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Industrial Assessment Directorate: Impact of the Navy's 30-Year Shipbuilding Plan on the U.S. Industrial Base

Timothy Shives, EdD—is a Department of Defense civil servant in the field of Cyberspace Operations and Information Technology management serving at the Naval Postgraduate School as the Fleet Cyber Command's Liaison Officer and Cyber Warfare Chair. He is also an officer in the United States Marine Corps and has served more than twenty years in both the active duty and reserve components. He holds a Doctor of Education (EdD) and an Education Specialist (EdS) postgraduate degree, an MS in information technology management and an MBA from NPS, and a MA in national security and strategic studies from the U.S. Naval War College and is currently an information science PhD student at NPS.

Johnathan Mun, PhD—is a research professor at the Naval Postgraduate School and teaches master's and doctoral courses as well as executive seminars in quantitative risk analysis, decision sciences, real options, simulation, portfolio optimization, and other related concepts. Mun received his PhD in finance and economics from Lehigh University. He also has an MBA in business administration, an MS in management science, and a BS in biology and physics. He has taught at universities all over the world and is considered a leading world expert on risk analysis/real options analysis with 13 patents and 32 books.

Thomas Housel, PhD—is a tenured, full professor for the Information Sciences (Systems) Department of the U.S. Naval Postgraduate School (NPS). He received his PhD from the University of Utah in 1980. He specializes in valuing intellectual capital, knowledge management, acquisitions research, telecommunications, information technology, value-based business process reengineering, and knowledge value measurement in profit and nonprofit organizations. He has managed a $5Mil+ portfolio of field studies, educational initiatives, and industry relationships. His current research focuses on determining the most promising methodologies for improving the acquisitions life cycle and developing a physics-based model to predict revenue growth in knowledge-intensive companies.

Shelley Gallup, PhD—is a Research Associate Professor within the Information Sciences department at the Naval Postgraduate School (NPS). With a distinguished career spanning both academia and military service, Dr. Gallup brings a wealth of experience and expertise that includes service as a Surface Warfare Officer (SWO) in the U.S. Navy. Dr. Gallup's research interests encompass the intricate domains of knowledge systems, organization development, and research methods applied to complex systems. Dr. Gallup's interdisciplinary background and deep understanding of both military and academic contexts are uniquely positioned to address multifaceted challenges in information sciences.

Abstract

This research aims to thoroughly examine and define critical assumptions within the Defense, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) framework, focusing on the intricate relationships among ship maintenance, force structure, and industrial capacity. The overarching goal is to establish an optimized array of viable options, considering factors such as talent availability, the utilization of smaller industrial plants, and overall costs within the shipbuilding industrial base.

The primary focus is on determining an optimal force structure, particularly in the U.S. Indo-Pacific Command's area of responsibility (AOR), aligning with the directives outlined in the Chief of Naval Operation's Guidance. The study acknowledges the need for a 500-ship, multitiered Navy to effectively meet the challenges posed by peer nation advances, especially in the context of distributed maritime operations.

Recognizing the inherent limitations of the current Navy for distributed maritime operations, this research explores strategic options for integrating smaller ships and autonomous surface and subsurface vessels into the shipbuilding industrial base. The analysis is conducted within the framework of a proposed five-tiered fleet structure, encompassing large combatants, aircraft carriers (CVs), guided-missile destroyers (DDGs), submarine forces, L-class ships, and smaller

lightly manned/unmanned surfaced vessels. The research anticipates that decisions pertaining to force structure will have profound implications on talent management, the efficient use of industrial plants, and overall operational costs within the shipbuilding domain.

In conclusion, this research endeavors to contribute insights into optimizing force structure within the U.S. Indo-Pacific Command's AOR, with a specific emphasis on the shipbuilding industrial base. By addressing the intricate interplay between ship maintenance, force structure, and industrial capacity, the study aims to inform strategic decision-making, aligning force structure with the evolving landscape of naval warfare and ensuring the continued strength and resilience of the shipbuilding industrial base.

Key Terms: force design, force structure, industrial capacity, distributed capabilities, ship maintenance, budget constraints, risk management, national deterrence strategy

Introduction

This section introduces the primary problem statement concerning the United States Navy's (USN) insufficient force structure and shipbuilding infrastructure to effectively combat near-peer competitors. The declining shipbuilding output over the years, as exemplified by the decrease in ship tonnage output from 1977 to 2005 and the reduction in the size of the Navy fleet, underscores the urgency of the situation (Hendrix, 2023, p. 54). Furthermore, reports such as Eric Lipton's article in the New York Times highlight the challenges faced by the Navy in adapting to evolving threats and maintaining operational capabilities (Lipton, 2023).

Problem Statement

The core issue lies in the USN's inability to match the naval capabilities and capacity of adversaries like China and Russia. While historical examples, such as the rapid expansion of shipbuilding capacity during World War II, demonstrate the nation's potential to ramp up production, current constraints hinder similar efforts. Factors contributing to this limitation include the decline in the number of shipyards and the increased cost of naval shipbuilding compared to commercial shipbuilding (Hendrix, 2023, p. 56). Political and economic pressures have also influenced procurement policies, resulting in the production of powerful yet cumbersome warships ill-suited for contemporary challenges (Lipton, 2023). Additionally, the absence of government subsidies for shipbuilding further impedes industrial capacity expansion.

Analysis of Constraints

The reduction in shipbuilding capacity can be traced back to cost-cutting measures in the early 1990s, leading to industry consolidations and decreased availability of shipyards for Navy maintenance and construction (Hendrix, 2023, p. 56). Efforts to increase capacity, such as the unbundling of merged companies like Northrop Grumman and Huntington Ingalls, have shown promise (Hendrix, 2023, p. 56). However, funding challenges persist, with Congress allocating significant resources to conventional shipbuilding programs while neglecting repairs and maintenance (Lipton, 2023).

Current Operational Challenges

The USN's current concept of operations (CONOPS) lacks credibility in deterring potential adversaries like the People's Liberation Army Navy (PLAN) due to insufficient force presence and capability deployment. To address this, the Navy's Chief of Naval Operations (CNO) has outlined a wishlist for new guided missile frigates and unmanned surface and subsurface platforms to enhance operational effectiveness (Hendrix, 2023, p. 57). The potential for unmanned platforms, such as the Lightly Manned Autonomous Combat Capability (LMACC), to fulfill strategic objectives underscores the need for innovative solutions (Hendrix, 2023, p. 57).

Research Objective

The overarching research question aims to determine the optimal force structure necessary for effective deterrence and success in war, considering regional influences, peacetime operations, and grey zone deterrence. Additionally, the study will explore options for integrating unmanned undersea capabilities into naval operations to support mission objectives (Hendrix, 2023, p. 57).

Further Discussion

Force structure decisions are pivotal and must align with national strategy, budgetary constraints, and operational requirements. The study will prioritize these factors to develop a comprehensive understanding of the optimal force structure, informed by critical assumptions and deeper resource analyses into the Defense, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities (DOTMLPF) framework. The deliverables will include a technical report, cost model, options model, and journal article, aiming to enhance multi-domain deterrence and operational resilience in degraded environments.

Literature and Current State

The literature provides insights into the challenges and potential solutions related to the national shipbuilding industrial base, shedding light on various facets of the issue.

National Shipbuilding Industrial Base

Captain Nelson (1986) emphasized the significance of the National Shipbuilding Research Program in supporting the U.S. Navy and the broader industrial base. The shipbuilding industry is recognized as a national asset, necessitating measures to preserve its capabilities (Nelson, 1986).

Decline and Preservation Efforts

The U.S. shipbuilding industry has faced a decline since the mid-19th century, except during wartime production periods. Government interventions, such as enacted laws and programs like the National Shipbuilding Research Program, have aimed to sustain shipbuilding capabilities (U.S. Congress, 1995).

Challenges and Alternatives

Studies have identified the falling rate of Navy construction and lack of commercial demand for large ships as key challenges. Recommendations include integrating commercial and defense bases, exploring export market opportunities, and supporting foreign military sales (U.S. Congress, 1995). However, concerns arise regarding potential threats to national security and the need for policy adjustments to support the shipbuilding industry.

Commercial Shipbuilding and Naval Fleet Affordability

Commercial shipbuilding in the U.S. has been overshadowed by global competition, with the naval fleet facing affordability issues due to high unit costs (Alberto et al., 2005). Recommendations include stabilizing the shipbuilding program, removing funding requirements for ships in the year of authorization, and reviewing laws to strengthen domestic shipbuilding (Alberto et al., 2005).

Capacity and Competitiveness

Concerns about future ship construction orders and the capacity of shipyards have been raised, alongside challenges in competing with the global market. Restructuring the shipbuilding industry, revitalizing commercial shipbuilding, and stabilizing naval build rates are proposed solutions (Alberto et al., 2005).

International Perspectives and Industry Improvements

International counterparts, such as the U.K. Ministry of Defense, emphasize the importance of long-term industrial planning and investment incentives (Arena et al., 2005). Improvements within the industry, including technology advancements and government support, are highlighted to reduce construction costs and enhance competitiveness (Zimmerman et al., 2005).

Recommendations for Industrial Base Enhancement

To boost and maintain the industrial base, recommendations include stabilizing demand, improving acquisition processes, promoting competition, and implementing longer-term funding strategies (Boward et al., 2007). Additionally, the establishment of interagency coordination, centralized management of capital investment, and preservation of shipbuilding intellect are suggested to strengthen the industry (Boward et al., 2007).

U.S. Navy Ship Classes Currently in Service and Plans for the Future

As of June 2023, per the Congressional Research Service, Naval Federal Register, the U.S. Navy's battle-force ships are categorized as follows:

Aircraft Carriers: 11
Surface Combatants: 115
Submarines: 68
Amphibious Warfare Ships: 31
Mine Warfare Ships: 8
Combat Logistics Ships: 29
Fleet Support: 33
Auxiliary Support: 1
Combatant Craft: 0
Other: 0
Total Battle-Force Ships in Inventory: 296
Total Active Ships in Commission: 251

This count includes commissioned ships that may not be battle-ready, such as the USS Constitution, and excludes most combat logistics and fleet support vessels. The Navy's future plans include significant investments in shipbuilding. The proposed FY2024 budget requests $32.8 billion for shipbuilding, aiming to procure nine new ships, including one Columbia class ballistic missile submarine, two Virginia class attack submarines, two Arleigh Burke class destroyers, two Constellation class frigates, one AS(X) submarine tender, and one John Lewis class oiler. Furthermore, the Navy's FY2024 five-year shipbuilding plan outlines the acquisition of a total of 55 ships, averaging 11 ships per year. Sustaining this rate for 35 years would lead to an increase in the Navy's size to 385 ships by the 2060s. These plans reflect the Navy's commitment to modernize and expand its fleet to meet evolving security challenges and maintain a robust presence in maritime domains. For real-time updates on fleet size, the Chief of Naval Operations staff should be contacted.

U.S. Naval Shipyards

Public shipyards in the United States have a long history dating back to the nation's earliest days, primarily operated by the U.S. Navy. At one point, there were 13 public shipyards, but currently, only four remain active. Additionally, eight naval stations, one in the U.S. and seven overseas, possessed shipbuilding capabilities. However, after World War II, the Navy terminated or canceled most new ship construction contracts, resulting in the closure of several shipyards. In 1972, a report revealed that ships built in naval shipyards cost about 30% more than those constructed by private-sector shipbuilders. Consequently, all new ship construction in naval shipyards ceased, and five of the remaining nine yards were closed. Presently, the U.S. Coast Guard maintains its own shipyard in Baltimore, primarily serving as a maintenance facility. While naval shipyards have historically played a significant role in ship construction, their focus has shifted towards maintenance and repair operations rather than new construction.

Table 1. Current Naval Shipyards (Shipbuilding History, n.d.)

Active Public Shipyards (5)					
Shipyard	*Location*	*State*	*Est.*	*Closed*	*Disposition*
Norfolk NSY	Portsmouth	VA	1767		Maintains ships of the Atlantic Fleet
Pearl Harbor NSY	Honolulu	HI	1908		Maintains ships of the Pacific Fleet
Portsmouth NSY	Kittery	ME	1800		Maintains nuclear submarines
Puget Sound NSY	Bremerton	WA	1901		Decommissions nuclear-powered submarines
Coast Guard Yard	Baltimore	MD	1899		Maintains Coast Guard cutters and craft

The Five Public Shipyards

Norfolk Naval Shipyard, Portsmouth, VA

Norfolk Naval Shipyard (NSY), established in 1767, is a critical facility in the shipbuilding landscape of the United States Navy. Located in Portsmouth, Virginia, it is the oldest, most multifaceted, and largest industrial facility within the U.S. Navy. With a workforce of approximately 12,000 military and civilian personnel, NSY plays a vital role in repairing, modernizing, and inactivating ships within the Atlantic Fleet. The shipyard's capabilities include dry-docking, overhauling, and repairing various naval vessels, including submarines and aircraft carriers. Through state-of-the-art technology and a skilled workforce, NSY is known for its ability to tackle complex projects efficiently and within budget constraints.

Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility, Honolulu, HI

Established in 1908, Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility (PHNSY & IMF) is strategically located in Honolulu, Hawaii, providing essential support to the Pacific Fleet. With a mission to repair, maintain, and modernize the fleet, PHNSY & IMF accommodates the largest ships in the Navy, including aircraft carriers and submarines. The shipyard boasts certified graving drydocks capable of servicing various naval vessels, ensuring operational readiness and effectiveness of the fleet. Through ongoing infrastructure improvements, PHNSY & IMF continues to enhance its capabilities to meet evolving maritime needs.

Portsmouth Naval Shipyard, Kittery ME

Portsmouth Naval Shipyard (PNSY), established in 1800, is dedicated to maintaining and modernizing the U.S. Navy's nuclear-powered attack submarines. Located in Kittery, Maine, PNSY employs a civilian workforce of approximately 8,000 professionals, supported by 1,000 officer and enlisted personnel. With a mission to support and defend the Constitution of the United States, PNSY focuses on ensuring the readiness of submarines to engage in missions effectively. The shipyard's expertise in submarine overhaul and repair positions it as a cornerstone in the nation's naval defense strategy.

Puget Sound Naval Shipyard & IMF, Bremerton WA

Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS & IMF), established in 1891, serves as a critical naval asset on the West Coast. Located in Bremerton, Washington, PSNS & IMF maintains, modernizes, and retires the Navy's fleet, encompassing various classes of ships. With six drydocks and extensive pier space, the shipyard provides comprehensive maintenance services, supporting fleet operations across multiple locations. Its strategic location and diverse capabilities contribute significantly to the Navy's operational readiness in the Pacific region.

U.S. Coast Guard Yard, Baltimore MD

The U.S. Coast Guard Yard, established in 1899, serves as the sole shipbuilding and major repair facility for the U.S. Coast Guard. Situated in Baltimore, Maryland, the Yard has a long history of building, repairing, and renovating ships for the Coast Guard. With a focus on quality, cost-effectiveness, and timeliness, the Yard operates as a revolving fund activity, generating annual revenue of approximately $100 million. Its capabilities and commitment to excellence ensure the Coast Guard's fleet remains mission-ready and effective in safeguarding the nation's maritime interests.

Private Shipyards

Private shipyards in the United States are crucial components of the maritime industry, contributing significantly to the nation's economy and defense capabilities. As of the latest data, there are 154 active private shipyards spread across 29 states and the U.S. Virgin Islands. These shipyards are engaged in various activities, including shipbuilding, ship repair, and renovation.

There are two main categories of private shipyards: mid-sized to large shipyards capable of building naval ships, submarines, oceangoing cargo ships, drilling rigs, and high-value, high-complexity mid-sized vessels; and smaller yards capable of building simpler types of commercial vessels such as tugs, towboats, offshore service vessels, fishing vessels, ferries, and barges.

Private shipyards play a vital role in supporting the nation's maritime infrastructure, providing essential services such as building and repairing ships for military, commercial, and governmental purposes. They also contribute significantly to the nation's gross domestic product (GDP), with a reported $42.4 billion in GDP supported by private shipyards in 2019. Additionally, private shipyards provide more than 107,000 direct jobs across the country. For a complete list, please see Appendix B.

Summary of U.S. Builders of Small Vessels

Since World War II, approximately 600 U.S. shipyards have been involved in the construction of smaller types of governmental and commercial vessels. These vessels include patrol craft, research vessels, tugs, towboats, offshore service vessels, fishing vessels, ferries, tour boats, and barges. The shipyards are categorized into four groups:

(1) 15 yards actively building significant numbers of more complex types of small vessels.

(2) 71 yards actively building significant numbers of simpler types of small vessels, such as towboats and inland barges.

(3) 107 yards are active but have only constructed a few boats in recent years.

(4) 195 yards have built a significant number of boats since WWII but are no longer active.

Additionally, there are at least 200 more yards that have constructed governmental and/or commercial boats since WWII, but they are not included in this section due to their smaller size. This summary excludes builders of recreational or other non-commercial boats unless they also produce commercial variations or operate waterfront boatyards. For a complete list, please see Appendix C.

Conclusion

The literature underscores the multifaceted challenges facing the national shipbuilding industrial base and proposes a range of solutions to enhance its resilience and competitiveness in the global market. Implementing these recommendations requires coordinated efforts from government agencies, industry stakeholders, and policymakers to ensure the long-term viability of the shipbuilding sector.

Proposed Methodology

Portfolio Optimization of Ships

Appendix A summarizes the current U.S. Naval fleet (as of June 2023). Additional details for the private sector are available in Appendix B and C. Appendix A summarizes the current ship portfolio of 239 active in-commission vessels, segregated by their ship class. The list is by no means comprehensive but presents the data that is available, such as the number of ships in a specific class, the approximate cost to build, time to build (starting from award dates to keel date, launch date and commission date), length, displacement, personnel (ship's company, air wing, Flag Staff, officers, and enlisted), as well as the ship's armament. The information in the table, as is, would be insufficient in building a portfolio optimization model, but with further refinement, optimization can be run. The following section provides some notional datasets and formulation that can be helpful and used to run the portfolio optimization.

Suppose that for each (i) of the different classes (C_i) of Navy ships (e.g., nuclear carriers, guided missile cruisers, guided missile destroyers, ballistic missile submarines, littoral combat ships), there are (j) different characteristics (x) such as tonnage (displacement), length, sailors (officers and enlisted), armaments (e.g., number of CIWS, RAM, guns, launch bays, missiles, torpedoes), and so forth, where we have

$$C_i(x_{i,1}, x_{i,2}, \dots x_{i,n}) \text{ or } C_i(x_{i,j}) \in \mathbb{R} \qquad \forall\, i \in I \text{ and } \forall\, j \in J.$$

Also, each class of ship has a probability distribution of cost to acquire, build, and maintain over time (ϕ_t). And from various stakeholders' points of view, we have an estimated military value (v). These values are a function of mission use (y) such as command ships, joint carriers, mine countermeasure, tenders, joint high-speed vessels, sea fighters, submersibles, surveillance, and so forth, such that we have

$$v_i(y_{i,1}, y_{i,2}, \dots y_{i,m}) \text{ or } v_i(y_{i,m}) \in \mathbb{R} \quad \forall\, m \in M.$$

The portfolio optimization is to hence

$$Max_{\ j,k} \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} C_i(x_{i,j}) v_i(y_{i,k})$$

$$s.t. \sum_{i \in I} \phi_{i,t} C_i \leq \ \Phi_{i,t}$$

$$s.t. \sum_{i \in I} x_i \geq \ \mathbf{X}$$

$$s.t. \sum_{i \in I} y_i \geq \ \mathbf{Y}$$

In simple terms, the portfolio is optimized multiple times, each time with respect to each stakeholder's point of view for strategic value, mapped against their characteristics for all ship classes in the portfolio. The objective function can also be a weighted average of all the various strategic value points of view. The typical constraints will be to optimize the portfolio subject to the time series cost cash outflow based on a total ownership cost from the cradle to the grave (throughout the acquisition process, build phase, commission, operations and maintenance, upgrades, and disposition) throughout its life cycle, to be under the projected total shipbuilding and ship maintenance budget. In addition, the portfolio will be optimized to exceed the minimal total characteristic requirements of all the ships in total (e.g., the total number of ships, the total number of missiles, the total number of planes, the total number of sailors, all the ships can carry must exceed a certain minimum threshold), or the various mission types (e.g., there must be at least 12 carriers, 85 guided missile destroyers) to be at the ready by the year 2030 and operational for the next 35 years.

Several types of algorithms have been created throughout the years to find the answers to optimization problems, ranging from basic linear optimization utilizing the simplex model to solving first partial differential equations in order to be thorough and inclusive. When more complicated real-world situations are imagined, however, these fundamental methods tend to fail, necessitating the use of more powerful algorithms. We used a combination of evolutionary algorithms, Lagrange multipliers, and taboo-based reduced gradient search approaches to solving our efficient frontier problem.

The Lagrange multiplier solution assumes a nonlinear issue of some kind.

$$\min or \max f(x)$$

$$s.t. \quad g_i(x) = \ b_i \ \ \forall \ i = 1, \ldots, m$$

where equality is often replaced by some inequality values indicating a ceiling or floor constraint (Mun, 2015).

From this functional form, we first derive the Lagrange multiplier v for all i values:

$$L(x, v) \triangleq f(x) + \sum_{i=1}^{m} v_i[b_i - g_i(x)]$$

$$s.t. constraints \ g_i(x) = b_1, \ldots, g_m(x) = b_m$$

The solution (x*, v*) is a set of points along the Lagrange function *L(x,v)* if it satisfies the condition:

$$\sum_i \nabla g_i(x^*)v^* = f(x^*)\ which\ requires\ \sum_i \frac{\partial g_i}{\partial x_j} v_i = \frac{\partial f}{\partial x_j} \forall j\ and\ \ g_i(x^*) = b_i$$

This method is straightforward and elegant, but it is confined to linear and quasi-linear functional forms of *f*, as well as some simple nonlinear functional forms (*x*). We need to add constraints to the solution set and use search techniques to cover a vast (and frequently infinite) set of optimal allocations in order to expand the functional form to generalized nonlinear applications. One restriction is that where nonlinear problems have a differentiable generic form, the Kuhn-Tucker condition must be satisfied:

$$\min or \max f(x)$$

$$s.t. \quad g_i(x) \geq\ b_i\ \ \forall\ i \in Feasible\ Set$$

$$g_i(x) \leq\ b_i\ \ \forall\ i \in Feasible\ Set$$

$$g_i(x) =\ b_i\ \ \forall\ i \in Feasible\ Set$$

And the inequality constraints will need to be active at a local optimum or when the Lagrange variable is set to null:

$$v_i[b_i - g_i(x)] = 0$$

In addition, mathematical algorithms for both ad-hoc and systematic searches of the optimal solution set will need to be developed. Even a supercomputer would take close to an unlimited number of years to outline all potential permutations using an enumeration method. As a result, search algorithms are frequently used in the optimization of an efficient frontier. The use of a reduced gradient search method is one basic method. To recap our strategy, we suppose

$$\nabla f(x) \cdot \Delta x$$

Where the functional form *f(x)* is the objective function and is divided into two parts, a basic (*B*) and a nonbasic portion (*N*) that is multiplied by the change in vector direction *x*. Using a Taylor expansion, we obtain

$$\begin{aligned}\nabla f(x) \cdot \Delta x &= \nabla f(x)^B \cdot \Delta x^B + \nabla f(x)^N \cdot \Delta x^N \\ &= \nabla f(x)^B \cdot (-B^{-1} N \Delta x^N) + \nabla f(x)^N \cdot \Delta x^N \\ &= (\nabla f(x)^N - \nabla f(x)^B B^{-1} N) \Delta x^N\end{aligned}$$

The reduced gradient with respect to the solution matrix B is

$$r \triangleq (r^B, r^N)$$

where

$$r^B \triangleq 0$$
$$r^N \triangleq \nabla f(x)^N - \nabla f(x)^B B^{-1} N$$

When the number of decision variables is modest (usually less than four or five), a manual solution is doable; but, when the number of decision variables is big, as it is in most real-life situations, a manual solution is intractable, and computer search algorithms must be used. The following are the stages used in the general method:

1. Estimate a good set of starting points.
2. Continue estimating sample test points and the direction of the reduced gradient vector.
3. Test for feasibilities of constraints at extreme limits.

4. Solve the Lagrange optimal set.
5. Generate a new set of starting points.
6. Change the basis set if a better set of points is obtained or stop optimization.
7. Repeat iteration and advance or stop when the tolerance level is achieved.

Apart from purely financial and economic values, and strategic values, we can also apply operational, logistic, and other values that can be constructed and used in the prescribed modeling approaches as discussed in this report. The following provides some examples of alternative value metrics. These metrics can be applied in future and subsequent research with actual data collected.

Operational and Logistics

- **Inherent Availability** (IA). Measures operational percentage in an ideal support environment per design specifications.

$$IA = \frac{MTBF}{MTBF+MTTR}$$

- **Effective Availability** (EA). Probability a ship's system is available at any instant during the maximum operational period, accounting for all critical failures, reparable and nonrepairable at sea, and preventive maintenance.

$$EA = 1 - \frac{MTTR}{MTBF+MTTR} - \frac{MDT}{MT} - 0.5\frac{MT}{MTTF}$$

- **Mission Reliability** (MR). Operational Ready Rate (ORR) at the start of a mission compared to its Inherent Reliability (IR).

$$MR = ORR * IR$$

- **Operational Dependability** (OD). Probability a system can be used to perform a specified mission when desired.

$$OD = \frac{MTTF}{MTBF}$$

- **Mean Down Time** (MDT), **Mean Maintenance Time** (MMT), **Logistics Delay Time** (LDT), and their combinations.
- **Achieved Availability** (AA), **Operational Availability** (OA), and **Mission Availability** (MA)

Alternative Financial and Economic

- **Cost Deterrence and Avoidance**. Soft or shadow revenue (cost savings) over the economic and operational life of the program or system. Milestones A, B, C.
- Traditional Financial Metrics. **Net Present Value** (NPV), **Internal Rate of Return** (IRR), **Return on Investment** (ROI), and other metrics, as long as there are financial and monetary values.
- **Budget Constraint**. FY Budget limitations and probabilities of budgetary overruns.
- **Total Ownership Cost** (TOC) and **Total Life Cycle Cost** (TLC). Accounting for the cost of developing, producing, deploying, maintaining, operating, and disposing of a system over its entire lifespan. Uses **Work Breakout Structures** (WBS), **Cost Estimating Categories** (CEC), and **Cost Element Structures** (CES).

- **Knowledge Value Added** (KVA). **Monetizing Learning Time**, **Number of Times Executed**, **Automation**, **Training Time**, and **Knowledge Content**.
- **Strategic and Capability.** Multiple value metrics can be determined by subject matter experts (SME), including:
    - **Expected Military Value**
    - **Strategic Value**
    - **Future Weapon Strategy**
- **Capability Measures** (CM). Difficult to quantify and needs SME judgment:
    - Innovation Index, Conversion Capability, Ability to Meet Future Threats
    - Force Structure (size/units), Modernization (technical sophistication), Combat Readiness, Sustainability
    - Future Readiness (ability to meet evolving threats, ability to integrate future weapons systems)
- **Domain Capabilities** (DC)
    - Portfolios are divided into different domains, and each domain is optimized separately and then combined at the enterprise level and re-optimized; example domains include Coastal Defense, Anti-Air Surface Warfare, Anti-Surface Warfare, Anti-Submarine Warfare, Naval Strike, Multi-Mission Air Control, Sea Control, Deep Strike, Missile Defense, and so on.
    - Constraints can be added whereby each domain needs to have a minimum amount of capability or systems, and within each domain, different "value" parameters can be utilized.

Conclusion, Limitations, and Future Research

This research has delved into the intricate relationships among ship maintenance, force structure, and industrial capacity, aiming to establish a potential optimization portfolio of ships. Strategic options, such as prioritizing the construction of numerous smaller vessels over a few large ships, have been identified, emphasizing the significant impact on talent availability, industrial plant utilization, and overall costs. The primary objective was to analyze force structure options, particularly in the Indo-Pacific region, aligning with directives from the Chief of Naval Operations and advocating for a 500-ship, multitiered Navy. Recognizing the evolving challenges posed by peer nation advances, an optimal force structure must encompass sufficient variety in distributed capabilities while considering budgetary constraints, risk management, national deterrence strategy, and operational requirements.

Portfolio optimization of ships offers a systematic approach, considering various Department of Defense stakeholders' strategic viewpoints and ship characteristics across all classes. The objective function may entail a weighted average of strategic values, while constraints ensure the portfolio remains within budgetary limits and meets operational requirements throughout the ship's life cycle.

Acknowledging the limitations of the current Navy for distributed maritime operations, the research advocates for the integration of smaller ships and autonomous vessels into the fleet, rather than moving away from traditional naval structures. Also, in the case of this research, the primary limitation of the study was the inability to collect the complete dataset required to run the optimization methods to effectively assess the shipbuilding industry. Despite efforts to gather comprehensive data, certain variables or parameters were missing in publicly available data and thereby may have been missing or unavailable, hindering the accuracy and robustness of the analysis if it were to be run. This is because this study's scope was restricted by factors such as time constraints, resource limitations, or access constraints to certain data sources. Consequently, the research may not have fully captured all relevant aspects or dimensions of the shipbuilding industry, potentially affecting the comprehensiveness of the findings. Future research should acknowledge and address the limitations encountered in data collection, emphasizing the challenges and constraints faced in obtaining a complete dataset for optimization methods.

In conclusion, the research provides insights into optimizing force structure and shipbuilding within the context of evolving naval warfare. By addressing the complexities of ship maintenance, force composition, and industrial capacity, strategic decision-making can be informed to ensure the Navy's readiness and effectiveness in meeting future challenges.

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Appendix A: Current State of the U.S. Naval Fleet (Updated June 2023)

CLASS	COUNT	COST TO BUILD	BUILD TIME	LENGTH	DISPLACE-MENT	PERSONNEL	ARMAMENT
CVN 68 (nuclear-powered multipurpose aircraft carrier)	10	*USS George H. W. Bush* (hull CVN 77; commissioned 2009) $6.3 billion	(*USS Nimitz* award date: 1967, keel date: 1968, launch date: 1972, commissioned: 1975) (*USS George H.W. Bush* award date: 2001, keel date: 2003, launch date: 2006, commissioned: 2009)	1,092 ft.	approx. 100,000 tons	ship's company: 3,200 air wing: 2,480 other: 500	4 Sea Sparrow launchers 3 Phalanx CIWS 20mm mounts [Nimitz & Ike] 4 Phalanx CIWS 20mm mounts [Vinson and later]
CVN 78 (nuclear-powered multipurpose aircraft carrier	1	*USS Gerald R. Ford* (hull CVN 78; commissioned 2017) $13.3 billion	(*USS Gerald R. Ford* award date: 2008, keel date: 2009, launch date: 2013, commissioned: 2017	1,092 ft.	approx. 100,000 tons	crew: 2,500 to 2,700 aircrew [approx.]: 2,480 Flag Staff: 70	Evolved Sea Sparrow Missile Rolling Airframe Missile Phalanx CIWS
CG 47 (guided missile cruiser)	17	*USS Cape St. George* (hull CG 71; commissioned 1993) approx. $1 billion	(*USS Cape St. George* award date: 1988, keel date: 1990, launch date: 1992, commissioned: 1993)	567 ft.	9,992 tons	30 officers 300 enlisted	MK41 vertical launching system Standard Missile (MR) Vertical Launch ASROC (VLA) Missile Tomahawk Cruise Missile 6 MK 46 torpedoes (from two triple mounts) 2 MK 45 5-inch/54 caliber lightweight guns

							2 Phalanx close-in-weapons systems
DDG 51 (guided missile destroyer)	70	currently, about $2.2 billion (from *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress*—Updated March 27, 2023)	(*USS Frank E. Petersen Jr.* award date: 2013, keel date: 2017, launch date: 2018, commissioned: 2022)	Flights I & II DDG 51-78: 505 ft or 153.92 m Flight IIA and III (DDG 79 AF): 509 1/2 feet (155.29 meters)	8,230 - 9,700 Ltons	Flight IIA: 329 Total (32 Officers, 27 CPOs, 270 Enlisted) Flight III: 359 Total (41Officers, 27 CPOs, 291 Enlisted)	Standard Missile Family Vertical Launch ASROC (VLA) missiles. Tomahawk 6 MK-46 torpedoes (from two triple tube mounts) Close In Weapon System (CIWS). 5-in. MK 45 Gun Evolved Sea Sparrow Missile (ESSM)
DDG 1000 (guided missile destroyer)	1	*USS Zumwalt* (com-missioned 2016) $4.4 billion	(*USS Zumwalt* award date: 2008, keel date: 2011, launch date: 2013, commissioned: 2016)	610 ft.	15,761 tons	197	80 advanced Peripheral Vertical Launch (PVLS) cells for Tomahawk, Evolved Sea Sparrow Missile (ESSM), Standard Missiles, and Vertical Launch Anti-Submarine Rockets (ASROC) (VLA) Two 30mm Close-in Guns Systems (CIGS)
LCS (littoral combat ship; two variants: Freedom & Independence)	24	approx. $500 million	(*USS Santa Barbara* award date: 2913, keel date: 2020, launch	388 ft.; 422 ft.	3,410 tons; 3,228 tons	ship's company: 40 mission crew: 35	1 - BAE Systems Mk 110 57 mm gun 4 - .50 cal (12.7 mm) guns (2 aft, 2 forward)

			date: 2021, commissioned: 2023)				1 - 11 cell Raytheon SeaRAM CIWS Other weapons as part of mission modules
SSBN 726 (ballistic missile sub, nuclear powered)	14	about $2 billion (the late 1990s)	(*USS Louisiana* hull 743; award date: 1990, keel date: 1992, launch date: 1996, commissioned: 1997)	560 ft.	16,764 surfaced 18,750 tons submerged	15 Officers 140 Enlisted	20 missile tubes (Trident II D5) 4 torpedo tubes (MK48 torpedoes)
SSGN 726 (guided missile sub, nuclear powered)	4	Estimated in 2008 at about $1 billion (including R&D and procurement)	(*USS Georgia* hull 729; award date: 1976, keel date: keel date: 1979, launch date: 1982, commissioned: 1984)	560 ft.	16,764 tons (17,033.03 metric tons) surfaced 18,750 tons (19,000. 1 metric ton) submerged	15 Officers 144 Enlisted	Up to 154 Tomahawk missiles 4 torpedo tubes (Mk48 torpedoes)
SSN 21 (Seawolf-class sub, nuclear-powered)	3	*USS Jimmy Carter* (commissioned 2005) $3.5 billion	(*USS Jimmy Carter* award date: 1996, keel date: 1995, launch date: 2004, commissioned: 2005)	453 ft.	9,138 tons (9,284 metric tons) submerged	14 officers 126 enlisted	Tomahawk missiles 8 torpedo tubes (MK48 torpedoes)
SSN 688 (Los Angeles class sub, nuclear powered)	26	*USS Cheyenne* (com-missioned 1996) approx. $900 million	(*USS Cheyenne* hull 773; award date: 1989, keel date: 1992, launch date: 1995, commissioned: 1996)	360 ft.	Approximately 6,900 tons (7011 metric tons) submerged	16 officers 127 enlisted	Tomahawk missiles VLS tubes (SSN 719 and later) 4 torpedo tubes (MK 48 torpedoes)

SSN 774 (Virginia class sub, nuclear powered)	21	*USS Montana* (com-missioned 2022) $2.7 billion	(*USS Montana* hull SSN 794; award date: 2014, keel date: 2018, launch date: 2021, commissioned: 2022)	377 ft. or 114.8 m and 461 ft. or 140.5 m with VPM	Approximately 7,800 tons (7,925 metric tons) submerged 10,200 tons (10,363.7 metric tons) with VPM	15 officers 117 enlisted	Tomahawk missiles, twelve VLS tubes (SSNs 774-783) or two VPTs (SSNs 784 and beyond, and four additional payload tubes (SSNs 803 and beyond) 4 torpedo tubes (Mk 48 ADCAP torpedoes)
LHA 6 (amphibious assault ship, general purpose)	2	*USS Tripoli* (commis-sioned 2020) $3.3 billion	(*USS Tripoli* hull LHA7; award date: 2012, keel date: 2014, launch date: 2017, commissioned: 2020)	844 ft.	4,4971 tons	1,059 (65 officers)	2 - Mk-29 NATO Evolved Sea Sparrow launchers 2 - MK49 Rolling Airframe Missile [RAM] 3 - 20mm Phalanx CIWS mounts 7 - .50 cal. machine guns
LHD 1 (amphibious assault ship, multipurpose)	7	approx. $822 million	(USS Makin Island hull LHD 8; award date: 2002, keel date: 2004, launch date: 2006, commissioned: 2009)	847 ft.	41,684 tons	73 officers 1,009 enlisted	2 - MK29 launchers for NATO Sea Sparrow 3 - MK15 20mm Phalanx CIWS mounts 8 - MK33 .50 cal. machine guns
LPD 17 (amphibious transport dock)	12	approx. $2 billion	(*USS Fort Lauderdale* hull LPD 28; award date: 2016, keel date: 2017, launch date: 2020, commissioned: 2022)	684 ft.	Approximately 24,900 long tons (25,300 metric tons) full load	383 Sailors 3 Marines	Two Mk 46 30 mm Close in Guns, fore and aft two Rolling Airframe Missile launchers, fore and aft ten .50 caliber machine guns
LSD 41 (dock landing ship)	6	(*USS Ashland* [see next column]) $149 million	(*USS Ashland* hull LSD 48; award date: 1985. keel date: 1988, launch date: 1989,	609 ft.	15,939 tons (16,194.79 metric tons) full load	22 officers 391 enlisted	Two 25mm MK 38 Machine Guns Two 20mm Phalanx CIWS mounts Six .50 cal. machine guns

			commissioned: 1992)				two Rolling Airframe Missile (RAM) mounts
LSD 49 (dock landing ship)	4	(*USS Oak Hill* hull LSD 51; award date: 1991, keel date: 1992, launch date: 1994, commissioned: 1996) about $135 million	(*USS Pearl Harbor* hull LSD 52; award date: 1993, keel date: 1995, launch date: 1996, commissioned: 1998)	609 ft.	16,708 tons (16,976.13 metric tons) full load	22 officers 397 enlisted	Two 25mm MK 38 Machine Guns Two 20mm Phalanx CIWS mounts Six .50 cal. machine guns two Rolling Airframe Missile (RAM) mounts
MCM 1 (mine counter- measures ship)	8	[unable to find in a reasonable amount of time spent searching]	(*USS Chief* hull MCM 14; award date: 1989, keel date: 1991, launch date: 1993, commissioned: 1994)	224 ft.	1,372 tons	8 officers, 76 enlisted	Mine neutralization system Two .50 caliber machine gun two M60.7 62 mm machine guns two MK19 grenade launchers
AS 39 (submarine tender)	2	[unable to find in a reasonable amount of time spent searching]	(*USS Frank Cable* hull AS 40; award date: 1974, keel date: 1976, launch date: 1978, commissioned: 1979)	644 ft.	approximately 23,000 tons (23,865.02 metric tons) full load	292 officers and enlisted, 158 CIVMARs Frank Cable [hull AS40]: 206 officers and enlisted, 158 CIVMARs	Four 25mm Mk38 guns
ESB 3 (expeditionary sea base)	3	(*USS Miguel Keith* [see next column]) $525 million	(*USS Miguel Keith* hull ESB 5; award date: 2016, keel date: 1/30/2018, launch date: 8/10/2018, commissioned: 2021	785 ft.	90,000 tons (fully loaded)	44 Military Sealift Command personnel	None

LCC 19 (command ship)	2	[unable to find in a reasonable amount of time spent searching]	(*USS Mount Whitney* hull LCC 20; award date: 1966, keel date: 1969, launch date: 1970, commissioned: 1971)	634 ft.	18,874 tons (19,176.89 metric tons) full load	34 officers 564 enlisted	2 Phalanx CIWS 2 - 25mm Mk38 guns
CONSTITUTION	1	not applicable?	*USS Constitution*; award date: 3/1/1794, keel date: 11/1/1794, launch date: 1797, commissioned: 1797)	204 ft.	2,200 tons		Currently, a museum ship stationed at Boston Harbor
AGER 2 (environmental research ship)	1	converted cargo ship; not applicable?	(*USS Pueblo* hull AGER 2; award date: ?, keel date: ?, launch date: 1944, commissioned: 1967)	177 ft.	895 tons		Captured by North Korea in the Vietnam War era, now a museum/tourist attraction there
Total Active In-Commission	239						

Appendix B: US Private Shipyards – Major Shipbuilding and Repair Base Overview

EAST COAST

Active Shipbuilding Yards (4)
Bath Iron Works Corporation - Bath, ME
Electric Boat Corporation - Groton, CT
Kvaerner Philadelphia Shipyard, Inc. - Philadelphia, PA
Northrop Grumman Newport News - Newport News, VA

Other Shipyards with Building Positions (1)
Atlantic Dry Dock Corporation - Jacksonville, FL

Repair Yards with Drydock Facilities (12)
Bayonne Dry Dock & Repair Corporation - Bayonne, NJ
Boston Ship Repair, Inc. - Boston, MA
Caddell Dry Dock & Repair Company, Inc. - Staten Island, NY
Colonna's Shipyard, Inc. - Norfolk, VA
Detyens Shipyards, Inc., Main Yard - North Charleston, SC
Detyens Shipyards, Inc., Wando Division - Mt. Pleasant, SC
GMD Shipyard Corporation - Brooklyn, NY
Metro Machine Corporation - Norfolk, VA
Metro Machine Corporation - Philadelphia Division - Philadelphia, PA
Norfolk Shipbuilding & Drydock Corporation, - Norfolk, VA
North Florida Shipyard, Inc. - Jacksonville, FL

SPEEDE Shipyard, LLC - Norfolk, VA

Topside Repair Yards (12)
Associated Naval Architects, Inc. - Portsmouth, VA
Kerney Service Group, Inc. - Norfolk, VA
Marine Hydraulics International, Inc. - Norfolk, VA
Metal Trades, Inc. - N. Charleston, SC
Moon Engineering Company, Inc. - Portsmouth, VA
Newport Shipyard Company, LLC - Newport, RI
Norfolk Shiprepair & Drydock Corporation - Norfolk, VA
Promet Marine Services Corporation - Providence, RI

Topside Repair Yards (12)
Reynolds Shipyard Corporation - Staten Island, NY
Steel Style, Inc. - Newburgh, NY
The General Ship Repair Corporation - Baltimore, MD
The Hinckley Company - Portsmouth, RI

EAST COAST TOTAL = 29 Yards

GULF COAST

Active Shipbuilding Yards (4)
Bender Shipbuilding and Repair Company, Inc. - Mobile, AL
Northrop Grumman Ship Systems, Avondale Operations - Avondale, LA
Northrop Grumman Ship Systems, Ingalls Operations - Pascagoula, MS
VT - Halter Marine Pascagoula - Pascagoula, MS

Other Shipyards with Building Positions (7)
Alabama Shipyard - Mobile, AL
AMFELS, Inc. - Brownsville, TX
Austal USA - Mobile, AL
Signal International, LLC - East Yard - Pascagoula, MS
Tampa Bay Shipbuilding & Repair Company - Tampa, FL
United Marine Enterprise, Inc., Port Arthur Shipyard - Beaumont, TX
VT - Halter Moss Point - Moss Point, MS

Repair Yards with Drydock Facilities (6)
Atlantic Marine - Mobile - Mobile, AL
Bollinger Gulf Repair, LLC - New Orleans, LA
Bollinger Houston, L.P. - Houston, TX
Gulf Marine Repair Corporation - Tampa, FL
International Ship Repair & Marine Services, Inc. - Tampa, FL
Signal International Texas, LP - D.O.C. Yard - Port Arthur, TX

Topside Repair Yards (17)
Boland Marine & Mfg. Company, Inc. - New Orleans, LA
Bollinger Algiers, LLC - New Orleans, LA
Bollinger Calcasieu, LLC - Sulphur, LA
Bollinger Lockport, LLC - Lockport, LA
Bollinger Texas City, L.P. - Texas City, TX
Buck Kreihs Company, Inc. - New Orleans, LA
CBH Services, Inc. - Orange, TX
Dixie Machine Welding & Metal Works, Inc. - New Orleans, LA
Gulf Copper & Manufacturing Corporation - Port Arthur, TX
Hendry Corporation - Tampa, FL
Houston Ship Repair, Inc., Brady Island Ship Repair Facility - Houston, TX
Newpark Shipbuilding & Repair, Inc., Brady Island Inc. - Houston, TX
Newpark Shipbuilding & Repair, Inc., Pasadena - Pasadena, TX

Newpark Shipbuilding & Repair, Inc., Pelican Island Inc. - Galveston, TX
Orange Shipbuilding Company, Inc. - Orange, TX
Sabine Shipyard, Inc. - Sabine Pass, TX
Signal International Texas, LP - Orange Yard - Orange, TX

GULF COAST TOTAL = 34 Yards

WEST COAST

Active Shipbuilding Yards (1)
National Steel and Shipbuilding Company - San Diego, CA

Other Shipyards with Building Positions (2)
Gunderson, Inc. - Portland, OR
Todd Pacific Shipyards Corporation - Seattle, WA

Repair Yards with Drydock Facilities (7)
Cascade General, Inc. - Portland, OR
Lake Union Drydock Company - Seattle, WA
MAR COM, Inc. - Portland, OR
Puglia Engineering, Inc. dba Fairhaven Shipyard - Bellingham, WA
San Francisco Drydock, Inc. - San Francisco, CA
Southwest Marine, Inc., San Diego Division - San Diego, CA
Southwest Marine, Inc., San Pedro Division - Terminal Island, CA

Topside Repair Yards (6)
Bay Ship & Yacht Company, Alameda - Alameda, CA
Bay Ship & Yacht Company, Richmond - Alameda, CA
Continental Maritime of San Diego, Inc. - San Diego, CA
Dakota Creek Industries, Inc. - Anacortes, WA
Everett Shipyard, Inc. - Everett, WA
Foss Shipyard dba Foss Maritime Company - Seattle, WA

WEST COAST TOTAL = 16 Yards

GREAT LAKES

Other Shipyards with Building Positions (5)
Bay Shipbuilding Company - Sturgeon Bay, WI
Fraser Shipyards, Inc. - Superior, WI
Marinette Marine Corporation - Marinette, WI
Metro Machine Corporation - Industrial Products Division - Erie, PA
Toledo Ship Repair Company, - Toledo, OH

Topside Repair Yards (2)
H. Hansen Industries - Toledo, OH
Nicholson Terminal & Dock Company - River Rouge, MI
GREAT LAKES TOTAL = 7 Yards

NON-CONUS
Repair Yards with Drydock Facilities (3)
Alaska Ship & Drydock, Inc. - Ketchikan, AK
Honolulu Shipyard, Inc. - Honolulu, HI
Marisco, Ltd. - Kapolei, HI
NON-CONUS TOTAL = 3 Yards

Appendix C: U.S. Builders of Small Vessels

Source: Dun & Bradstreet. (n.d.).

Group A - Major Active Builders of Complex Small Vessels (15)				
#	*Builder*	*Builder Since*	*Location*	*State*
1	All American Marine	1987	Bellingham	WA
2	Blount Boats	1949	Warren	RI
3	C. & C. Marine and Repair	1997	Belle Chasse	LA
4	Chesapeake Shipbuilding	1980	Salisbury	MD
5	Conrad Industries	1948	Morgan City/Amelia	LA
6	Dakota Creek Industries	1977	Anacortes	WA
7	Eastern Shipbuilding	1976	Panama City	FL
8	Gladding-Hearn Shipbuilding	1955	South Somerset	MA
9	Gunderson Marine	1944	Portland	OR
10	Master Boat Builders	1977	Coden	AL
11	Metal Shark Boats	1983	Franklin	LA
12	Nichols Bros. Boatbuilders	1964	Freeland	WA
13	Swiftships (inc. Sewart Seacraft)	1942	Morgan City	LA
14	Textron Marine Systems	1978	New Orleans	LA
15	Washburn & Doughty	1966	East Boothbay	ME
Group B - Other Active Builders of Small Vessels (71)				
#	*Builder*	*Builder Since*	*Location*	*State*
1	Aluma Marine	2004	Harvey	LA
2	Arcosa Ashland City (formerly Nashville Bridge, Trinity Ashland City)	1977	Ashland City	TN
3	Arcosa Caruthersville (formerly Caruthersville SY, Trinity Caruthersville)	1950s	Caruthersville	MO
4	Bay Welding	1974	Homer	AK
5	Blackwell Boat Works	1988	Wanchese	NC
6	Blakely Boat Works (formerly C. & G. Boat Works)	2001	Mobile	AL
7	John Bludworth Shipyard	1998	Corpus Christi	TX
8	Bourg Dry Dock (inc. Leboeuf Bros. Towing)	1975	Bourg	LA
9	Breaux Bros. Enterprises	1983	Loreauville	LA
10	Breaux's Bay Craft		Loreauville	LA
11	Brix Marine (formerly Armstrong Marine)	2002	Port Angeles	WA
12	Cooper Marine	1984	Saint Petersburg	FL
13	Corinthian Catamarans	1984	Tarpon Springs	FL
14	Corn Island Shipyard	1990	Lamar	IN
15	Duckworth Steel Boats	1972	Tarpon Springs	FL
16	Eagle Fabrication	2003	Sauget	IL
17	Eymard & Sons Shipyard	1972	Harvey	LA
18	Gold Coast Yachts	1983	St. Croix	VI
19	Gulf Craft	1965	Franklin	LA
20	Halimar Shipyard	2002	Morgan City	LA
21	Hansen Boat Company	1927	Everett	WA
22	Heartland Fabrication 1938-2003 (formerly Hillman Barge)	1938	Brownsville	PA
23	Heartland Fabrication 2004-present (formerly Brownsville Marine)	2006		
24	Hope Services	1990	Dulac	LA

25	Inland Boat Works (IBW)		Orange/Bridge City	TX
26	Intracoastal Iron Works		Bourg	LA
27	JamesBuilt	2007	Paducah	KY
28	Jemison Marine & Shipbuilding	1996	Bayou La Batre	AL
29	Main Iron Works	1947	Houma	LA
30	Marine Group Boat Works (formerly South Bay Multihulls and Knight & Carver)	1977	San Diego	CA
31	Marine Inland Fabricators (also known as Sisco)	1988	Panama City	FL
32	Master Marine	1961	Bayou La Batre	AL
33	Mavrik Marine	2010	La Conner	WA
34	Metal Shark Alabama (formerly Horizon SB)		Bayou La Batre	AL
35	Metalcraft Marine	1987	Cape Vincent	NY
36	Midship Marine	1989	Harvey	LA
37	Mobro Marine	1992	Green Cove Springs	FL
38	Moe Enterprises, Howard (formerly Little Hoquiam SY)	1967	Hoquiam	WA
39	Moose Boats	2003	Petaluma	CA
40	Newton Boats	1982	Slidell	LA
41	Orange Shipbuilding (division of Conrad Industries)	1974	Orange	TX
42	Patti Marine Enterprises	1977	Pensacola	FL
43	Progressive Industrial		Palmetto	FL
44	Rodriguez Boatbuilding	1976	Coden	AL
45	Rodriguez Boatbuilding	1976	Bayou La Batre	AL
46	Rozema Boat Works	1955	Mount Vernon	WA
47	SanJac Marine (formerly Sneed SB Channelview)	2000	Channelview	TX
48	Scarano Boat Building	1974	Albany	NY
49	Scarborough Boat Works	1977	Wanchese	NC
50	SENESCO	1999	North Kingstown	RI
51	Serodino	1954	Guild	TN
52	Sneed Shipbuilding	1964	Orange	TX
53	Southwest Shipbuilding (formerly Todd Galveston Fab. Shop)		Galveston	TX
54	Southwest Shipbuilding (formerly three Brady Island yards)		Houston	TX
55	Spencer Yachts	1996	Wanchese	NC
56	St. Johns Shipbuilding (formerly Offshore SB)	1970	Palatka	FL
57	Steiner Construction	2005	Bayou La Batre	AL
58	Steiner Shipyard	1954	Bayou La Batre	AL
59	Sterling Shipyard	2009	Port Neches	TX
60	Thoma-Sea Marine (formerly Thoma-Sea Boatbuilders)	1993	Houma	LA
61	Thoma-Sea Marine (formerly Halter Lockport)		Lockport	LA
62	United States Marine	1987	Gulfport	MS
63	Verret Shipyard	1966	Plaquemine	LA
64	Vessel Repair (formerly Burton Shipyard)	1997	Port Arthur	TX
65	Vigor Ballard (formerly Kvichak Marine)	1981	Seattle	WA
66	Vigor Vancouver (formerly Christensen Yachts)	2018	Vancouver	WA
67	Fred Wahl Marine Construction	1988	Reedsport	OR
68	Wesmac Custom Boats	1995	Surry	ME

69	West Gulf Marine (formerly Kelso Marine, Galveston SB)	1966	Galveston	TX
70	Williams Fabrication	1998	Bayou La Batre	AL
71	Yank Marine (including Sunsplash Marina LLC)	1969	Tuckahoe	NJ
Group C - Other Builders Who Have Only Produced a Few Boats in Recent Years (107)				
#	*Builder*	*Builder Since*	*Location*	*State*
1	A & B Industries	1996	Morgan City	LA
2	ABL Fabricators	2005	Amelia	LA
3	Allen Marine	1985	Sitka	AK
4	Arcosa Madisonville (formerly Equitable Equipment, Trinity Madisonville)	1921	Madisonville	LA
5	Barbour JB Shipyard (formerly Barbour Metal Boat Works)	2017	Oakville	MO
6	Beoufway Contractors	2006	Houma	LA
7	Boconco	1997	Bayou La Batre	AL
8	Bonner Boats		Wetumpka	AL
9	Bordelon Marine Shipbuilders (formerly Mariner SY)		Houma	LA
10	Briggs Boat Works	1980	Wanchese	NC
11	Canal Boats	1996	Fort Lauderdale	FL
12	Candies Shipbuilders (formerly Houma Fab.)	1965	Houma	LA
13	Carolina Yacht Enterprises	2001	Wanchese	NC
14	Central Gulf Shipyard (formerly Oil Barges, Inc.)	1912	New Iberia	LA
15	Chesapeake Boats	1997	Crisfield	MD
16	Colonna's Shipyard	2005	Norfolk	VA
17	CTCO Shipbuilding	1972	Houma	LA
18	Custom Steel Boats	1981	Merritt	NC
19	Derecktor Connecticut (now Hornblower SY)	2001	Bridgeport	CT
20	Diversified Marine	1995	Portland	OR
21	Diversified Marine Services		Chauvin	LA
22	Donjon Shipbuilding (formerly Erie Marine)	2006	Erie	PA
23	Douglas Marine Services	1978	Franklin	LA
24	Edwing Boat		Chinook	WA
25	Elevating Boats	1955	Houma	LA
26	F. & S. Yachts (formerly F. & S. Boat Works)	1997	Bear	DE
27	Fairhaven Shipyard	2007	Fairhaven	MA
28	Feeney's Shipyard	1904	Kingston	NY
29	Fitzgerald Marine Fabricators	1998	Fairhaven	MA
30	FMT Shipyard	2017	Harvey	LA
31	Foss Shipyard	2003	Seattle	WA
32	G. & S. Marine (formerly Lockport Fab'n and R. & S. Fab'n)	1995	Lockport	LA
33	Geo Shipyard	1979	New Iberia	LA
34	Giddings Boat Works	1979	Charleston	OR
35	GNOTS Reserve	2008	Destrehan	LA
36	Great Lakes Towing	2008	Cleveland	OH
37	Gretna Machine & Iron Works (later Halter Gretna and Bollinger Gretna)	1935	Harvey	LA

38	Gulf Coast Steel (formerly J & J Marine, B & B Boat Builders)	1993	Bayou La Batre	AL
39	Gulfbound	2000	Chauvin	LA
40	Gulfstream Shipbuilding (formerly Freeport SB)	1981	Freeport	FL
41	Halter Gulfport (later Trinity Yachts, TY Offshore, now Harvey SY Group)	1992	Gulfport	MS
42	Halter Lockport (now Thoma-Sea Marine)		Lockport	LA
43	Halter Moss Point (later VTHM Moss Point)	1940	Moss Point	MS
44	Halter Pascagoula (later VTHM Pascagoula)	1968	Pascagoula	MS
45	Halter Port Bienville (formerly Gulf Coast Fabrication)	1981	Pearlington	MS
46	Harvey Shipyard Group (formerly TY Offshore)	2008	Gulfport	MS
47	Honolulu Shipyard	1982	Honolulu	HI
48	Intercoastal Marine Fabricators	2013	Larose	LA
49	Island Boats	2000	Jeanerette	LA
50	J-Built	1994	Bayou La Batre	AL
51	JANTRAN	2009	Rosedale	MS
52	JeffBoat (Boats) (formerly Howard's Shipyard)	1939	Jeffersonville	IN
53	JeffBoat (Barges) (being reworked)	1939	Jeffersonville	IN
54	JT Marine	2013	Vancouver	WA
55	Kennedy Construction (formerly Kennedy Ship & Repair)	2001	Galveston	TX
56	Kody Marine	1998	Harvey	LA
57	L A D Services	1980	Stephensville	LA
58	Leevac Shipyards (formerly Zigler SY, later Gulf Island Jennings)	1956	Jennings	LA
59	Madison Boat & Barge	1973	Madison	IN
60	Mann Custom Boats	1988	Manns Harbor	NC
61	Marine Builders	1972	Utica	IN
62	Marine Partners	2007	Bell City	LA
63	Maritime Applied Physics Corp. (MAPC)	2008	Baltimore	MD
64	Martinac Shipbuilding	1924	Tacoma	WA
65	May Ship Repair	1980	Mariners Harbor	NY
66	McDermott Shipbuilding (now Bollinger Marine Fab.)		Morgan City/Amelia	LA
67	Metal Trades	2007	Hollywood	SC
68	Miller Marine		Deltaville	VA
69	Moran Iron Works	2013	Port Calcite	MI
70	Moss Point Marine (later VTHM Escatawpa)	1978	Escatawpa	MS
71	Nashville Bridge (Boats)	1915	Nashville	TN
72	Nashville Bridge (Barges)	1915	Nashville	TN
73	Neuville Boat Works	1969	New Iberia	LA
74	New Generation Shipbuilding	2010	Houma	LA
75	New Orleans Shipyard	2017	Waggaman	LA
76	Newcastle Shipyards (formerly Keith Marine)	1977	Palatka	FL
77	NewSouth Marine Builders	2002	Greenville	MS
78	Nichols Boat Company	2005	Greenville	MS
79	North Shore Marine Terminal (formerly Basic Marine)	1979	Escanaba	MI

80	Noyo Boat Works (formerly Van Peer Boat Works)	1975	Fort Bragg	CA
81	Omega Protein	1967	Moss Point	MS
82	Ocean Marine (formerly Quality Marine)	1972	Bayou La Batre	AL
83	Penn Cove Shellfish/Everest Marine	2005	Coupeville	WA
84	Portier Shipyard	1977	Chauvin	LA
85	Progressive Industrial		Palmetto	FL
86	Quality Shipyards (formerly Quality Eqpmt., later Gulf Island Houma)	1969	Houma	LA
87	Queen Craft	1975	Panama City	FL
88	Raymond & Associates (formerly La Force SY)	1975	Bayou La Batre	AL
89	RiverHawk Fast Sea Frames (formerly Trident Yachts, now Lazzara Yachts)	2012	Tampa	FL
90	Rockland Marine (formerly Snow Shipyards)	1862	Rockland	ME
91	Schooner Creek Boat Works	1977	Portland	OR
92	SEMCO	1994	Lafitte	LA
93	Signet Shipbuilding (formerly Colle SB)	1995	Pascagoula	MS
94	SkipperLiner	1971	La Crosse	WI
95	Sundial Marine Construction	1977	Troutdale	OR
96	Susquehanna Santee Boat Works		Willow Street	PA
97	TEC Skanska (formerly Tidewater Equipment)	1947	Chesapeake	VA
98	Tell City Boat Works	2009	Tell City	IN
99	Tres Palacios Marine	2006	Palacios	TX
100	Trident Pontoons	1998	Tavares	FL
101	Trinity Port Allen (formerly Port Allen Marine Service)	1963	Port Allen	LA
102	U.S. Workboats	2015	Hubert	NC
103	Vigor Alaska (formerly Alaska Ship & Dock)	2002	Kodiak	AK
104	Western Towboat	1982	Seattle	WA
105	Westport Orange SY (formerly TDI Halter and Signal International)	1985	Orange	TX
106	Williams Boat Works	1975	Coden	AL
107	Zidell Marine (formerly Commercial Iron Works)	1960	Portland	OR

Acquisition Research Program
Department of Defense Management
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net