
CVN 78	USS Gerald R. Ford	2015	2060
CVN 79		2019	2064
CVN 80		2023	2068
CVN 81		2027	2072
CVN 82		2031	2076
CVN 83		2035	2080

Table 6. CVN 68 and CVN 78 Commissioning Dates

a. CVN 68 Aircraft Carrier

As with the current inventory analysis, CVN 68 ship crew of 3200 and aircrew of 2480 were taken directly from JFS.

b. CVN 78 Aircraft Carrier

As stated previously, CVN 78 is the lead ship for the next generation CVN 21 program, also formerly known as CVN (X). Northrop Grumman, the shipbuilder for

CVN 78 estimated a reduction in manning of 30%. ("Gerald R. Ford Class of Nuclear-Powered Aircraft Carriers," 2009) This seems overambitious, placing manning (ship crew plus aircrew) at around 3976. No other estimates provide numbers that low. JFS lists a ship complement (ship and aircrew) of 4660. This is a reduction of approximately 18% from the CVN 68 class. A United States Navy CVN 21 Fact File (2009) claims "1000–1200 billet reductions (ships crew and air wing)" and a naval-technology.com estimation of ship crew is between 2500 to 2700 ("Aircraft Carriers – CVN 21 Program," 2009). CVN 78 ship's crew will be estimated at 2700 as it is 500 less than CVN 68 ship's crew and approximately 18% less. The remaining 1960 will be used to estimate the aircrew.

2. Cruisers and Destroyers

Cruisers and destroyers will continue to carry out their missions of surface and anti-submarine warfare to operations against enemy aircraft and land targets. There will be 19 cruisers and 69 destroyers. It is important to reflect manpower reduction and adjustment effects on crew size for forecasting into future requirements for the 313 Ship Navy. With Smart Ship (SS) developed in current cruisers and OM initiatives introduced in DDG 1000, future CG (X) and DDG (X) crew sizes should be quite lean and mean. Aircrew for these ships will be estimated as previously developed, specifically 19.

a. CG (X) Cruiser

CG (X) is the proposed replacement for the Ticonderoga (CG 47) class cruisers. It is expected to be a follow-on variant of the DDG 1000. (Jane's Fighting Ships, 2009) A CRS Report for Congress ("Navy DD(X) and CG(X) Programs: Background and Issues for Congress," 2005) projects 125 to 175 for CG (X) and DD (X). These low numbers reflect a very optimistic expectation of manpower reduction. A cruiser crew size of 175 would be a reduction of approximately 47% from current sizes. Although ambitious, 175 will be used to capture the possible results of OM initiatives by the year 2035. CG(X) will carry the equivalent of two SH-60B Seahawks, so an aircrew of 19 will be included.

b. DDG 51 Destroyer

As stated previously, the Arleigh Burke destroyer class had two versions, Flight I and Flight II. Assuming no procurement of Arleigh Burke class destroyers past to currently authorized DDG 112 and an expected service life of 35 years, 34 of these destroyers will remain in the 313 Ship Navy. It is likely that the most recent versions of the ship (DDG 79–112) will be the ones to remain. Current manpower levels represent modernization and OM initiatives, this DDG 85–90 SMD data of 276 will be applied. DDG 51's typically carry one SH-60B Seahawk, so an aircrew of 10 will be included.

c. DDG 1000 Destroyer

According to JFS, the DDG 1000 program has been curtailed and only three ships are to be built. However, the 313 Ship Navy still calls for 7 DDG 1000 destroyers on the assumption that the program may be restarted sometime in the future. Navy PEO Ships projects a DDG 1000 crew size of 114. ("Zumwalt Class (DDG 1000)," 2009) This seems unrealistically ambitious. JFS reports a more pragmatic crew size of 142. The model will use the lower number from the CRS report ("Navy DD(X) and CG(X) Programs: Background and Issues for Congress," 2005) of 125. This number seems practical while still reflecting the OM initiatives by year 2035. DDG 1000 will carry 2 MH-60 or 1 MH-60 and 3 UAV's; an aircrew of 19 will be included.

d. DDG (X) Destroyer

Sixty-nine total destroyers are called for in the 313 Ship Navy. Presumably, the ships will range somewhere between current destroyers, DDG 1000, and some future DDG (X). The DDG 1000 program, formerly DD (X), has been cancelled due to cost overruns, with only three ships to be built, but 7 are still included in the 313 ship plan. It is assumed that 39 DDG 51 class ships will still be active. Twenty-eight DDG (X) class destroyers must then be commissioned to fulfill the 69 ship requirement.

Manning should be lower than current destroyer levels of 333, but more than the ambitious 114 projected by Navy PEO Ships for DDG 1000. The relative size differences between current cruisers and destroyers listed in Table 7 will be used to determine the DDG (X) crew size.

Cruiser	Crew	Destroyer	Crew
CG52 w/o SS	339	DDG51 FLIA	271
CG52 w SS	326	DDG51 FLIIA	278
		DDG51 FLIIB	276
Avg. crew size:	332.5	Avg. crew size:	275
		CG/DDG ratio:	.827

Table 7. DDG and CG crew sizes

The crew size ratio between current CG and DDG ships is approx .827. If 175 is used to estimate CG (X) crew size, and the .827 ratio is used to maintain relative sizes between the ships, then DDG (X) crew size will be estimated at 145. Like the CG (X) estimate, it is an ambitious number, attempting to capture manpower reductions by 2035, but it is more conservative than DDG 1000's crew of 114. DDG(X) will also carry the equivalent of two SH-60B Seahawks, so an aircrew of 19 is included.

3. Littoral Vessels

The 313 Ship Navy only has one class of ship, the LCS, specifically designed to operate in littoral environment. It has done away with the mine warfare ship and the patrol craft, missions presumably to be filled by the LCS.

a. LCS 1 Littoral Combat Ship

As previously mentioned, JFS states a crew size of 50 for the LCS 1 class and 40 for the LCS 2 class. An average estimate of 45 billets will be used. LCS carries 2 MH-60 or 1 MH-60 and 3 UAV's; an aircrew of 19 will be included.

4. Submarines

The submarine force of the 313 Ship Navy is 40 SSN, 14 SSBN, and 4 SSGN. A Defense Science Board panel report in 1998 rejected "the suggestion for a force mix that includes diesel-electric submarines" and asserts that "the Virginia-class follow-on should be a "large" nuclear ship" ("Future Attack Submarine," 2005)

According to JFS, a program of 30 Virginia class submarines is planned. A military.com compilation of OMB data projects the last SSN 774 to be commissioned by 2026. There are currently 45 active Los Angeles class submarines. If the older submarines are retired when the newer submarines are commissioned, the Fast Attack submarine force in 2035 may be modeled as a mix of 30 SSN 774, 3 SSN 21, and 15 SSN 688.

Little information on SSN (X) and SSBN (X) is programs available. They will not be included in this work. It is assumed that the total number of submarines would remain constant and any "X" submarine will likely have manpower requirements similar to its predecessor.

a. SSN 688 Fast Attack Submarine (Los Angeles)

As previously stated, there is a relatively large difference between JFS and SMD data. The JFS number of 134 will be used as the estimate for consistency when comparing crew sizes to foreign ships

b. SSN 21 Fast Attack Submarine (Seawolf)

Again, there is a relatively large difference between JFS data and SSN 21 SMD data. Again JFS numbers of 140 will be used to provide consistency with foreign classes.

c. SSN 774 Fast Attack Submarine (Virginia)

Ship's crew of 134 was taken directly from JFS. SSN 774 SMD data was not available at the time of this study.

d. SSBN 730 Strategic Missile Submarines

Ship's crew of 155 was taken directly from JFS. SSN 730 SMD has a ship's crew of 159.

e. SSGN 726 Cruise Missile Submarines

Ship's crew of 155 was taken directly from JFS. SSN 726 SMD data was not available at the time of this study. It is assumed that crew size and structure would be closely analogous to the SSBN crew.

f. AS 39 Sub Tenders

Ship's crew of 1268 was taken directly from JFS.

5. Amphibious Ships

Marine Corps plans project 15 Amphibious Task Force ships (1 LHA, 4 LHD, 5 LPD-17, and 5 LSD) are required to deploy the Assault Echelon (AE) of an Amphibious MEB. Thirty such ships would be required to deploy the 2 MEB Assault Echelons prescribed in Strategic Planning Guidance. The Marine Corps estimates that 33 ships are the minimum needed to account for a ship availability of 85% (Strock, 2004). The 313 Ship Navy plans for 31 Amphibious ships.

a. LHA/D (X) Amphibious Assault Ship

According to JFS, the LHA Replacement (LHA I) design was to be a modified version of the LHD 8 design. Apparently, however, LHA 6 will fill the requirement of LHA I until LH (X) is developed. Three or four LHA 6 will be ordered, with 7 LHA (X) to follow, the first being operational around FY 2030. ("LH(X) Amphibious Assault Ship," 2008) Ship specifications, including manpower requirements, are still to be determined.

As was seen previously, there appears to be a learning curve with respect to crew size. The last several LHA and LHD ships are listed above in Table 1. A regression of the data shown in Figure 10, including Tarawa's crew data, produces a power series equation, $y = 0.0364*x^{-0.2462}$, where y is the crew/weight ratio and x is the number of the ship in succession, with an adjusted R^2 value of 0.9590. Using LHA/D (X) as ship number six produces a predicted crew/weight ratio of 0.0234. With some insight that LHA/D (X) will be a modification of LHD 8 and LHA 6, an estimated ship displacement of 43000 tons is multiplied to the ratio producing a prediction of 1006 ship's crew.

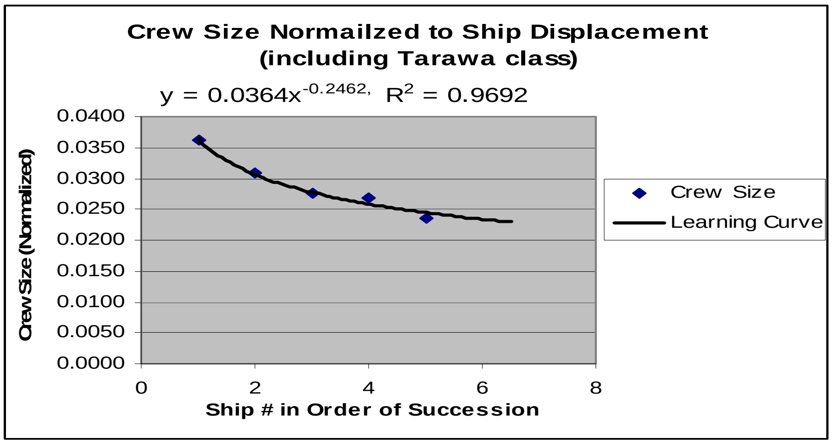

Figure 10. Normalized Crew Size

The air wing capacity is expected to be similar to that of current Wasp class amphibious assault ships: "a mix of 25 helicopters and six to eight Harriers" or "20 AV-8B Harriers and four to six SH-60B Seahawk helicopters." (Jane's Fighting Ships, 2009) An estimate of 511 aircrew requirements will be used. See section 7 "Aircrew" above for further discussion of aircrew estimates.

b. LPD 17 Amphibious Transport Dock

Ship's crew of 360 was taken directly from JFS. San Antonio class ships have the capacity for 1 CH-53E Sea Stallion, or 2 CH-46E Sea Knights, or 1 MV-22 Osprey. Aircrew will be estimated to be 35. See Section 7 "Aircrew" above for further discussion of aircrew estimates.

c. LSD (X) Landing Ship Dock

Little information is available on design characteristics for LSD (X). Mr. Jim Strock, Director, Seabasing Integration Division, states in a brief titled "Seabasing A Joint Force Enabler In Area-Denial and Anti-Access Environments" (2004) that "LPD 17 is the likely candidate for LSD (X)." LPD 17 requirements of 360 ship's crew and 35 aircrew will therefore be used for LSD (X) manpower.

6. Maritime Prepositioning Ships (Future)

The Maritime Prepositioning Force (Future), or MPF(F), are squadrons of various support ships strategically located around the world. Each squadron is to be able to load and transport all MEB equipment to any required location. MPF(F) is to provide indefinite "sea-basing" support to the MEB from safe international waters (Cook, 2004, p. 55). Senate Report 110–077 "National Defense Authorization Act For Fiscal Year 2008" confirms that MPF(F) ships are planned to be operated by a Military Sealift Command (MSC) crew. There are two military crew components in addition to the civilian MSC crew ("Marine Air Ground Task Force Composition and Utilization brief," 2008, p. 14). The Navy Support Element (NSE) is a "detachment of Navy cargo handling force personnel…tasked with conducting the off-load and ship-to-shore movement of maritime prepositioned equipment/supplies." ("Department of Defense Dictionary of Military and Associated Terms," 2001, p. 376) The Sea Base Echelon (SBE) typically consists of the assault echelon's support crews, which remain at the sea-base away from the assault operations, providing support by vertical replenishment. Only notional crew sizes are available at this time. The data in Table 8 was extracted from a 2005 brief ("Maritime Prepositioning Force (Future)," p. 12). Like MSC supply/support ships, MPF(F) ships do not generally have the displacement/crew relationship that warships exhibit. Aircrew is assumed to be included in the SBE numbers.

Ship	MSC	SBE	NSE
MPF(F) LHD/LHA (R)	285	1542	554
MPF(F) LMSR	30	205	110
MPF(F) MLP	50	1112	114
MPF(F) T-AKE	123	10	61

Table 8. Notional MPF(F) Crew

7. Naval Fleet Auxiliary Force

a. T-AO, T-AOE, T-AKE, ARS, T-AGOS, and T-ATF

With the sea-basing concept expanding in the future, the MSC NFAF "will continue to be a vital, cost- effective and innovative element of the U.S. Navy." ("Naval Fleet Auxiliary Force," 2009) T-AO(X), T-AOE(X), ARS(X), and T-ATF(X) are the next generation NFAF ships. Focus of improvement will likely be on cargo handling and capacity. For example, the new T-AOE(X) class will provide a next generation of triple product replenishment capabilities. ("T-AOE(X) Replenishment Ship / Triple Product Station Ship," 2006) It is unclear when the "X" class NFAF will be deployed; it has been reported that DoD cancelled the T-AOE(X) program in the FY 2007 defense budget process (Castelli, 2005). Manpower requirements are also unclear. Large MSC supply/support ships do not generally have the displacement/crew relationship that warships exhibit. Current numbers of equivalent current ships, provided in Table 9 should suffice.

Class	Type	Civilian Crew	Military Crew	Aircraft	Aircrew
T-AO (X)	Oiler	89	5	N/A	0
T-AOE (X)	Fast Combat Support	160	28	2 MH-60	19
T-AKE 1	Cargo and Ammo	113	11	2 MH-60	19
T-ARS (X)	Salvage ship	26	4	N/A	0
TAGOS 23	Ocean Surveillance	26	16	N/A	0
T-ATF (X)	Fleet Ocean Tug	16	4	N/A	0

Table 9. Future Naval Fleet Auxiliary Force

b. JHSV High Speed Connector

"The JHSV program would provide high speed intra-theater surface connector capability…capable of transporting personnel, equipment and supplies over operational distances in support of maneuver and sustainment operations." ("Joint High Speed Vessel (JHSV)," 2008) Contracts for the preliminary design of JHSV were awarded to Austal USA, Bath Iron Works and Bollinger Shipyards (teamed with Incat) It is likely that the vessel will model the WestPac Express or the Jervis Bay. It is unclear as to whether it will be manned with a civilian or navy crew. For this study, the JHSV crew will be estimated with Jervis Bay's complement of 20 (Jane's Fighting Ships, 2009).

c. JCC(X) Command Ship

Naval command ships provide communications, coordinate activities, and serve as the flagships of Fleet Commanders. The Navy currently has two dedicated command ships after the decommissioning of USS La Salle and the USS Coronado. The USS Blue Ridge and USS Mount Whitney have been in service for approximately 40 years. Two new LPD 17 ships, configured as command ships, may be commissioned to replace LCC 19 and 20. LCC or AGF Command Ship classes are most likely to be models for JCC(X).

Crew size has been sharply reduced from 786 to 600 (LCC 19) to 303 (LCC 20) using crew optimizing techniques and a civilian/military mixed crew policy. It may be unlikely; however, that manpower can be reduced much more for JCC(X). GAO-03–520 reported unfavorably on the "lack of any formal reduction goal on the JCC(X) command ship" (GAO-03–520, 2003, p. 10). It is further reported that the "JCC(X) command ship program made very limited use of human systems integration to optimize crew size…The program also did not hold program managers accountable for reducing crew size below that of the legacy command ships." (GAO-03–520, 2003, p. 16) Reflecting this insight, current crew sizes 146 civilian and 157 sailor requirements for LCC20 will be used to estimate JCC(X). An aircrew of 10 requirements for 1 SH-3H Sea King will also be included. This study does not include the varying command staff embarked.

313 Ship Navy	Number of Ships	Civilian Crew	Air Crew	Ship Crew	Total Civilian Crew	Total Air Crew	Total Ship Crew	Total Manpower
CVN 68 Aircraft Carrier	5	0	2480	3200	0	12400	16000	28400
CVN 78 Aircraft Carrier	6	0	1960	2700	0	11760	16200	27960
CG (X) Cruiser	19	0	19	175	0	361	3325	3686
DDG 51 (w/SS) Destroyer	34	0	10	276	0	340	9384	9724
DDG 1000 Destroyer	7	0	19	125	0	133	875	1008
DDG (X) Destroyer	28	0	19	145	0	532	4060	4592
LCS 1 Littoral Combat Ship	55	0	19	45	0	1045	2475	3520
SSN 688 Fast attack submarine	15	0	0	134	0	0	2010	2010
SSN 21 Fast attack submarine	3	0	0	140	0	0	420	420
SSN 774 Fast attack submarine	30	0	0	134	0	0	4020	4020
SSBN 730 Strategic missile submarines	14	0	0	155	0	0	2170	2170
SSGN 726 Cruise missile submarines	4	0	0	155	0	0	620	620
AS 39 Sub Tenders	2	0	0	1268	0	0	2536	2536
LHA/D (X) Amphib Assault Ship	9	0	511	1006	0	4599	9054	13653
LPD 17 Amphib Transport Dock	10	0	35	360	0	350	3600	3950
LSD (X) Amphib Landing Dock	12	0	35	360	0	420	4320	4740
MPF(F) LHD	1	285	1542	554	285	1542	554	2381
MPF(F) LMSR	3	30	205	110	90	615	330	1035
MPF(F) MLP	3	50	1112	114	150	3336	342	3828
MPF(F) T-AKE	3	123	10	61	369	30	183	582
MPF(F) LHA(R)	2	285	1542	554	570	3084	1108	4762
T-AO (X) Oiler	15	89	0	5	1335	0	75	1410
T-AOE (X) Fast Combat Support	4	160	19	28	640	76	112	828
T-AKE 1 Cargo and Ammo	11	113	19	11	1243	209	121	1573
ARS (X) Salvage Ship	4	26	0	4	104	0	16	120
T-AGOS 23 Ocean Surveillance	5	26	0	16	130	0	80	210
T-ATF (X) Fleet Ocean Tug	4	16	0	4	64	0	16	80
JHSV High Speed Connector	3	0	0	20	0	0	60	60
JCC (X) Command Ship	2	146	10	157	292	20	314	626
	313				5272	32245	92987	130504

Table 10. Model of Proposed 313 Ship Navy Manpower

C. NEW NAVY FIGHTING MACHINE

The NNFM puts forward a bi-modal navy of 677 ships plus 400 small inshore patrol craft. The “blue water” component is to consist of 6 nuclear powered aircraft carriers (CVN), 10 light aircraft carriers (CVL), 30 destroyers, 90 frigates, 20 land attack corvettes, and 9 Ballistic Missile Defense destroyers. The submarine force completes the “blue water” fleet, but is sure to play a role in the “green water” fleet as well; especially the Air-Independent Propulsion (AIP) subs. The force consists of 40 nuclear attack submarines, 40 AIP submarines, and 9 strategic ballistic missile submarines. The “green water” component is made up of 8 CVLs, 12 fleet station ships, 12 naval gunfire frigates, 12 fast mine warfare vessels, 12 anti-submarine warfare corvettes, 160 offshore patrol vessels, and 30 coastal combatants. The fleet is supported by 125 “deliver and sustain” MSC ships and 50 NFAF combat logistics ships.

As with the 313 ship analysis, this alternative configuration is projected to around 2035, allowing any new ship types to be designed, built, and incorporated into the fleet. Attempts were made to capture the benefits of optimal manning initiatives to shape future crew sizes whenever possible.

Table 23 on page 69 summarizes the final numbers based on the discussions below.

1. Aircraft Carriers

As stated previously, the mix of aircraft carrier classes that will exist in 2035 must be determined to credibly forecast required carrier personnel. Based on the previous discussion, 6 new carriers are projected to be delivered by 2035. These new CVNs will be the 6 required for the NNFM. In addition, the NNFM calls for 18 new light aircraft carriers (CVL) “specifically designed for STOVL, UAV, and VTOL operations.” (NNFM, 2009, p.22) Ten CVL would be designated for “Blue Water” operations and the remaining eight designated for the “Green Water” component. Manpower requirements would likely be similar for either version. The CVL will be discussed in more depth below.

a. CVN 78 Aircraft Carrier

CVN 78 is the lead ship for the next generation CVN 21 program, also formerly known as CVN (X). JFS lists a ship complement (ship and aircrew) of 4660. Through some estimation of projected manpower reductions discussed previously, CVN 78 ship's crew will be estimated at 2700, an 18% reduction of requirements from CVN 68. The remaining 1960 will be used to estimate the aircrew. See Part B. 313 Ship Navy, Section 1 Aircraft Carriers above for further explanation.

b. CVL (X) Light Aircraft Carrier

The NNFM calls for smaller, less expensive, more numerous aircraft carriers specifically designed for STOVL, VTOL, and possibly UAV; the notional capability of carrying and conducting operations for 20 F-35B aircraft. A CVL of 20000 to 30000 would likely suffice. This is a novel idea for the modern U.S. fleet although there are many examples in foreign fleets. A sample of 14 carriers is provided in Table 11.

Country	Ship	Displacement	Crew	Approx # of planes	aircrew
Thailand	Chakri Naruebet	11485	455	12	146
Italy	Garibaldi	13850	582	15	230
Spain	Prinipe De Asturias	17188	555	10	201
UK	Illustrious	20600	685	24	366
Spain	Juan Carlos I	27079	243	20	172
Italy	Cavour	27,100	528	20	168
India	Vikrant	37500	1400	12	N/A
France	Charkes De Gaulle	42500	1256	30	610
USA	America (LHA-6)	44850	1059	23	N/A[12]
Russia	Kuznetsov	45900	1960	22	626
USA	Kitty Hawk	83960	2930	52	2480
U.S.	Enterprise	89,600	3350	52	2480
U.S.	Nimitz	91,487	3200	52	2480
U.S.	Gerald R Ford	100000	2700	75	1960

Table 11. Sample of Various Aircraft Carriers

[12] No aircrew data was available from JFS. These two ships are not included in the aircrew regression.

Regression analyses were conducted, using displacement as a proxy for capability, and by extension, a factor of crew size. First the number of planes versus displacement was examined for all the carriers in the sample to estimate the size of aircraft carrier needed.

The linear regression, seen in Figure 11, produced an equation of: y = .0006 * x + 2.286, where y is capacity of planes an aircraft carrier of x tons can carry. The adjusted R^2 value is 0.8732. Additional regression statistics can be found in Appendix D. An aircraft carrier carrying 20 planes is estimated to displace 29500[13] tons.

With an F-score significance of 6.11E-07, there is certainty that the number of planes an aircraft carrier can operate is a function of its size. The U.S. carriers, clustered at the top right of the graph, may be influencing the slope of the regression line with their large economies of scale that smaller CV's may not have. An additional regression was performed without the U.S. CVN's and also provided in Figure 11. Its resultant equation is y = 0.0003 * x + 10.475. Additional regression statistics can be found in Appendix D. Its F-score significance is acceptable at 0.0711, although not as good. Its adjusted R^2 value of 0.2698 is not good, but its Coefficient of Variation (CV) is good at 0.182. (The previous regression with U.S. CVN's had a CV of 0.236.) An aircraft carrier carrying 20 planes is estimated to displace 31750[14] tons with this regression.

Arguments for either regression model can be made. The first regression with all the carriers in the sample is realistic and has strong statistical numbers but may be influenced by the large American super-carriers. The second regression without the U.S. ships does not have as strong statistical support, but it is also realistic and may better model aircraft carrier characteristics at the size of interest. The average of the two predicted values, 30600 will be used to estimate the displacement of a CVL capable of carrying a mix of aircraft, up to 20 planes.

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[13] y = .0006 * x + 2.286 = 29523.3.

[14] y = 0.0003 * x + 10.475 = 31750.

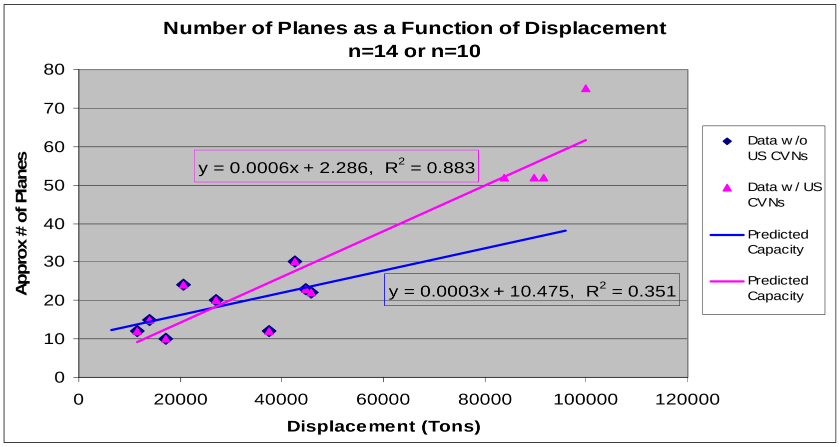

Figure 11. Number of Planes as a Function of Size

Crew size versus displacement was examined next. Crew size estimates were developed in a similar manner to the method used to determine displacement. Two linear regressions were performed, one with U.S. carriers and the other without. As shown in Figure 12, the lines are nearly comparable in the vicinity of the determined ship size.

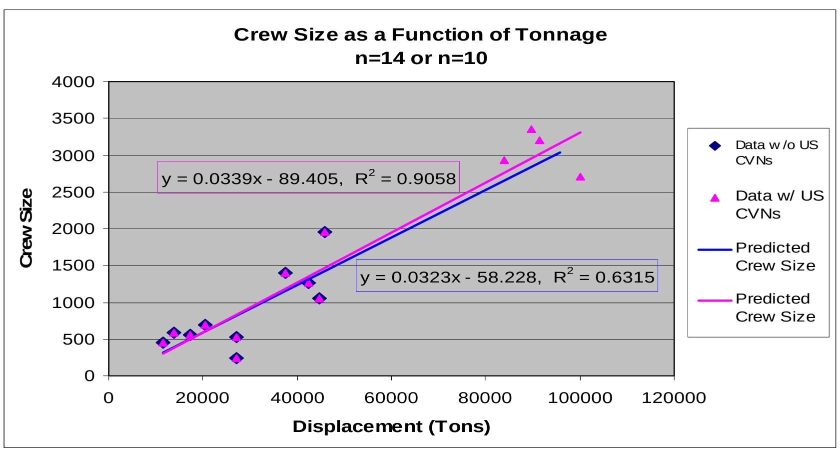

Figure 12. CV Crew Size as a Function of Tonnage

The first regression with all aircraft carriers in the sample produced equation: y = .0339 * x – 89.405, where y is the estimated crew size given a ship displacement x tons. The adjusted R^2 value is 0.8980. The second regression was performed without the outliers and produced an equation of: y = 0.0323 * x – 58.228, with an adjusted R^2 value of 0.5854. Additional regression statistics can be found for both in appendix D.

Predicted values were 930 and 948, respectively, using the estimate of 30600 tons. The average of 940[15] was used to estimate the manpower required for the NNFM light carrier. This is a conservatively high estimate. Based on the above data, the HMS Illustrious with a crew size of 685 would be good model to build from.

A similar approach was used to estimate CVL aircrew. Two linear regressions of aircrew versus displacement were performed; one with U.S. carriers and the other without. Two carriers without aircrew data were omitted from the regression. As shown in Figure 13, the lines diverge sharply. The first regression with all aircraft carriers in the sample produced equation: y = 0.0288x – 375.26, where y is the estimated aircrew size given a ship displacement x tons. The adjusted R^2 value is 0.9141. The second regression was performed without the American outliers and produced an equation of: y = 0.0132x – 23.895, with an adjusted R^2 value of 0.7108. Both are good models. Additional regression statistics can be found for both in appendix D. Predicted values were 506 and 380 respectively using the estimate of 30600 tons.

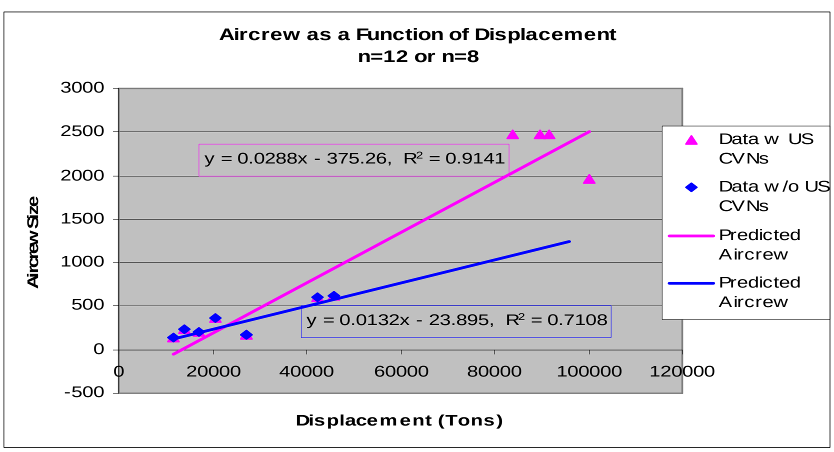

Figure 13. CV Aircrew Size as a Function of Tonnage

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[15] y = .0339 * 30600 – 89.405 = 930.2, y = 0.0323 * 30600–58.228 = 947.9. (930.2+947.9)/2 = 939.1.

An alternate analysis on aircrew versus number of aircraft was also conducted. Again, two linear regressions were performed with the results shown in Figure 14. Additional regression statistics can be found for both in Appendix D. The results were 461 for the regression with U.S. CVNs and 334[16] for the regression without U.S. CVNs.

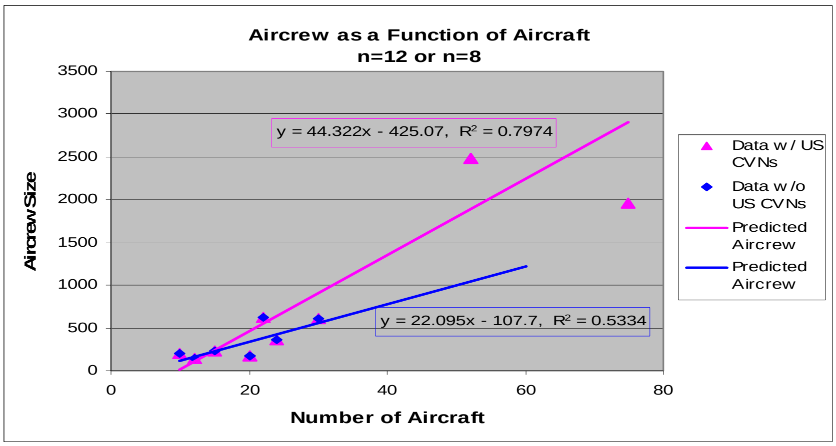

Figure 14. CV Aircrew Size as a Function of Aircraft (Alternate Analysis)

American warships tend to be larger and generally have larger crews. This is reflected in the U.S. CVNs' influence on the regression. By using an average of all four predictions, American naval propensities may be captured while avoiding an overestimation. An aircrew estimation of 420 will be used for the CVL.

2. Destroyers, Frigates, and Corvettes

Destroyers, frigates, and corvettes perform the day-to-day missions of surface warfare, anti-air warfare, anti-submarine warfare, and land strike. Although not multi-mission or as heavily armed as their 313 Ship counterparts, in the NNFM fleet they are more numerous and more distributable, and therefore able to work in mutually supporting complementary groups of ships. The NNFM proposes 149 of these ships; 39 destroyers, 90 frigates, and 20 land attack missile corvettes.

[16] Based on 20 planes.

a. DDG 51 Destroyer

The NNFM includes 30 blue water Aegis destroyers. It is likely that approximately 34 Arleigh Burke class destroyers will be in service in 2035, assuming no procurement past 2009 and an expected service life of 35 years. Because there will be three DDG 1000 destroyers in service as well, only 27 DDG 51 class destroyers will be used in this model. The remaining seven can be made available for possible conversion and experimentation of new ship types, such as the DDG-BMD ship below. Current manpower levels represent results of modernization and OM initiatives. DDG 85–90 SMD data of 276 will be used.

DDG 51s typically carry one SH-60B Seahawks. An aircrew of 10 will be included.

b. DDG 1000 Destroyer

As stated previously, the DDG 1000 program has been curtailed and only three ships are to be built. Although the 313 Ship plan calls for a total of 7 Zumwalt class destroyers to be built, the NNFM does not require any more than what has already been procured. The model will use a crew size estimate of 125 as discussed earlier. This number seems practical while still reflecting OM results hoped for in the year 2035.

DDG 1000 will carry 2 MH-60 or 1 MH-60 and 3 UAV's; an aircrew of 19 will be included.

c. FF (X) Blue Water Frigate

The NNFM also calls for 90 "Blue Water" frigates. Because the last FFG 7 class frigate was commissioned in 1989 and there are no current USN procurement plans, a new FF (X) frigate is envisioned for the NNFM. The frigate will be a cost effective surface combatant emphasizing sea control and protection of shipping, such as Anti-Submarine Warfare (ASW) and close in air defense. The frigate should have well integrated hard and soft kill point defense capabilities. "There are many international frigates and corvettes that serve as examples for developing and affordable design" (NNFM, 2009, p. 46)

Frigates have grown in size from about 1,500 tons displacement to over 4,000 tons (large corvettes to frigates). A sample of 22 frigates from various countries has been collected in Table 12. Although crew sizes are greater relative to displacement than for the much larger DDG 1000, a cautious approach will be taken regarding manning reduction. The new frigate crew size will be based on a simple regression model.

Type	Country	Ship	Displacement	Crew Size	Air Crew	# of helos
Frigate	France	Destienne dOrves	1330	90	0	0
Frigate	Iran	Alvand	1350	125	0	0
Frigate	Iran	Moudge	1400	130	0	0
Corvette	India	Kora	1460	134	0	1
Corvette	Malaysia	Kedah	1650	68	0	1
Frigate	Japan	Ishikari/Yuubari class	1690	95	0	0
Corvette	Germany	Braunschweig	1840	58	0	1
Corvette	Turkey	Milgem	2000	93	0	1
Frigate	Poland	Gawron II	2035	74	0	1
Frigate	Italy	Lupo	2525	177	N/A	1
Frigate	France	Floreal	2950	90	11	1
Frigate	Italy	Maestrale	3200	205	N/A	2
Frigate	Singapore	Formidable	3200	71	15	1
Frigate	Greece	Hydra	3350	199	13	1
Frigate	Turkey	Barbaros	3380	187	9	1
Frigate	France	La Fayette	3750	153	N/A	1
Frigate	China	Type 054	3900	190	N/A	1
Frigate	U.S.	Oliver Hazard Perry	4100	200	19	2
Frigate	UK	Duke	4200	181	N/A	1
Frigate	Canada	Halifax	4770	198	17	1
Frigate	UK	Type 22	4900	250	10	2
Frigate	Germany	Sachsen	5600	255	13	2

Table 12. Sample of 20 Frigates and Corvettes

A linear regression of the data seen in Figure 15 produces an equation of: y = .0371 * x + 37.635, where y is the estimate manpower requirement for a frigate of x tons. The adjusted R^2 value is 0.6062 and the F-score significance is 1.2E-05. Additional regression statistics can be found in Appendix D.

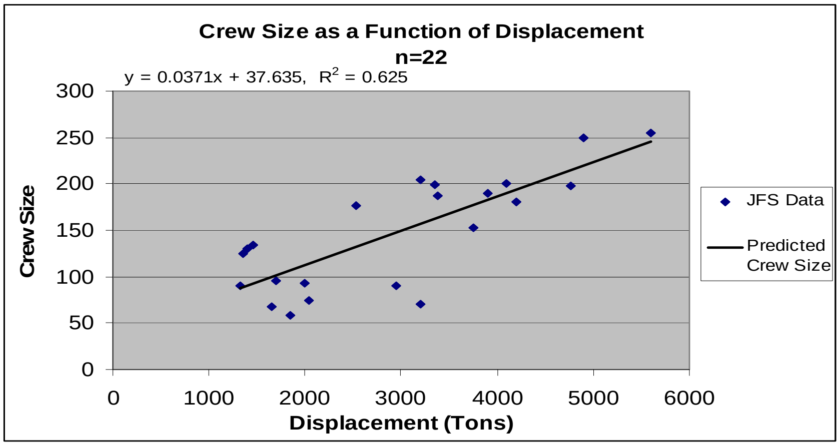

Figure 15. Frigate Crew Size as a Function of Tonnage

The NNFM calls for a frigate of approximately 2500–3000 tons, so the average of 2750 tons was used. So: y = .0371 * (2750) + 37.635 = 139.66. A frigate of 2750 would require a crew of approximately 140. Any of the ships between Turkey's Milgem and Singapore's Formidable would make strong candidates with the desired characteristics. An estimated crew size of 140 is credible yet conservative. These frigates will also carry the equivalent of two SH-60B Seahawks. An aircrew of 19 requirements will be included.

d. LA (X) Land Attack Corvettes

The NNFM diminishes the land-attack capability of the DDG force. To replace that capability, it proposes a small "Arsenal" ship, a land attack vessel reminiscent of the Arsenal Attack ship promoted by ADM Boorda, but armed with one-tenth of the missiles carried in his design. The concept is a simple corvette (around 1000 tons) carrying 50 land attack missiles; small, stealthy and inexpensive. A small Arsenal ship would be a new type of vessel. For an estimate of crew size a sample of 22 foreign corvettes, missile attack craft, and small frigates, listed in Table 13, are used.

Type	Country	Ship	Displacement	Crew Size	Air Crew	# of helos
Frigate	Turkey	Barbaros	3380	187	9	1
Frigate	Greece	Hydra	3350	199	13	1
Frigate	Italy	Maestrale	3200	205	N/A	2
Frigate	Singapore	Formidable	3200	71	15	1
Frigate	France	Floreal	2950	90	11	1
Frigate	Italy	Lupo	2525	177	N/A	1
Frigate	Poland	Gawron II	2035	74	N/A	1
Frigate	Japan	Ishikari/Yuubari class	1690	95	0	0
Frigate	Iran	Moudge	1400	130	0	0
Frigate	Iran	Alvand	1350	125	0	0
Frigate	France	Destienne dOrves	1330	90	0	0
Corvette	Turkey	Milgem	2000	93	N/A	1
Corvette	Germany	Braunschweig	1840	58	N/A	1
Corvette	Malaysia	Kedah	1650	68	N/A	1
Corvette	India	Kora	1460	134	N/A	1
Corvette	Israel	Sa’ar V	1295	64	0	0
Corvette	Sweden	Visby	620	43	0	0
Fast Attack Craft	Greece	Super Vita	660	45	0	0
Fast Attack Craft	Singapore	Fearless	500	32	0	0
Fast Attack Craft	Norway	Skjold	273	20	0	0
Fast Attack Craft	Finland	Hamina	270	29	0	0
Fast Attack Craft	China	Houbei	220	12	0	0

Table 13. Sample of 22 Ships for small Arsenal Land Attack Ships

The regression, shown in Figure 16, produced an equation of y = 0.0433 * x + 19.633, where y is the estimate of crew size for a “Light Arsenal” corvette of x tons. The adjusted R^2 value is 0.5804 and the F-score significance is 2.297E-05. Additional regression statistics can be found in Appendix D. The Center for Strategic and Budgetary Assessment (CSBA) provided a notional land attack ship based on the Israeli Sa’ar V in a July 2009 “Green Water Navy 2029” war game. Therefore, a displacement of 1300 tons was used to model the land attack ship, resulting in an estimated crew size of 76 (y = 0.0433 * (1300) + 19.633 = 75.923). The estimate of 76 may be a high. Versions of the larger 20000 ton, 500 missile Arsenal ship were envisioned to have a very small crew of 55. No aircraft are to be embarked, and thus no aircrew is included.

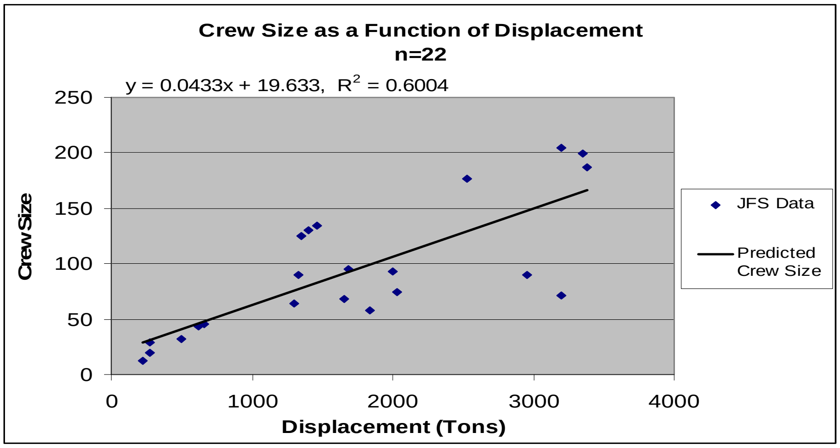

Figure 16. Land Attack Crew Size as a Function of Tonnage

e. DDG-BMD (X) Ballistic Missile Defense

The NNFM includes a Ballistic Missile Defense (BMD) component consisting of a force of 9 DDGs. The seven surplus DDG 51 class destroyers designated above can be modified for strong, dedicated BMD. A ship's crew of 276 and an aircrew of 10 will be used for these ships. The remaining two DDG-BMD ships will be modified versions of the DDG (X), with 145 ship's crew and 19 aircrew.

3. Littoral Vessels (Green Water Component)

The green water component is made up of relatively small, single-purpose, distributable vessels. It can be used for forward presence for peacekeeping and stability with a host nation or to punch through coastal clutter, securing the area for high value national assets. Key to the green water component is the capability to "clear mines, take out small combatant threats, and deal with coastal submarines." (NNFM, 2009, p. 11)

a. GFS (X) Global Fleet Station Ships

Global Fleet Station ships function like a command ship with facilities for staff, work/berthing spaces for various numbers of NGO humanitarian assistance personnel, and berthing for inshore and offshore patrol craft when necessary. It offers limited logistics support as well. "The Navy has been working on projects like the Global Fleet Station, a forward operating base at sea capable of surging military forces and humanitarian aid to shore." (Mcleary, 2009) The NNFM proposes a ship approximately two-thirds the size of an LPD-17 or JCC(X) with a command ship configuration. LPD 17 will be used as a basis for estimation.

The reconfiguration of the amphibious transport dock USS Coronado (LPD 11) to a command ship (AGF 11) will be used as an analogy for crew size estimation. LPD 11 initially had a manpower requirement of 420. After reconfiguration, it had a crew size of 243 (117 USN, 126 civilian). This is a 42% reduction in size, split approximately 50% USN and 50% civilian. The command ship LCC 20 has a similar mix of manpower (156 USN, 146 civilian). Following this example, LPD 17 with a crew size of 360, would have a manpower requirement of 208[17] after reconfiguration. The 50/50 split would result in a crew of 104 USN and 104 civilian. A conservatively high estimate of 115 USN and 115 civilians will be used.

Three or four helicopters will be embarked, so an aircrew detachment of 38 will be included. This study does not include the varying command staff onboard.

b. NGFS (X) Naval Gunfire Support

The NNFM enhances its littoral warfare operations ashore by utilizing low cost, high volume naval gunfire support (NGFS). The NGFS ship will be a single-purpose ship carrying two Advanced Gun Systems (AGS) with 2000 rounds. New high-capacity projectiles are being developed with increased payloads and extended ranges. "Hull size will be determined by minimum space and sturdiness required for the two guns and their ammunition." (NNFM, 2009, p 22)

The modern U.S. Navy has not had a ship with the sole role of NGFS since the battleship. DDG 1000 is planned to play a NGFS role, but this multi-purpose ship is larger than necessary and too expensive for NNFM requirements. Advanced guns

[17] 360–360 * 42.1% = 208.29.

are part of the modernization programs for DDG 51 class and CG 47 class ships to provide improved gunfire support. CSBA proposed a gunship based on the frigate RSN Formidable (3200 tons) in a July 2009 “Green Water Navy 2029” war game. A sample of 22 cruisers, destroyers, and frigates, shown in Table 14, are used to develop a manpower estimate for NGFS (X).

Type	Country	Ship	Displacement	Crew Size	Aircrew	# of helos
Cruiser	Ukraine	Slava	11490	476	N/A	1
Cruiser	U.S.	Ticonderoga	9957	358	N/A	2
Cruiser	Russia	Kara	9900	390	N/A	1
Destroyer	Japan	Kongou	9485	300	N/A	1
Destroyer	U.S.	DDG 51	8946	274	N/A	1
Destroyer	UK	Daring	7450	191	N/A	1
Destroyer	France	Forbin	7050	195	N/A	1
Destroyer	Italy	Andrea Doria	6635	200	N/A	1
Frigate	Germany	Baden-Württemberg	6800	110	N/A	2
Frigate	Spain	Alvaro De Bazán	5853	200	N/A	1
Frigate	Germany	Sachsen	5600	255	13	2
Frigate	UK	BroadSword	4900	250	10	2
Frigate	Canada	Halifax	4770	198	17	1
Frigate	UK	Duke	4200	181	N/A	1
Frigate	U.S.	Oliver Hazard Perry	4100	200	19	2
Frigate	China	Type 054	3900	190	N/A	1
Frigate	France	La Fayette	3750	153	N/A	1
Frigate	Turkey	Barbaros	3380	187	9	1
Frigate	Greece	Hydra	3350	199	13	1
Frigate	Italy	Maestrale	3200	205	N/A	2
Frigate	Singapore	Formidable	3200	71	15	1
Frigate	France	Floreal	2950	90	11	1
Frigate	Italy	Lupo	2525	177	N/A	1
Frigate	Poland	Gawron II	2035	74	0	1

Table 14. Sample of 24 Ships for NGFS Ships

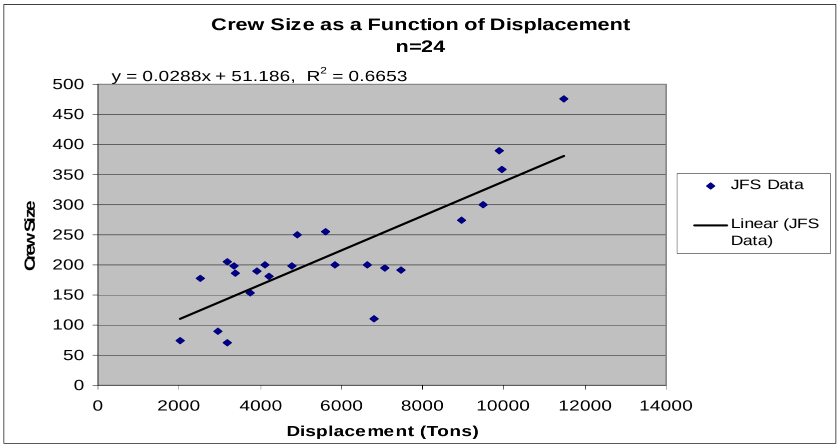

Figure 17. NGFS Crew Size as a Function of Tonnage

The regression, shown in Figure 17, produced an equation of y = 0.0288 * x + 51.186, where y is the estimate of crew size for a NFGS ship of x tons. The adjusted R2 value is 0.6500 and the F-score significance is 1.195E-06. Additional regression statistics can be found in Appendix D. A crew size of 152[18] is estimated for a midrange frigate sized NFGS ship of 3500 tons. NFGS (X) will likely carry a helicopter or UAV for reconnaissance, so an aircrew of 10 is included.

c. FMW (X) Fast Mine Warfare

The NNFM calls for 12 Fast Mine Warfare ships. High speed is crucial for strategic mobility, allowing these ships to arrive in theater in advance of the operation. Fast and carrying UUV for sweeping operations, new technology may be needed in this case. The LCS MIW module can serve as a prototype.

A regression crew size versus displacement was performed on 28 MCM vessels. The sample is provided in Table 15. The result was statistically poor with an F-score significance of 0.0106 and an adjusted R^2 of 0.1959. A regression of crew size versus speed likewise produced statistically poor results, with an F-score significance of 0.3881 and adjusted R^2 value of -0.0085. The regression models are statistically no better than the average of the ships. Additional regression statistics can be found in Appendix D.

[18] y = 0.0288 * 3500 + 51.186 = 151.86.

Because speed is important for this class, the sample was reduced to only the ships with speeds of 17 knots or greater. A regression of this sample still proves unhelpful, with an F-score significance of 0.3791 and an adjusted R^2 value of -0.0118. It is likely that the sample size of seven is just too small. Instead, the average displacement, crew size, and speed are calculated. The resultant composite ship is 500 tons, has a crew size of 36, and speed of 20 knots. This is comparable to the fast mine warfare ship of 375 tons, 40 crew members, and a speed of 20 knots proposed in CSBA's July 2009 "Green Water Navy 2029" war game. An estimate of 36 will be used for an FMW (X) that can travel at 20 knots.

Country	Ship	Displacement	Crew Size	Speed
Denmark	Flyvefisken	480	29	30
Norway	Oskoy/Alta	375	40	23
France	Eridan	615	49	18
Germany	Ensdorf	635	34	18
Germany	Kulmbach	635	37	18
Indonesia	Kondor II	310	31	17
Thailand	Bang Rachan	444	33	17
South Africa	River	380	40	16
Russia	Natya I	804	67	16
Canada	Kingston	962	37	15
Sweden	Koster	360	29	15
Greece	Evropi	750	46	15
Turkey	Circe	460	48	15
Sweden	Landsort	360	29	15
Korea	Swallow	520	44	15
Belgium	KMV	644	27	15
Montenegro	Sirius	424	40	15
Cuba	Sonya	450	43	15
Belgium	Flower	650	46	15
UK	Hunt	740	45	15
Pakistan	Munsif	595	46	15
Poland	Mamry	216	27	14
Japan	Sugashima	590	45	14
Australia	Houn	720	40	14
Italy	Lerici	620	44	14
Spain	Segura	530	41	14
Finland	MCMV 2010	697	36	13
Estonia	Sandown	484	34	13
	Avg:	551.79	39.54	16.04

Table 15. Sample of 36 Ships for Fast Mine Warfare

d. ASW (X) Anti-Submarine Warfare ship

The Inshore Anti-Submarine Warfare ship is a special, single purpose ship, designed to operate in the littorals. Twenty-six ships chosen ranging patrol craft, corvettes, frigates, and DDG were selected and are provided in Table 16. Selected ships were required to have ASW capabilities listed in JFS.

Type	country	Ship	Displacement	Crew Size	ln(Disp)	ln(Crew)
Corvette	Sweden	Goteborg	399	36	5.989	3.584
Patrol Forces	Ukraine	Pauk I	440	32	6.087	3.466
Patrol Forces	Indonesia	Singa	447	42	6.103	3.738
Patrol Forces	Denmark	Flyvefisken	480	29	6.174	3.367
Patrol Forces	Singapore	Fearless	500	32	6.215	3.466
Corvette	Singapore	Victory	595	49	6.389	3.892
Corvette	Thailand	Khanronsin	630	57	6.446	4.043
Patrol Forces	Spain	Serviola	1147	42	7.045	3.738
Corvette	Isreal	Sa’ar V	1295	64	7.166	4.159
Frigate	France	D’Estienne d’Orves	1330	90	7.193	4.500
Corvette	Portugal	Baptista de Andrade	1380	71	7.230	4.263
Corvette	India	Khukri	1423	112	7.261	4.718
Corvette	Thailand	Pattani	1440	78	7.272	4.357
Frigate	Poland	Gawron	2035	74	7.618	4.304
Frigate	Turkey	Tepe (Knox)	3011	288	8.010	5.663
LCS	U.S.	Freedom	3089	55	8.036	4.007
Frigate	Portugal	Vasco Da Gama	3300	182	8.102	5.204
Frigate	Taiwan	Kang Ding	3800	134	8.243	4.898
Frigate	Taiwan	Cheng Kung	4105	215	8.320	5.371
Frigate	UK	Duke	4200	181	8.343	5.198
Frigate	Canada	Halifax	4770	198	8.470	5.288
Frigate	UK	Broadsword	4900	250	8.497	5.521
Destroyer	France	Georges Leygues	4910	233	8.499	5.451
Frigate	Norway	Fridtjof Nansen	5290	120	8.574	4.787
Frigate	Italy	Bergamini	5950	145	8.691	4.977
Destroyer	Japan	Takani	6300	176	8.748	5.170
Destroyer	U.S.	Arleigh Burke	8946	274	9.099	5.613

Table 16. Sample of 26 Ships for Inshore ASW Ship

A regression on crew size versus displacement was performed. The best fit line was a power series equation of y = 0.5783 * x^0.6747, where y is an estimate of crew size for an ASW ship of x tons. Figure 18 shows the trend line.

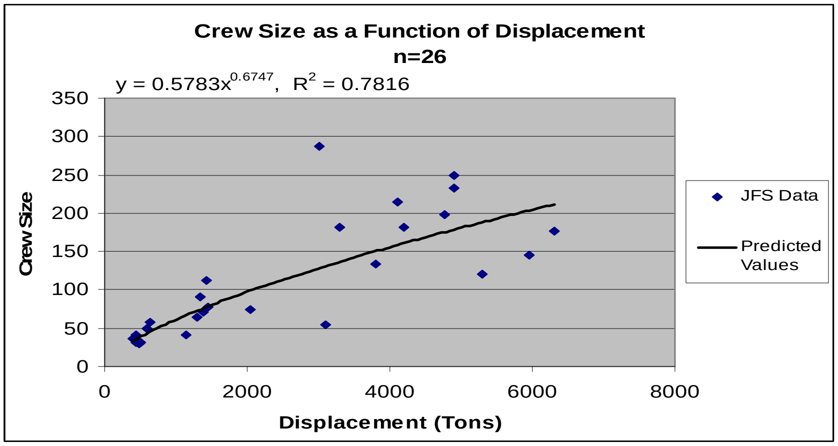

Figure 18. ASW Ship Crew Size as a Function of Tonnage

A logarithmic transformation of the data was done to perform a linear regression of the model and obtain statistical analysis. The resulting trend line shown in Figure 19 is y = 0.6747 * x – 0.5477, where y is the natural log of the crew size estimate and x is the natural log of displacement. The F-score significance is 3.2852E-10 and the adjusted R2 is 0.7915. Additional regression statistics can be found in Appendix D.

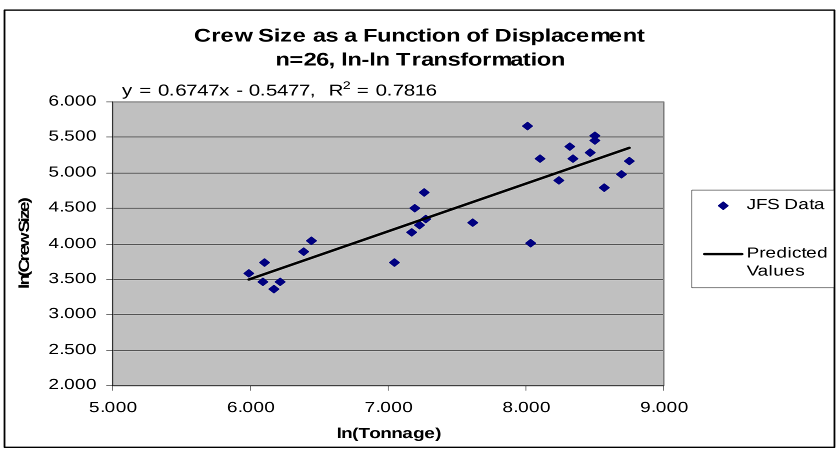

Figure 19. ASW Ship Crew Size as a Function of Tonnage, ln-ln Transformation

Because the ASW ship will be working in the littoral environment, a corvette sized model will likely suffice. The Israeli Sa’ar with 1300 tons and 64 crew members was used as a model in the CSBA July 2009 “Green Water Navy 2029” war game. A crew size estimate of 73[19] was developed using 1300 tons. A ship of this size may have a small helicopter embarked, so an aircrew of 10 will also be included.

e. IPC Inshore Patrol Craft

The NNFM proposes 400 inshore patrol vessels to provide theater security. The concept is to provide a flotilla of two squadrons as aide to selected friendly but poor nations to develop a coastal patrol fleet. The squadrons would conduct anti-piracy and counter-smuggling operations in coordination with host nation sailors. It is assumed that approximately 2/3 of the ships will be manned and maintained by the foreign navy, with the U.S. in a supporting and training role. Developing the inshore capability of the host nation is the primary goal.

A squadron organization was developed after discussions with Captain B. S. Yates, USNR, Emerging Threats and Small Boats, Office of Naval Intelligence. A Detachment is made up with one lead boat, manned by USN sailors, and two “under-instruction” boats, manned by foreign sailors. Four Detachments make up a Division, four Divisions make up a Squadron, two Squadrons make a Flotilla, and four Flotillas make up the Inshore Patrol Fleet. One Squadron of 12 boats fully manned with USN sailors, is set aside for training and surge capability when needed. The four remaining boats are held as reserve assets.

The boats must be simple to operate and inexpensive, as they are likely to be given away as aide to the host country at end of their 5-year life-cycle. Small inshore and riverine patrol craft were considered. Crew sizes vary from two to as many as 12. Some suggested boats are the Special Operations Craft-Riverine, the Patrol Boat-River, the USCG Defender, and the Sea Ark Patrol Craft. The Sea Ark was used with a crew size of 6 was used as a model to give most flexibility in estimation. Personnel numbers are provided in Table 17. See Appendix E for further details.

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[19] $y = 0.5783 * (1300)^{0.6747} = 72.97$.

Level	Consists of:	Boats	USN Sailors	USN Maintenance	USN Command/Support
Lead Boat	N/A	1	6	2	N/A
Detachment	3 boats[20]	3	6	3	N/A
Division	4 Detachments	12	24	12	17
Squadron	4 Divisions	48	96	48	68
Flotilla	2 Squadrons	96	192	96	136
Fleet	4 Flotillas	384	768	384	544
Training/Surge	1 Division	12	72	36	17
Reserve	4 boats	4	N/A	N/A	N/A

Table 17. Inshore Patrol Organization

The forward deployed or afloat manpower estimate for the 400 Inshore Patrol Fleet is 1821; 424 in each Flotilla for 1696 in the Fleet and 125 in the training/surge Division. Approximately 4125 sailors and officers would be required, if the Inshore Patrol Fleet were manned entirely with USN personnel.

f. OPV (X) Offshore Patrol Vessel

The NNFM calls for 160 offshore patrol vessels. With a planned cost limit of $60M, they are not likely to be very large or have a great number of capabilities. They are to be used for theater security, not combat operations. There are a large range of vessels that can be described as offshore coastal ships. A sample of 20 ships ranging between 90 to 2000 tons was selected and shown in Table 18.

Country	Name	Displacement	Crew Size	Ln(Disp)	Ln(Crew)
U.S.	Marine Protector	91	10	4.51	2.30
Poland	Pilica	93	14	4.53	2.64
U.S.	Island	168	16	5.12	2.77
Barbados	Damen Stan	205	14	5.32	2.64
France	Thomson	227	7	5.42	1.95
India	Bangaram	260	34	5.56	3.53
Australia	Armidale	270	21	5.60	3.04
U.S.	Sentinel FSC	353	22	5.87	3.09

[20] 1 lead boat, 2 Under Instruction manned by host nation sailors.

U.S.	Cyclone	354	39	5.87	3.66
Turkey	Dearson	400	34	5.99	3.53
Lithuania	Flyvefisken	480	29	6.17	3.37
Portugal	LFC 2005	660	20	6.49	3.00
Taiwan	Kinmen	688	38	6.53	3.64
Australia	OPV	1100	44	7.00	3.78
India	Vikram	1224	96	7.11	4.56
UK	Castle	1427	45	7.26	3.81
Italy	Comandante	1520	60	7.33	4.09
Taiwan	Ho Hsing	1823	80	7.51	4.38
India	Vishwast	1840	118	7.52	4.77
Spain	Alboran	1963	37	7.58	3.61

Table 18. Sample of 20 Ships for Offshore Patrol Vessels

A regression on crew size versus displacement was completed. The best fit line was a power series equation of y = 0.6205* x^0.6251, where y is an estimate of crew size for an offshore patrol craft of x tons. Figure 20 shows the trend line.

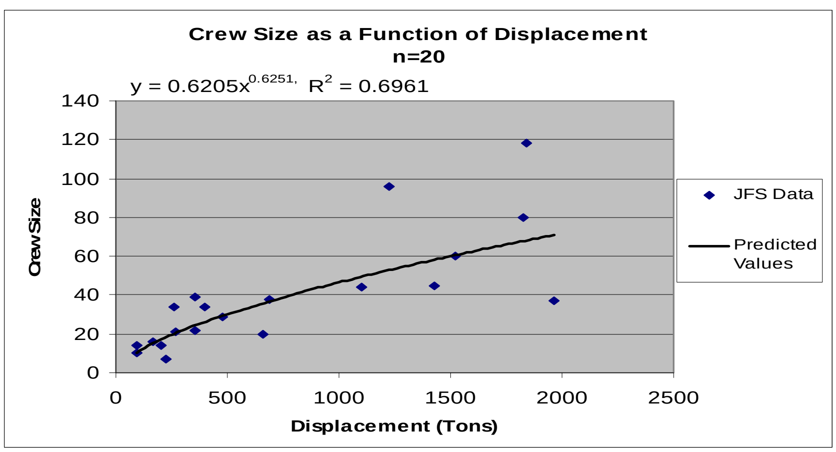

Figure 20. Offshore Patrol Craft Crew Size as a Function of Tonnage

A logarithmic transformation of the data was done to perform a linear regression of the model and obtain statistical analysis. The resulting trend line shown in Figure 21 is y = 0.6251 * x–0.4772, where y is the natural log of the crew size estimate and x is the natural log of displacement. The F-score significance is 4.81E-06 and the adjusted R2 is 0.6792. Additional regression statistics can be found in Appendix D.

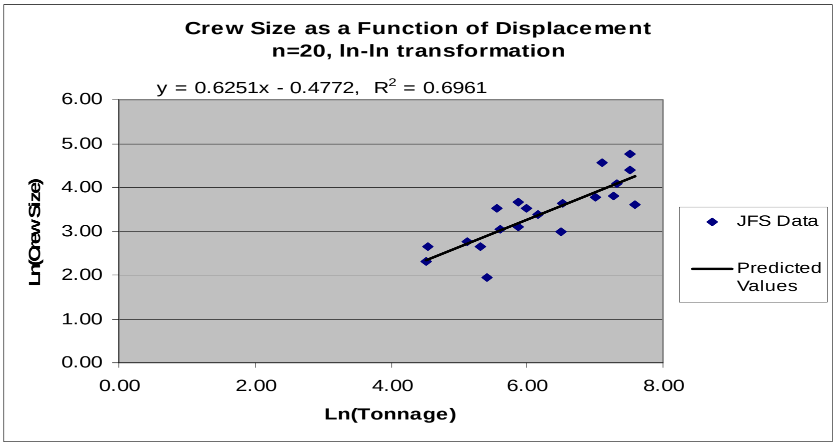

Figure 21. OPC Crew Size as a Function of Tonnage, ln-ln Transformation

The American Sentinel and Cyclone class vessels are promising, as well as the Turkish Dearson. With that insight, the median of 440 tons was used in developing the crew size, an estimation of 28[21]. A ship of this size will not have a helicopter detachment.

g. CC (X) Coastal Combatant

"The coastal combatant is not a patrol vessel for theater security operations." (NNFM, 2009, p. 20) Coastal Combatants (CC) are small, fast, and lethal fighters. They are heavily armed ships designed to clear a littoral area of enemy craft and coastal clutter. These ships will see action and losses should be expected. These ships must be "small enough to accept affordable losses." (NNFM, 2009, p. 21) Likewise, crews must also be small. As before, many examples can be found in foreign fleets. China's Houbei and Norway's Skjold both appear to be excellent candidates. The estimate will be based on the average displacement (384 tons) of the ships to avoid underestimating the crew size. Only small, fast, heavily armed vessels were included in the sample provided in Table 19.

[21] y = 0.6205* (440)^0.6251 = 27.87

Country	Name	Displacement	Crew Size
China	Houbei	220	12
Finland	Hamina	270	29
Sweden	Visby	620	43
Greece	Super Vita	660	45
Singapore	Fearless	500	32
Norway	Skjold	273	20
Russia	Svetlyak	375	36
Pakistan	Kaan 33	120	18
Denmark	Flyvefisken	480	24
Egypt	Ambassador III	550	36
Denmark	Willemoes	260	25
Israel	Aliya	498	53
Sweden	Kaparen	170	22

Table 19. Sample of 13 Ships for Coastal Combatants

The regression produces an equation of y = .0531 * x + 9.9606, where y is the estimate crew size for a CC of x tons. The F-score significance is 0.0012 and the adjusted R2 value is 0.5982. Additional regression statistics can be found in Appendix D.

Using a displacement of 385 tons, crew size for a CC is estimated at 30[22]. This is comparable to Finland's Hamina, the basis of the proposed CC in CSBA's July 2009 war game, "Green Water Navy 2029."

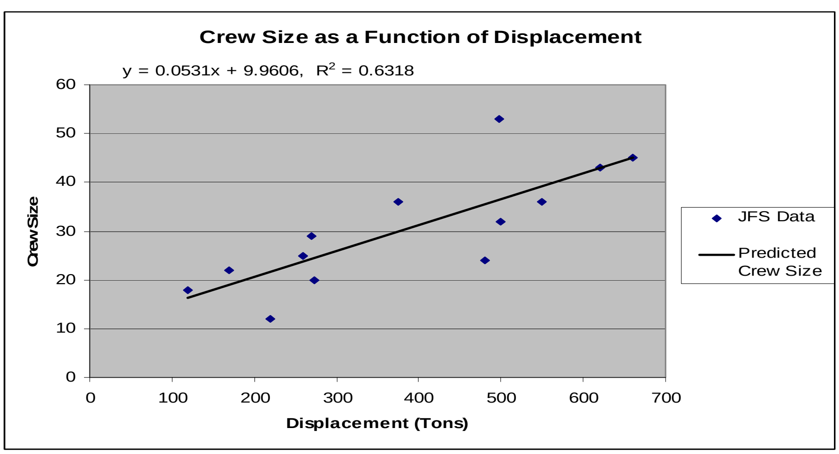

Figure 22. CC Crew Size as a Function of Tonnage

[22] y = .0531 * 384 + 9.9606 = 30.35.

h. CC Tender

The NNFM Coastal Combatants are designed for "short range, short duration sorties." (NNFM, 2009, p. 21) Two tenders are listed in the NNFM to provide logistical support for up to ten CCs when they cannot be supported ashore. LT B. Christiansen proposed a simplified variant of the San Antonio class LPD in his thesis: Littoral Combat Vessels: Analysis and Comparison of Designs[23].

> The advantages of using this concept is that it utilizes an existing hull with air support capability (for the inclusion of Unmanned Aerial Vehicles, or UAVs, to improve scouting and helicopters for personnel recovery) and is already designed to support a large number of personnel in addition to the organic crew as well as interface with smaller seaborne vessels. (Christiansen, 2008, p. 17)

The previous developed LPD 17 ship's crew of 360 and aircrew of 35 will be used to estimate manpower requirements for the CC tender.

4. Submarines

The NNFM speculates that a fleet of 80 attack submarines might be needed at the outset of hostilities with a peer maritime nation. It argues that an all-SSN fleet of such numbers would be difficult to afford. The NNFM further argues that Air-Independent Propulsion (AIP) submarines have their advantages and at a much more affordable price. The submarine force of the NNFM is 40 SSNs, 40 AIP diesel SSKs, and 9 SSBNs. The 30 planned Virginia class submarines will provide the bulk of the nuclear fast attack subs, while the 3 Seawolf and 7 Los Angeles class submarines will round out the fleet at 40 SSNs. The 40 AIP diesel submarines would be developed from foreign examples.

Little information on SSN (X) and SSBN (X) programs is available. They will not be included in this work. It is assumed that the total number of submarines would remain constant and any "X" submarine will likely have manpower requirements similar to its predecessor.

[23] NPS Master's Thesis: "Littoral Combat Vessels: Analysis and Comparison of Designs" by Brian J. Christiansen, LT, USN, Sept 2008.

a. SSN 688 Fast Attack Submarine (Los Angeles)

The JFS number of 134 will be used as the estimate for SSN 688. This provides consistency when comparing crew sizes to foreign submarines. SMD data differs from JFS.

b. SSN 21 Fast Attack Submarine (Seawolf)

JFS numbers of 140 will be used to provide consistency with foreign submarines. SMD data differs from JFS.

c. SSN 774 Fast Attack Submarine (Virginia)

Ship's crew of 134 was taken directly from JFS. SSN 774 SMD data was not available at the time of this study.

d. SSK (X) AIP Diesel Submarine

AIP submarines are attractive because they offer "an underwater endurance far in excess of the average diesel-electric submarine" (De Lionis, 1998) at a much more affordable cost than nuclear power. AIP propulsion can allow submarines "to cruise submerged at low speed for over two weeks." (Scott, 1999) While obviously not equivalent to a nuclear-powered sub, the extended endurance and larger potential quantities can provide tactical options to the fleet.

Similar to other proposed ships in the NNFM, AIP Submarines are not part the modern U.S. naval fleet, but there are many foreign examples to use as models. Sixteen submarines within the displacement/capability range were selected, as shown in Table 20.

Country	Submarine	Displacement	Crew Size
Greece	Type 209	1285	38
Sweden	Gotland A17	1599	27
Sweden	Sodermanland	1600	27
Malaysia	Scorpene	1758	31
Spain	Agosta 90B	1760	36

Germany	Type 212A	1830	28
Turkey	Type 214	1860	27
China	Song	2250	60
Russia	Lada Project 677	2650	37
France	Rubis SSN	2670	68
Japan	Harushio SS583	3200	75
Japan	Oyashio SS90	3500	70
Japan	Soryu	4200	65
U.S.	LA SSN688	7011	134
UK	Astute SSN	7400	140
U.S.	Virginia SSN	7800	134

Table 20. Sample of 16 Submarines for AIP Submarines

The regression shown in Figure 23 produced an equation of y = 0.0177 * x + 4.2705, where y is the estimate of crew size for an AIP submarine of x tons. The adjusted R^2 value is 0.9285 and the F-score significance is 1.2710E-09. Additional regression statistics can be found in Appendix D. The average tonnage of the 12 non-nuclear submarines in the sample was used to develop the crew size estimate. A crew size of 45[24] will be used for an AIP submarine of 2300 tons.

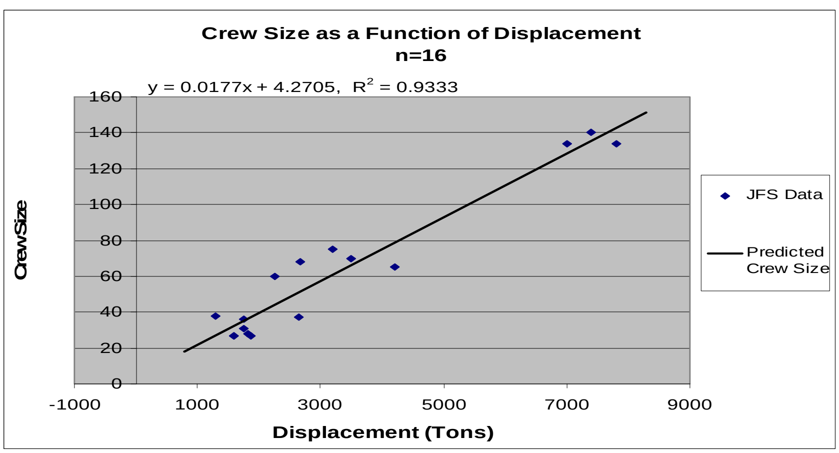

Figure 23. AIP submarine Crew Size as a Function of Tonnage

There was concern that, like the aircraft carriers analysis, the larger U.S. SSNs may be influencing outliers. A regression was performed without the three SSNs

[24] y = 0.0177 * 2300 + 4.2705 = 44.98.

for a comparison. The resulting line, y = 0.0176 * x + 4.497 with an adjusted R^2 value of 0.6210, provides nearly identical estimates, validating the previous regression.

e. SSBN 730 Strategic Missile Submarines

Ship's crew of 155 was taken directly from JFS. SSN 730 SMD has a ship's crew of 159.

f. AS 39 Submarine Tender

Ship's crew of 1268 was taken directly from JFS.

5. Delivery and Sustainment Ships

The delivery of small vessels to distant theaters and their sustainment is a concern in the NNFM. It fills this requirement with 125 "Deliver and Sustain" sealift ships of the MSC. NNFM distinguishes "between sealift ships for delivery and sustainment from ships for amphibious lift and preposition." (NNFM, 2009, p 41) The NNFM strategy excludes amphibious assault so "Delivery and sustainment ships are not expected to be attacked." (NNFM, 2009, p 41)

The Deliver and Sustain component will be composed of Fast Sealift Ships (FSS), Large, Medium-Speed, Roll-on/Roll-off ship (LMSR), High Speed Vessels, and a variety of other Ready Reserve Force (RRF) ships of the MSC. Large supply/support ships like these do not generally have the displacement/crew relationship that warships exhibit.

FSS can be ready to load cargo and get underway within 96 hours. It has "large open bay interiors and roll-on/roll-off ramps—make them particularly well suited for the transport of tanks, helicopters and other military vehicles and supplies." ("Fast Sealift Ships—Fact Sheet," 2003) These ships have a crew size of 42 MSC civilians and may have an additional 12 USAR cargo handlers. "LMSRs can carry an entire U.S. Army Task Force, including 58 tanks, 48 other tracked vehicles, plus more than 900 trucks and other wheeled vehicles." ("Large, Medium-speed, Roll-on/Roll-off Ships T-AKR," 2009) The ships can support humanitarian missions as well. LMSRs normally have a crew size of 26 to 45 civilians and up to 50 USN sailors. Twenty-five of these ships (10

FSS and 15 LMSR) will be kept activated or dedicated to prepositioning, and manned at military levels. Military manning for these ships will be estimated at four times the normal civilian crew plus NSE and SBE[25] crew for cargo handling and vertical lift (as previously identified for similar MPF(F) ships).

"The RRF includes fast sealift ships, roll-on/roll-off ships, lighter aboard ships, modular cargo delivery system ships, heavy lift ships, crane ships and government-owned tankers." ("Ready Reserve Force Ships," 2008) Most of the RRF ships are normally kept in a Reduced Operating Status (ROS)[26] but can be fully activated to Full Operating Status (FOS) within 96 hours. To develop conservative MSC crew sizes, 50% of the ships will be estimated with an average FOS and the other 50% estimated at ROS.

Crew sizes will be estimated, as shown in Table 21.

Ship	Example	Civilian	USN Aircrew[27]	USN Ship Crew
FSS	T-AKR 287	0	10	233[28]
LMSR	T-AKR 300	0	205	290[29]
RRF (FOS) [30]	Various	32	0	2
RRF (ROS)	Various	9	0	0
JHSV	Jervis Bay	20	0	0

Table 21. Deliver and Sustain MSC ships

6. Naval Fleet Auxiliary Force

The numbers and costs of these ships in the NNFM are unchanged from the 313 ship plan. Refer to the equivalent section in the 313 Ship Navy section above for detailed discussion.

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[25] Reminder: The Navy Support Element (NSE) is a detachment of active duty USN cargo handlers who conduct the off-load and ship-to-shore movement of equipment and supplies.

The Sea Base Echelon (SBE) typically consists of the assault echelon's support crews providing support by vertical replenishment. SBE numbers are assumed to be part of the aircrew.

[26] Ships in ROS have a small crew onboard to assure the readiness of propulsion and other primary systems if the need arises to activate the ship. (www.msc.navy.mil/inventory/glossary.htm).

[27] Equivalent to SBE

[28] 4 * 43 (civ crew) + 61 (NSE).

[29] 4 * 45 (civ crew) + 110 (NSE).

[30] Average of the 50 RRF MSC ships at FOS and ROS, see RRF ship data.

a. T-AO, T-AOE, T-AKE, ARS, T-AGOS, and T-ATF

T-AO(X), T-AOE(X), ARS(X), and T-ATF(X) are the next generation NFAF ships. Focus of improvement will likely be on cargo handling and capacity. Large MSC supply/support ships do not generally have the displacement/crew relationship that warships exhibit. Current numbers of equivalent current ships, provided in Table 22 should suffice.

Class	Type	Civilian Crew	Military Crew	Aircraft	Aircrew
T-AO (X)	Oiler	89	5	N/A	0
T-AOE (X)	Fast Combat Support	160	28	2 MH-60	19
T-AKE 1	Cargo and Ammo	113	11	2 MH-60	19
T-ARS (X)	Salvage ship	26	4	N/A	0
TAGOS 23	Ocean Surveillance	26	16	N/A	0
T-ATF (X)	Fleet Ocean Tug	16	4	N/A	0

Table 22. Future Naval Fleet Auxiliary Force

b. JHSV High Speed Connector

Manning of these high-speed intra-theater surface connectors should be similar to the WestPac Express or the Jervis Bay. For this study, the JHSV crew will be estimated with Jervis Bay’s complement of 20 (Jane’s Fighting Ships, 2009).

c. JCC(X) Command Ship

Naval command ships provide communications, coordinate activities, and serve as the flagships of Fleet Commanders. Two new LPD 17 ships, configured as command ships, may be commissioned to replace LCC 19 and 20. Crew size has been sharply reduced by manpower efficiencies. It is unlikely that manpower will be reduced much more for JCC(X). Current crew sizes of 146 civilian and 157 sailor requirements for LCC20 will be used to estimate JCC(X). An aircrew of 10 for 1 SH-3H Sea King will also be included. This study does not include the varying command staff embarked.

New Navy Fighting Machine	Number of Ships	Civilian Crew	Air Crew	Ship Crew	Total Civilian Crew	Total Air Crew	Total Ship Crew	Total Manpower
CVN 78 Aircraft Carrier	6	0	1960	2700	0	11760	16200	27960
CVL (X)	18	0	420	940	0	7560	16920	24480
DDG 51 Destroyer	27	0	10	276	0	270	7452	7722
DDG 1000	3	0	19	125	0	57	375	432
FF (X) Frigate	90	0	19	140	0	1710	12600	14310
LA (X) Land attack (missiles)	20	0	0	76	0	0	1520	1520
DDG 51 BMD	7	0	10	276	0	70	1932	2002
DDG (X)	2	0	19	145	0	38	290	328
Global Fleet Station Ships	12	104	38	104	1248	456	1248	2952
NGFS (X) Gunfire support	12	0	10	152	0	120	1824	1944
FMW (X) Fast MIW	12	0	0	36	0	0	432	432
ASW (X) Anti-submarine ship	12	0	10	73	0	120	876	996
Inshore patrol (# per div of 12 boats)	400	0	0	53	0	0	1821	1821
OPV (X) Offshore patrol	160	0	0	28	0	0	4480	4480
CC (X) Coastal Combatant	30	0	0	30	0	0	900	900
CC Tender	2	0	35	360	0	70	720	790
SSN 688 Fast attack submarine (LA)	7	0	0	134	0	0	938	938
SSN 21 Fast attack submarine (Seawolf)	3	0	0	140	0	0	420	420
SSN 774 Fast attack submarine (Virginia)	30	0	0	134	0	0	4020	4020
SSK (X) AIP Submarine	40	0	0	45	0	0	1800	1800
SSBN 730 Strategic missile submarines	9	0	0	155	0	0	1395	1395
AS 39 Sub tenders	2	0	0	1268	0	0	2536	2536
T-AKR 287 Deliver/Sustain Fast Sealift	10	0	100	233	0	0	2430	2430
T-AKR 300 Deliver/Sustain LMSR	15	0	205	290	0	0	7425	7425
RRF Deliver/Sustain (FOS)	45	32	0	2	1440	0	90	1530
RRF Deliver/Sustain (ROS)	45	9	0	0	405	0	0	405
JHSV Deliver/Sustain	10	20	0	0	200	0	0	200
T-AO (X)	15	89	0	5	1335	0	75	1410
T-AOE (X)	4	160	19	28	640	76	112	828
T-AKE 1 Cargo and Ammo	11	113	19	11	1243	209	121	1573
ARS (X)	4	26	0	4	104	0	16	120
T-AGOS 23 Ocean surveillance ship	5	26	0	16	130	0	80	210
T-ATF (X)	4	16	0	4	64	0	16	80
JHSV	3	0	0	20	0	0	60	60
JCC (X)	2	146	10	157	292	20	318	630
	677				7101	25954	88263	121318

Table 23. Model of Proposed New Navy Fighting Machine Manpower

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IV. RESULTS AND CONCLUSIONS

A. MAIN RESULTS

Detailed results of the manpower estimates can be found at the conclusion of each analysis section, on pages 28, 40, and 69. The results are summarized below. Although these results must be regarded as preliminary, they are as thorough as the data and statistical analysis appear to justify. More detailed discussions follow.

Table 24 provides a summary of total manpower estimates:

	Number of Ships	Total Civilian Crew	Total Air Crew	Total Ship Crew	Total Manpower
Current Ship Inventory	280	3953	34930	95825	134708
313 Ship Navy	313	5272	41158	84380	130810
New Navy Fighting Machine	677	7101	25954	88263	121318

Table 24. Final Manpower Estimates

B. MAIN CONCLUSIONS

The “New Navy Fighting Machine” impression was that manning 650 ships would be about the same as for the 313 Ship Navy. The conjecture was actually incorrect. Even with its final number increasing to 677 ships and 400 inshore patrol craft, the manpower required is actually smaller, by approximately 9500 less billets.

By introducing many smaller, more focused vessels instead of large multi-missions ships, manpower requirements were decreased from 130,810 to 121,318, 7% less than the 313 ship plan. In addition, the NNFM also appears to be more evenly distributed among its missions. Fifty-six percent of its total afloat manpower is designated to blue water missions, 21% are allocated to green water vessels, and 7% to the submarine force. The shift from 11 CVNs for 6 CVNs and 18 CVLs produced the largest shift in manpower utilization, transferring nearly 9% of the manpower from a blue to green water focus.

"Secretary Robert M. Gates cited the value of developing a viable force of small warships that are better suited to face current threats in the littorals than vessels designed for blue-water operations." (McLeary, 2009) With regards to manpower, the NNFM appears to succeed in achieving the former while sustaining the strength of the latter.

C. OTHER RESULTS AND CONCLUSIONS

Table 25 summarizes the distribution of ships and manpower:

	Current Inventory				313 Ship Navy Plan				NNFM Plan[31]			
	Ships		Manpower		Ships		Manpower		Ships		Manpower	
Aircraft Carriers	11	4%	62630	46%	11	4%	56360	43%	24	4%	52440	43%
Blue Water[32]	104	37%	29082	22%	88	28%	19316	15%	149	22%	26557	22%
Green Water[33]	23	8%	1552	1%	55	18%	3520	3%	240	35%	14315	12%
Submarines	71	25%	9910	7%	66	21%	9240	7%	89	13%	8573	7%
Amphib., Delivery, and Sustainment[34]	32	11%	24398	18%	43	14%	34931	27%	125	18%	11990	10%
Support Ships	39	14%	7136	5%	50	16%	7443	6%	50	7%	7443	6%
Totals	**280**		**134708**		**313**		**130810**		**677**		**121318**	

Table 25. Ship and Manpower Distribution

1. NNFM Resources are More Widely Distributed

Of particular interest for the baseline results is that the 11 aircraft carriers (4% of the Navy's warships) constitute 46.5% of the manpower afloat. The fleet has a focus on blue water operations with 68% of its afloat manpower on aircraft carriers, cruisers, destroyers, and frigates. Only 1.2% of its manpower is dedicated to green water operations.

[31] The 18 CVLs are dual-capable for both blue and green water operations, depending on airwing configuration. The NNFM study assigns 8 CVLs (contains 9% of the total afloat manpower) to the green water fleet.

[32] Including Cruisers, Destroyers, Frigates, and/or Corvettes.

[33] Including Theater Security Craft and Coastal Combatant Vessels.

[34] Including prepositioning ships.

The proposed 313 ship fleet remains dominated by aircraft carriers, with 43% of the manpower on the 11 ships. It also remains blue water centric with nearly 58% of the manpower afloat aboard aircraft carriers, cruisers, and destroyers. Although the number of littoral ships increased from 8% to 18%, the amount of manpower dedicated to the green water and littoral operations vital to the Navy's new strategic mission is still low at 3%. This limits the influential impact that the U.S. Navy might gain through combined operations with foreign countries.

Manpower in the NNFM is more widely distributed throughout the Navy's missions. There is still a large percent of manpower (43%) aboard aircraft carriers, although there are now 24 of them. Sixteen of the carriers with only 34% of the total manpower afloat are allocated for blue water operations. The total number of manpower required aboard the 165 blue water ships decreased slightly to 56%. The remaining eight light carriers are allotted to the green water mission. With a total of 248 ships and 400 inshore patrol craft, the green water manpower forces increased dramatically, from 1.2% in the current inventory and 3% in the 313 Ship Navy design, to 21% in the NNFM. This mix provides a viable presence in the littorals to conduct green water operations, perform humanitarian assistance, and provide training to local naval forces, as required in the Navy's new maritime strategy, while maintaining a credible blue water component.

2. The Impact of AIP Submarines will be Significant

The percentage of manpower dedicated to submarines remains nearly the same for all three fleet arrangements, but the total number of submarines and submariners differs. It can be noted that there is a decrease in submarines from 71 in the current inventory to 66 in the 313 ship plan. This is in stark contrast to the 89 submarines in the NNFM. Interestingly, the manpower numbers actually reduce from 9,910 submariners in the current fleet and 9,240 in the 313 ship plan to 8,573 submariners in the NNFM. The low cost and small crews of the AIP diesel submarines in the NNFM make the higher number of submarines possible. This is significant as recruiting and training cost are typically higher in the nuclear submarine community. While quality sailors will still be required to operate AIP diesel submarines, training methods and other resources are likely to be quite different.

3. Technology Will Likely Affect Manpower Needs

Automation and other technological improvements are expected to be future advantages in reducing the crew size per displacement ton without affecting combat effectiveness. Reduction by automation has proven to be successful in some foreign ships, commercial ocean liners, and civilian-manned MSC ships. Although the 313 Ship Navy has more ships (an increase of approximately 12%), the afloat manpower requirements decreased to 130,810 (a decrease of nearly 3%). This reduction is credible assuming current technological advances and optimal manning initiatives successfully shape future crew sizes as proposed and that manpower saving technology will continue to evolve.

The result of the NNFM is an even lower manpower requirement of 121,318 (a reduction of 7% from the 313 Ship Navy and nearly 10% less than the Current Fleet Inventory) for even more ships (116% more ships than 313 and 141% more than the current inventory). Crew sizes for the three warships in common (CVN 78, DDG 1000, and DDG(X)) between the 313 Ship Navy and the NNFM were consistent, therefore, any crew reductions assumed in the 313 ship plan would likewise reduce NNFM crew estimates. In general, however, technology induced manpower reductions were not assumed as a driving factor in crew size estimation. Instead, only U.S. and foreign navy ships currently available or near completion were taken into consideration. Hence, if manpower reductions are successful, it is likely that the NNFM manpower requirements will be even smaller.

4. Displacement Relationships are Helpful, but Cannot Estimate Everything

Sound projections of manpower for warships appear to fit a linear relationship between displacement and manpower. In a sample of 149 warships, displacement was found to be a statistically significant factor for determining crew size. As was shown in the analysis, estimations could be developed with some degree of statistical significance. However, there were some ship types in which displacement was not a key factor in estimating crew size, such as the inshore patrol craft squadrons, mine warfare ships, and support, prepositioning, and delivery/sustainment ships.

There does appear to be a relationship between displacement and crew size even for small craft such as the Sea Ark SOCR, and PBR MkII. However, the USN manpower requirements for such patrol craft squadrons were to be developed with training and development of foreign forces in mind. In this case, subject matter experts can be of assistance in developing new or undeveloped ideas. The newly formed Maritime Expeditionary Security Force of the Navy Expeditionary Combat Command may point the way. (http://www.necc.navy.mil/)

The mine warfare ships were not described well by a relationship between crew size and displacement. Whether crew size did in fact have a relationship with displacement or some other ship characteristic was outside the focus of this work. That the relationship was not easily discernable was more important. In such cases, just taking an average may have to suffice.

Combat logistics/support, prepositioning, and delivery/sustainment ships do not demonstrate the crew size versus displacement relationship either. Crew operations and management on these ships are considerably different as are the watch standing and training requirements. As such, these large support ships require substantially less manpower per displacement ton. Both the 313 Ship Navy and the NNFM plans introduce new seabasing, prepositioning, and delivery/sustainment concepts. Significant resources and personnel are dedicated to these areas. Without the displacement relationship to rely on, estimation of manpower was much less well-defined.

D. RECOMMENDATIONS FOR FURTHER RESEARCH

This thesis compared the manpower requirements for three U.S. Navy fleet compositions: the current fleet, the projected 313 ship plan, and the proposed NNFM. Although only exploratory, it showed that a fleet with smaller, more focused, yet more numerous vessels could capably provide a more distributed manpower structure at appreciably lower numbers. Several areas could benefit from further research to examine the manpower challenges involved, if a bimodal fleet of the sort proposed by the NNFM is developed.

1. Further Validation of Estimates

The crew size estimates for the NNFM were largely developed from regressions performed on samples of ships with similar sizes and capabilities. Because of its exploratory nature, this study did not delve into some statistical details. Sensitivity analysis could be done to investigate the robustness of the study. Multi-variable regressions could also be examined. How does armament or propulsion affect manpower requirements? A multi-variable regression with the year of commission may provide additional insight to how future crew sizes might decrease over time, as Figure 5 and Figure 8 imply.

2. Alternative Manpower Estimation Methods

An alternative method might build up a desired vessel based on size, armament, propulsion, flight deck, etc. Each characteristic could be matched to a current U.S. ship with that particular capability. Different ship "parts" could be combined to create a completely new vessel. Section V of that ship's SMD provides the functional workload for that class of ship. The functional workloads, adjusted up or down to better match desired size and capabilities, could then serve as building blocks for total manpower estimation.

3. New Ratings/Designators and Training?

With a more distributed manpower structure with personnel aboard more focused vessels, a study of the relationship between ship mission and training may be fruitful.

The large increase in the green water component will surely create challenges along with the opportunities. A dedicated organization may be needed to for theater security and coastal combat operations. New ratings and designators may even be required. Manpower distribution, training, and support should be studied.

In addition, manning adjustments will be made as the proposed fleet moves from CVN focused operations to more CVL missions. Increased UAV operations seem a natural fit for the CVL. This in turn could greatly affect naval aviation manpower requirements, as well as answering the question of whether a new UAV rating might be desirable.

Finally, the impact of AIP diesel submarines on recruiting, training, and developing submariners should be considered. It is believed that ships and submarines with nuclear power require more training. Training resources and methods should be studied to ensure the quality of both the nuclear and AIP submariners.

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APPENDICES

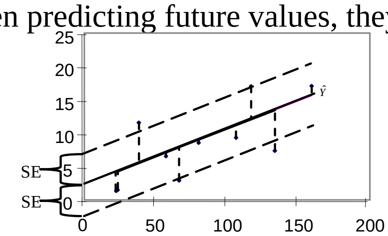
A. SUMMARY OF REGRESSION ANALYSIS TERMS

Taken from NPS Cost Estimation Course Notes, with permission from Dr. D. A. Nussbaum, Professor, NPS

Standard Error: the standard deviation about the regression line. (The smaller the better.) This means that on "average" when predicting future values, they will be off by that much

Eqn:

$$SE = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n-2}}$$



Coefficient of Variation (CV): On "average," the prediction will be off by this much when predicting future values. (The smaller the better.)

Eqn:

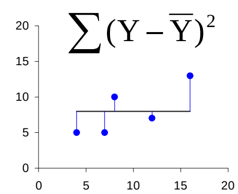
$$CV = \frac{SE}{\overline{Y}}$$

Analysis of Variance (ANOVA) Measures of Variation:

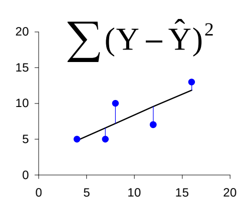
SST = SSE + SSR

"total" = "unexplained" + "explained"

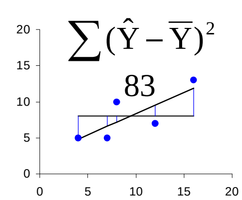
Total Sum of Squares (SST): The sum of the squared deviations between the data and the average



Residual or Error Sum of Squares (SSE): The sum of the squared deviations between the data and the regression line. "The unexplained variation"



Regression Sum of Squares (SSR): The sum of the squared deviations between the regression line and the average. "The explained variation"



Coefficient of Determination:

Coefficient of Determination (R^2) represents the percentage of total variation explained by the regression model. (The larger the better.)

Eqn:

$$R^2 = \frac{\text{Explained Variation}}{\text{Total Variation}} = \frac{SSR}{SST} = 1 - \frac{SSE}{SST}$$

R^2 adjusted for degrees of freedom (Adj. R^2) takes into account the increased uncertainty due to a small sample size.

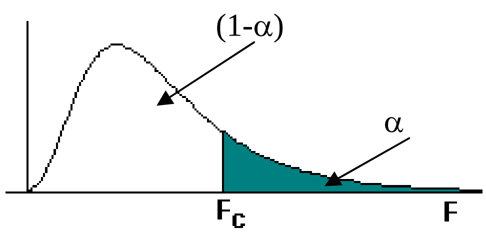
Eqn:

$$R_{adj}^2 = 1 - \frac{SSE / (n-(k+1))}{SST / (n-1)}$$

The F Statistic:

- The F statistic tells us whether the full model is preferred to the mean.

- If the F value falls within the rejection region, we reject the null hypothesis (that the coefficients of all the independent variables are zero) and say the full model is better than the mean as a predictor.



Significance of F: If less than a then we prefer the model to the mean.

The t statistic:

- For a regression coefficient, the determination of statistical significance is based on a t test
  - o The test depends on the ratio of the coefficient's estimated value to its standard deviation, called a t statistic
- This statistic tests the strength of the relationship between Y and X (or between Crew Size and Displacement) by testing the strength of the coefficient.
- Another way of looking at this is that the t-statistic tells us how many standard deviations the coefficient is from zero.
- The t-statistic is used to test the hypothesis that X and Y (or Displacement and Crew Size) are NOT related at a given level of significance.
- If the test indicates that that X and Y <u>are</u> related, then we say we prefer the model <u>with</u> b1 to the model <u>without</u> b1.

For a single variable regression as is performed in this work, the t and F test results are the same.

Summary:

- CV: The smaller the better.
- R2 or Adj. R2: The bigger the better.
- Significance of F: If less than α then we prefer the model to the mean
- P-value of coefficient b1: If less than α, then we prefer the model with b1, else we prefer it without b1.

B. SHIP AND USN/USMC AFLOAT PERSONNEL LEVELS

Ship and USN/USMC Afloat Personnel levels from 1980 to 2007		
Year	Ships[35]	USN/USMC Afloat Personnel[36]
1980	530	210780
1981	521	214301
1982	555	228883
1983	533	234390
1984	557	229722
1985	571	230613
1986	583	240393
1987	594	246022
1988	573	247710
1989	592	245992
1990	570	251796
1991	529	243288
1992	471	218260
1993	454	199649
1994	404	179955
1995	392	167415
1996	375	154664
1997	359	144755
1998	344	139564
1999	337	145132
2000	318	138140
2001	316	146070
2002	313	149772
2003	297	152068
2004	292	137358
2005	282	130026
2006	281	126613
2007	279	115811
2008	280	108269
2009	283	105480

[35] Data taken from http://www.history.navy.mil/branches/org9-4.htm#1993.

[36] Data taken from http://siadapp.dmdc.osd.mil/personnel/MILITARY/miltop.htm.

C. SAMPLE OF 149 WARSHIPS

Foreign and U.S. Navy Warship Data							
	Type	Country	Ship	Disp. (Tons)	Crew	Aircrew	# Aircraft
1	Aircraft Carrier	USA	Gerald R Ford	100000	2700	1960	75
2	Aircraft Carrier	USA	Nimitz	91,487	3200	2480	52
3	Aircraft Carrier	USA	Enterprise	89,600	3350	2480	52
4	Aircraft Carrier	USA	Kitty Hawk	83960	2930	N/A	52
5	Aircraft Carrier	Russia	Kuznetsov	45900	1960	626	22
6	Aircraft Carrier	France	Charkes De Gaulle	42500	1256	610	30
7	Aircraft Carrier	India	Vikrant	37500	1400	N/A	12
8	Aircraft Carrier	France	Clemenceau	32,780	1017	358	20
9	Aircraft Carrier	Italy	Cavour	27,100	528	168	20
10	Aircraft Carrier	Italy	Cavour	27,100	528	168	20
11	Aircraft Carrier	Spain	Juan Carlos I	27079	243	172	20
12	Aircraft Carrier	UK	Illustrious	20600	685	366	24
13	Aircraft Carrier	Spain	Prinipe De Asturias	17188	555	201	13
14	Aircraft Carrier	Italy	Garibaldi	13850	582	230	15
15	Aircraft Carrier	Thailand	Chakri Naruebet	11485	455	146	12
16	LHA	USA	America (LHA-6)	44850	1059	N/A	23
17	LHD	USA	Wasp	40,650	1123	N/A	20
18	LSD	USA	Whidbey Island	16,740	413	N/A	2
19	Cruiser	Ukraine	Slava	11,490	476	N/A	1
20	Cruiser	USA	Ticonderoga	9,957	358	N/A	2
21	Cruiser	Russia	Kara	9,900	390	N/A	1
22	Destroyer	Japan	Kongou	9,485	300	N/A	1
23	Destroyer	USA	Arleigh Burke	8946	274	0	1
24	Destroyer	UK	Daring	7450	191	0	1
25	Destroyer	France	Forbin	7050	195	0	1
26	Destroyer	Italy	Andrea Doria	6635	200	0	1
27	Destroyer	Japan	Takani	6300	176	N/A	N/A
28	Destroyer	France	Georges Leygues	4910	233	N/A	2
29	Frigate	Germany	Baden-Württemberg	6800	110	0	2
30	Frigate	Italy	Bergamini	5950	145	N/A	2
31	Frigate	Spain	Alvaro De Bazán	5853	200	0	1
32	Frigate	Germany	Sachsen	5600	255	13	2
33	Frigate	Norway	Fridtjof Nansen	5290	120	N/A	1

34	Frigate	UK	BroadSword	4900	250	10	2
35	Frigate	Canada	Halifax	4770	198	17	1
36	Frigate	UK	Duke	4200	181	N/A	1
37	Frigate	Taiwan	Cheng Kung	4105	215	19	2
38	Frigate	USA	Oliver Hazard Perry	4100	200	19	2
39	Frigate	China	Type 054	3900	190	N/A	1
40	Frigate	Taiwan	Kang Ding	3800	134	N/A	1
41	Frigate	France	La Fayette	3750	153	N/A	1
42	Frigate	Turkey	Barbaros	3380	187	9	1
43	Frigate	Greece	Hydra	3350	199	13	1
44	Frigate	Portugal	Vasco Da Gama	3300	182	16	2
45	Frigate	Italy	Maestrale	3200	205	N/A	2
46	Frigate	Singapore	Formidable	3200	71	15	1
47	Frigate	Turkey	Tepe (Knox)	3011	288	N/A	1
48	Frigate	France	Floreal	2950	90	11	1
49	Frigate	Italy	Lupo	2525	177	N/A	1
50	Frigate	Poland	Gawron II	2035	74	0	1
51	Frigate	Japan	Ishikari/Yuubari	1,690	95	0	0
52	Frigate	Iran	Moudge	1400	130	0	0
53	Frigate	Iran	Alvand	1350	125	0	0
54	Frigate	France	Destienne dOrves	1330	90	0	0
55	LCS	U.S.	Freedom	3089	50	N/A	2
56	Corvette	Turkey	Milgem	2000	93	0	1
57	Corvette	Germany	Braunschweig	1840	58	0	1
58	Corvette	Malaysia	Kedah	1650	68	0	1
59	Corvette	India	Kora	1460	134	0	1
60	Corvette	Thailand	Pattani	1440	78	0	0
61	Corvette	India	Khukri	1423	112	0	0
62	Corvette	Portugal	Baptista de Andrade	1380	71	0	0
63	Corvette	Isreal	Sa’ar V	1295	64	0	0
64	Corvette	Thailand	Khanronsin	630	57	0	0
65	Corvette	Sweden	Visby	620	43	0	1
66	Corvette	Singapore	Victory	595	49	0	0
67	Corvette	Sweden	Goteborg	399	36	0	0
68	MCM	Canada	Kingston	962	37	0	0
69	MCM	Russia	Natya I	804	67	0	0
70	MCM	Greece	Evropi	750	46	0	0

71	MCM	UK	Hunt	740	45	0	0
72	MCM	Australia	Houn	720	40	0	0
73	MCM	Finland	MCMV 2010	697	36	0	0
74	MCM	Taiwan	Kinmen	688	38	0	0
75	MCM	Portugal	LFC 2005	660	20	0	0
76	MCM	Belgium	Flower	650	46	0	0
77	MCM	Belgium	KMV	644	27	0	0
78	MCM	Germany	Ensdorf	635	34	0	0
79	MCM	Germany	Kulmbach	635	37	0	0
80	MCM	Italy	Lerici	620	44	0	0
81	MCM	France	Eridan	615	49	0	0
82	MCM	Pakistan	Munsif	595	46	0	0
83	MCM	Japan	Sugashima	590	45	0	0
84	MCM	Spain	Segura	530	41	0	0
85	MCM	Estonia	Sandown	484	34	0	0
86	MCM	Turkey	Circe	460	48	0	0
87	MCM	Cuba	Sonya	450	43	0	0
88	MCM	Thailand	Bang Rachan	444	33	0	0
89	MCM	Montenegro	Sirius	424	40	0	0
90	MCM	Norway	Oskoy/Alta	375	40	0	0
91	MCM	Sweden	Koster	360	29	0	0
92	MCM	Sweden	Landsort	360	29	0	0
93	MCM	Indonesia	Kondor II	310	31	0	0
94	MCM	Poland	Mamry	216	27	0	0
95	PC-Missile	Greece	Super Vita	660	45	0	0
96	PC-Missile	Singapore	Fearless	500	32	0	0
97	PC-Missile	Norway	Skjold	273	20	0	0
98	PC-Missile	Finland	Hamina	270	29	0	0
99	PC-Missile	China	Houbei	220	12	0	0
100	PC-Missile	Sweden	Kaparen	170	22	0	0
101	Patrol Craft	Spain	Alboran	1963	37	0	0
102	Patrol Craft	India	Vishwast	1840	118	0	1
103	Patrol Craft	Taiwan	Ho Hsing	1823	80	0	0
104	Patrol Craft	Italy	Comandante	1520	60	N/A	1
105	Patrol Craft	UK	Castle	1427	45	0	0
106	Patrol Craft	India	Vikram	1224	96	N/A	1
107	Patrol Craft	Spain	Serviola	1147	42	0	0
108	Patrol Craft	Australia	OPV	1100	44	0	0

109	Patrol Craft	Egypt	Ambassador III	550	36	0	0
110	Patrol Craft	Korea	Swallow	520	44	0	0
111	Patrol Craft	Israel	Aliya	498	53	0	0
112	Patrol Craft	Lithuania	Flyvefisken	480	29	0	0
113	Patrol Craft	Indonesia	Singa	447	42	0	0
114	Patrol Craft	Ukraine	Pauk I	440	32	0	0
115	Patrol Craft	Turkey	Dearson	400	34	0	0
116	Patrol Craft	South Africa	River	380	40	0	0
117	Patrol Craft	Russia	Svetlyak	375	36	0	0
118	Patrol Craft	USA	Cyclone	354	39	0	0
119	Patrol Craft	USA	Sentinel FSC	353	22	0	0
120	Patrol Craft	Australia	Armidale	270	21	0	0
121	Patrol Craft	India	Bangaram	260	34	0	0
122	Patrol Craft	Denmark	Willemoes	260	25	0	0
123	Patrol Craft	France	Thomson	227	7	0	0
124	Patrol Craft	Barbados	Damen Stan	205	14	0	0
125	Patrol Craft	USA	Island	168	16	0	0
126	Patrol Craft	Pakistan	Kaan 33	120	18	0	0
127	Patrol Craft	Poland	Pilica	93	14	0	0
128	Patrol Craft	USA	Marine Protector	91	10	0	0
129	Small PC	USA	Sea Ark	9.3	6	0	0
130	Small PC	USA	SOCR	9.1	4	0	0
131	Small PC	USA	PBR MkII	8	4	0	0
132	Small PC	USA	HSIV	3.4	2	0	0
133	Small PC	USA	Defender	2.7	4	0	0
134	Submarine	USA	Virginia SSN	7800	134	0	0
135	Submarine	UK	Astute SSN	7400	140	0	0
136	Submarine	USA	LA SSN688	7011	134	0	0
137	Submarine	Japan	Soryu	4200	65	0	0
138	Submarine	Japan	Oyashio SS90	3500	70	0	0
139	Submarine	Japan	Harushio SS583	3200	75	0	0
140	Submarine	France	Rubis SSN	2670	68	0	0
141	Submarine	Russia	Lada Project 677	2650	37	0	0
142	Submarine	China	Song	2250	60	0	0
143	Submarine	Turkey	Type 214	1860	27	0	0
144	Submarine	Germany	Type 212A	1830	28	0	0
145	Submarine	Spain	Agosta 90B	1760	36	0	0
146	Submarine	Malaysia	Scorpene	1758	31	0	0

147	Submarine	Sweden	Sodermanland	1600	27	0	0
148	Submarine	Sweden	Gotland A17	1599	27	0	0
149	Submarine	Greece	Type 209	1285	38	0	0

D. REGRESSION STATISTICS

Summary Output LHA Regression
Summary Output Aircraft Carrier Regression (All Carriers in Sample)
Summary Output Aircraft Carrier Regression (Without U.S. Carriers)
Summary Output Aircraft Carrier Regression (All Carriers in Sample)
Summary Output Aircraft Carrier Regression (Without U.S. Carriers)
Summary Output Aircraft Carrier Regression (All Carriers in Sample)
Summary Output Aircraft Carrier Regression (Without U.S. Carriers)
Summary Output Aircraft Carrier Regression (All Carriers in Sample – Alternate Method)
Summary Output Aircraft Carrier Regression (Without Us Carriers – Alternate Method)
Summary Output Blue Water Frigates
Summary Output Light Arsenal Land Attack Vessel
Summary Output Light Naval Gunfire Support Ship
Summary Output Air-Independent Propulsion Submarine
Summary Output Fast Mine Warfare
Summary Output Offshore Patrol Vessel

SUMMARY OUTPUT FOR 149 SHIP REGRESSION

CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics					
Multiple R	0.9769	Observations	149		
R Square	0.9543	Mean crew	236.7181		
Adjusted R Square	0.9540	CV	0.4931		
Standard Error	116.7241				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	41813910	4.2E+07	3069.02	2.18E-100
Residual	147	2002804	13624.5		
Total	148	43816714			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	10.6914	10.3964	1.0284	0.3055	
Displacement	0.0319	0.0006	55.3987	2E-100	

SUMMARY OUTPUT w/o 4 outliers (USN Carriers)					
Regression Statistics					
Multiple R	0.9404	Standard Error	94.9361		
R Square	0.8844	Observations	145		
Adjusted R Square	0.8836				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9862557	9862557	1094.28	7.00E-69
Residual	143	1288840	9012.87		
Total	144	1.1E+07			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	21.3840	8.9178	2.3979	0.0178	
X Variable 1	0.0290	0.0009	33.0798	7E-69	

SUMMARY OUTPUT w/o 8 outliers					
Regression Statistics					
Multiple R	0.9703	Standard Error	56.5283		
R Square	0.9414	Observations	141		
Adjusted R Square	0.9410				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7136795	7136795	2233.42	1.6E-87
Residual	139	444167	3195.45		
Total	140	7580962			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	24.8212	5.3544	4.6356	8.1E-06	
Displacement	0.0290	0.0006	47.2591	1.6E-87	

SUMMARY OUTPUT LHA REGRESSION
(LOGARITHMIC TRANSFORMATION)
NORMALIZED CREW SIZE TO DISPLACEMENT

SUMMARY OUTPUT (excluding questioned data)					
Regression Statistics					
Multiple R	0.9836		Standard Error	0.0393	
R Square	0.9675		Observations	4	
Adjusted R Square	0.9513				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0920	0.0920	59.6116	0.0164
Residual	2	0.0031	0.0015		
Total	3	0.0950			
	Coefficients	*Std Error*	*t Stat*	*P-value*	
Intercept	-3.3164	0.0380	-87.2928	0.0001	
ln(Ship)	-0.2453	0.0318	-7.7209	0.0164	

SUMMARY OUTPUT (including JFS data)					
Regression Statistics					
Multiple R	0.7739		Standard Error	0.1239	
R Square	0.5989		Observations	5	
Adjusted R Square	0.4652				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0688	0.0688	4.4788	0.1246
Residual	3	0.0461	0.0154		
Total	4	0.1148			
	Coefficients	*Std Error*	*t Stat*	*P-value*	
Intercept	-3.4014	0.1086	-31.3333	0.0001	
ln(#)	-0.2063	0.0975	-2.1163	0.1246	

SUMMARY OUTPUT (including SMD data)					
Regression Statistics					
Multiple R	0.9845		Standard Error	0.0322	
R Square	0.9692		Observations	5	
Adjusted R Square	0.9590				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.0979	0.0979	94.5383	0.0023
Residual	3	0.0031	0.0010		
Total	4	0.1010			
	Coefficients	*Std Error*	*t Stat*	*P-value*	
Intercept	-3.3145	0.0282	-117.5578	0.0000	
ln(#)	-0.2462	0.0253	-9.7231	0.0023	

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(All Carriers in Sample)
APPROXIMATE NUMBER OF PLANES AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.9397
R Square	0.8830
Adjusted R Square	0.8732
Standard Error	7.0520
Observations	14
Mean	29.9
CV	0.2358

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4502.16	4502.16	90.53	6.11E-07
Residual	12	596.77	49.73		
Total	13	5098.93			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	2.2860	3.4630	0.6601	0.5216
Displacement	0.0006	6.2277E-05	9.5148	6.11E-07

RESIDUAL OUTPUT			
Observation	*Predicted approx # of planes*	*Residuals*	*Standard Residuals*
1	14.4926	9.5074	1.4032
2	10.4929	4.5071	0.6652
3	28.8620	-5.8620	-0.8652
4	29.4842	-7.4842	-1.1046
5	24.5068	-12.5068	-1.8459
6	27.4695	2.5305	0.3735
7	12.4708	-2.4708	-0.3647
8	18.3318	1.6682	0.2462
9	9.0915	2.9085	0.4293
10	18.3442	1.6558	0.2444
11	52.0368	-0.0368	-0.0054
12	56.4969	-4.4969	-0.6637
13	61.5413	13.4587	1.9864
14	55.3788	-3.3788	-0.4987

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(Without U.S. Carriers)
APPROXIMATE NUMBER OF PLANES AS A FUNCTION OF DISPLACEMENT

Regression Statistics				
Multiple R	0.5924			
R Square	0.3510			
Adjusted R Square	0.2698			
Standard Error	5.4611			
Observations	10			
Mean	29.9		CV	0.182645

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	129.0112	129.0112	4.3258	0.0711
Residual	8	238.5888	29.8236		
Total	9	367.6			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	10.4752	4.3592	2.4030	0.0430
Displacement	0.0003	0.0001	2.0799	0.0711

RESIDUAL OUTPUT			
Observation	*Predicted approx # of planes*	*Residuals*	*Standard Residuals*
1	16.4287	7.5713	1.4705
2	14.4779	0.5221	0.1014
3	23.4370	-0.4370	-0.0849
4	23.7404	-1.7404	-0.3380
5	21.3128	-9.3128	-1.8087
6	22.7578	7.2422	1.4066
7	15.4426	-5.4426	-1.0571
8	18.3011	1.6989	0.3300
9	13.7944	-1.7944	-0.3485
10	18.3072	1.6928	0.3288

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(All Carriers in Sample)
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.9517
R Square	0.9058
Adjusted R Square	0.8980
Standard Error	357.5586
Observations	14

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	14754999.4672	14754999.4672	115.4104	0.0000
Residual	12	1534177.4614	127848.1218		
Total	13	16289176.93			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-89.4050	175.5862	-0.5092	0.6199
Displacement	0.0339	0.0032	10.7429	0.0000

RESIDUAL OUTPUT			
Observation	*Predicted Crew*	*Residuals*	*Standard Residuals*
1	609.3959	75.6041	0.2201
2	380.4199	201.5801	0.5868
3	1432.0136	-373.0136	-1.0858
4	1467.6321	492.3679	1.4333
5	1182.6841	217.3159	0.6326
6	1352.2960	-96.2960	-0.2803
7	493.6528	61.3472	0.1786
8	829.1790	-586.1790	-1.7063
9	300.1935	154.8065	0.4506
10	829.8914	-301.8914	-0.8788
11	2758.7177	171.2823	0.4986
12	3014.0515	185.9485	0.5413
13	3302.8327	-602.8327	-1.7548
14	2950.0400	399.9600	1.1643

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(Without U.S. Carriers)
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.7947
R Square	0.6315
Adjusted R Square	0.5855
Standard Error	342.8666
Observations	10

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1611915.8815	1611915.8815	13.7117	0.0060
Residual	8	940460.2185	117557.5273		
Total	9	2552376.1			

	Coefficients	*Standard Error*	*t Stat*
Intercept	-58.2276	273.6873	-0.2128
Displacement	0.0323	0.0087	3.7029

RESIDUAL OUTPUT			
Observation	*Predicted Crew*	*Residuals*	*Standard Residuals*
1	607.2380	77.7620	0.2406
2	389.1849	192.8151	0.5965
3	1390.6137	-331.6137	-1.0258
4	1424.5330	535.4670	1.6565
5	1153.1781	246.8219	0.7635
6	1314.6989	-58.6989	-0.1816
7	497.0162	57.9838	0.1794
8	816.5366	-573.5366	-1.7742
9	312.7856	142.2144	0.4399
10	817.2150	-289.2150	-0.8947

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(All Carriers in Sample)
AIRCREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.9561
R Square	0.9141
Adjusted R Square	0.9056
Standard Error	314.5701
Observations	12

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	10535067	10535067	106.4639	0.0000
Residual	10	989543.7	98954.37		
Total	11	11524610			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-375.2581	160.7398	-2.3346	0.0417
Displacement	0.0288	0.0028	10.3181	1.19E-06

RESIDUAL OUTPUT			
Observation	*Predicted aircrew*	*Residuals*	*Standard Residuals*
1	217.4634	148.5366	0.4952
2	23.2464	206.7536	0.6893
3	945.4175	-319.4175	-1.0650
4	847.5897	-237.5897	-0.7921
5	119.2903	81.7097	0.2724
6	403.8829	-231.8829	-0.7731
7	-44.8015	190.8015	0.6362
8	404.4872	-236.4872	-0.7885
9	2040.5136	439.4864	1.4653
10	2257.0871	222.9129	0.7432
11	2502.0307	-542.0307	-1.8072
12	2202.7927	277.2073	0.9242

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(Without U.S. Carriers)
AIRCREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.8431
R Square	0.7108
Adjusted R Square	0.6626
Standard Error	115.5790
Observations	8

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	197035.9	197035.9	14.7498	0.0086
Residual	6	80151	13358.5		
Total	7	277186.9			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-23.8954	97.2142	-0.2458	0.8140
Displacement	0.0132	0.0034	3.8406	0.008553

RESIDUAL OUTPUT			
Observation	*Predicted aircrew*	*Residuals*	*Standard Residuals*
1	247.5135	118.4865	1.1073
2	158.5810	71.4190	0.6674
3	580.8459	45.1541	0.4220
4	536.0502	73.9498	0.6911
5	202.5598	-1.5598	-0.0146
6	332.8756	-160.8756	-1.5034
7	127.4217	18.5783	0.1736
8	333.1523	-165.1523	-1.5434

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(All Carriers in Sample – Alternate Method)
AIRCREW SIZE AS A FUNCTION OF NUMBER OF AIRCRAFT

Regression Statistics	
Multiple R	0.8930
R Square	0.7974
Adjusted R Square	0.7771
Standard Error	483.1989
Observations	12

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9189798	9189798	39.3599	9.22E-05
Residual	10	2334812	233481.2		
Total	11	11524610			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-425.0655	265.6409	-1.6002	0.1406
approx # of planes	44.3224	7.0647	6.2737	9.22E-05

RESIDUAL OUTPUT			
Observation	*Predicted aircrew*	*Residuals*	*Standard Residuals*
1	638.6711	-272.6711	-0.5918
2	239.7699	-9.7699	-0.0212
3	550.0264	75.9736	0.1649
4	904.6053	-294.6053	-0.6395
5	18.1581	182.8419	0.3969
6	461.3817	-289.3817	-0.6281
7	106.8028	39.1972	0.0851
8	461.3817	-293.3817	-0.6368
9	1879.6972	600.3028	1.3030
10	1879.6972	600.3028	1.3030
11	2899.1115	-939.1115	-2.0384
12	1879.6972	600.3028	1.3030

SUMMARY OUTPUT AIRCRAFT CARRIER REGRESSION
(Without U.S. Carriers – Alternate Method)
AIRCREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.7304
R Square	0.5334
Adjusted R Square	0.4557
Standard Error	146.8117
Observations	8

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	147864.8	147864.8	6.8603	0.039628
Residual	6	129322.1	21553.69		
Total	7	277186.9			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-107.6983	169.4799	-0.6355	0.5486
approx # of planes	22.0953	8.4359	2.6192	0.039628

RESIDUAL OUTPUT			
Observation	*Predicted aircrew*	*Residuals*	*Standard Residuals*
1	422.5898	-56.5898	-0.4163
2	223.7317	6.2683	0.0461
3	378.3991	247.6009	1.8216
4	555.1618	54.8382	0.4035
5	113.2551	87.7449	0.6456
6	334.2084	-162.2084	-1.1934
7	157.4457	-11.4457	-0.0842
8	334.2084	-166.2084	-1.2228

SUMMARY OUTPUT BLUE WATER FRIGATES
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.7905
R Square	0.6250
Adjusted R Square	0.6062
Standard Error	38.1494
Observations	22

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	48505.92	48505.92	33.3287	1.2E-05
Residual	20	29107.58	1455.38		
Total	21	77613.50			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	37.6353	20.5365	1.8326	0.0818
Displacement	0.0371	0.0064	5.7731	1.2E-05

RESIDUAL OUTPUT			
Observation	*Predicted Crew Size*	*Residuals*	*Standard Residuals*
1	86.9598	3.0402	0.0817
2	87.7016	37.2984	1.0018
3	89.5559	40.4441	1.0863
4	91.7811	42.2189	1.1340
5	98.8274	-30.8274	-0.8280
6	100.3109	-5.3109	-0.1427
7	105.8738	-47.8738	-1.2859
8	111.8076	-18.8076	-0.5052
9	113.1056	-39.1056	-1.0504
10	131.2778	45.7222	1.2281
11	147.0394	-57.0394	-1.5321
12	156.3110	48.6890	1.3078
13	156.3110	-85.3110	-2.2915
14	161.8739	37.1261	0.9972
15	162.9865	24.0135	0.6450
16	176.7084	-23.7084	-0.6368
17	182.2713	7.7287	0.2076
18	189.6885	10.3115	0.2770
19	193.3971	-12.3971	-0.3330
20	214.5363	-16.5363	-0.4442
21	219.3575	30.6425	0.8231
22	245.3178	9.6822	0.2601

SUMMARY OUTPUT LIGHT ARSENAL LAND ATTACK VESSEL
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.7748
R Square	0.6004
Adjusted R Square	0.5804
Standard Error	37.881
Observations	22

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	43114.03	43114.03	30.0448	2.2970E-05
Residual	20	28699.83	1434.99		
Total	21	71813.86			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	19.6330	15.5973	1.2587	0.2226
Displacement	0.04326	0.0079	5.4813	2.3E-05

RESIDUAL OUTPUT			
Observation	*Predicted Crew Size*	*Residuals*	*Standard Residuals*
1	165.8416	21.1584	0.5723
2	164.5439	34.4561	0.9320
3	158.0554	46.9446	1.2699
4	158.0554	-87.0554	-2.3549
5	147.2411	-57.2411	-1.5484
6	128.8569	48.1431	1.3023
7	107.661	-33.661	-0.9105
8	92.7373	2.2627	0.0612
9	80.1928	49.8072	1.3473
10	78.0300	46.9700	1.2705
11	77.1648	12.8352	0.3472
12	106.147	-13.147	-0.3556
13	99.2259	-41.2259	-1.1152
14	91.0071	-23.0071	-0.6223
15	82.7882	51.2118	1.3853
16	75.6508	-11.6508	-0.3152
17	46.4524	-3.4524	-0.0934
18	48.1826	-3.1826	-0.0861
19	41.2615	-9.2615	-0.2505
20	31.4422	-11.4422	-0.3095
21	31.3124	-2.3124	-0.0626
22	29.1496	-17.1496	-0.4639

SUMMARY OUTPUT LIGHT NAVAL GUNFIRE SUPPORT SHIP
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.8156
R Square	0.6653
Adjusted R Square	0.6500
Standard Error	56.5387
Observations	24

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	139762.15	139762.15	43.72	1.20E-06
Residual	22	70325.85	3196.63		
Total	23	210088.00			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	51.18552	27.1252	1.8870	0.0724
Displacement	0.028765	0.0044	6.6122	1.2E-06

RESIDUAL OUTPUT			
Observation	*Predicted Crew Size*	*Residuals*	*Standard Residuals*
1	381.6969	94.3031	1.7054
2	337.6000	20.4000	0.3689
3	335.9604	54.0396	0.9773
4	324.0228	-24.0228	-0.4344
5	308.5184	-34.5184	-0.6242
6	265.4858	-74.4858	-1.3470
7	253.9797	-58.9797	-1.0666
8	242.0422	-42.0422	-0.7603
9	246.7885	-136.7885	-2.4738
10	219.5479	-19.5479	-0.3535
11	212.2703	42.7297	0.7727
12	192.1347	57.8653	1.0465
13	188.3952	9.6048	0.1737
14	171.9991	9.0009	0.1628
15	169.1226	30.8774	0.5584
16	163.3696	26.6304	0.4816
17	159.0548	-6.0548	-0.1095
18	148.4117	38.5883	0.6979
19	147.5487	51.4513	0.9305
20	143.2340	61.7660	1.1170
21	143.2340	-72.2340	-1.3063
22	136.0427	-46.0427	-0.8327
23	123.8175	53.1825	0.9618
24	109.7226	-35.7226	-0.6460

SUMMARY OUTPUT AIR-INDEPENDENT PROPULSION SUBMARINE
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.9661
R Square	0.9333
Adjusted R Square	0.9285
Standard Error	10.7841
Observations	16

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	22773.2911	22773.2911	195.8215	1.27E-09
Residual	14	1628.1464	116.2962		
Total	15	24401.4375			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	4.2705	4.9470	0.8633	0.4025
Displacement	0.0177	0.0013	13.9936	1.27E-09

RESIDUAL OUTPUT			
Observation	*Predicted Crew Size*	*Residuals*	*Standard Residuals*
1	27.0560	10.9440	1.0505
2	32.6238	-5.6238	-0.5398
3	32.6415	-5.6415	-0.5415
4	35.4431	-4.4431	-0.4265
5	35.4786	0.5214	0.0500
6	36.7198	-8.7198	-0.8370
7	37.2518	-10.2518	-0.9840
8	44.1672	15.8328	1.5197
9	51.2600	-14.2600	-1.3687
10	51.6146	16.3854	1.5727
11	61.0125	13.9875	1.3426
12	66.3321	3.6679	0.3521
13	78.7444	-13.7444	-1.3192
14	128.5888	5.4112	0.5194
15	135.4865	4.5135	0.4332
16	142.5792	-8.5792	-0.8235

SUMMARY OUTPUT FAST MINE WARFARE
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Crew Size as A Function Of Displacement

Regression Statistics					
Multiple R	0.475029				
R Square	0.225652				
Adjusted R Square	0.19587				
Standard Error	7.727423				
Observations	28				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	452.4246	452.4246	7.576643	0.010636
Residual	26	1552.54	59.71307		
Total	27	2004.964			

Crew Size as A Function Of Speed

Regression Statistics					
Multiple R	0.169664				
R Square	0.028786				
Adjusted R Square	-0.00857				
Standard Error	8.654144				
Observations	28				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	57.71472	57.71472	0.770617	0.388067
Residual	26	1947.25	74.89421		
Total	27	2004.964			

Crew Size as A Function Of Displacement (Small sample)

Regression Statistics					
Multiple R	0.395988				
R Square	0.156807				
Adjusted R Square	-0.01183				
Standard Error	6.783381				
Observations	7				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	42.78585	42.78585	0.929839	0.379192
Residual	5	230.0713	46.01426		
Total	6	272.8571			

SUMMARY OUTPUT OFFSHORE PATROL VESSEL
(LOGARITHMIC TRANSFORMATION)
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.834325
R Square	0.696099
Adjusted R Square	0.679215
Standard Error	0.420071
Observations	20

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7.275383	7.275383	41.22977	4.81E-06
Residual	18	3.17627	0.176459		
Total	19	10.45165			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.47717	0.612353	-0.77924	0.445965
Ln(Disp)	0.625105	0.097353	6.421041	4.81E-06

RESIDUAL OUTPUT			
Observation	*Predicted Ln(Crew)*	*Residuals*	*Standard Residuals*
1	2.342592	-0.04001	-0.09785
2	2.356182	0.282875	0.691852
3	2.725847	0.046742	0.114321
4	2.850271	-0.21121	-0.51658
5	2.913994	-0.96808	-2.36772
6	2.998841	0.52752	1.290199
7	3.022433	0.02209	0.054027
8	3.18999	-0.09895	-0.242
9	3.191758	0.471804	1.15393
10	3.268125	0.258235	0.631587
11	3.382096	-0.0148	-0.0362
12	3.581163	-0.58543	-1.43184
13	3.607135	0.030451	0.074477
14	3.900482	-0.11629	-0.28443
15	3.967252	0.597096	1.460368
16	4.063174	-0.25651	-0.62737
17	4.102641	-0.0083	-0.02029
18	4.216268	0.165758	0.405409
19	4.222071	0.548614	1.341791
20	4.26252	-0.6516	-1.59368

E. INSHORE PATROL CRAFT SQUADRON ORGANIZATION

Sea Ark Patrol Craft		
	Displacement, tons:	full load
	Dimensions, feet:	34.0 × 12.0 × 2.7
	Speed, knots:	36
	Complement:	6
	Guns:	4-12.7 mm MGs.
	Radars:	Furuno; I-band.
	Picture and data from Jane's Fightinf Ships	

CO
XO
Senior Enlisted
Medical Officer
Intelligence Div Officer
Operations Div Officer
Supply Div Officer
Maintenance Div Officer
9 Trainers

Operational

	Det 1 Boat 1	Det 1 Boat 2	Det 1 Boat 3		Det 2 Boat 1	Det 2 Boat 2	Det 2 Boat 3		Det 3 Boat 1	Det 3 Boat 2	Det 3 Boat 3		Det 4 Boat 1	Det 4 Boat 2	Det 4 Boat 3
	USN crew	Host nation crew	Host nation crew		USN crew	Host nation crew	Host nation crew		USN crew	Host nation crew	Host nation crew		USN crew	Host nation crew	Host nation crew
1	OIC / Sr Rate	OIC U/I	OIC U/I	10	OIC / Sr Rate	OIC U/I	OIC U/I	19	OIC / Sr Rate	OIC U/I	OIC U/I	28	OIC / Sr Rate	OIC U/I	OIC U/I
2	Deck-Senior Rate	Deck-Senior Rate	Deck-Senior Rate	11	Deck-Senior Rate	Deck-Senior Rate	Deck-Senior Rate	20	Deck-Senior Rate	Deck-Senior Rate	Deck-Senior Rate	29	Deck-Senior Rate	Deck-Senior Rate	Deck-Senior Rate
3	Engineer-Sr Rate	Engineer-Jr Rate	Engineer-Jr Rate	12	Engineer-Sr Rate	Engineer-Jr Rate	Engineer-Jr Rate	21	Engineer-Sr Rate	Engineer-Jr Rate	Engineer-Jr Rate	30	Engineer-Sr Rate	Engineer-Jr Rate	Engineer-Jr Rate
4	Engineer-Jr Rate	Engineer-Jr Rate	Engineer-Jr Rate	13	Engineer-Jr Rate	Engineer-Jr Rate	Engineer-Jr Rate	22	Engineer-Jr Rate	Engineer-Jr Rate	Engineer-Jr Rate	31	Engineer-Jr Rate	Engineer-Jr Rate	Engineer-Jr Rate
5	Weapons-Sr Rate	Weapons-Jr Rate	Weapons-Jr Rate	14	Weapons-Sr Rate	Weapons-Jr Rate	Weapons-Jr Rate	23	Weapons-Sr Rate	Weapons-Jr Rate	Weapons-Jr Rate	32	Weapons-Sr Rate	Weapons-Jr Rate	Weapons-Jr Rate
6	Ops-Jr Rate	Ops-Jr Rate	Ops-Jr Rate	15	Ops-Jr Rate	Ops-Jr Rate	Ops-Jr Rate	24	Ops-Jr Rate	Ops-Jr Rate	Ops-Jr Rate	33	Ops-Jr Rate	Ops-Jr Rate	Ops-Jr Rate

	Maintenance				Maintenance				Maintenance				Maintenance		
	Det 1 Boat 1	Det 1 Boat 2	Det 1 Boat 3		Det 2 Boat 1	Det 2 Boat 2	Det 2 Boat 3		Det 3 Boat 1	Det 3 Boat 2	Det 3 Boat 3		Det 4 Boat 1	Det 4 Boat 2	Det 4 Boat 3
	USN	Host nation	Host Nation		USN	Host nation	Host Nation		USN	Host nation	Host Nation		USN	Host nation	Host Nation
7	sr maintainer			16	sr maintainer			25	sr maintainer			34	sr maintainer		
8	Engineer	Engineer	Engineer	17	Engineer	Engineer	Engineer	26	Engineer	Engineer	Engineer	35	Engineer	Engineer	Engineer
9	Weapons	Weapons	Weapons	18	Weapons	Weapons	Weapons	27	Weapons	Weapons	Weapons	36	Weapons	Weapons	Weapons

Boat Unit Crew Critical Skills Implied by rating — 45 Enlisted

Communications	Operations	Administration	Supply	Medical	Engineering-EN	Engineering-HT	Engineering-EM	Engineering-ET	Weapons	Deck
3	4	3	3	3	5	4	4	4	6	6
RM-Sr	OS-Sr	YN-Sr	SK-Sr	Corpman-Sr	EN-Sr	HT-Sr	EM-Sr	ET-Sr	GM-Sr	BM
RM	OS	YN	SK-Sr	Corpman	EN	HT	EM	ET	GM	BM
RM	QM	DP	SK	Corpman	EN	SN	SN	SN	GM	BM
	QM				SN	SN	SN	SN	GM	BM
					SN				SN	SN
									SN	SN

SUMMARY

Operational, working with host nation		In Surge/Reserve/Training status	
7	Officers	7	officers
1	Sr Enlisted	1	Sr Enlisted
24	Sailors	72	sailors
12	Maintenance	36	maintenance
9	Trainers	9	trainers
53	per 12 boat squadron	125	fully manned 12 boat squadron

F. READY RESERVE FORCE SHIPS

From Military Sealift Command Website: www.msc.navy.mil

Type	RRF Ship	Civilian FOS	Civilian ROS	Military
Fast Sealift Ship	ALGOL, SS	42	N/A	12
Fast Sealift Ship	ANTARES, SS	42	N/A	12
Fast Sealift Ship	BELLATRIX, SS	42	N/A	12
Roll-on/Roll-off Ship	ADM WM. M. CALLAGHAN, GTS	25	9	0
Roll-on/Roll-off Ship	CAPE DECISION, MV	27	10	0
Roll-on/Roll-off Ship	CAPE DIAMOND, MV	27	9	0
Roll-on/Roll-off Ship	CAPE DOMINGO, MV	27	9	0
Roll-on/Roll-off Ship	CAPE DOUGLAS, MV	27	9	0
Roll-on/Roll-off Ship	CAPE DUCATO, MV	27	9	0
Roll-on/Roll-off Ship	CAPE EDMONT, MV	27	9	0
Lighter Aboard Ship	CAPE FAREWELL, SS	31	N/A	0
Lighter Aboard Ship	CAPE FLATTERY, SS	31	N/A	0
Modular Cargo Delivery System Ship	CAPE GIBSON, SS	32	9	0
Modular Cargo Delivery System Ship	CAPE GIRARDEAU, SS	32	9	0
Roll-on/Roll-off Ship	CAPE HENRY, MV	28	9	0
Roll-on/Roll-off Ship	CAPE HORN, MV	27	9	0
Roll-on/Roll-off Ship	CAPE HUDSON, MV	27	9	0
Roll-on/Roll-off Ship	CAPE INSCRIPTION, SS	31	9	0
Roll-on/Roll-off Ship	CAPE INTREPID, SS	31	9	0
Roll-on/Roll-off Ship	CAPE ISABEL, SS	31	9	0
Roll-on/Roll-off Ship	CAPE ISLAND, SS	31	9	0
Modular Cargo Delivery System Ship	CAPE JACOB, SS	38	9	0
Roll-on/Roll-off Ship	CAPE KENNEDY, MV	25	9	0
Roll-on/Roll-off Ship	CAPE KNOX, MV	25	9	0
Heavy Lift Ship	CAPE MAY, SS	34	9	0
Heavy Lift Ship	CAPE MOHICAN, SS	36	N/A	0
Roll-on/Roll-off Ship	CAPE ORLANDO, MV	25	9	0
Roll-on/Roll-off Ship	CAPE RACE, MV	29	9	0
Roll-on/Roll-off Ship	CAPE RAY, MV	29	9	0
Roll-on/Roll-off Ship	CAPE RISE, MV	29	9	0
Roll-on/Roll-off Ship	CAPE TAYLOR, MV	27	9	0
Roll-on/Roll-off Ship	CAPE TEXAS, MV	27	9	0
Roll-on/Roll-off Ship	CAPE TRINITY, MV	27	9	0
Roll-on/Roll-off Ship	CAPE VICTORY, MV	25	9	0
Roll-on/Roll-off Ship	CAPE VINCENT, MV	25	9	0
Roll-on/Roll-off Ship	CAPE WASHINGTON, MV	28	9	0
Roll-on/Roll-off Ship	CAPE WRATH, MV	28	9	0
Fast Sealift Ship	CAPELLA, SS	42	N/A	12

Crane Ship	CORNHUSKER STATE, SS	32	9	0
Aviation Maintenance Logistics Ship	CURTISS, SS	40	9	0
Fast Sealift Ship	DENEBOLA, SS	42	N/A	12
Crane Ship	FLICKERTAIL STATE, SS	32	9	0
Crane Ship	GEM STATE, SS	37	9	0
Crane Ship	GOPHER STATE, SS	32	9	0
Crane Ship	GRAND CANYON STATE, SS	37	10	0
Crane Ship	KEYSTONE STATE, SS	37	9	0
Government-owned Tanker	PETERSBURG, SS	38	N/A	0
Fast Sealift Ship	POLLUX, SS	42	N/A	12
Fast Sealift Ship	REGULUS, SS	42	N/A	12
Aviation Maintenance Logistics Ship	WRIGHT, SS	41	9	0
	Avg:	31.92	9.05	1.68

SUMMARY OUTPUT
CREW SIZE AS A FUNCTION OF DISPLACEMENT

Regression Statistics	
Multiple R	0.220435
R Square	0.048592
Adjusted R Square	0.0319
Standard Error	30.64503
Observations	59
CV	0.806448

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2733.945	2733.945	2.911185	0.093411
Residual	57	53529.72	939.1178		
Total	58	56263.66			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	19.96346	11.69948	1.706355	0.093386
Displacement	0.000489	0.000287	1.706219	0.093411

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