GLOBAL SHIPBUILDING INDUSTRIAL BASE BENCHMARKING STUDY

PART I: MAJOR SHIPYARDS

MAY 2005

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This report was produced for the Under Secretary of Defense (Acquisition, Technology, & Logistics) by the Deputy Under Secretary of Defense (Industrial Policy) from March 2004 through May 2005. Commander John Zimmerman, USN, and Mr. John Bissell led this effort. Gary Powell, Dawn Vehmeier, Dawana Branch, Ronald Genemans, and other Industrial Policy staff also had major roles in the production of this report. Carmen Alatorre-Martin of Booz Allen Hamilton made significant contributions during the final review and editing of the report. The team would like to acknowledge the contributions of John Craggs, Damien Bloor, Malcolm Bell, John Softley, Hamish Bullen, and Gilly Fox, with First Marine International, whose benchmarking assessments and recommendations formed the basis for this study. The National Shipbuilding Research Program also made significant contributions to this body of work. Special thanks are due to the 14 members of the government Red Team, and to all the industry representatives who reviewed the report.

The team would especially like to acknowledge the cooperation of the participating U.S. and international shipyards, whose support made this study possible. Inclusion or exclusion in the report does not imply future business opportunities with or endorsement by the Department. Report inquiries or technical inputs should be directed to Commander Zimmerman at (703) 602-4326 or Dawn Vehmeier at (703) 602-4322.

GLOBAL SHIPBUILDING INDUSTRIAL BASE BENCHMARKING STUDY
PART I: MAJOR SHIPYARDS

OFFICE OF THE DEPUTY UNDER SECRETARY OF DEFENSE
(INDUSTRIAL POLICY)

MAY 2005

Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS) Objectives

Survey current manufacturing and business practices of selected global shipyards, leveraging benchmarking work completed in previous studies.

Assess U.S. private shipyards using a standardized benchmarking system. Provide specific site and comparative analysis of each major U.S. shipyard.

Compare the U.S. shipbuilding industry against leading international shipyards and identify key opportunities for improvement.

Identify DoD, Navy, and industry actions, policies, and contract incentives to implement remedies in the U.S. shipbuilding industrial base.

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Findings

As a result of Navy and industry initiatives and investment, the use of best practice in the U.S. shipbuilding industry has improved significantly over last five years. Some U.S. shipyards substantially increased capital expenditures and most made a concerted effort to employ higher levels of technology. Measured on a scale of 1 to 5, the industry average best practice rating increased from 3.1 in 2000 to 3.6 in 2005, an accelerated rate of improvement for the U.S. industry which compares favorably with rates of leading international (commercial and military) shipyards, whose scores average 3.8 in this study.

The technology gap between the U.S. industry and leading international shipbuilders is closing. However, there are still large technology gaps in some U.S. shipyards that present opportunities to make further substantial improvements, particularly in the pre-production functions which include design, production engineering, and planning.

The best productivity achieved by the higher performing U.S. shipyards appears to be approaching that of the best international naval shipyards. However, it still significantly trails that of high output international commercial shipyards and appears to decline by as much as 50 percent on complex, first-of-class vessels.

A high-level review of ship complexity indicated that the inherent work content of some typical U.S. ship designs is substantially higher than similar modern international designs. In addition, as in many other nations, government acquisition rules and practices create an additional burden (the "Customer Factor") on shipbuilders. This appears to be about ten percent for naval auxiliaries and possibly 15 percent or more for surface combatants. It is likely significantly higher for nuclear-powered vessels.

Recommendations

1) The Department should seek multi-year funding in FY07 to establish a Shipbuilding Industrial Base Investment Fund (SIBIF). This fund would be administered jointly by the Office of the Secretary of Defense and the Navy, and over the next five years would be used to implement the remedies proposed in this study. Forty-four percent of the total SIBIF funds—55 percent of the first-year funding profile—would be devoted to Design, Engineering, and Production Engineering as the focus area with the greatest leverage.
2) The Navy and industry should reduce construction costs for years to come by applying state-of-the-art practices in design producibility that will facilitate a move to 21st century manufacturing processes. With seven new designs (LCS Flight 1, DD(X), CG(X), LHA(R), MPF(F), SSBN(X), CVN 21) to be built in the 2007-2020 timeframe, the shipbuilding enterprise must act now. Failure to do so will waste limited resources over the entire ship series construction cycle.
3) The Department should endeavor to limit to the extent practicable unnecessary technical, administrative, and regulatory requirements that contribute to the cost penalties associated with the "Customer Factor."

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FOREWORD

Global Shipbuilding Industrial Base Benchmarking Study, Part I: Major Shipyards is the first of a two-part series which assesses the capability of the industrial base to produce the ships most critical for 21st century American warfare. This effort essentially meets the intent of language contained in the National Defense Authorization Act for Fiscal year 2005, Section 1014, requiring the Secretary of Defense to submit a report to the Congressional defense committees based on an "independent study to assess cost effectiveness of the Navy ship construction program."

This study focuses on the six largest U.S. private shipyards,[1] and benchmarks their manufacturing practices relative to ten leading international shipyards. The second study in this series will focus on smaller shipyards, such as Marinette Marine, Bollinger, Austal USA, and other industrial enterprises which have capability relevant to shipbuilding, but are not traditionally thought of as part of the U.S. naval shipbuilding industrial base. Examples of such companies, which are already making contributions to U.S. shipbuilding designs and component production are Caterpillar, Native American Technologies, and RLW Inc.

> *"In view of the U.S. Navy's quest for modular designs and the LCS class of ships, the emergence of smaller yards that have not been traditional suppliers to the Navy or Department of Defense is anticipated."*
>
> *Michael W. Wynne, Under Secretary of Defense (AT&L), October 12, 2004*

The *Global Shipbuilding Industrial Base Benchmarking Study* (GSIBBS) initiative, which was begun early in 2004, proved to resonate with broad consensus in the Congress, the Department of Defense (DoD), and shipbuilding industry that action needs to be taken <u>now</u> to reverse the troubling course of the U.S. shipbuilding industrial base. As this initiative developed, it combined the thinking of the best organizations the Department could draw on to empirically and objectively characterize major issues facing the industry and to prepare an implementation plan to remedy these issues.

- First Marine International (FMI)[2] was awarded a contract by the Office of the Deputy Under Secretary of Defense (Industrial Policy) (ODUSD(IP)) in June 2004 to benchmark the six major U.S. shipyards and compare them to the best shipbuilding practices in ten leading international shipyards. FMI then modeled other key elements of overall shipyard productivity using available data and observations from visits to the shipyards, as well as discussions with shipbuilding experts in the U.S. government and industry. FMI's work drew on its own proprietary analytical tools, which have been used in over 150 shipyards worldwide. While DoD representatives participated in all of the shipyard visits

[1] General Dynamics—Bath Iron Works, Electric Boat, National Steel and Shipbuilding Company, and Northrop Grumman—Newport News Shipbuilding Company and Ship Systems (comprised of Ingalls and Avondale Operations).

[2] FMI is a leading international shipbuilding consultancy firm, founded in 1991, whose members have worked on shipbuilding projects in over 50 countries. In the 1970s, FMI's managing director and principal consultants were involved in the design and engineering of some of the world's largest and most successful shipyards.

and coordinated foreign disclosure and logistics details of the visits, the generation of the FMI benchmarking and other productivity data was an independent assessment. This effort was the second largest single study contract ever awarded by the ODUSD(IP) and was one of the most ambitious studies FMI conducted in its history.

- The National Shipbuilding Research Program (NSRP)[3] was provided preliminary results of the FMI analysis in January 2005 in order to draw on this organization's professional standing and domain knowledge of the U.S. shipbuilding industrial base. In addition to the six large shipyards, NSRP membership also includes the smaller, private U.S. shipyards and, as such, draws expertise from the broad U.S. shipbuilding industrial base. NSRP was consulted to evaluate, prioritize, cost, and time-phase the issues and associated remedies which FMI identified as most critical to improving the health of the U.S. shipbuilding industrial base. As part of its analytical contribution to the overall GSIBBS effort, NSRP also applied the considerable experience of its individual company members in dealing with the U.S. military customer for recommendations relating to reducing the "Customer Factor" issue identified by FMI. If the Department resolves to implement the recommendations of this study, the NSRP would be used as the organizational structure for this important task, based on its substantial experience in implementing manufacturing and business practice improvements in U.S. shipyards.
- The U.S. Navy also played an important role with the Office of the Chief of Naval Operations (N-7) assigning the restoration of NSRP FY06 funds the highest level of priority within unfunded budget items. This funding had been cut in earlier budget deliberations, and as the importance of this study and its recommendations became apparent, restoring these funds became even more important in order to have funding available for NSRP to be able to develop and then implement the action plan expected to result from FMI research and this study.
- Congress has an important role in this undertaking as well. This study recommends that the Department request Congressional appropriation of a $148.2 million multi-year program using FY07-11 funding to establish the Shipbuilding Industrial Base Investment Fund (SIBIF) to implement the action plan proposed in this study. It is important that this program be established as a multi-year initiative with sufficient funding and structure to ensure clarity and consistency of purpose relative to the goals of improving manufacturing and business practices—and not yield to the temptation to use these funds for other purposes. Office of the Secretary of Defense (OSD) direct involvement will ensure sustained resolve in executing the plan.

Congressional members who share common concerns about the health of the U.S. shipbuilding industrial base have asked that financial return on investment (ROI) calculations be provided for these initiatives. While the NSRP has much experience in measuring such returns for its previous investments, its experience has been that

[3] Created by U.S. shipyards at the Navy's request in 1998 to reduce the cost of building and maintaining U.S. Navy warships, NSRP is a collaboration of 11 major U.S. shipyards focused on industry-wide implementation of solutions to common cost drivers.

predicting industry-wide ROI across an unstable acquisition environment is a highly inexact science, especially given the unpredictability of future ship procurements. However, after-the-fact actuals from comparable recent investments contribute to understanding the value of the investment and confirm validity of the project. Given the fact that industry will also be investing in these projects, it is not likely that low-value investments will be funded. In addition, FMI research in over 150 shipyards, as well as other analyses of the global shipbuilding industry, has documented a strong direct correlation between shipbuilding best practices and productivity.

> *"A business relationship characterized by **stability and predictability** is essential to future affordability and to preserve specific critical skills in an industry struggling to maintain skilled employees and capabilities, given the gaps in contract awards and low order quantities. The danger to the industrial base's capacity to design, develop, and produce weapon systems posed by this instability extends beyond the shipyards to second and third tier suppliers. Stability should be the most important consideration for Pentagon planners as they try to balance combat needs, long-term strategy, and budget constraints. With notice, shipyards can adapt their workforce and capacity; however, they cannot size to low requirements without significantly restricting their ability to grow a skilled workforce to meet future requirements. Shipyards are encouraged by recent statements by Congress, the CNO, and others that recognize the overwhelming influence of low, unstable ship orders on ship affordability and industrial base health."*
>
> *National Shipbuilding Research Program*
> *Executive Control Board*
> *March 31, 2005*

While GSIBBS revealed many areas where shipyards should improve their processes and productivity, the study concludes that the military customer's unique requirements and business processes impact productivity in U.S. shipyards by 15 percent or more relative to commercial customers. In fact, the remedies that are likely to provide the greatest return in increasing productivity and reducing costs are associated with the complex relationship of the shipyards and its military customer. Unfortunately, this relationship often unintentionally impedes the progress U.S. shipyards could make in improving best manufacturing practices. Major features of this relationship are difficulties associated with: (1) optimizing shipbuilding designs for state-of-the-art manufacturing;[4] (2) unstable and unpredictable ship procurement budgets; and, (3) other challenges associated with the government customer. These factors are among the most significant impeding productivity of U.S. military shipbuilding programs.

While some U.S. shipyards still have much progress to make, on average the U.S. shipyards are now within two decimal points of the best shipbuilding practices employed at international shipyards sampled. But even the availability of near world-class best manufacturing practices in U.S. shipyards is only part of what will ensure world-class productivity. Congress and the Department must do their parts as well: the Department must do its part to ensure sufficiently mature, stable designs are used for construction and Congress must provide predictable—preferably multi-year—funding. The relationship the Department and the Navy maintains with this industry (both through contracts and other guidance) must reinforce, not perturb, the predictability so important

[4] There has been considerable learning in the shipbuilding industrial base with respect to design optimization, particularly in submarines and DDG 51.

for optimal productivity in shipyards. Studies conducted since the mid-1990s have shown that U.S. shipyards' actual performance is often 20-50 percent less than its core productivity—because of immature designs and a customer relationship that interferes with shipyard productivity.

> ***Lessons Learned in Design Optimization: Submarines***
>
> *In the 1990s, the VIRGINIA Class submarine became the first Navy warship design to fully embrace the principles of the integrated product and process development approach. This included 1) an electronic database that supported integrated design and manufacturing, 2) a complete electronic mockup of the entire ship with visualization systems that allowed design build teams to assess producibility and to plan for the most efficient construction.*
>
> *These developments have produced impressive results in the last ten years. Delivery of the VIRGINIA Class lead ship was accomplished within four months of a contract delivery date that was established a decade earlier. The ship has exceeded all expectations of the fleet during its shakedown period. Subsequently, the experienced VIRGINIA workforce, with continued improvements in tools, processes, and acquisition reform initiatives, have continued to deliver substantial new capability for the nation's defense.*
>
> *The SSN 23 Multi-Mission Platform (MMP) was a major ship redesign as complex as the construction of an entire LOS ANGELES Class submarine. This special purpose submarine was developed from concept design to completion of detail design in 29 months—half the time historically required to advance through this development cycle. Five months later this unique 2,500-ton module was delivered to the shipyard for assembly with the host ship and subsequently delivered to the Navy in 2004.*
>
> *Most recently, the on-going conversion of four OHIO Class submarines to a new SSGN Class is on schedule and has been greatly facilitated by lessons learned from these earlier program developments.*

Congressional, Department, and Navy interest in a radical change to improve the U.S. shipbuilding industrial base has come just in time. Some of the current designs of ships intended to commence construction in FY07-12 have taken steps forward in terms of optimization for state-of-the-art production. However, more work needs to be done. Without such action, U.S. shipbuilding programs will be burdened with the 20th century manufacturing practices imposed by these designs well into the 21st century. These shipbuilding programs will then be further undermined by the learning curve perturbations that have plagued this industry for the better part of the last half century. Not to optimize designs will have strategic implications on U.S. national security as the United States becomes increasingly unable to afford the Navy it needs.

The U.S. national strategy will continue to rely on a Navy sufficient in numbers and capabilities to protect U.S. national security and commercial interests. This is especially true at a time when terrorism continues its assault on U.S. security, and when vital commercial sea lanes in Asia could be undermined by strategic imperatives of emerging peer competitors.

If implemented with sufficient funding and the unrelenting resolve of the Congressional-Defense Department-Navy-industry team, the recommendations of this study will make the productivity of U.S. military shipbuilding world-class by the 2010-2012 timeframe.

Stability and predictability in the shipbuilding program and the Navy's dealings with the shipbuilding industry will continue to be important enablers of this success. The nation and future generations of sea-based warfighters deserve nothing less.

A Note on Report Scope

This report focuses primarily on ship design and construction and also addresses the impact of customer requirements and unstable procurements. Despite the fact that combat systems and their integration are significant cost factors, this report focuses on the value-added work performed by U.S. shipbuilders and the impact the Congress, Department, and Navy have on that work. This focus enables the development of specific actionable recommendations that can have a profound, positive effect on the U.S. shipbuilding enterprise.

RED TEAMS

The following groups were provided the *Global Shipbuilding Industrial Base Benchmarking Study, Part I: Major Shipyards* for review. The Government Red Team reviewed the report and provided comments individually and collectively. Industry representatives were provided individual copies of the GSIBBS report and asked to provide their comments separately without collaboration.

Government Red Team

Ms. Allison Stiller, Deputy Assistant Secretary of the Navy for Ships
Ms. Darlene Costello, Deputy Director Naval Warfare, Defense Systems, OUSD(AT&L)
Mr. Dan Stanley, Acting Assistant Secretary of Defense for Legislative Affairs, OSD
Ms. Kathy Brown, Associate General Counsel (Acquisition & Logistics), Office of the DoD General Counsel
Rear Admiral Charles Hamilton II, Program Executive Officer for Ships
Rear Admiral Paul Sullivan, Deputy Commander for Ship Design, Integration and Engineering, NAVSEA
Rear Admiral Raymond Spicer, Deputy Director, Surface Warfare (CNO N76B)
Mr. Jack Evans, Technical Director, Program Executive Officer for Submarines
Mr. Edward Comstock, Executive Director, Ship Design, Integration and Engineering, NAVSEA
Mr. Chris Deegan, Director, Cost Engineering and Industrial Analysis Division, NAVSEA
Captain Michael Schwartz, CVN 21 Program Manager, Program Executive Officer for Carriers
Captain Dale Nees, Head of Submarine Platforms and Strategic Programs, Submarine Warfare (CNO N77)
Dr. Mark Montroll, Professor of Acquisition, Industrial College of the Armed Forces
Commander Chuck Marks, Surface Warfare (CNO N76)

Industry Representatives

Mr. Steven Welch, Chairman & CEO, Todd Pacific Shipyards
Mr. Steve Strom, Vice President, Quality & Process Improvement, NGSS Ingalls Operations
Mr. Paul Albert, Vice President, Production, VT Halter Marine, Inc.
Mr. Dennis Fanguy, Vice President of Engineering, Bollinger Shipyards, Inc.
Mr. Jeff Geiger, Vice President of Manufacturing and Facilities, Bath Iron Works
Mr. Pete Halvordson, Vice President of Engineering, Electric Boat Corporation
Mr. Dave Whiddon, Vice President, Research and Development, NGSS Avondale Operations
Mr. Ed Fleming, President, Jacksonville Operations, Atlantic Marine Holding Company
Mr. Rick Spaulding, Director, Central Planning, Northrop Grumman Newport News
Mr. Harvey Walpert, Senior Advisor, Military Affairs, Bender Shipbuilding & Repair Company
Mr. Steve Eckberg, T-AKE Program Manager, National Steel and Shipbuilding Company
Mr. Rick Self, Senior Vice President, Advanced Technology Institute

EXECUTIVE SUMMARY

U.S. shipbuilders produce the finest warships in the world, but cost growth continues to erode the purchasing power of the Navy's Shipbuilding and Conversion (SCN) budget. There are many reasons for cost growth: commencing construction with immature designs; material and other schedule delays; inexperienced labor; and drops in productivity due to new construction facilities or the introduction of a new series of a given combatant. In short, there is no single culprit for cost growth. It can result from actions taken by Congress, the Department of Defense (DoD), the Navy, shipyards, suppliers—or all in combination.

While Department and industry officials have taken steps to address these issues, their efforts have not stopped the cost growth that continues to plague the industry. Conditions within the Department and industry—unstable and declining build rate, lack of true competition, suboptimal acquisition strategies, and sufficient profitability—provide inadequate incentive to invest in improvements for enterprise-wide manufacturing and business practices, keys to reducing costs.

> *"I'm very concerned about the runaway increases in shipbuilding costs, the viability of our future force structure, and the ambiguity and volatility in shipbuilding plans. The lack of discipline in both the requirements development process and the systems design and demonstration process are making new ships unaffordable. We must take these steps to end the practice of designing and trying to build ships that we don't need and cannot afford."*
>
> *Chairman Duncan Hunter (R-CA)*
> *House Armed Services Committee*
> *May 11, 2004*

Fortunately, a confluence of events offers a unique opportunity to change the current environment and address significant issues in the U.S. shipbuilding enterprise. Within Congress, the Department, Navy, and industry, there is consensus that change is absolutely necessary.

SCOPE AND METHODOLOGY

Commissioned by the Office of the Deputy Under Secretary of Defense (Industrial Policy) (ODUSD(IP)) in June 2004, the Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS) is an independent survey of current manufacturing and business practices and productivity at major domestic and selected global shipyards.

The GSIBBS methodology:

- Surveys current manufacturing and business practices and productivity of selected international shipyards, leveraging benchmarking work completed in previous studies.
- Assesses U.S. private shipyards using a standardized benchmarking system.
- Provides specific site and comparative analysis of each major U.S. private shipyard.
- Compares the U.S. shipbuilding industry against leading international shipyards and identifies key opportunities for improvement.

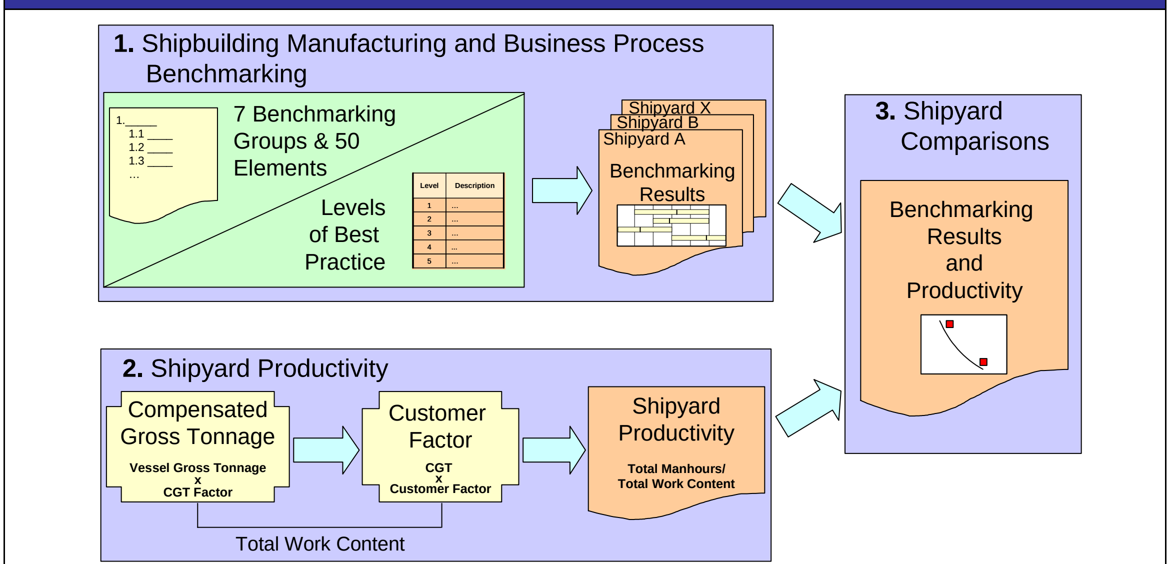
– Identifies DoD, Navy, and industry actions necessary to implement remedies in the U.S. shipbuilding industrial base.

This study methodology is based on the methodology of the 2001 report by the National Shipbuilding Research Program (NSRP)—*Benchmarking of U.S. Shipyards*. That study was the result of the NSRP Executive Control Board's decision to establish a baseline measure of the performance of the U.S. shipbuilding industry. First Marine International, Ltd. (FMI), a global leader in shipbuilding consultancy, used its proprietary benchmarking system for that study. The methodology used in this study builds on FMI's previous work and benchmarks current U.S. and international shipbuilding practices and examines productivity issues. Choosing FMI for this follow-on survey leverages their demonstrated knowledge and expertise, enables comparisons with the 2001 study to show how the industry has fared over time, and provides the domain expertise of an independent, outside source for the assessments.

The benchmarking system was established in 1975 and has been refined through more than 150 world-wide benchmarking surveys since. This benchmarking system is a widely recognized method of assessing shipyard manufacturing and business practices. The process also includes a normalized measure of shipyard productivity, accounting for disparate ship complexity and varying customer profiles, to further evaluate the effective implementation of manufacturing and business best practices. The FMI benchmarking system, as outlined in the chart below, is used to:

1. Evaluate individual shipyard manufacturing and business practices in 50 benchmarking elements using best practice criteria;
2. Estimate a shipyard's current productivity; and,
3. Compare use of best shipbuilding practices and productivity among shipyards to identify improvements opportunities.

ANALYTICAL PROCESS UNDERLYING GSIBBS FINDINGS



Source: First Marine International and ODUSD(IP)

This first study in the two-part series assessed ten world-class international shipyards and the six major U.S. shipyards—expending more than 9,000 manhours for data collection and analysis over a one-year period, and involving over 100 shipbuilding experts from industry and government. Part Two of the study series will address second-tier shipyards and potential new sources of supply.

BENCHMARKING RESULTS: 2005

As a result of Navy and industry initiatives and investment, the use of best practice in the U.S. shipbuilding industry has improved significantly over last five years. Some U.S. shipyards substantially increased capital expenditures and most made a concerted effort to employ higher levels of technology. Measured on a scale of 1 to 5, the industry average best practice rating increased from 3.1 in 2000 to 3.6 in 2005, an accelerated rate of improvement for the U.S. industry which compares favorably with rates of leading international (commercial and military) shipyards, whose scores average 3.8 in this study.

The technology gap between the U.S. industry and leading international shipbuilders is closing. However, there are still large technology gaps in some U.S. shipyards that present opportunities to make further substantial improvements, particularly in the pre-production functions which include design, production engineering, and planning.

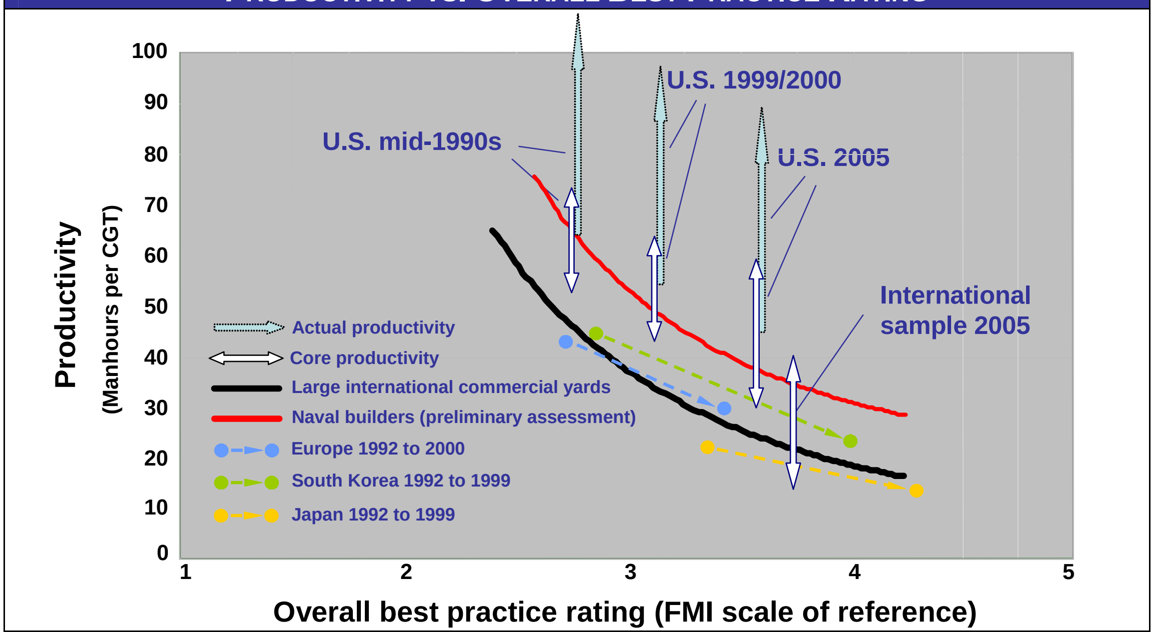
In Outfit Manufacturing and Storage, U.S. shipyards are ahead of international shipyards. Some U.S. shipyards also lead the international shipyards in Pre-Erection Activities; Ship Construction and Outfitting; Design, Engineering, and Production Engineering (DE/PE); and Organization and Operating Systems. In these areas, however, because there is a greater dispersion of performance among U.S. shipyards, the average U.S. shipyard benchmarking score continues to trail the international shipyards. In general, the facilities and equipment employed by the U.S. shipbuilding industry are largely appropriate for the military products and quantities it constructs. U.S. shipyards lag farthest behind in Steelwork Production, partly due to the design issues discussed below, in spite of the great strides made since 2000.

It is in the areas of Design, Engineering, and Production Engineering, and Organization and Operating Systems where additional focus could produce the greatest improvement. With seven new designs (LCS flight 1, DD(X), CG(X), LHA(R), MPF(F), SSBN(X), CVN 21) to be built in the 2007-2020 timeframe, this area offers the greatest leverage—in terms of cost benefits associated both with state-of-the-art manufacturing practices and new vessel designs that would facilitate a move to 21st century manufacturing practices. It is important that, as appropriate, these designs be optimized for state-of-the-art manufacturing. Conversely, if these new designs are not optimized for 21st century manufacturing practices, their presence on U.S. production lines will undermine achieving the improved productivity made possible with recent improvements.

PRODUCTIVITY FINDINGS

As shown on the following chart, currently, U.S. shipyard core productivity[5] appears to be in the range of 30 to 60 manhours per compensated gross ton (CGT). The higher performing U.S. shipyards are approaching the core productivity levels of the best international naval shipyards, while still significantly trailing that of high-output international commercial shipyards. It also shows that U.S. shipyards now are experiencing <u>actual</u> productivity levels comparable to their own <u>core</u> productivity levels of the mid-1990s. If U.S. shipyards realized the full potential of their manufacturing best practices and were able to operate at core productivity, their actual productivity could improve by as much as 50 percent—and the best would be within the range of international shipyards. Unfortunately, for a variety of reasons, U.S. shipyards often do not operate at their core productivity. To reach core productivity, more emphasis is required in the areas in which U.S. shipyards historically lag high performing international shipyards: simplifying designs, ensuring throughput stability, and reducing the extensive overhead required to work in a naval environment (Customer Factor).

PRODUCTIVITY VS. OVERALL BEST PRACTICE RATING



Source: First Marine International

IMPLEMENTATION PLAN

Based on its benchmarking and productivity analysis, FMI prioritized issues and proposed remedies. FMI presented these results, issues, and remedies to the National Shipbuilding Research Program[6] (NSRP) in January 2005. FMI's results provided the

[5] Core productivity is the best productivity a shipyard achieves with its current facilities and workforce, a stable design, and stable manufacturing processes.

[6] Created by U.S. shipyards at the Navy's request in 1998 to reduce the cost of building and maintaining U.S. Navy warships, the NSRP is a collaboration of 11 major U.S. shipyards focused on industry-wide implementation of solutions to common cost drivers.

strategic baseline from which a plan for corrective action could be developed. By including industry (via the NSRP), its knowledge of current near-term efficiency initiatives and high-leverage infrastructure investments could be tapped. Over a six-week period this working group developed an investment strategy.

This process produced a solid consensus among the U.S. shipyards on the highest priority actionable recommendations—and in large measure validated FMI's prioritized remedies. NSRP published a 75-page report: *Proposed Investment Strategy to Address the Findings of the 2004 Global Shipbuilding Industrial Base Benchmarking Study* in March 2005. ODUSD(IP) considered these recommendations in its proposed Shipbuilding Industrial Base Investment Fund (SIBIF). The table below summarizes remedies proposed for funding in the SIBIF.

PROPOSED SIBIF INVESTMENTS

	Thrust Area	Project Area/Description	Investment Est. ($M)
Shipyard Remedies	Design, Engineering, and Production Engineering	Design for Production	$ 21.4
		Improve the Naval Ship Design Process	8.0
		Elevate Production Engineering	8.0
		Enable Enterprise Interoperability of Design/Production Data	20.0
		Format Outfit Production Information	1.0
		Improve Dimensional and Quality Control Tools and Practices	2.0
	Production Processes	Eliminate Non-Value-Added Production Activity	8.0
		Expand the Use of Module Building (Outfitting Packages)	5.0
		Balance the Use of Technology in Shipyards	2.0
		Develop and Implement Advanced Material Handling	10.0
		Develop Production Process Standards	2.0
	Organization and Operating Systems	Improve Shipyard Planning and Scheduling Systems	5.0
		Consolidate/Streamline Production Management Information Systems	5.0
		Optimize Manpower and Work Organization	3.0
		Improve Production Control Processes	5.0
Outsourcing and Supply	Shipyard Outsourcing and Supply Chain Integration	Apply Lean/Six Sigma Tools to Streamline Shipbuilding Supply Chains	6.0
		Eliminate Outsourcing Disincentives	0.5
		Outsourcing Strategies, Including Regionalization and Consolidation of Work	20.0
		Enable Supply Chain Data Sharing	1.8
Customer Factor	Joint Navy/ OSD/Industry Actions	Stabilize the Navy's Ship Acquisition Strategy	-
		Eliminate Disincentives and Improve Incentives	0.5
		Streamline Navy Technical Oversight	6.0
		Change Weight-Based Cost Estimating Relationship	1.0
		Manage Change Orders to Reduce Productivity Impact	1.5
		Enable Resource Sharing Among Private/Public Shipyards	0.5
		Rationalize Design Rule Methodologies on Naval Ships	5.0
		Total	$ 148.2

Source: NSRP and ODUSD(IP)

GLOBAL SHIPBUILDING INDUSTRIAL BASE BENCHMARKING STUDY (GSIBBS) RECOMMENDATIONS

GSIBBS demonstrated continuing progress in the U.S. shipbuilding industry; however, it also made clear that opportunities for significant improvement remain. Shipbuilders, the Department, and state and local governments have funded targeted investments at individual shipyards. These investments and NSRP-sponsored collaborative improvements have resulted in a 0.5 average improvement in benchmarking scores. However, the NSRP's impact is limited in that: 1) constrained funding limits its aggressive pursuit of large scale challenges; 2) NSRP's existing funding agreement precludes buying services or equipment, thereby inhibiting developments that are hardware intensive; and 3) NSRP's current scope does not include Department policies and processes—arguably the areas with the largest impact on the performance of the shipbuilding industrial base. These issues need a new mechanism which can focus multi-year resources on the shipbuilding areas that will have the largest impact on industry performance and productivity. Performing these actions will require cooperation and participation from Navy, OSD, and Congress, and a structured and time-phased SIBIF.

Recognizing the overall importance of DE/PE, this thrust area represents almost 60 percent of the funding proposed for collaborative shipyard remedies. The large investment specified for Design for Production not only represents the major benefits to be gained by reducing production costs to a minimum, but also the substantial investment needed to coordinate member shipyards and the Department. Enabling Enterprise Interoperability of Design and Production Data also is a major investment priority for the DE/PE thrust area. The relatively large initial investment in this initiative will likely have long-term positive impact on a number of new designs produced well into the 21st century.

SIBIF Precepts

1. *Multi-year funding profile that will enable action on more difficult problems.*
2. *Joint OSD/Navy/NSRP administration.*
3. *Focus on upfront processes involved in naval ship design.*
4. *Increased Department involvement in industrial base investment decisions.*
5. *Government/industry cost share.*
6. *Requires action by Navy/OSD and Congress.*

RECOMMENDATION 1

The Department should seek multi-year funding in FY07 to establish a Shipbuilding Industrial Base Investment Fund (SIBIF). This fund would be administered jointly by the Office of the Secretary of Defense and the Navy, and over the next five years would be used to implement the remedies proposed in this study. Forty-four percent of the total SIBIF funds—55 percent of the first-year funding profile—would be devoted to DE/PE as the focus area with the greatest leverage.

RECOMMENDATION 2

The Navy and industry should reduce construction costs for years to come by applying state-of-the-art practices in design producibility that will facilitate a move to 21st century manufacturing processes. With seven new designs (LCS Flight 1, DD(X), CG(X), LHA(R), MPF(F), SSBN(X), CVN 21) to be built in the 2007-2020 timeframe, the shipbuilding enterprise must act now. Failure to do so will waste limited resources over the entire ship series construction cycle.

RECOMMENDATION 3

The Department should endeavor to limit to the extent practicable unnecessary technical, administrative, and regulatory requirements that contribute to the cost penalties associated with the “Customer Factor.”

THE LARGER GSIBBS EFFORT

A strong shipbuilding industry requires a combination of productive and competitive major shipyards, second tier shipyards and suppliers. ODUSD(IP) will undertake a follow-on study to examine medium-tier shipyards and other non-traditional shipbuilding sources of supply to publish by early 2006.

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PART I

THE CHALLENGE TO THE U.S. SHIPBUILDING INDUSTRIAL BASE

Problems in the military sector of the U.S. shipbuilding industrial base, such as cost growth and schedule slips, have plagued the industry for a number of years. When coupled with lower procurement quantities and an increasing desire for more capable, complex ships, these factors have compounded this industry's health and performance problems. This study compares the business and manufacturing practices of U.S. and leading international shipyards, and then proposes remedies to make the U.S. shipbuilding enterprise more effective and efficient. The thesis of this study is that if manufacturing and business processes are improved in U.S. shipyards, costs will decline—as shown in numerous examples of lean, state-of-the-art manufacturing elsewhere in the defense industrial base.

CONDITION OF THE U.S. SHIPBUILDING INDUSTRY

The U.S. shipbuilding industry produces the finest warships in the world, but cost growth—caused by government and industry—continues to erode the purchasing power of the Navy's Shipbuilding and Conversion (SCN) budget. This cost growth is shown in the chart below. For example, the Navy awarded the LPD 17 contract in FY97 for $954 million to cover the lead ship. The current cost projection for that ship in the FY05 budget is $1,758 million, an $804 million (84.2 percent) increase. The Government Accountability Office (GAO) has projected an additional cost growth of $112-197 million for this vessel, representing a total cost growth of $959 million—more than doubling the

COST GROWTH IN U.S. NAVY WARSHIPS

Initial and Current Budget Request ($ millions)

Case Study Ship	Initial	Current	Difference (%)	Projected Additional Cost Growth	Total Cost Growth (%)[a]
DDG 91	$ 917	$ 997	$ 80 (8.7%)	$ 28-32	$ 110 (12.0%)
DDG 92	925	979	55 (5.4%)	9-10	65 (7.0%)
CVN 76	4,266	4,600	334 (7.8%)	4	338 (7.9%)
CVN 77	4,975	5,024	49 (1.0%)	485-637	610 (12.3%)
LPD 17	954	1,758	804 (84.2%)	112-197	959 (100.5%)
LPD 18	762	1,011	249 (32.6%)	102-136	368 (48.3%)
SSN 774	3,260	3,682	422 (12.9%)	(-54)-(-40)	375 (11.5%)
SSN 775	2,192	2,504	312 (14.2%)	103-219	473 (21.6%)
Total	**$ 18,251**	**$ 20,556**	**$ 2,305 (12.6%)**	**$ 789-1,195**	**$ 3,298 (18.1%)**

[a] Total cost growth was calculated using the current budget request plus the midpoint of the additional cost growth.

Source: *Improved Management Practices Could Help Minimize Cost Growth in Navy Shipbuilding Programs*, GAO Report, February 2005.

initial budget request. In addition, LPD 17, originally scheduled to deliver in July 2002, will now be commissioned in the fall of 2005—over three years late. CVN 77 cost growth, which was estimated to be a maximum of $637 million, is now projected to be $869.9 million—a $233 million increase—just months after the GAO estimate.

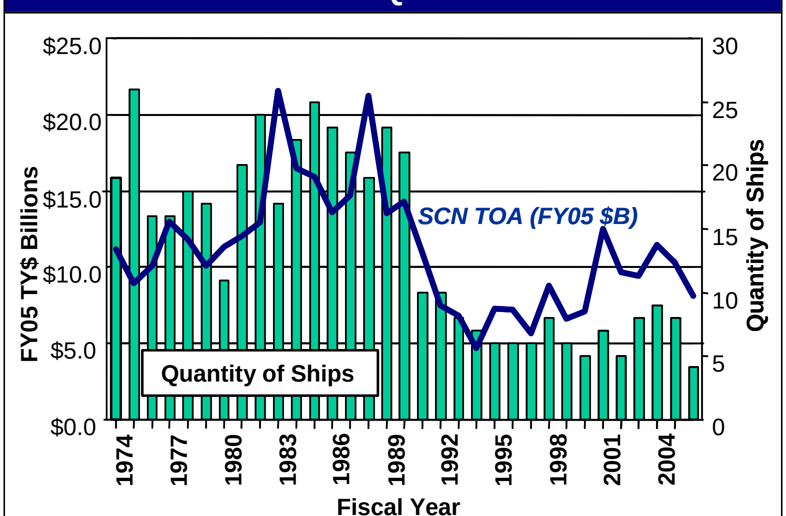
> *"The George H.W. Bush aircraft carrier [CVN 77] needs $869.9 million between 2006 and 2008 to cover cost overruns and other increases encountered during the ship's construction, according to details of the budget proposal President Bush recently submitted to Congress."*
>
> *Newport News Daily Press*
> *March 2, 2005*

By cost growth standards being established elsewhere in the Department, or in the Nunn-McCurdy legislation, the 18 percent total cost growth estimated in the GAO report may appear modest. However, the fact that such a large proportion of the Navy's budget is allocated to shipbuilding and spread over only a very few vessels causes any cost growth to have disproportionate consequences.[7]

The SCN budget for the past seven years has represented on average 33 percent of the Navy's and 12 percent of the Department's overall procurement budget—with on average, seven combatants per year. In the eight examples shown in the chart on the previous page, the estimated total cost growth of these units alone is equivalent to one VIRGINIA Class SSN, three ARLEIGH BURKE Class Destroyers, or six Littoral Combat Ships—*not procured*.

As a consequence, the Navy has consistently reduced the number of combatants procured to absorb current cost growth, as shown in the table opposite. For example, in FY03, the Navy took one combatant (a San Antonio Class Amphibious Transport Dock Ship) out of that year's budget to re-baseline budgets to accurately reflect total procurement costs. In FY04, the Navy budgeted for nine ships. However, in FY06 the Navy plans to procure only four ships.

SCN BUDGET VS QUANTITY OF SHIPS



Source: Naval Sea Systems Command—Cost Engineering and Industrial Analysis Division (NAVSEA 017)

Fewer ship procurements not only affect the shipbuilding industry, but they affect the Navy as well. As the Navy procures fewer ships—while attempting to provide necessary warfighting capabilities—the warships become progressively more complex. For example, the Navy is no longer building mine countermeasure class ships, but has

[7] Cost growth is compounded when the Department uses SCN accounts to pay other bills (Operation and Maintenance, Research and Development, and other procurements).

instead installed mine countermeasure capabilities aboard six ARLEIGH BURKE Class Destroyers, and is planning a similar capability to be installed on the new Littoral Combat Ship. Similarly, fewer naval ships in production increases the need to extend the designed service life of these vessels. Longer service life and combat conditions require strengthening critical structural components and compensatory weight reduction in less critical areas. This process further increases complexity. For example, in most commercial ships, plate metal thickness is limited to four to seven standard sizes. Using such a small number of standard plate thicknesses greatly simplifies the production of commercial ships, leading to significant improvements in construction efficiency. By comparison, U.S. warships employ hundreds of different sizes of plate in order to meet service life and strength criteria. This large number of plate thicknesses greatly increases naval ship construction difficulty. Whether the requirement is for increased capability, increased survivability, or longer service life, the end result is incrementally increased design complexity which negatively impacts shipbuilding productivity—presenting fewer opportunities for modularization and outsourcing, and additional requirements for more experienced engineers, workers, and supervisors.

There are many reasons for cost growth—including procurement instability, commencing construction with immature designs; material and other schedule delays; inexperienced labor; and drops in productivity due to new construction facilities or the introduction of a new series of a given combatant. In short, there is no single culprit for cost growth. It can result from actions taken by the Department, the Navy, shipyards, or suppliers—or all in combination, as shown below.

SOURCES OF COST GROWTH (EXAMPLES)

Reason for Cost Growth	DoD/Navy	Shipyard	Suppliers and Integrators
Procurement instability	✓✓✓		
Immature design at the start construction	✓✓✓	✓✓✓	✓✓
Material ordering, delivery, and schedule delays	✓✓	✓✓	✓✓
Schedule slippage		✓✓✓	✓✓✓
Capability enhancement	✓✓✓		
Poor estimating	✓✓✓	✓✓✓	✓✓✓
Change orders	✓✓✓	✓✓	✓✓
Material and equipment costs			✓✓✓
Poor project management	✓✓	✓✓✓	✓
Unable to recruit appropriate labor		✓✓✓	✓✓
Poorly defined construction specifications	✓✓	✓✓	

Source: ODUSD(IP)

Key:
✓ Some impact
✓✓ Moderate impact
✓✓✓ Significant impact

Coupled with the Navy's quest for increasingly advanced warships, the combination of fewer, more complex ships has placed the industry into a vicious cycle that continues to erode the predictability of funding and platform mix so important to industry.

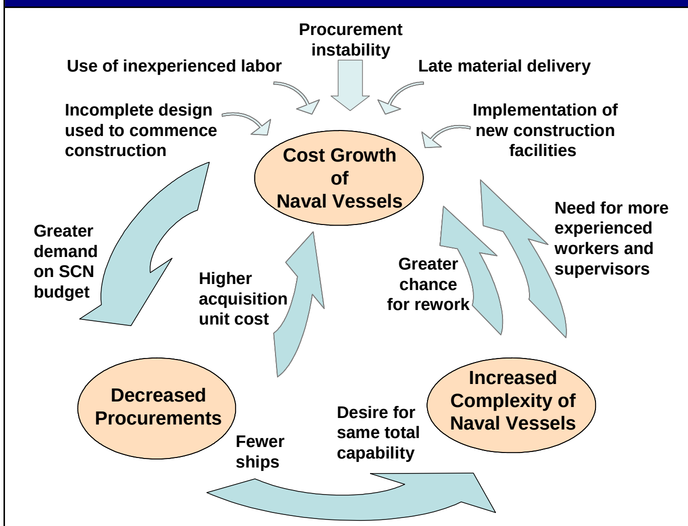
THE VICIOUS CYCLE IN THE INDUSTRIAL SETTING

Iterative quantity changes have had serious ramifications on the U.S. shipbuilding industrial base. Reductions have resulted in excess capacity and layoffs. Increases have necessitated rapid hiring and training, creating additional management burden and a less experienced workforce. Reductions in ship procurements also create the additional burden of raising material costs for shipyard suppliers, and reducing the effectiveness of new efficiency initiatives. These factors tend to discourage new and innovative firms from entering the shipbuilding industry. By contrast, successful international commercial shipyards achieve the highest level of performance by maintaining steady production levels.

The Department's interaction with the shipbuilding industry also adds costs. For example, previous studies have long indicated that customer oversight, reporting requirements, and unique administrative requirements add significant cost to ship construction programs and are atypical of business practice in other shipbuilding settings.[8]

Cost growth—whether resulting from DoD or industry—leads to decreased procurements, greater complexity, and additional cost growth which brings the shipbuilding vicious cycle full circle.

SHIPBUILDING'S VICIOUS CYCLE



Source: ODUSD(IP)

INSUFFICIENT INCENTIVES FOR INDUSTRY TO IMPROVE

The issues discussed above have affected the U.S. shipbuilding industry for a number of years. While Department and industry officials have taken steps to address them, their efforts have not stopped the cost growth that continues to plague the industry. Conditions within the Department and industry—unstable and declining build rate, lack of true competition, suboptimal acquisition strategies, and sufficient profitability—provide inadequate incentive to invest in improvements for enterprise-wide manufacturing and business practices, keys to reducing costs.

Two corporations now own the six major U.S. shipyards. General Dynamics owns Electric Boat, Bath Iron Works (BIW), and National Steel and Shipbuilding Company (NASSCO). Northrop Grumman owns Newport News Shipbuilding Company, and Northrop Grumman Ship Systems—Ingalls and Avondale Operations. Each corporation

[8] *The DoD Regulatory Cost Premium: A Quantitative Assessment.* Coopers & Lybrand/TASC, December 1994.

has the ability to produce the majority of combatants needed by the Navy, with the exception of the aircraft carrier.[9]

MAJOR U.S. PRIVATE SHIPYARDS

	Shipyard		Recent Products
General Dynamics	Bath Iron Works		DDG 51
General Dynamics	Electric Boat		Submarines – SSN & SSBN (VIRGINIA, SEAWOLF, OHIO, LOS ANGELES)
General Dynamics	NASSCO		RO-RO Strategic Sealift Ships, T-AKE, Oil Tankers, Trailer Ships
Northrop Grumman	NGSS	Avondale Operations	LPD 17, Naval Auxiliaries, Oil Tankers, RO-RO Strategic Sealift Ships
Northrop Grumman	NGSS	Ingalls Operations	LPD 17, DDG 51, LHD 8
Northrop Grumman	Newport News Shipbuilding Co.		NIMITZ CVN, VIRGINIA SSN

Source: ODUSD(IP)

In an effort to maintain a competitive prime supplier base, the Navy, sometimes directed by Congress, has allocated most combatant class construction contracts among competing shipyards. Current examples are the ARLEIGH BURKE Class (DDG 51) destroyer produced by BIW and Northrop Grumman Ship Systems-Ingalls Operations; and the VIRGINIA Class submarine produced by Electric Boat and Newport News. This approach does not foster the true competition that drives innovation and reduces costs.

The Department's continued refinement of acquisition strategies to address shipbuilding sector performance has likewise not yielded the hoped-for results. "Cost-plus" contracts used to overcome technological and design maturity uncertainties pay contractors for actual labor and parts plus an award or incentive fee. These contracts are intended to reduce risk when the Navy pursues a revolutionary approach to new vessels and major upgrades. Unfortunately, they also can lead to inadequate cost estimates and budget shortfalls. Shipbuilders and their suppliers are less motivated to control costs because of the "cost-plus" provisions. The awards and incentives included in these

A Case of Successful Incentives

The special incentive clause of the VIRGINIA multi-year contract allows the contractor to submit projects, with corresponding business case analyses, for facilities and process improvements that result in long-term savings to the Government for the VIRGINIA Class submarine program.

After approval and commencement of a project, a special incentive of 50 percent of the estimated investment cost is paid to the shipbuilder. Upon successful implementation and proof of the business case, the remaining 50 percent is paid. For any Government approved project that fails to meet the business case analysis savings estimates, as solely determined by the contracting officer, the contracting officer may unilaterally revoke the Government's prior approval and recover all or any portion of amount paid by withholding such amounts from future payments.

To date $11.1 million of incentives have been approved resulting in a savings of $31 million. An additional $22.4 million of incentives are pending approval with an estimated savings of $129 million.

[9] Northrop Grumman's Newport News Shipbuilding Company is the only producer of aircraft carriers for the U.S. Navy.

contracts are also meant to better incentivize on-time delivery. But these incentives, in many cases, have been insufficient to significantly change performance. From the Navy's view, the share lines are intended to represent an equitable distribution of risk between the Navy and industry, while ensuring good value for the taxpayer. From industry's viewpoint, the share lines do not always provide a sufficiently strong business case for the shipyard to make major investments to improve manufacturing and business processes to bring costs down.

Difficulties in the U.S. shipbuilding industry have not translated into profits that are low by global standards or other defense businesses. In fact, U.S. shipbuilding profitability substantially outpaces many world-class international shipyards and, from time to time, overall defense industry profitability, as illustrated in the chart below.

OPERATING MARGIN COMPARISON – INTERNATIONAL VS U.S. SHIPYARDS

Company	2000	2001	2002	2003	2004	Average (2000-2004) Corporate	Average (2000-2004) Total
Chantiers de l'Atlantique (Alstom Marine)	5.4%	4.3%	3.8%	1.5%	-1.9%	2.6%	2.6%
Mitsui Engineering and Shipbuilding Company	1.3	3.9	4.4	5.4	3.9	3.8	
Samsung Heavy Industries	-9.3	2.5	3.4	5.0	-2.3	-0.1	
Fincantieri	4.7	4.6	5.0	5.2	6.2	5.1	
Kawasaki Heavy Industries	0.1	0.4	2.7	2.5	1.9	1.5	
General Dynamics Ship Sector	9.5	8.6	7.9	5.1	6.2	7.5	6.8%
Northrop Grumman	11.6	1.0	6.5	5.4	6.2	6.1	
S&P Aerospace/Defense	9.8	8.0	8.8	8.1	8.7	8.7	8.7%

Source: First Equity Development, Inc.

International commercial shipyard operating margins are low compared to that of U.S. shipyards and below the risk-free Treasury bond rate, emblematic of the extremely competitive nature of the global shipbuilding industry. Given well-entrenched international competitors in this extremely competitive environment, and commensurate depressed profit margins, it would be very difficult for U.S. shipyards to compete successfully in the global market. In recent years, U.S. shipyard operating margins have begun to trail those in the aerospace/defense industry. Given these margins, the economies of the global commercial market, and the fact that available U.S. military ship construction effectively is allocated among them, U.S. shipyards may not feel compelled to make substantial improvements in their enterprise without stable DoD demand, and consistent encouragement and support.

THE TIME IS NOW

> *"I believe we must change the way we buy ships."*
>
> *Admiral Vern Clark,*
> *Chief of Naval Operations,*
> *Defense Today, February 11, 2005*

Fortunately, a confluence of events offers a unique opportunity to change the current environment and address significant issues in the shipbuilding enterprise. Within Congress, the Department, and industry, there is consensus that change is absolutely necessary. This study provides explicit remedies and an associated implementation plan to accomplish these changes, which Congress appears willing to consider funding. In fact, the current trough in shipbuilding procurement should allow the shipyards to commit the manpower, time, and resources for this improvement. Finally, newer program designs, such as LCS flight 1, DD(X), CG(X), LHA(R), MPF(F), SSBN(X), and CVN 21, could be further optimized for state-of-the-art production and their contracts structured to induce improved performance as part of this study's recommendations.

> *"If it takes an infusion of public money to help them get there, I am perfectly willing to do that because we're going to get it back… through lower shipbuilding costs."*
>
> *Representative Roscoe Bartlett (R-MD)*
> *Inside the Navy, February 14, 2005*

Now more than ever, Congress, the Department, and industry must take action to ensure the U.S. shipbuilding enterprise provides the capabilities our warfighters need, today and into the future.

THE CHALLENGE ADDRESSED: THE GLOBAL SHIPBUILDING INDUSTRIAL BASE BENCHMARKING STUDY

Commissioned by the Office of the Deputy Under Secretary of Defense (Industrial Policy), the Global Shipbuilding Industrial Base Benchmarking Study (GSIBBS) is an independent survey of current manufacturing and business practices and productivity at major domestic and selected global shipyards.[10]

The GSIBBS methodology:

- Surveys current manufacturing and business practices and productivity of selected international shipyards, leveraging benchmarking work completed in previous studies;
- Assesses U.S. private shipyards using a standardized benchmarking system.
- Provides specific site and comparative analysis of each major U.S. private shipyard;
- Compares the U.S. shipbuilding industry against leading international shipyards and identifies key opportunities for improvement;
- Identifies DoD, Navy, and industry actions, policies, and contract incentives to implement remedies in the U.S. shipbuilding industrial base.

[10] This study intentionally focuses on the value-added work performed by U.S. shipbuilders and the impact the Congress, Department, and Navy have on that work. It does not address other important issues such as combat systems development and integration or government subsidies.

This first study in the two-part series assessed ten leading international shipyards and the six major U.S. shipyards—expending more than 9,000 manhours for data collection and analysis over a period of one year. Part Two of the study series will address second-tier shipyards and potential new sources of supply.

INTERNATIONAL SHIPYARDS PARTICIPATING IN GSIBBS[a]		
Company	**Location Visited**	**Product Lines**
Aker Finnyards	Turku, Finland	Cruise ships, ferries, ice breakers, and naval craft
Aker Ostsee	Wismar, Germany	Tankers, ferries, container and passenger vessels
Chantiers de l'Atlantique	Saint Nazaire, France	Cruise liners, ferries, tankers, and naval vessels
Daewoo Shipbuilding & Marine Engineering Company	Geoje Island, South Korea	Gas and bulk carriers, container vessels, and tankers
Fincantieri Cantieri Navali Italiani SPA	Monfalcone, Italy	Cruise ships, ferries, container and passenger vessels, naval vessels
Hanjin Heavy Industries	Geoje Island, South Korea	Container vessels, tankers, product carriers, and special purpose vessels
IZAR Construcciones Navales, S.A.	El Ferrol, Spain	Naval and merchant vessels
Kawasaki Heavy Industries	Kobe, Japan	Gas carriers and naval vessels
Mitsui Engineering & Shipbuilding Company	Chiba, Japan	Gas and bulk carriers, tankers, and naval vessels
Samsung Heavy Industries	Geoje Island, South Korea	Tankers, container vessels, gas carriers, cruise ships, and ferries

[a] While a large majority of these shipyards accepted full benchmarking visits, a few only allowed site visits. Full company profiles for international shipyards are provided in Appendix A.

Source: ODUSD(IP)

This report focuses on the value-added work performed by U.S. shipbuilders and the impact the Congress, Department, and Navy have on that work. It is the intention of this study to objectively assess these issues in the U.S. shipbuilding industrial base, cost and prioritize remedies for them, and propose a plan to implement long-term improvement of the U.S. shipbuilding industrial base. An objective methodology is crucial to such analysis. This study methodology is based on the methodology of the 2001 report by the National Shipbuilding Research Program (NSRP)—*Benchmarking of U.S. Shipyards*. That study was the result of the NSRP Executive Control Board's decision to establish a baseline measure of the performance of the U.S. shipbuilding industry. First Marine International, Ltd. (FMI), a global leader in shipbuilding consultancy, used its proprietary benchmarking system for that study. During that period, FMI surveyed Asian and European shipyards with which to compare the U.S. industry. The methodology used in this study builds on FMI's previous work, benchmarks current U.S. and international shipbuilding practices, and examines productivity issues.

Choosing FMI for this follow-on survey leverages their demonstrated knowledge and expertise, enables comparisons with the 2001 study to show how the industry has fared over time, and provides the domain expertise of an independent, outside source for the assessments. This study then develops actionable recommendations for implementation by the Department, Navy, and industry, proposing the Shipbuilding Industrial Base Investment Fund as the vehicle to accomplish these.

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PART II

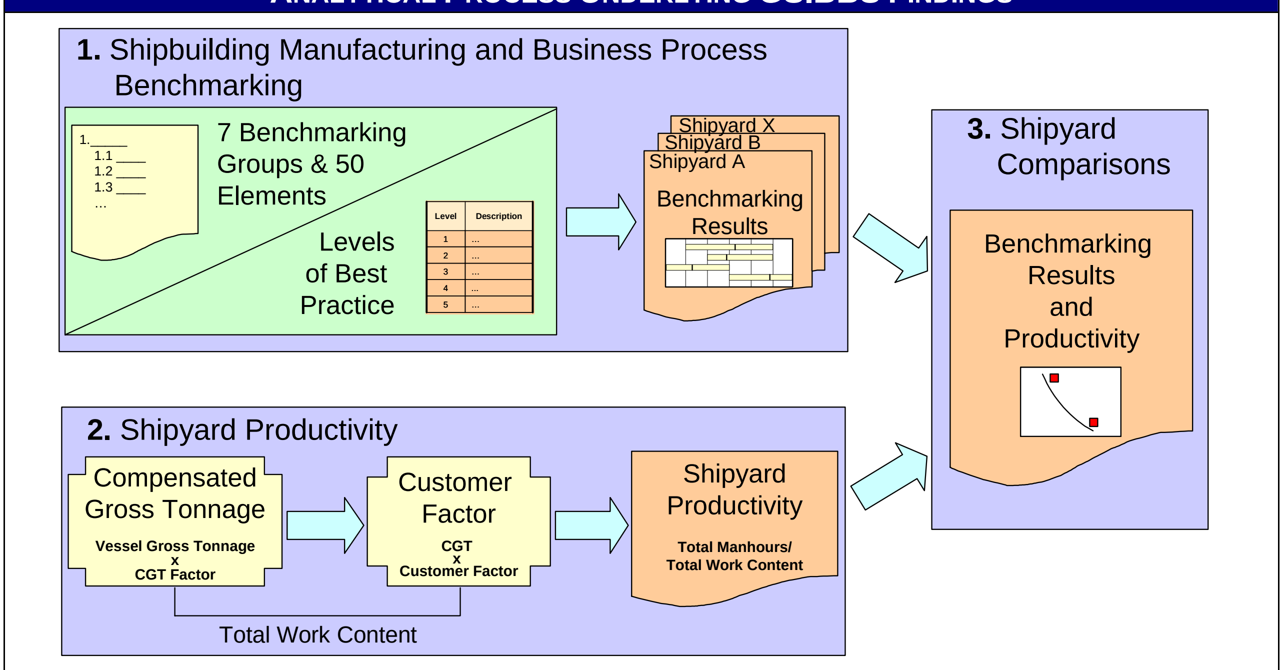
THE GLOBAL SHIPBUILDING INDUSTRIAL BASE BENCHMARKING STUDY (GSIBBS) METHODOLOGY

The GSIBBS is based on a systematic, rigorous methodology that focuses on business and manufacturing practices and allows comparisons among companies and across products.

The GSIBBS uses the First Marine International (FMI) benchmarking system. The benchmarking system was established in 1975 and has been refined through more than 150 world-wide benchmarking surveys since. This benchmarking system is a widely recognized method of assessing shipyard manufacturing and business practices. The process also includes a normalized measure of shipyard productivity, accounting for disparate ship complexity and varying customer profiles, to further evaluate the effective implementation of manufacturing and business best practices. The FMI benchmarking system, as outlined in the chart below, is used to

1. Evaluate individual shipyard manufacturing and business practices in fifty benchmarking elements using best practice criteria;
2. Estimate a shipyard's current productivity; and,
3. Compare use of best shipbuilding practices and productivity among shipyards to identify improvements opportunities.

ANALYTICAL PROCESS UNDERLYING GSIBBS FINDINGS



Source: First Marine International and ODUSD(IP)

This FMI methodology allows for the comparison of military and commercial shipyards with products ranging from liquid natural gas carriers to nuclear powered fast attack submarines.

STEP 1: INDIVIDUAL SHIPYARD BENCHMARKING

The process begins with the evaluation of 50 distinct elements within seven benchmarking groups, as shown below. In a given shipyard, each benchmarking element is scored for the level of technology in use. These scores range from level 1 (very basic 1960s level of technology) to level 5 (state-of-the-art technology). The benchmarking process explicitly characterizes levels of technology for each element within a given benchmarking group.

BENCHMARKING GROUPS AND ELEMENTS

1. Steelwork Production
- 1.1. Plate Stockyard and Treatment
- 1.2. Stiffener Stockyard
- 1.3. Plate Cutting
- 1.4. Stiffener Cutting
- 1.5. Plate and Stiffener Forming
- 1.6. Minor Assembly
- 1.7. Sub-assembly
- 1.8. Flat Unit Assembly
- 1.9. Curved and 3D Unit Assembly
- 1.10. Superstructure Unit Assembly
- 1.11. Outfit Steel

2. Outfit Manufacturing and Storage
- 2.1. Pipe Shop
- 2.2. Machine Shop
- 2.3. Sheet Metal Working
- 2.4. Electrical
- 2.5. General Storage and Warehousing
- 2.6. Storage of Large Heavy Items

3. Pre-erection Activities
- 3.1. Module Building
- 3.2. Outfit Parts Marshalling
- 3.3. Pre-erection Outfitting
- 3.4. Block Assembly
- 3.5. Unit and Block Storage
- 3.6. Materials Handling

4. Ship Construction and Outfitting
- 4.1. Ship Construction
- 4.2. Erection and Fairing
- 4.3. Welding
- 4.4. Onboard Services
- 4.5. Staging and Access
- 4.6. Outfit Installation
- 4.7. Painting

5. Yard Layout and Environment
- 5.1. Layout and Material Flow
- 5.2. General Environment

6. Design, Engineering, and Production Engineering
- 6.1. Ship Design
- 6.2. Steelwork Production Information
- 6.3. Outfit Production Information
- 6.4. Steelwork Coding System
- 6.5. Parts Listing Procedure
- 6.6. Production Engineering
- 6.7. Design for Production
- 6.8. Dimensional Accuracy and Quality Control
- 6.9. Lofting Methods

7. Organization and Operating Systems
- 7.1. Manpower and Organization of Work
- 7.2. Master Planning
- 7.3. Steelwork Scheduling
- 7.4. Outfit Scheduling
- 7.5. Production Control
- 7.6. Stores Control
- 7.7. Performance and Efficiency Calculations
- 7.8. Quality Assurance
- 7.9. Production Management Information Systems

LEVELS OF TECHNOLOGY

Level	Description
1	Reflects shipyard practice of the early 1960s.
2	Technology employed in the modernized or new shipyards of the late 1960s and early 1970s.
3	Good shipbuilding practice of the late 1970s. Represented by the new or fully re-developed shipyards of that time in the US, Europe, South Korea, and Japan.
4	Typical of shipyards that have improved their technology during the 1980s and 1990s, but not up to leading standards.
5	State-of-the-art technology.

Source: First Marine International

The scoring of each element is based on detailed observations in the shipyards by a team of subject matter experts, as well as comprehensive discussions with shipyard personnel. For example, welding is observed throughout the entire production and construction process to assess the Welding element (see 4.3 below) in the Ship Construction and Outfitting benchmarking group. If, in a benchmarked yard, significant portions of production still employ hand welding, resulting in labor inefficiency, lack of repeatability and consistency of welds—and the associated requirement to frequently inspect during the production process—the Welding element for this shipyard would be scored level 1. If another shipyard made extensive and effective use of robotic welding, it would be scored 5.

4. Ship Construction and Outfitting

- 4.1. Ship Construction
- 4.2. Erection and Fairing
- 4.3. Welding
- 4.4. Onboard Services
- 4.5. Staging and Access
- 4.6. Outfit Installation
- 4.7. Painting

In each benchmarking assessment of the Welding element, the full range of practice throughout the shipyard is documented. For the example, in the shipyard cited above, this would mean that even if many of the other elements of the Ship Construction and Outfitting group had been levels 3 or 4 (1970s-1990s practices), the range of this group would have been from level 1 (the lowest observed) to level 4 (the highest observed). In this way, the group scorings provide a comprehensive snapshot of the processes employed in each shipyard.

1. Steelwork Production

- 1.1. Plate Stockyard and Treatment
- 1.2. Stiffener Stockyard
- 1.3. Plate Cutting
- 1.4. Stiffener Cutting
- 1.5. Plate and Stiffener Forming
- 1.6. Minor Assembly
- 1.7. Sub-assembly
- 1.8. Flat Unit Assembly
- 1.9. Curved and 3D Unit Assembly
- 1.10. Superstructure Unit Assembly
- 1.11. Outfit Steel

As another example, the Plate Stockyard and Treatment (element 1.1) of one shipyard was found to have low storage levels of steel plate due to the just-in-time delivery of needed material. The material was handled by a computer-controlled crane which delivered the plates to an integrated and automated shot-blasting and painting line. This element received a very high score of 4.5. However, if, in this same yard, there was lack of workstation organization, use of out-dated fitting and fairing tools and poor housekeeping in Sub-assembly (element 1.7), this element would be scored 2.5. Again, the range of scores in this group would be wide (2.5 to 4.5), indicating the yard had a mixture of 1970s processes and some that were nearly state-of-the-art.

It is important to note that individual benchmarking scores must be placed in the specific context of factors affecting the shipyard. In the Plate Stockyard and Treatment example above, the level 4.5 technology would be most appropriate for a shipyard with high steel throughput. If steel throughput was low, this level of technology may not be cost effective. Each shipyard is scored relative to the scale of reference in the benchmarking system which provides the objective basis for comparison. However, the appropriateness of the technology for a given shipyard's throughput, product mix, and

EXCERPT FROM THE SCALE OF REFERENCE FOR THE PRODUCTION ENGINEERING ELEMENT

6.6 Production Engineering

1 No formal production engineering function. Little involvement of the production departments in the design process. Few shipyard standards.
2 - *Omitted for brevity*
3 Formalized production engineering. Well established links with design and production at all levels with a structured approach to producibility considerations. Well developed production standards with some standard methods and processes.
4 - *Omitted for brevity*
5 Production engineering function fully integrated with the design process. A small production engineering department maintained for R&D.

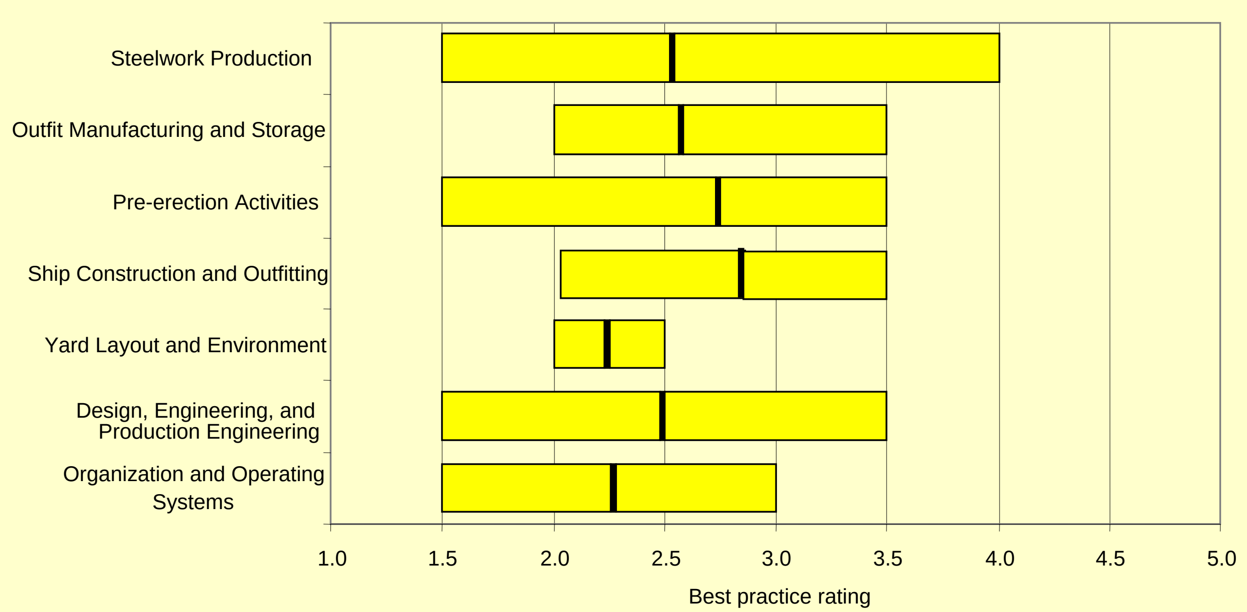
Source: First Marine International

labor cost needs to be taken into account when making recommendations for improvement.

In another shipyard, in evaluating the element of Production Engineering, the subject matter experts found that production engineering was performed subsequent to the functional design of the vessel. Since the design of this vessel did not incorporate the constraints and attributes of the production lines, the optimum use of facilities and equipment was not achieved. The net result was a much lower level of productivity than could have been achieved had the design initially considered the facilities and production technologies available in the shipyard. This element was assigned a score of 2.5 of the total 5. The team recommended that the shipyard synchronize the production engineering and design processes to maximize performance on the production lines.

Once the benchmarking visit is complete, the team prepares a summary of all benchmarking scores in bar chart format, an example of which is provided below. This provides a summary view of a shipyard's overall use of shipbuilding best practices and applied technologies. Individual bar length indicates the range of scores received for all elements within a particular benchmarking group, from the minimum to the maximum

NOTIONAL BENCHMARKING RESULTS



Source: First Marine International

score. The darkened black line indicates the average of all elements in a particular benchmarking group for that shipyard. The most efficient shipyards tend to have a narrow spread of benchmarking scores within the benchmarking groups and an appropriate balance between the groups.

STEP 2: ESTABLISHING SHIPYARD PRODUCTIVITY

In order to further evaluate the effective implementation of manufacturing and business practices at different shipyards, the benchmarking process includes a normalized measure of shipyard productivity, accounting for disparate ship complexity and varying customer profiles. The ship complexity factor (compensated gross tonnage factor) quantitatively corrects for differences in production work content of various ship types. The Customer Factor adjusts for different administrative and operational requirements of different customers.

COMPENSATED GROSS TONNAGE (CGT)

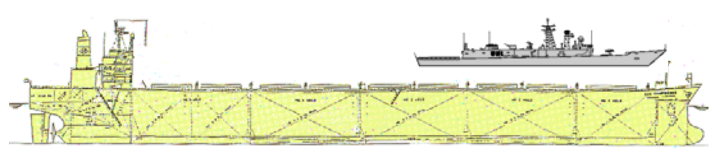
CGT normalizes the production work content within a vessel by multiplying the vessel's gross tonnage (a measure of internal volume) by a factor that accounts for the vessel's complexity. This CGT factor is determined by characteristics such as: vessel specifications (combat systems, survivability, shock, etc.), design standards, outfit density, average compartment size, and the complexity of structural arrangements.

Compensated Gross Tonnage = Vessel Gross Tonnage x CGT Factor

Vessels that have a low level of complexity, such as bulk carriers, have lower CGT factors than more complex vessels such as naval combatants. These factors can range from a low value of 0.3 for bulk carriers to a high of 80 for nuclear powered, fast attack submarines. For commercial vessels these factors have been developed and refined over more than 30 years by leading international shipbuilding organizations. There are currently no agreed CGT factors for U.S. naval vessels. This study estimates CGT factors for U.S. naval vessels based on previous work conducted by FMI for the

COMPARISON OF VESSEL WORK CONTENT BY THE COMPENSATED GROSS TONNAGE (CGT) METHOD

CGT = Vessel Gross Tonnage X CGT Factor



Bulk Carrier	Notional Frigate
Gross Tonnage = 113,606	Gross Tonnage = 5,000
CGT factor = 0.31	CGT factor = 9.0
CGT = 35,218	CGT = 45,000

The frigate has 28% more work content but only 4% of the volume of the bulk carrier.

Source: First Marine International

United Kingdom Ministry of Defence which calculated CGT factors for more than 20 European naval auxiliaries and combatants.

In the example on the chart on the previous page, the CGT factor for a large bulk carrier, which can be characterized as a steel box with an engine room attached, is very low: 0.31. By contrast, work content of a typical frigate would be much higher and would yield a CGT factor of 9.0. Hence, the CGT of the large bulk carrier would be just over 35,000 compensated gross tons (113,606 GT x 0.31 CGT factor); the notional frigate's CGT would be 45,000 compensated gross tons (5,000 GT x 9.0 CGT factor). In this example, the frigate has 28 percent more work content but only four percent of the volume of the bulk carrier.

It must be recognized that even apparently similar ship types can be very different in their construction, leading to large differences in their CGT factors. For example, a Japanese KONGO Class destroyer has a very different structure and work content than a U.S. ARLEIGH BURKE Class destroyer due to different mission requirements. This study recognizes and accounts for these differences in order to provide better productivity assessments. To complete comparisons, however, the Customer Factor must also be considered.

CUSTOMER FACTOR

CUSTOMER FACTORS FOR VARIOUS SHIPBUILDING CUSTOMERS

Customer Factor	Description
1.00	Normal commercial contract
1.06	Naval auxiliaries for MoD and typical export combatants
1.12	Combatants built for MoD and demanding export customer

Source: First Marine International

Like the CGT factor, which is used to normalize the work content across differing ship types and sizes, the Customer Factor is used to normalize the amount of work necessary for differing customers. Generally, the differences between the practices of two commercial owners are trivial and are ignored. However, the difference between naval and commercial practices is often so large that compensation factors need to be applied to take this into account. The Customer Factor is based on myriad factors such as customer oversight, reporting requirements, and unique administrative requirements. The table above shows the factors that were developed for a recent United Kingdom Ministry of Defence (MoD) study. This table indicates that MoD requirements for combatants increased the shipyards' work content by about 12 percent.[11] The GSIBBS series, in consultation with members of the U.S. shipbuilding industry, has refined this factor for application to U.S. naval auxiliaries, and further extrapolated to develop estimates for U.S. combatants.

[11] As early as 1994, studies assessing the U.S. customer factor attributed a cost premium of as high as 18 percent for companies working with the U.S. government. *The DoD Regulatory Cost Premium: A Quantitative Assessment.* Coopers & Lybrand/TASC, December 1994.

This factor is applied to the base CGT for the work content required by non-commercial contracts to correct for the additional work relative to standard commercial practices. This computation provides the total work content for a shipyard.

Total Work Content = CGT x Customer Factor

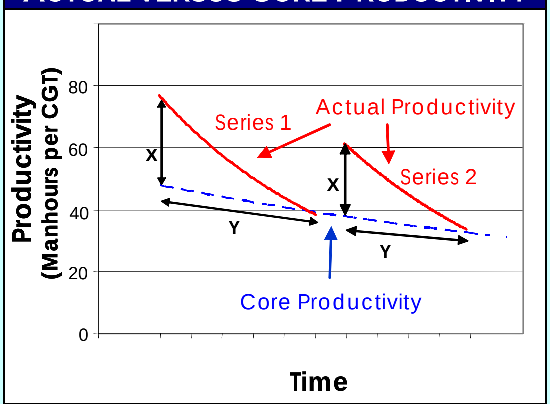
By taking into account the CGT and Customer Factors, productivity can be compared between different shipyards producing different ships for various customers. Productivity is then calculated by dividing the total shipyard manhours expended by the total work content.[12]

Shipyard Productivity = Total Shipyard Manhours Expended/Total Work Content

A NOTE ABOUT CORE VERSUS ACTUAL PRODUCTIVITY

Core productivity is the best productivity a shipyard achieves with its current facilities and workforce, a stable design, and stable manufacturing processes. Core productivity is related to the learning curve for the overall shipyard. In contrast, actual productivity is core productivity decremented by the learning curve associated with a vessel series. The goal for the Navy and the shipyards should be to minimize the decline in productivity seen during the introduction of a new series of vessels so that shipyards can operate closer to core productivity, thereby saving the wasted resources and costs expended during the traditional learning process. This delta between core and actual productivity on the first vessel in a new series is known as first-of-class performance drop-off, and is represented by the "x" on the chart to the right.

ACTUAL VERSUS CORE PRODUCTIVITY



Source: First Marine International

In the example shown, a shipyard took approximately 75 manhours per compensated gross ton for the first ship in the Series 1 class. By the last ship in this class, this shipyard had improved its productivity to 40 manhours per compensated gross ton, reaching its core productivity. However, for the first of the Series 2 class, productivity dropped off to 60 manhours per compensated gross ton. The typical first-of-class performance drop-off for a commercial shipyard with an overall best practice rating of 3.5 is approximately 10 percent. In a shipyard building naval vessels, the performance drop-off could be as high as 60 percent. The large difference between shipyards producing commercial and naval vessels is often due to the complexity of the vessel involved, and design maturity at start of lead ship construction. Commercial shipyards production processes, once optimized, yield similar results when building new series of vessels. In contrast, shipyards building warships often are faced with dramatic design changes or designs that are not fully mature.

These factors significantly contribute to the drop-off in productivity performance. For U.S. shipyards building naval vessels, core productivity is usually reached between the 8th and 10th vessel constructed versus as few as one to two vessels in commercial shipyards. This study assesses both core productivity and actual productivity, and has found this area to be a major opportunity for improvement in U.S. shipyards—with cooperation from the Navy.

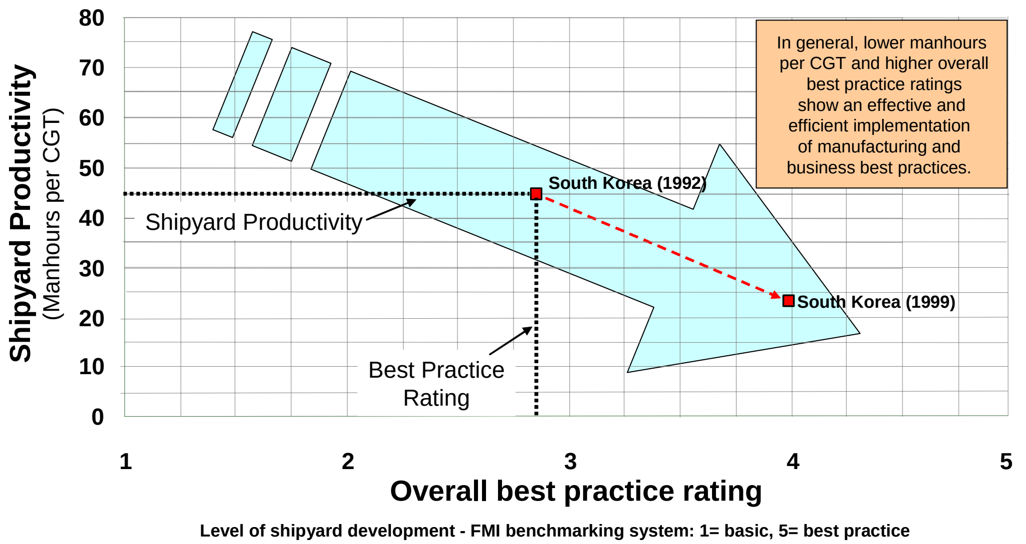
[12] For a more complete description of the development of CGT factors and example productivity calculations see Appendix E.

STEP 3: COMPARISON OF PRODUCTIVITY VERSUS USE OF BEST SHIPBUILDING PRACTICES

The last step of the benchmarking process is to compare a shipyard's productivity and their use of best practices to other U.S. and global shipyards.[13] The shipyard's productivity—measured in manhours per total work content—is plotted against its overall best practice rating to compare its manufacturing and business practices with those of other shipyards.

Shipyards that effectively implement higher levels of shipbuilding best practices typically see a corresponding reduction in the number of manhours required to produce a compensated gross ton. To be truly efficient, each shipyard must maximize its use of resources by ensuring that it is using best practices appropriate to its size, type, and individual business objectives. A good example is shown in the chart below. In 1992, the South Korean shipbuilding industry was operating at an overall use of best practice rating of approximately 2.8 while their overall productivity was approximately 45 manhours per CGT. By 1999, improvements in the South Korean shipbuilding industry had led to an overall use of best practice rating of 4.0, while at the same time driving the number of manhours to produce one compensated gross ton from 45 in 1992 to approximately 24 in 1999, a decrease of almost half.

PRODUCTIVITY VS. USE OF BEST PRACTICE



Source: First Marine International and ODUSD(IP)

This example illustrates the extraordinary leverage that business and manufacturing practices represent in reducing manhours. However, minimum costs result from having the most appropriate use of shipbuilding best practice. It is to induce similar progress in the U.S. shipbuilding industrial base that the Department commissioned this study.

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[13] Past competitiveness studies have established a correlation between use of best practices and overall shipyard productivity. One of the most thorough of these studies was the 1992 European Commission Study of the Competitiveness of European Shipyards carried out by KPMG (United Kingdom) and First Marine International.

PART III

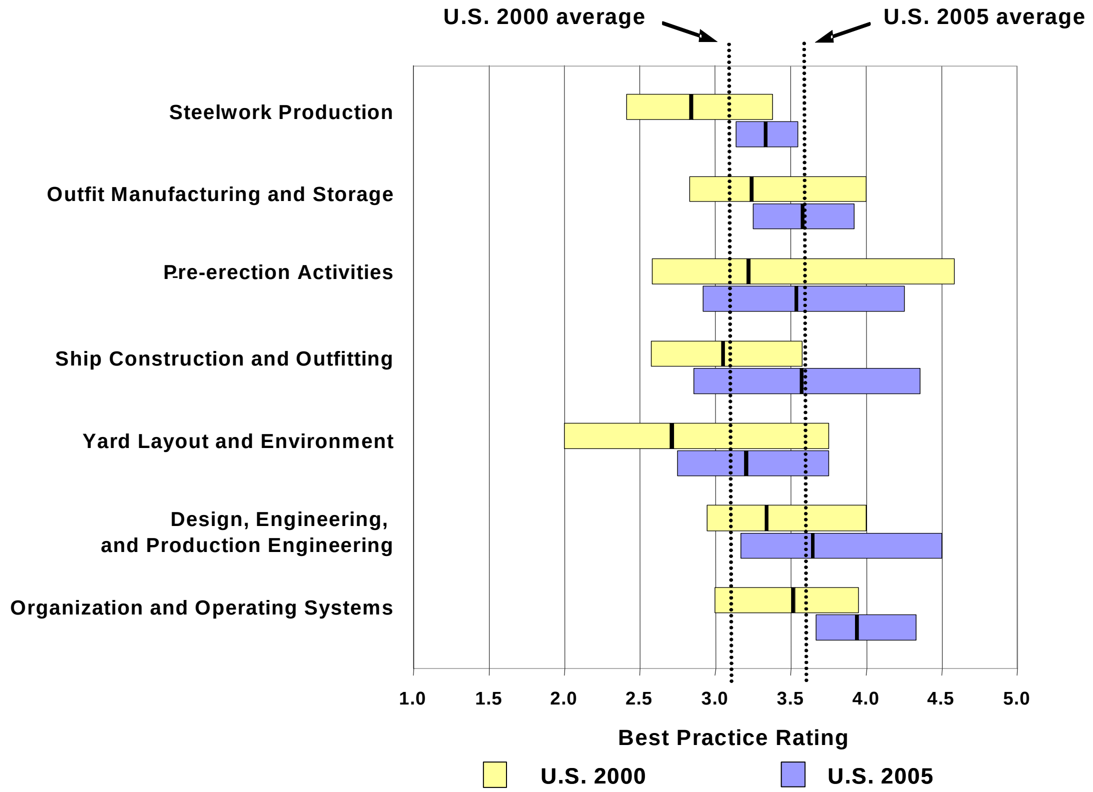
BENCHMARKING RESULTS

Although U.S. shipyards have improved significantly in their use of best shipbuilding practices, there still are significant opportunities for both the industry and the Department to improve. This part of the study presents the benchmarking results.[14]

PROGRESS SINCE 2000

The chart below summarizes the benchmarking results of the U.S. shipyards in the 2000 study and the current study. The range of each bar represents the lowest and highest score in each element group for every U.S. shipyard benchmarked. The small vertical black line on each bar represents the average score for that element. The dotted vertical lines are the overall benchmarking averages for U.S. shipyards in 2000 and 2005. As shown in the chart, the U.S. shipbuilding industrial base has made

BENCHMARKING COMPARISON[a]—U.S. 2000 VS U.S. 2005



[a] Site specific results have been provided to the respective yards and the Department, but will not be made publicly available.

Source: First Marine International

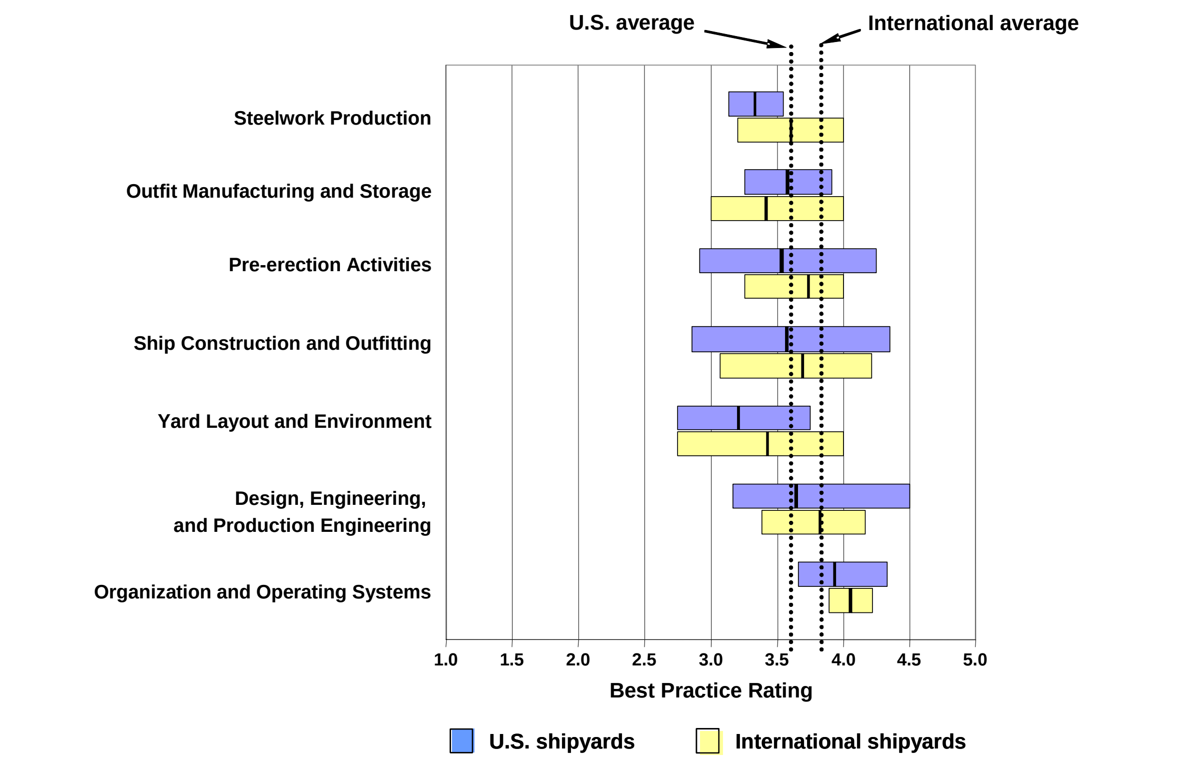
[14] Part IV will propose remedies to implement business and manufacturing process improvements; Parts V and VI will discuss the Shipbuilding Industrial Base Investment Fund intended to implement identified remedies.

significant strides in the last five years: in every benchmarking group the average U.S. benchmarking score improved appreciably. The overall benchmarking average for the U.S. shipyards increased from 3.1 in 2000 to 3.6 in this study. Some shipyards substantially increased capital expenditures, and most made a concerted effort to employ a higher level of technologies. However, there still are large disparities among individual U.S. shipyard benchmarking scores—and in practices within individual shipyards.

The largest average benchmarking score improvements were in Steelwork Production (2.8 to 3.3); Ship Construction and Outfitting (3.0 to 3.6); and Yard Layout and Environment (2.7 to 3.2). These areas scored significantly below average in 2000. A good example of a major investment in this area is NASSCO's installation of a new, automated stiffener cutting line and a new panel line in 2003, which significantly improved steelwork production, and consequently improved the industry's average benchmarking score in this area. Improvements in all other benchmarked areas were slightly more modest, but, notably, those in Design, Engineering, and Production Engineering (DE/PE), as well as Organization and Operating Systems moved some shipyards' performance in those areas ahead of overall 2005 averages.

Turning now to U.S. shipyards' comparisons with international shipyards in 2005, U.S. shipbuilders' benchmarking average of 3.6 is now close to the international shipyards' average benchmark score of 3.8. Paradoxically, however, it is in the two areas where U.S. shipyards are above average—DE/PE and Organization and Operating Systems—

U.S. AND INTERNATIONAL BENCHMARKING COMPARISON—2005



Source: First Marine International

that international shipyards' average scores still beat U.S. shipyards by a comfortable margin—and in spite of the fact that some U.S. shipyards' results beat those of the international shipyards in these areas. Some U.S. shipyards also outperform international shipyards in Ship Construction and Outfitting, and Pre-erection Activities. Worst average U.S. shipyards comparisons are in the Steelwork Production and Yard Layout and Environment areas, as shown on the opposite page.

In general, the facilities and equipment employed by the U.S. shipbuilding industry are largely appropriate for the military products and quantities it constructs. Answers to the U.S. shipyards' cost and performance problems lie elsewhere: in other productivity measures and the adverse impact of the "Customer Factor." It must also be noted that the U.S. shipyards' continued lag in DE/PE and Organization and Operating Systems may suggest that it is in these areas where additional focus could produce the greatest leverage. This is particularly the case with seven new designs (LCS flight 1, DD(X), CG(X), LHA(R), MPF(F), SSBN(X), CVN 21) to be built in the 2007-2020 timeframe that this area could offer the greatest leverage—if designs of these new vessel classes help U.S. shipyards move to 21st century manufacturing processes. To achieve this result, the Department must ensure that these designs fully exploit state-of-the-art production engineering techniques to minimize inherent work content and realize the benefits of optimized production processes—as opposed to incremental improvements to legacy design practices. To extend the benefit of state-of-the-art designs produced in modern facilities, the Navy and Congress must allow the program and funding stability associated with predictable rate production.

The summary of FMI benchmarking results is below and detailed in Appendix B. While the group averages show improvement for the U.S. shipyards over the last five years, significant technology gaps in several critical elements between U.S. and international shipyards indicate important action areas that form the basis for the detailed remedies in Part IV.

BENCHMARKING RESULTS SUMMARY			
Benchmarking Groups	**U.S. Shipyards**		**International Shipyards**
	2000	**2005**	**2005**
Steelwork Production	2.8	3.3	3.6
Outfit Manufacturing and Storage	3.2	3.5	3.3
Pre-erection Activities	3.2	3.5	3.7
Ship Construction and Outfitting	3.0	3.6	3.7
Yard Layout and Environment	2.7	3.2	3.4
Design, Engineering, and Production Engineering	3.3	3.6	3.8
Organization and Operating Systems	3.5	3.9	4.0
Source: First Marine International			

PRODUCTIVITY FINDINGS

Recall that benchmarking results are but one of two elements this study uses to analyze a shipyard's performance. The other is productivity—the number of manhours expended by a shipyard divided by the corresponding total work content. It is this measure that also accounts for the "Customer Factor."

Shipyard Productivity = Total Shipyard Manhours Expended/Total Work Content

where

Total Work Content = CGT x Customer Factor

Considering productivity in combination with the use of best shipbuilding practices (benchmarking results) provides a comprehensive assessment of the effectiveness of the practices employed.

CGT CALCULATIONS FOR BENCHMARKED SHIPYARDS

Productivity calculations, which include CGT factor development,[15] are based on open source information, previous studies, data analysis, historical trends, and shipyard inspections.[16] Company proprietary and security classification issues limited the technical data available to the benchmarking team for CGT calculations. Nevertheless, the productivity results compiled for this study are indicative of industry performance observed through other methods.

Building on CGT factors developed for the UK Ministry of Defence, FMI refined factors for application to U.S. naval vessels. These U.S. naval vessel CGT factors are consistently higher than those of UK and European naval vessels. Assessments for this study suggest that U.S. naval vessel designs are more complex than similar foreign warship designs because of increased capabilities, multi-mission roles, and a stronger emphasis on performance rather than producibility.[17]

Next, in order to develop the total work content for each U.S. shipyard, FMI determined the customer factor.

CUSTOMER FACTOR ANALYSIS

FMI estimated the individual customer factors for U.S. naval combatant and auxiliary vessels. For a range of commercial and naval vessels built at one U.S. shipyard, the proportion of manhours spent in each major area of the shipyard (Management, Engineering, Production, Quality Assurance, etc.) was calculated as a percentage of the touch-labor manhours. The analysis then compared the averages for the commercial

[15] CGT factor (ship complexity factor) quantitatively corrects for differences in production work content of various ship types.

[16] For a more thorough discussion of CGT and productivity calculations performed for this study, see Appendix E.

[17] These observations were consistent with the observations from a 1994 study which showed that a U.S. frigate had approximately ten percent more work content per gross ton than a typical UK frigate.

vessels built in that shipyard with those of the naval vessels to determine if there were consistent differences between the data sets. Significant differences were found in eight areas that can add costs that would not be analogous in a commercial setting. The following areas are listed in order of greatest impact; however items five through eight were all of relatively equal value.

1. Engineering not associated with first-of-class design
2. Production and Support Services
3. Industrial Engineering
4. Administration
5. Program Management
6. Master Planning
7. Material Procurement and Warehousing
8. Quality Assurance

The commercial customer factor of 1.0 is the baseline for comparison. FMI estimated the customer factor to be about ten percent for naval auxiliaries and possibly 15 percent or more for surface combatants. It is likely significantly higher for nuclear-powered vessels.

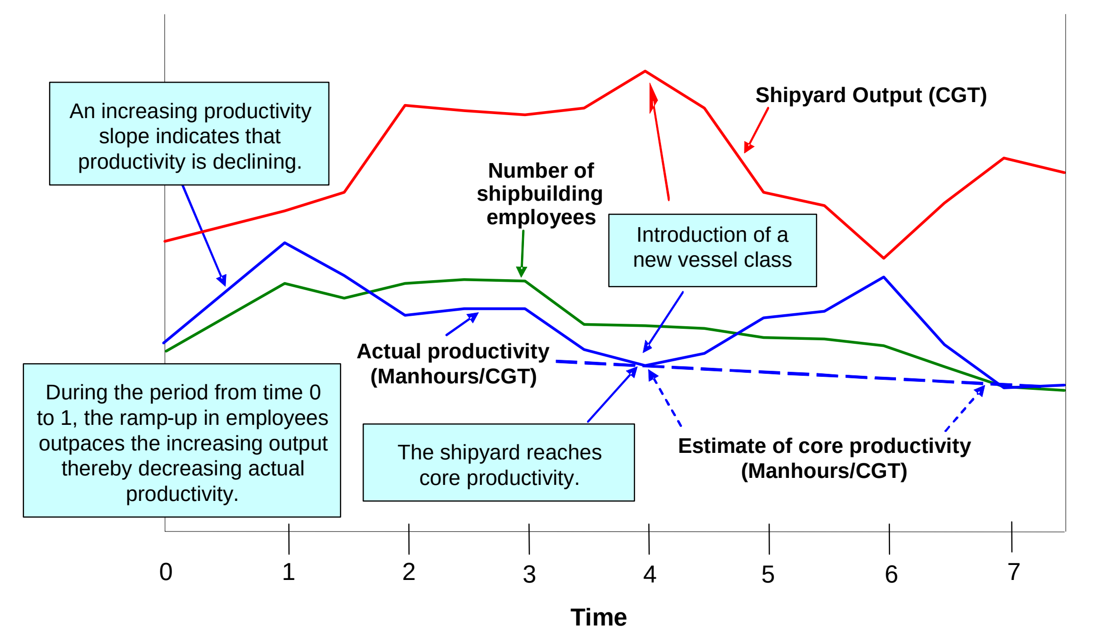
CORE VERSUS ACTUAL PRODUCTIVITY

As discussed in Part II of this report, core productivity is the best productivity a shipyard achieves with its current facilities and workforce, a stable design, and stable manufacturing processes. Productivity information is proprietary and most U.S. shipyards declined to provide it for this study. However, it is possible to perform a high-level estimate of shipyard productivity using publicly-available information, specifically by comparing annual shipyard output to the number of shipyard manhours expended.

FMI estimated productivity for each U.S. shipyard benchmarked.[18] The graph on the following page shows notional productivity results for a single shipyard. The red line represents actual CGT output and the blue line represents actual shipyard productivity. Since productivity is measured in manhours per compensated gross ton, improving levels of productivity are indicated by lower values on the chart (fewer manhours to produce one compensated gross ton). Core productivity is determined by the best actual productivity over a given timeframe. The dashed blue line—the shipyard's core productivity—is determined by linear regression.

[18] For a more thorough discussion of CGT and productivity calculations performed for this study, see Appendix E.

NOTIONAL PRODUCTIVITY GRAPH



Source: First Marine International and ODUSD(IP)

These graphs compare core and actual productivity for the major U.S. shipyards. Productivity and this issue of core versus actual productivity are critical because they demonstrate the interplay of factors other than those benchmarked, which can erode productivity and cost-effectiveness in a shipyard. In the example above, actual productivity decreased steadily from Time 0 to 1 as the increasing number of employees outpaced the increasing output. Core productivity was reached at Time 4. However, the start of a new class of vessel immediately resulted in a decline in shipyard output and a corresponding decline in productivity. Charts like these—showing major swings in productivity—were more typical of U.S. shipyards than leading international shipyards.

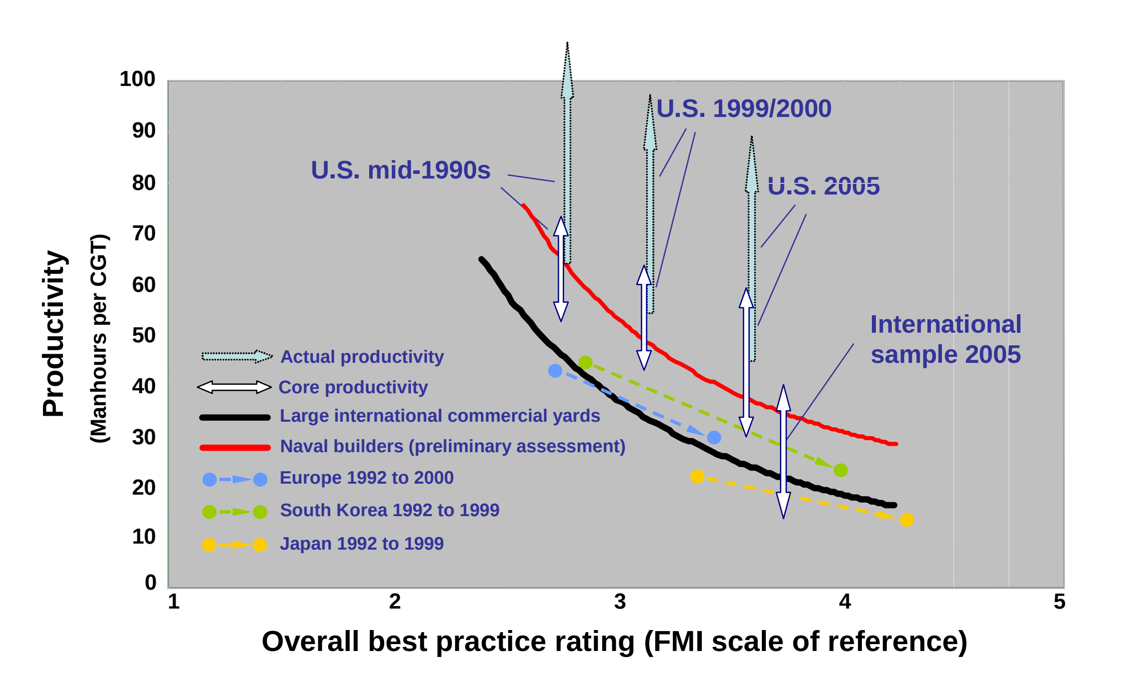
This sawtooth pattern away from core productivity is likely attributable to many factors. First, complex and immature designs cause inefficient production and costly change orders. In addition, throughput instability translates to production line instability and results in employment fluctuations. Finally, while not directly related to changes in output, the administrative burden associated with doing business with the Department (customer factor) hampers productivity by requiring extensive overhead. Thus, the vortex of underperformance in U.S. shipyards can undoubtedly best be addressed with remedies relating to pre-production issues—given that many of the benchmarked manufacturing practices are approaching world standards.

RESULTS SUMMARY

The chart on the following page plots the productivity data (vertical axis) and the best practice ratings (horizontal axis) of U.S. and international shipyards. Historical performance for large international commercial shipyards is based on previous benchmarking studies; and is shown as the black line. The red line represents the preliminary results of a recent FMI assessment of U.S. and international naval shipyards.[19] These lines represent the average productivity correlated to best practice ratings. Productivity improvement is related directly to continued application and improvement of appropriate shipbuilding practices. Yards that perform less well tend to be above these lines, indicating they have "wasted" some potential benefits of the applied practices. The white arrows show the range of core productivity (the best productivity demonstrated by U.S. shipyards) and the blue arrows show the range of actual productivity for them.

Currently, U.S. shipyard core productivity appears to be in the range of 30 to 60 manhours per CGT. The higher performing U.S. shipyards are approaching the core productivity levels of the best international naval shipyards, while still significantly trailing that of international commercial shipyards.

PRODUCTIVITY VS. OVERALL BEST PRACTICE RATING



Source: First Marine International

It also shows that U.S. shipyards are only now experiencing actual productivity levels comparable to their own core productivity levels of the mid-1990s. If U.S. shipyards realized the full potential of their manufacturing best practices and were able to operate at core productivity, their actual productivity could improve by as much as 50 percent—and the best would be within the range of high output international shipyards. Unfortunately, for a variety of reasons, U.S. shipyards often do not operate at their core productivity. To reach core productivity, more emphasis is required in the areas in

19 *Naval CGT Coefficients and Shipyard Learning*. John Craggs, Damien Bloor, and Hamish Bullen (FMI); and Brian Tanner (Ministry of Defence), March 2003.

which U.S. shipyards historically lag high performing international shipyards: simplifying designs, ensuring throughput stability, and reducing the extensive overhead required to work in a naval environment (customer factor). The table below further elaborates the causes which make U.S. shipyards operate at less than their core productivity.

SIGNIFICANT FACTORS UNDERMINING U.S. SHIPYARD CORE PRODUCTIVITY	
Factor	**Cause**
First-of-class performance drop-off	Start of a new class of vessel often causes a decline in productivity due to: immature and complex designs, ineffective planning, decreased worker efficiency, and lack of production optimization.
Excessive change orders	Immature and complex designs cause numerous and costly change orders to be made during the production process.
Interference between concurrent series	Concurrent ship series often compete for the same constrained resources. When this happens, productivity in both ship series drop.
Introduction of new facilities or processes	When new processes or facilities are employed, productivity declines during the transition process due to employee training, learning, and startup problems.
Workforce variation	Vessel procurement fluctuations necessitate commensurate changes in employment. Ramp-ups/drawdowns contribute to worker inefficiency.
Source: First Marine International	

Between 2000 and 2005, the U.S. shipyard best practice rating improved substantially from 3.1 to 3.6—approaching the 2005 international average of 3.8. However, it appears gains in core productivity have been more modest. Core productivity ranged from 55-75 manhours per CGT in the mid-1990s, progressed to 45-65 manhours per CGT by 2000; and reached 30-60 manhours per CGT in 2005. On an average basis, core productivity was at 65 manhours per CGT in the mid-1990s, 55 manhours per CGT in 2000, and 45 manhours per CGT in 2005. However, the broad range of benchmarking results makes clear that some yards have improved their core productivity quite significantly, others perhaps not at all.

These results demonstrate the need to redouble focus on the factors that impede shipyards from operating at core productivity levels. Parts IV and V will discuss remedies essential to reversing the trend of U.S. shipyards operating at less than optimal productivity. Part VI proposes a Shipbuilding Industrial Base Investment Fund (SIBIF) that would facilitate the effective implementation of these remedies.

PART IV

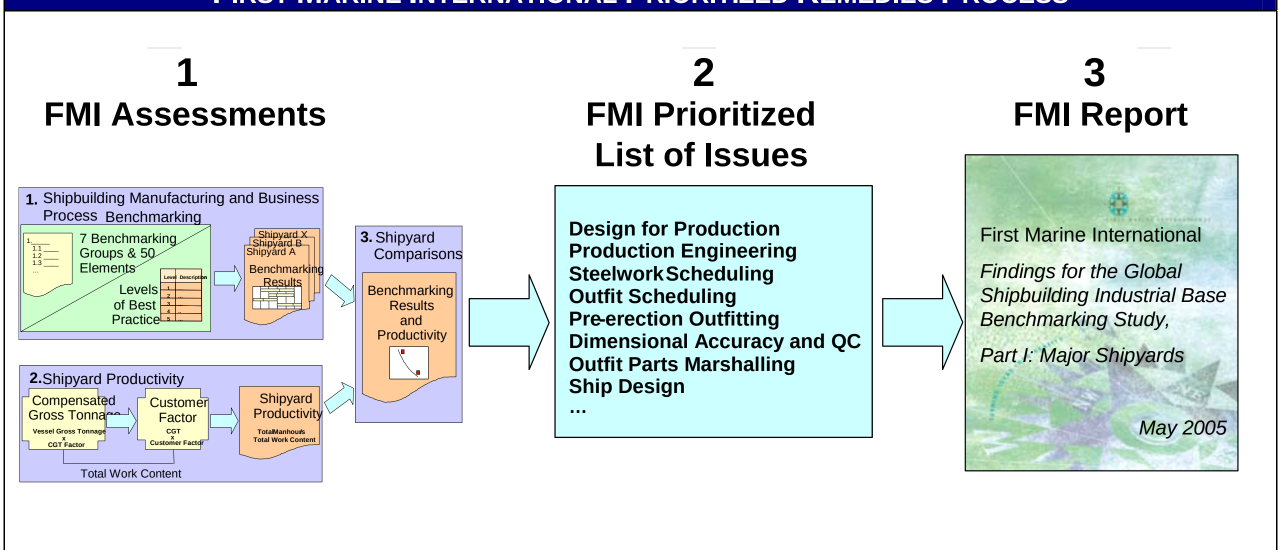
GSIBBS REMEDIES AND RECOMMENDATIONS

The GSIBBS proposes remedies and recommendations to improve the U.S. shipbuilding industrial base based on a collaborative process that drew on the most qualified expertise available to the Department. First, FMI independently prioritized issues and associated remedies based on its benchmarking and associated productivity analyses. Then, these issues and remedies were validated, prioritized, and costed by the National Shipbuilding Research Program (NSRP).[20] Finally, these remedies were consolidated into a time-phased plan, a Shipbuilding Industrial Base Investment Fund (SIBIF), for which the Department may request multi-year funding.

ISSUES IDENTIFIED BY FIRST MARINE INTERNATIONAL (FMI)

FMI's issues and proposed remedies are based on its benchmarking and productivity analyses. As summarized in the chart below, FMI assessed U.S. shipyards in the global context relative to manufacturing practices and productivity; prioritized issues using standard criteria; and published its independent report, *First Marine International Findings for the Global Shipbuilding Industrial Base Benchmarking Study, Part I: Major Shipyards.*

FIRST MARINE INTERNATIONAL PRIORITIZED REMEDIES PROCESS



Source: First Marine International

The following table summarizes FMI's prioritization of issues in the 50 benchmarking elements. It is color-coded to categorize important groups of issues: blue for those relating to Design, Engineering, and Production Engineering; purple for those relating to

[20] Created by U.S. shipyards at the Navy's request in 1998 to reduce the cost of building and maintaining U.S. Navy warships, NSRP is a collaboration of 11 major U.S. shipyards focused on industry-wide implementation of solutions to common cost drivers.

Production Processes; and pink for those relating to Organization and Operating Systems.

FMI PRIORITIZED ISSUES			
Rank	Issue (Benchmarking Element)[a]	Rank	Issue (Benchmarking Element)
1	Design for Production (6.7)	26	Steelwork Production Information (6.2)
2	Production Engineering (6.6)	27	Onboard Services (4.4)
3	Steelwork Scheduling (7.3)	28	Profile Stockyard and Treatment (1.2)
3	Outfit Scheduling (7.4)	28	Module Building (3.1)
5	Pre-erection Outfitting (3.3)	28	Block Assembly (3.4)
5	Master Planning (7.2)	31	Curved and 3D Unit Assembly (1.9)
7	Dimensional Accuracy and Quality Control (6.8)	32	Profile Cutting (1.4)
8	Ship Design (6.1)	32	Staging and Access (4.5)
9	Outfit Parts Marshalling (3.2)	34	Layout and Material Flow (5.1)
10	Steelwork Coding System (6.4)	35	Plate Stockyard and Treatment (1.1)
11	Materials Handling (3.6)	35	Storage of Large Heavy Items (2.6)
12	Pipe Shop (2.1)	37	Flat Unit Assembly (1.8)
13	Manpower and Organization of Work (7.1)	38	Welding (4.3)
14	Outfit Production Information (6.3)	39	Sub-assembly (1.7)
15	Erection and Fairing (4.2)	40	Superstructure Unit Assembly (1.10)
16	General Storage and Warehousing (2.5)	41	Outfit Steel (1.11)
16	Painting (4.7)	42	Minor Assembly (1.6)
18	Outfit Installation (4.6)	43	Quality Assurance (7.8)
19	Production Control (7.5)	44	Electrical (2.4)
20	Parts Listing Procedure (6.5)	45	Sheet Metal Working (2.3)
20	Performance and Efficiency Calculations (7.7)	45	Unit and Block Storage (3.5)
22	Plate and Profile Forming (1.5)	47	Machine Shop (2.2)
22	General Environment (5.2)	48	Plate Cutting (1.3)
24	Ship Construction (4.1)	48	Stores Control (7.6)
25	Lofting Methods (6.9)	48	Production Management Info Systems (7.9)
[a] See "Benchmarking Groups and Elements" chart on page 20.			
Source: First Marine International			

Of the top ten priority issues identified by FMI, half are in the benchmarking group relating to Design, Engineering, and Production Engineering; three involve Pre-Erection Activities; and two relate to Organization and Operating Systems. Six lower priority issues which are key enablers to the top ten issues are discussed in the sections relating to these three benchmarking groups. The associated remedies are compiled in the tables that begin on page 41.

Design, Engineering, and Production Engineering Issues

Ship Design (6.1) and Design for Production (6.7)

Inconsistent and ill-defined design processes in the U.S. shipbuilding industry have led to excessive design lead times and design manhours. International shipyards have a standard approach to ship design with well-defined design stages and clearly specified outputs for each stage. In addition, design for production in U.S. shipyards is a low priority when compared to international norms. U.S. design and engineering staff are relatively uninformed about production processes and methodologies compared to their international counterparts. The practice of incorporating producibility in design through the formation of ship-specific design/build teams without shipyard-wide design producibility standards leads to inconsistency across ship classes. While some improvement may result, the overall achievement is inferior to the process employed in many international yards where design producibility is embedded at the very start of design and is based on shipyard standards optimized for the shipyard facilities and processes.

To optimize production performance at the shipyard level, each shipyard should have a formalized and consistent shipbuilding strategy from which design rules and guidelines are developed for each stage of the design process. If the Navy continues acquisition strategies requiring teaming, or wants to provide for later cooperation of given designs, industry-wide design standards would have to be developed if this level of flexibility is desired without impairing productivity.

Production Engineering (6.6)

Lack of emphasis on production engineering is one of the major inhibitors of improvement in U.S. shipbuilding productivity. This issue needs to be addressed by the Navy, the shipbuilding industry overall, and individual shipyards. Current U.S. Navy vessel acquisition practices are not conducive to producible designs. These practices create excessive design lead times with a low priority on producibility and include: widespread use of legacy designs; design and build contracts awarded to separate shipyards; and fundamental changes to the basic design of a vessel at any stage in the design cycle. At the shipyard level, production engineering must assume a leading role in performance improvement and facilities and methods development.

Dimensional Accuracy and Quality Control (6.8)

Although most U.S. shipyards have established accuracy control departments and have made progress toward implementing statistical process control, they have not fully realized these benefits due to lack of stable production processes and the low level of confidence placed on dimensional control. As a consequence, most U.S. shipyards leave excess material on units, blocks, and outfitting items which create future rework. Strong proficiency in dimensional and accuracy control in international shipyards permits further automation, lower work content, and faster construction times.

Steelwork and Other Coding Systems (6.4)

To be effective, any coding system must embrace all areas of ship pre-production and production operations—not just steelwork. Only with networked coding systems in a shipyard can various databases be effectively and efficiently navigated without extensive manual intervention.

All the U.S. shipyards surveyed have a coding system of one form or another that includes various aspects of material and labor control. Although some are semi-intelligent, in that they identify some interim products to areas of production, the majority are little more than numbering systems that are generally specific to individual areas of operation without a common shipyard-wide structure. For example, the steelwork coding structure is different than the outfit coding structure which is again different than the workstation coding structure.

If it is the intention to continue with the current practice of having a lead shipyard for the design of naval vessels with a number of yards involved in construction, there should be an industry-wide common coding structure applied throughout all levels of the design process that at a minimum identifies vessel types, systems, zones, and products. Ideally, this system would encompass workforce and workstation identification in a common structure of code fields. Any industry-wide structure must be hierarchical and capable of top-down application so that a lead design yard can apply the higher levels of the coding system in the various fields that will be further populated by the various yards constructing the vessels.

Steelwork and Outfit Production Information (6.2/6.3)

In almost all U.S. shipyards, there is a lack of practical shipbuilding knowledge in the engineering departments that makes the preparation of workstation specific production information extremely difficult. International yards have clearly specified outputs from each stage of design so that necessary production information flows smoothly from the earliest stages of construction.

There is a heavy reliance on production feed-back for the completion and development of production information for subsequent vessels in the series. This process of developing production information during production is inefficient and results in U.S. engineering manhours and design cycle times that are excessive by international standards.

Throughout the U.S. shipbuilding industry, remedying the production engineering, ship design, design for production and planning issues would help stabilize the design process and provide for efficient development of optimized production information.

PRODUCTION PROCESS ISSUES

Module Building (3.1) and Pre-erection Outfitting (3.3)

Even though some equipment is supplied by vendors as packaged units, U.S. shipyards could make significant productivity gains through increasing the number of outfit modules[21] used in ship construction. U.S. shipyards frequently employ legacy designs in which outfit modules are not incorporated.[22] Although most shipyards accept the benefits of module building, they and the Navy are reluctant to spend resources re-designing legacy vessels to incorporate more outfit modules despite the savings that would accrue to subsequent ships. Increased use of outfit modules could permit increased outsourcing, which could result in significant cost savings.

U.S. shipyards should also increase the percentage of pre-erection outfitting in order to reduce outfitting work at the more costly, onboard stage. This issue once again emphasizes the importance of production engineering and design-for-production in new classes of vessels.

Outfit Parts Marshalling (3.2) and Materials Handling (3.6)

Outfit parts marshalling, general storage and warehousing, and the storage of large and heavy items are all important because of the significant cost associated with receiving and storing material and equipment and then delivering it to the point of use. Lean doctrines have been well applied in some U.S. shipyards, but in most shipyards, inventory levels are very high. The solutions required in each yard are slightly different but there are several general solutions. In the longer term, a move towards a palletized system where the production pallet is compiled in the warehouse from Day One would be most beneficial. This would align U.S. shipyards with lean manufacturing processes employed elsewhere within the U.S. industrial base. In addition, the Navy should ensure contract arrangements do not encourage the buildup of inventory in shipyards.

Materials handling is an essential but nevertheless non-value-added activity which must be minimized and eliminated as much as possible. Typical problems in the U.S. yards are that transport systems are not integrated, material handling distances are long, and too often, overhead cranes are used for the movement of materials and parts between stages rather than customized transport systems.

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[21] The assembly of functionally-related outfit components onto a steel frame which can be manufactured in the shipyard or vendor supplied. These should not be confused with ship modules which may be a complete cross section of the ship.

[22] The exception is submarine construction, where designs incorporate a very large portion of pre-determined modules.

ORGANIZATION AND OPERATING SYSTEMS ISSUES

Master Planning (7.2), Steelwork Scheduling (7.3), Outfit Scheduling (7.4), and Manpower and Organization of Work (7.1)

In general, planning systems in international shipyards are simpler and require a much lower level of effort to operate than those in U.S. shipyards. International shipyards focus on and succeed at schedule adherence—with systems that are more flexible and responsive to change.

U.S. shipyard planning and manpower utilization have been undermined by instability in ship procurement levels and the resultant change in industry employment levels. This in turn has had a deleterious effect on U.S. shipbuilding industry worker proficiency. This is compounded by the strong union influence in most U.S. shipyards which limits effective practices such as use of cross-training (i.e., a steelworker performing pipefitting), multidisciplinary teams, and area management. In the international setting, it is customary for workers to be flexibly employed and trained in a number of disciplines.

> *"The FY2006 Navy shipbuilding plan reflects a procurement rate of one submarine per year until FY2012… This is the 12th change to the VIRGINIA procurement plan in ten years. Over this time, the forecast for nuclear submarines has been reduced by almost 40 percent, a reduction from 24 ships to 15 over the 1998-2012 time frames. This is estimated to be a reduction of about $20 billion to our single product market."*
>
> *Michael W. Toner*
> *Executive Vice President Marine Systems,*
> *General Dynamics Corporation,*
> *Testimony before the*
> *U.S. Senate Armed Services Committee,*
> *Sea Power Subcommittee,*
> *April 12, 2005*

FMI REMEDIES

The following tables summarize FMI's enterprise-wide remedies for the highest priority benchmarking elements. FMI provided shipyard-specific remedies to the individual shipyards. For reasons of layout, remedies associated with DE/PE are below; those related to Pre-erection Activities, Organization and Operating Systems, and Customer Factor are on page 42.

FMI REMEDIES

Group	Element description	Remedies
Design, Engineering, and Production Engineering	Ship Design (6.1) and Design for Production (6.7)	1. Develop a standard and consistent design approach to be applied to all vessel types. 2. Develop a ship design and production definition strategy that reflects each shipyard's shipbuilding strategy, including rules and guidelines for each stage of the design and engineering process to the level of individual production workstation information requirements. 3. Establish a progressive design approval program with design freeze points at prescribed intervals in the design process. 4. Conduct regular reviews of legacy designs to define the cost benefits of a re-design exercise to reduce production costs. 5. Establish multi-yard teams for the development of vessel designs to a predetermined preliminary level that enable individual shipyards to continue the detail design for optimum producibility.
	Production Engineering (6.6)	1. Develop an industry shipbuilding production engineering charter defining the role and functional responsibilities of production engineering in U.S. yards to correspond with those of the world's leading shipyards. 2. Establish a production engineering requirement for future ship acquisition. This would be introduced as part of the design process to demonstrate the developing production methodology at each stage of design. 3. Use regular design upgrades of legacy designs to incorporate up-to-date production engineering principles.
	Dimensional Accuracy and Quality Control (6.8)	1. Eliminate sources of inherent process rework throughout the shipbuilding process. 2. Promote the use of statistical analysis as an intrinsic part of the performance improvement process.
	Steelwork Coding System (6.4)	1. Develop a common coding structure for application throughout the design and engineering process that consistently identifies vessel types, shipboard zones, ship systems and interim products.
	Steelwork Production Information (6.2) and Outfit Production Information (6.3)	1. Develop an industry-wide design and engineering methodology template to standardize the development of production information.

Source: First Marine International

Many of these FMI remedies can be specified in Navy shipbuilding contracts and appropriately incentivized to achieve desired process and cultural changes—but not all remedies can be achieved through contract incentives.

FMI REMEDIES CONTINUED		
Group	**Element description**	**Remedies**
Pre-Erection Activities	Module Building (3.1) and Pre-erection Outfitting (3.3)	1. Develop the production engineering process to provide specific design for production guidance emphasizing module building and higher percentages of pre-erection outfitting. 2. Quantify the savings from advancing outfit to earlier build stages. 3. Encourage funding of purpose-designed module building facilities. 4. Investigate the feasibility of regional module assembly facilities.
	Outfit Parts Marshalling (3.2)	1. Achieve schedule stability and adherence. 2. Reduce warehouse inventory levels. 3. As far as practicable, order and receive goods just-in-time. 4. Take large and heavy items directly to the point of use. 5. Place more reliance on the suppliers' quality assurance systems to provide the quality required. 6. In the longer term, move towards a palletized system where the production pallet is compiled in the warehouse from Day One.
	Materials Handling (3.6)	1. Promote awareness of the true costs of materials handling and storage through training, seminars, and workshops. 2. Develop industry-wide guidance for materials handling and storage requirements, including the design of specialized equipment and cost reduction goals.
Organization and Operating Systems	Master Planning (7.2), Steelwork Scheduling (7.3), and Outfit Scheduling (7.4)	1. Develop a model planning framework to provide guidance for updating U.S. shipyard planning systems. This framework should consider the development of vessel design and provide guidance for the structuring and simplification of the planning process. 2. Reduce major schedule disruptions by establishing rigorous guidance covering the amount and timing of Navy change orders.
	Manpower and Organization of Work (7.1)	1. Establish a stable Navy ship procurement plan. 2. Expand use of flexible working, multidisciplinary teams and area management.
Customer Factor		1. The Navy, with participation from industry, should identify areas where unnecessary practices and procedures can be eliminated to reduce the burden on shipyards.

Source: First Marine International

Supplemental funding is necessary to help the shipbuilding industry address the identified issues and accelerate the rate of improvement of the industry. To ensure that investments are made in the most appropriate areas, industry and the Department must work together to develop a prioritized implementation plan. To facilitate this dialogue across the shipbuilding enterprise, FMI forwarded suggested remedies to the NSRP for evaluation, prioritization, and costing. Part V discusses this implementation plan.

PART V

FUNDING REMEDIES IN THE SHIPBUILDING INDUSTRIAL BASE INVESTMENT FUND

The language contained in the National Defense Authorization Act for Fiscal Year 2005 requiring this study also directed that an implementation plan be developed to improve the health and viability of the U.S. shipbuilding industry. The proposed Shipbuilding Industrial Base Investment Fund (SIBIF) does that. If funded and executed deliberately, it holds the promise of dramatically improving productivity and reducing costs in the U.S. shipbuilding industrial base.

Industry participation was crucial in order to develop a specific, actionable plan based on FMI results and recommendations. FMI's results provided the strategic baseline from which a plan for corrective action could be developed. However, only by including industry, and their knowledge of current near-term efficiency initiatives and ongoing infrastructure investments, could an effective plan be developed. The National Shipbuilding Research Program (NSRP) served as a "bridge" to the SIBIF.

THE NSRP AS A "BRIDGE" TO THE SHIPBUILDING INDUSTRIAL BASE INVESTMENT FUND

Created by U.S. shipyards at the Navy's request in 1998 to reduce the cost of building and maintaining U.S. Navy warships, the NSRP is a collaboration of 11 major U.S. shipyards focused on industry-wide implementation of common solutions to cost drivers. The NSRP has been used to target solutions to consensus priority issues with a compelling business case to improve the efficiency of the U.S. shipbuilding industry. This study's recommendations and the SIBIF would expand NSRP's role and impact significantly.[23]

> *"We encourage the shipbuilding industry to build on the significant NSRP Advanced Shipbuilding Enterprise investments made over the last five years by continuing to strive for ways in which to revolutionize manufacturing technologies that reduce ship construction costs. Let me assure you that the Navy is committed, to the maximum extent practical, to continue working with you to find new efficiencies in production and manufacturing while we together design and build the most capable and affordable warships."*
>
> *John Young (Assistant Secretary of the Navy for Research, Development, & Acquisition)*
> *September 2002*

Once benchmarking of the international and U.S. shipyards was completed, FMI presented its results to a NSRP working group over a two-day period in January 2005. Each recommendation was described in terms of the issue addressed, actionable solutions, benefits to be expected, anticipated difficulties, and an estimated cost of collaborative efforts that would precede individual shipyard implementation.

[23] A change in the NSRP's charter may be necessary for this expanded scope.

Over a six-week period this working group developed an investment strategy. Besides the core working group, participation in this effort also included the NSRP's Executive Control Board, major initiative teams, and subject area panels, along with internal review by public and private members of the extended enterprise. This process produced a solid consensus among the U.S. shipyards on the highest priority actionable recommendations, and was in large agreement with FMI's prioritized list of remedies. The culmination of these efforts resulted in NSRP's publication of their 75-page report: *Proposed Investment Strategy to Address the Findings of the 2004 Global Shipbuilding Industrial Base Benchmarking Study* in March 2005. The remedies proposed in the SIBIF are based on recommendations from this report.

> *"In studying and deliberating the results of ODUSD(IP)'s shipbuilding industrial benchmarking initiative, it is clear that U.S. shipbuilders have much to gain from this effort. Shipyard management found that the draft reports confirmed, and supported with hard data, many of our known best practices challenges. More importantly, the reports called our attention to some areas that have not been getting an appropriate level of attention. We are already aggressively pursuing identified shortfalls, and we look forward to a Government/industry partnership that can take us farther, faster."*
>
> *NSRP Working Group Member*
> *March 2005*

In this part of the study, proposals for the SIBIF address three major components of the shipbuilding enterprise: the shipyards themselves, issues related to outsourcing and supply chain management; and perhaps most importantly, those relating to the industry's interaction with the government—the customer factor.

The table on the following page summarizes all the individual remedies (totaling $148.2 million) proposed for funding in the SIBIF. For each proposed remedy, NSRP assessed the rationale, costs, benefits and potential impediments. Due to the length and breadth of the discussions for these remedies, this section discusses only the remedies for the DE/PE benchmarking group. Appendix C contains full descriptions of all other SIBIF remedies.

The following color scheme has been applied throughout the remainder of the report to aid the reader in recognizing the thrust areas and benchmarking groups for shipbuilding issues and remedies.

KEY TO COLORS USED THROUGHOUT THIS DOCUMENT
Blue—Shipyard Remedies: Design, Engineering, and Production Engineering
Purple—Shipyard Remedies: Production Processes
Pink—Shipyard Remedies: Organization and Operating Systems
Yellow—Outsourcing & Supply: Shipyard Outsourcing & Supply Chain Integration
Green—Customer Factor: Joint Navy/OSD Issues

		PROPOSED SIBIF INVESTMENTS	
	Thrust Area	**Project Area/Description**	**Investment Est. ($M)**
Shipyard Remedies	Design, Engineering, and Production Engineering	Design for Production	$ 21.4
		Improve the Naval Ship Design Process	8.0
		Elevate Production Engineering	8.0
		Enable Enterprise Interoperability of Design/Production Data	20.0
		Format Outfit Production Information	1.0
		Improve Dimensional and Quality Control Tools and Practices	2.0
	Production Processes	Eliminate Non-Value-Added Production Activity	8.0
		Expand the Use of Module Building (Outfitting Packages)	5.0
		Balance the Use of Technology in Shipyards	2.0
		Develop and Implement Advanced Material Handling	10.0
		Develop Production Process Standards	2.0
	Organization and Operating Systems	Improve Shipyard Planning and Scheduling Systems	5.0
		Consolidate/Streamline Production Management Information Systems	5.0
		Optimize Manpower and Work Organization	3.0
		Improve Production Control Processes	5.0
Outsourcing and Supply	Shipyard Outsourcing and Supply Chain Integration	Apply Lean/Six Sigma Tools to Streamline Shipbuilding Supply Chains	6.0
		Eliminate Outsourcing Disincentives	0.5
		Outsourcing Strategies, Including Regionalization and Consolidation of Work	20.0
		Enable Supply Chain Data Sharing	1.8
Customer Factor	Joint Navy/ OSD/Industry Actions	Stabilize the Navy's Ship Acquisition Strategy	-
		Eliminate Disincentives and Improve Incentives	0.5
		Streamline Navy Technical Oversight	6.0
		Change Weight-Based Cost Estimating Relationship	1.0
		Manage Change Orders to Reduce Productivity Impact	1.5
		Enable Resource Sharing Among Private/Public Shipyards	0.5
		Rationalize Design Rule Methodologies on Naval Ships	5.0
		Total	$ 148.2

Source: NSRP and ODUSD(IP)

FOCUS ON DESIGN, ENGINEERING, AND PRODUCTION ENGINEERING (DE/PE) REMEDIES

The design processes for today's complex ships require the ability to integrate the requirements not only for design, but for manufacturing and lifecycle. The design process for U.S. Navy ships is required by the customer to predict, early in the product development process, the lifecycle requirements of a ship design and the lifecycle impacts of design changes. Failure to do so can lead to product designs that cause unforeseen problems and rework. Accurate predictions enable a product development team to create a superior design that performs satisfactorily in all ways through the entire life of the vessel.

DE/PE is the largest and most complex area to remedy. The top investment recommendations in this area are listed in the table below and further elaborated in the following sections. Four of these issues are production design issues; a further two are other related issues.

DESIGN, ENGINEERING, AND PRODUCTION ENGINEERING			
	Investment Priorities	**Rationale/Description**	**Investment Est. ($M)**
Production Design Issues	1. Design for Production Improvements	Focusing on producibility in the design phase will reduce production costs to a minimum, compatible with the requirements of the vessel to fulfill its operational functions with acceptable safety, reliability, and efficiency.	$ 21.4
	2. Improve the Naval Ship Design Process	Legacy naval designs are not significantly modified to reflect advances in production and design technology, thus the shipyards and government continue to carry the productivity burden of dated legacy designs.	8.0
	3. Elevate Production Engineering	Significant joint industry/government cooperation is required to make substantive gains in the production engineering arena.	8.0
	4. Enable Enterprise Interoperability of Design and Production Data	Enterprise interoperability is a pre-requisite for many other areas. This will provide the interoperability access to shipyards, streamline design review/authorization processes, and support the "One National Shipyard" initiative.	20.0
Other Issues	5. Format Outfit Production Information	A clearly defined production methodology, developed and implemented in full, is necessary to produce workstation information tailored to a predetermined outfitting strategy.	1.0
	6. Improve Dimensional and Quality Control Tools and Practices	Use of accuracy control techniques ensures that parts are cut to required tolerances, minimizing scrap, reducing rework, and enabling the building of large ship sections with minimum distortion. These advantages equate to reduced cycle time and lower material and labor costs.	2.0
Source: NSRP and ODUSD(IP)			

Production Design Issues

The most important remedies this study proposes deal with production design issues in U.S. military ships. These remedies (numbers 1-4 in the table above), if implemented, would represent the largest single investment in the SIBIF: $57.4 million over five years, 39 percent of the proposed SIBIF. To address these production design issues, specific initiatives would have to be undertaken to improve design for production; enhance the naval ship design process; elevate production engineering; and enable industry-wide interoperability of design and production data.

1 Design for Production (DFP) Improvements

DFP requires formalizing the shipbuilding strategy, including subcontracting and teaming aspects. The design should facilitate the strategy and ensure that each element of the design optimizes manufacturing and outfitting processes. Optimization includes use of standard and commercial off-the-shelf (COTS) parts, the right amount of oversight, and process control requirements. Consequently, it is vital that DFP efforts start early in the design process. The designer has the greatest influence on the cost of the vessel during the earliest design stages when primary parts, materials and equipment, and the basic configuration are being decided. The influence the designer has on cost drops off quite rapidly in the later design stages.

In the DFP area, U.S. shipyards' average rating of 3.0 was considerably lower than the 3.9 average in international shipyards. FMI concluded that it is more difficult for U.S. shipyards to realize the full benefits of recent advancements since most U.S. shipyards are currently building to legacy designs (i.e., designs developed three or more years ago). Not only has the continued use of legacy designs minimized the opportunities for applying DFP principles and methods, but also the relatively high turnover of design and engineering staff in many U.S. shipyards means there is often a loss of DFP knowledge during lengthy gaps in design activity. As a result, U.S. shipbuilders have limited experience in DFP, while foreign shipbuilders and other world-class manufacturing industries made great strides in the development of DFP techniques. The table below, which will be featured for each of the six DE/PE remedies, proposes discrete steps viewed as necessary to improve DFP in U.S. shipyards.

DESIGN FOR PRODUCTION IMPROVEMENTS: $21.4 MILLION	
Item	**Description**
Upgrade of Designs for Producibility	Conduct frequent producibility reviews/upgrades of legacy and current designs, facilitate the development of DFP guidelines, and maintain the national design knowledge base.
Benchmark Design Process	Analyze recent designs and design processes to identify and verify best practices to be used in future design work; will enable more informed decisions on future designs.
Adopt Product-Oriented or Activity-Based Cost Estimating Models	Develop and implement product-oriented or activity-based costing models that accurately reflect the productivity improvements associated with the application of DFP principles, as well as facility and production process improvements.
Develop Pilot DFP Implementation Program and Develop DFP Standards	Develop a shipbuilding pilot DFP implementation program to run concurrent with a shipbuilding program. The dedicated DFP team would be tasked to identify DFP opportunities, quantify the associated costs and benefits, and make periodic recommendations as to changes/improvements that should be implemented. Update the NSRP DFP Manual.
Conduct Pre-Contract DFP Assessment	Require shipyards to provide a DFP analysis/assessment as part of their proposal for a detail design and construction contract.
Benefit	Single most influential factor to reduce ship production cycle time and reduce costs.
Difficulty	Requirement to document the as-built condition and support lifecycle operation and maintenance with extensive design data dilutes the cost-effectiveness of DFP measures. Justification of engineering rework cost for a DFP upgrade over the assured number of ships, rather than the total number that may be built, artificially inflates rework costs.
Comments	Implements application to the entire shipbuilding industrial base. Cost benefit estimates range from 10-25 percent. Will improve complex designs that are expensive to produce and are based on the fallacy that weight reduction equates to cost reduction.
Source: NSRP and ODUSD(IP)	

2 Improve the Naval Ship Design Process

Increasingly capable ship design tools (e.g., CAD/CAM systems for the creation of product models) have enabled U.S. shipyards to employ a product model-based design process that can offer considerable downstream benefit. Despite these advances, the manhours and lead times associated with U.S. naval vessel design remain substantially higher than in leading foreign commercial shipyards. FMI concluded U.S. design practices could be improved considerably in the following areas:

- Low and erratic frequency of new U.S. designs leads to atrophied design capability and high first-of-class performance drop off. The continuing use of legacy designs for a number of years means that new design methods and techniques aimed at reducing lead times and improving producibility are not introduced as frequently as in the international shipyards where even repeat designs are regularly reviewed and updated.
- Legacy naval designs are not significantly modified to reflect advances in production and design technology. Thus the shipyards and government continue to carry the productivity burden of dated legacy designs.

The table below deploys remedies and rationale associated with improving the naval ship design process.

IMPROVING THE NAVAL SHIP DESIGN PROCESS: $8 MILLION	
Item	**Description**
Routine Design Upgrades of Current/Legacy Programs	Upgrade designs more frequently to reduce the productivity burden associated with legacy designs. Maintain the national design capability and promote continuous performance improvement. Promote and support the development of modern design organizations and strategies that will benefit subsequent new designs.
Improving Overall Product Design Standards	Improve overall product design standards, to include aligning existing or planned production processes and facilities; developing material standards for purchased equipment and outsourced components; and developing process standards.
Design/Engineering Process Improvement	An enterprise-wide collaborative environment is essential for the improvement of design/engineering processes. Processes that should be addressed include: the requirements definition process; agreed-to contract/specification compliance programs; equipment/material approval, technical review/approval, test/trials/acceptance; and the change order processes.
Design Tool Development and Validation	Create and maintain an inventory of design/engineering/analysis tools, their verification and validation status, and range of applicability. Ensure that those who develop design/engineering data review and approve the data being used in order to learn innovative methods for maximum, enterprise-wide application to all production planning functions. Coordinate and integrate tool development across the shipbuilding enterprise, eliminating overlapping development efforts and minimizing the number of alternative tools for a particular task.
Expand Design Resources Utilization	Utilize design resources in non-traditional roles, such as broad program management or task-specific support, during gaps in design capacity utilization. Such tasks could include performance of planning yard tasks; support of Navy laboratories; performance of analysis and tradeoff studies; and support of Navy independent reviews of technical data.
Benefit	Improvements in this area offer significant leverage, as design drives 85 percent of ship costs.
Difficulty	Organizational/cultural barriers characterized by numerous disparate layers of decision-makers in the Navy/OSD and Congress will be difficult to overcome.
Comments	Shortening the gap between designs supports retention of experienced personnel with corporate memory. It also supports focusing personnel resources toward improvements that will have long-term benefits over many future design projects, rather than ship- or class-specific design issues.
Source: NSRP and ODUSD(IP)	

3 Elevate Production Engineering

Production Engineering is the definition and organization of preferred production standards for product, methods, and industrial engineering into readily accessible libraries of best practices, so that once a production engineering solution has been arrived at, the designer can employ those standards to produce design details which can be efficiently produced. Production engineering in U.S. shipyards lags seriously behind international shipyards. Leading foreign shipyards consistently place much stronger emphasis on Production Engineering, giving it the leading role in performance improvement and facility development activities to realize the best possible performance on current contracts and to achieve continuous performance improvement.

Over the last ten years, U.S. shipyards have developed a wide variety of commercially producible ship design standards. Recognizing the potential benefit, the Navy has increasingly attempted to adopt commercial standards and performance requirements where practical. While pure combatant ship designs continue to present producibility challenges that arise as a result of mission capability requirements (i.e. speed, weight, survivability, outfit density, system redundancy, radar detection, etc), "hybrid" commercial/military designs such as T-AKE have introduced some new challenges. Multi-mission ships such as the Littoral Combat Ship with selective military requirements also present their own unique producibility hurdles. Whether pure military or hybrid commercial/military, producibility limitations are built into the very earliest design requirements and criteria. Of primary importance in this study is the recognition that the production engineering challenge for naval ship design and construction is not one that can be solved by the shipyards alone. Significant joint industry/government cooperation will be required to make substantive gains in the production engineering arena. The table below deploys the specific action plan to elevate production engineering in U.S. shipyards.

ELEVATE PRODUCTION ENGINEERING: $8 MILLION	
Item	**Description**
Business Case Analysis	Develop a pilot program based on more extensive benchmarking analysis and adopt best practices. Develop a detailed set of production standards and determine process reengineering requirements. Evaluate production and design tools, incorporate lessons learned, and implement organizational structure changes.
Benefit	Productivity improvement through process improvement and bridging organizational boundaries provides very high leverage for minimal investment in training.
Difficulty	Some level of production engineering is ongoing in most U.S. shipyards building commercial and naval vessels. Full implementation on Navy programs would require a major culture shift where the customer would be required to assess production costs as well as technical adequacy during ship design and when evaluating several possible solutions to a design problem.
Comments	The difference between no production engineering and mature/integrated Production Engineering functionality is estimated to represent a 20-30 percent difference in total production labor cost.
Source: NSRP and ODUSD(IP)	

4 Enable Enterprise Interoperability of Design and Production Data

> *Enterprise Interoperability*
>
> *"Ship design and production software systems change continuously. In contrast, a class of ships has a "life" of perhaps up to 50 years. To deal with this mismatch, we need a robust standards-based capability to exchange ship design and production data now. It is a national imperative that we be able to exchange product data freely between shipbuilders, the government, design agents, classification societies, system integrators, and component vendors. In the long run, this will significantly expedite and reduce the cost of Naval ship design, construction and service-life support. We must build upon the strong foundation of ISO/STEP product data exchange standards developed by the Navy and the marine industry over the last two decades. Secretary Young's Product Data Policy Memo of October 2004, directing Program Managers to procure product model data in compliance with ISO/STEP standards, must be fully implemented as soon as possible across all programs."*
>
> *Rear Admiral Paul E. Sullivan*
> *Deputy Commander for Ship Design, Integration and Engineering, NAVSEA*
> *May 17, 2005*

FMI did not explicitly cite Enterprise Interoperability of Design and Production Data in its analysis. But, once evaluated by NSRP as an investment candidate, ODUSD(IP) revisited the matter and determined it deserved a high priority. Today, each major shipbuilding program tailors integrated product data environments (IPDEs) to individual program requirements, team member work practices, and team member business relationships. As a result, there are substantial duplicative IPDE development costs ($150-200 million) and sustainment costs ($10-30 million annually) for each program. Such practices lead to multiple "data islands" in each shipyard that are not interoperable with each other. The underlying business processes which shipyards rely on to provide an up-to-date model of a ship remain unique for each class of Navy ship—with few common elements across ship classes and many lost opportunities to preserve learning and promote synergies from one ship class to the next. Unique program business processes optimized for independent team members lead to redundant data and significant data configuration, management, and access issues.

Such practices also increase obsolescence risks. Each individual program IPDE development employs the latest hardware and software. But the rate of change of information technology (IT) is much higher than the typical 50-year lifecycle of a ship class. Therefore, software components and even operating systems fade from common use, and are no longer supported effectively by vendors. It also becomes difficult to maintain staff with the requisite skills and background. Many shipyards have experienced IPDE system obsolescence problems during ship class construction. Some shipyards have been unable to retrieve valuable product information for follow-on ship developments because the data is archived in defunct formats.

Enterprise-wide agreement and use of interoperable processes, tools, and procedures (IT format) will result in lower costs of Navy ship construction by reducing training costs, standardizing testing and certifications, and enabling the sharing of manpower, facilities and workload. It would facilitate real-time electronic access to design, configuration, modeling/simulation/visualization, scheduling, and cost information within and across shipyard programs. It would reduce or eliminate redundant data, lengthy acquisition processes, and inefficiencies associated with directly supporting enterprise stakeholders. Interoperability also would facilitate sharing teaming/subcontracting design and production data across shipyards. Since shipyards have data requirements embedded in their manufacturing and assembly processes, product model technology would be available to transfer or integrate product model data between shipyards. Common specifications/standards for electronic data (content and format) would enable shipyards to develop the necessary translations and applications, and import design data that conforms to the specifications and standards (regardless of origin) into current and future data systems. The table below deploys the specific action plan to develop the minimum set of standards that will enable enterprise interoperability piloting and implementation.

ENABLE ENTERPRISE INTEROPERABILITY: $20 MILLION	
Item	**Description**
Establish Enterprise-Wide Access to Ship Design Data	Integrated product data environments (IPDEs) provide real-time electronic access to design and current ship configuration data throughout the lifecycle. This item would establish the minimum set of standards to enable the final pilot and implementation of enterprise-wide access.
Benefit	Enables opportunities for significant business process improvement. Allows contractor to choose the appropriate tools yet provides access and/or common format to benefit the enterprise. Focuses resources on the adoption of a single approach, and common standards data access and interchange, rather than multiple independent and redundant efforts. Reduces total ownership costs and enables sharing of manpower, facilities, and workload.
Difficulty	Requires: • Cultural change within the entire (Navy/industry) enterprise. • High-level leadership. • Close Navy/industry coordination to manage common architectures to guide future development. • Policies and guidance, with standard contractual language, to enact IT interoperability • Significant resource commitment to implement and maintain interoperable tools, processes, and procedures. • Sustaining commitment to standardization while not stifling innovation. • Addressing the challenges associated with application to large, complex organizations.
Comments	IPDEs can lead to major reductions in design/manufacturing costs. However, IPDEs pose a significant software development and integration challenge and expense. IPDE cost for a major shipbuilding program can total $150-200 million (of which 45-55 percent is for integration planning, information engineering, and interface software development).
Source: NSRP and ODUSD(IP)	

Providing Enterprise-Wide Access to Ship Design Data is difficult, time consuming, and costly; and would require high-level, sustained commitment from the Navy and industry. Fundamentally, enterprise-wide interoperability is based on access to information, the ability to agree on open standards and leadership to change multi-layered processes across multiple industry and government organizations. As would be the case in attempting to change any widespread practice, cultural resistance will be difficult to overcome. Close Navy/industry and inter-industry coordination will be necessary to establish and maintain standard contract requirements and common information architectures without stifling innovation. High-level, sustained Navy, industry, and individual firm commitment will be necessary to apply these concepts to the large and complex shipbuilding organizations and the just-as-complex military vessels they construct.

Other Issues

5

Format Outfit Production Information

In the area of outfit production information, U.S. shipyards scored roughly even with international shipyards; however all U.S. shipyards use a block and zone-based composite format for information rather than a product-oriented concept. Most U.S. shipyards surveyed were currently mid-way or nearing the end of a long series of vessels in the same class and this may have inflated U.S. scores. U.S. shipyards place a high reliance on production feedback over a series of vessels to progressively develop and improve the production information, whereas the international shipyards achieve high levels of production information on the first-of-class. A clearly defined production methodology developed and implemented in full for the first-of-class is necessary to produce workstation information tailored to a predetermined outfitting strategy. The table below deploys the specific action plan to format outfit production information in U.S. shipyards.

FORMAT OUTFIT PRODUCTION INFORMATION: $1 MILLION	
Item	**Description**
Define Outfit Information Data Architecture	Develop a general methodology that reformats outfit production information to provide information specific for all stages of construction with a minimum level of information on a new design.
Benefit	Production information is considered to be one of the most important design development data requirements. First-of-class construction cost savings for fully outfitted modular construction are estimated at 20-30 percent. First-of-class full-up outfitting is achievable when utilizing advanced design tools and design management methodology.
Difficulty	Will require shifting contract costs from acquisition account (SCN) funding to R&D funding, which is not always viable for the Navy authorization process; and a re-sequencing of design priorities. Long lead-time material requirements will also change since parts and components are installed earlier in steel units than when utilizing more traditional work sequencing.
Comments	Collaborative efforts and documenting best practices will accelerate subsequent implementation by individual shipyards.
Source: NSRP and ODUSD(IP)	

6

Improve Dimensional and Quality Control Tools and Practices

Although there has been a recent focus on the implementation of accuracy control (AC) and quality control (QC) procedures in many U.S. shipyards, there still remains a significant gap in the use of best practice between the U.S. average of 3.5 and the international average of 4.1. Accuracy control involves the use of statistical techniques to monitor, control, and continuously improve shipbuilding design details and work methods so as to maximize production efficiency. The focus of modern manufacturing methods is on building in quality while in process, rather than attempting to inspect it in the completed product. While the benefits of accuracy control have long been touted, there still appears to be a lack of understanding of the real costs of poor accuracy and quality within the U.S. shipbuilding industry. Leading international shipyards have adopted a total quality approach and no longer have dedicated AC and QC departments. AC and QC requirements are fully integrated into all pre-production and production activities with cross-functional teams meeting at regular intervals to discuss problem areas. The table below proposes a solution to this issue in U.S. shipyards.

IMPROVE DIMENSIONAL AND QUALITY CONTROL TOOLS AND PRACTICES: $2 MILLION	
Item	**Description**
Develop and Prove the Business Case for Accuracy Control in U.S. Shipyards	Develop a center of excellence for use by shipbuilders that applies outside sources of technology. Identify tools and processes well-suited to naval shipbuilding applications to instill confidence in the capability of accuracy control procedures necessary to successfully eliminate inherent process rework.
Benefit	The successful implementation of accuracy control will remove substantial quantities of in-process rework, shorten construction cycle times, and facilitate the implementation of higher levels of technology (e.g., automated welding processes) in many manufacturing and installation activities. First-of-class and follow-on ship construction cost savings would be significant with a fully integrated accuracy control measurement plan.
Difficulty	Must be part of the design build and work package process, with budgeting of tolerances identified. First-of-class full-up outfitting without trial pairings and templating is achievable when utilizing advanced measuring tools. Implementation will require growing confidence in trade personnel regarding the quality and repeatability of the accuracy control data.
Comment	Separate shipyard-specific funding may also be necessary to deploy the tools in U.S. shipyards.
Source: NSRP and ODUSD(IP)	

The remaining SIBIF recommended remedies—including Production Processes and Organization and Operating Systems in the Shipyard Remedies thrust area, and the Outsourcing and Supply and the Customer Factor thrust areas—are contained in Appendix C.

With clearly defined remedies established, the final step remaining is to fully develop the SIBIF concept of operations with which these remedies can be funded and implemented.

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PART VI

THE SHIPBUILDING INDUSTRIAL BASE INVESTMENT FUND: CONCEPT OF OPERATIONS

To maintain consistency of purpose and continuity of action in implementing the remedies discussed, this study recommends that the Department seek multi-year funding in FY07 for a Shipbuilding Industrial Base Investment Fund (SIBIF). This fund would be administered jointly by the Office of the Secretary of Defense and the Navy. Over the next five years, it would be used to implement the improvements detailed in Part V in the U.S. shipbuilding industrial base.

SIBIF PRECEPTS/CHARACTERISTICS

GSIBBS demonstrated continuing progress in the U.S. shipbuilding industry; however, it also made clear that opportunities for significant improvement remain. Shipbuilders, the Department, and state and local governments have funded targeted investments at individual shipyards. These investments and NSRP-sponsored collaborative improvements have resulted in a 0.5 average improvement in benchmarking scores. However, the NSRP's impact is limited in that: 1) constrained funding limits its aggressive pursuit of large scale challenges; 2) NSRP's existing funding agreement precludes buying services or equipment, thereby inhibiting developments that are hardware intensive; and 3) NSRP's current scope does not include Department policies and processes—arguably the areas with the largest impact on the performance of the shipbuilding industrial base. These issues need a new mechanism which can focus multi-year resources on the shipbuilding areas that will have the largest impact on industry performance and productivity. Performing these actions will require cooperation and participation from Navy, OSD, and Congress, and a structured and time-phased SIBIF.

SIBIF Precepts

1. *Multi-year funding profile that will enable action on more difficult problems.*
2. *Joint OSD/Navy/NSRP administration.*
3. *Focus on upfront processes involved in naval ship design.*
4. *Increased Department involvement in program investment decisions.*
5. *Government/industry cost share.*
6. *Required action by Navy/OSD and Congress.*

The U.S. shipbuilding industry is committed to improve productivity and support the Navy's need to maintain industrial capacity and key shipbuilding skills. The NSRP costed and time-phased the remedies detailed in Part V and Appendix C in response to FMI's results and recommendations. This actionable plan has broad consensus from the eleven NSRP shipyards, and there is overall agreement that immediate action is needed. The NSRP's endorsement of SIBIF is on the following page.

NSRP ENDORSEMENT OF SIBIF

The U.S. shipbuilding industry is committed to improve productivity and support the Navy's need to maintain industrial capacity and key shipbuilding skills. GSIBBS demonstrated progress and pointed to actionable solutions for industry, Navy, OSD, and joint action. *The plan herein provides broad consensus on an actionable plan– and agreement that the plan merits immediate action.* We encourage readers to participate in a joint effort to strengthen this vital industry.

THE EXECUTIVE CONTROL BOARD OF THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

STEPHEN G. WELCH, *NSRP CHAIRMAN* **TODD PACIFIC SHIPYARDS CORP.**	STEVE STROM, *NSRP VICE CHAIRMAN* **NORTHROP GRUMMAN SHIP SYSTEMS** **INGALLS OPERATIONS**	
PAUL ALBERT **VT HALTER MARINE, INC.**	STEVE ECKBERG **NATIONAL STEEL & SHIPBUILDING CO.** **A GENERAL DYNAMICS COMPANY**	DENNIS FANGUY **BOLLINGER SHIPYARDS, INC.**
ED FLEMING **ATLANTIC MARINE HOLDING CO.**	JEFF GEIGER **BATH IRON WORKS CORP.** **A GENERAL DYNAMICS COMPANY**	PETE HALVORDSON **ELECTRIC BOAT CORP.** **A GENERAL DYNAMICS COMPANY**
RICK SPAULDING **NORTHROP GRUMMAN NEWPORT NEWS**	HARVEY WALPERT **BENDER SHIPBUILDING & REPAIR CO., INC.**	DAVE WHIDDON **NORTHROP GRUMMAN SHIP SYSTEMS** **AVONDALE OPERATIONS**

Source: NSRP Executive Control Board

SIBIF INVESTMENTS AND IMPACT

Proposed annual SIBIF funding is grouped into three collaborative/industry-wide project areas: Shipyard Remedies; Outsourcing and Supply; and Customer Factor. The funding logic and proposed multi-year profile, by project area, are at Appendix D. The table on the next page and the sections that follow address these project areas in detail.

	Thrust Area	Project Area/Description	Investment Est. ($M)
PROPOSED SIBIF INVESTMENTS			
Shipyard Remedies	Design, Engineering, and Production Engineering	Design for Production	$ 21.4
		Improve the Naval Ship Design Process	8.0
		Elevate Production Engineering	8.0
		Enable Enterprise Interoperability of Design/Production Data	20.0
		Format Outfit Production Information	1.0
		Improve Dimensional and Quality Control Tools and Practices	2.0
	Production Processes	Eliminate Non-Value-Added Production Activity	8.0
		Expand the Use of Module Building (Outfitting Packages)	5.0
		Balance the Use of Technology in Shipyards	2.0
		Develop and Implement Advanced Material Handling	10.0
		Develop Production Process Standards	2.0
	Organization and Operating Systems	Improve Shipyard Planning and Scheduling Systems	5.0
		Consolidate/Streamline Production Management Information Systems	5.0
		Optimize Manpower and Work Organization	3.0
		Improve Production Control Processes	5.0
Outsourcing and Supply	Shipyard Outsourcing and Supply Chain Integration	Apply Lean/Six Sigma Tools to Streamline Shipbuilding Supply Chains	6.0
		Eliminate Outsourcing Disincentives	0.5
		Outsourcing Strategies, Including Regionalization and Consolidation of Work	20.0
		Enable Supply Chain Data Sharing	1.8
Customer Factor	Joint Navy/ OSD/Industry Actions	Stabilize the Navy's Ship Acquisition Strategy	-
		Eliminate Disincentives and Improve Incentives	0.5
		Streamline Navy Technical Oversight	6.0
		Change Weight-Based Cost Estimating Relationship	1.0
		Manage Change Orders to Reduce Productivity Impact	1.5
		Enable Resource Sharing Among Private/Public Shipyards	0.5
		Rationalize Design Rule Methodologies on Naval Ships	5.0
		Total	$ 148.2

Source: NSRP and ODUSD(IP)

SHIPYARD REMEDIES

Shipyard Remedies account for almost 75 percent ($109 million) of the total funding ($148.2 million) recommended for collaborative/industry-wide projects that improve common in-yard processes. Shipyard Remedies are categorized into three thrust areas: Design, Engineering, and Production Engineering (DE/PE); Production Processes; and Organization and Operating Systems.

Recognizing the overall importance of DE/PE, this thrust area represents almost 60 percent of the funding proposed for collaborative shipyard remedies. The large investment specified for Design for Production not only represents the major benefits to be gained by reducing production costs to a minimum, but also the substantial investment needed to coordinate participating shipyards. Enabling Enterprise

Interoperability of Design and Production Data also is a major investment priority for the DE/PE thrust area. The relatively large initial investment in this initiative will likely have long-term positive impact on a number of new designs produced well into the 21st century.

In the Production Processes thrust area, major priorities include eliminating non-value-added production activity and implementing advanced material handling. The NSRP already has a number of lean initiatives addressing waste elimination in the production cycle. These initiatives can be leveraged to eliminate waste throughout all phases of production. Increased standardization of processes and products will assist improvements in material handling. This thrust area will also benefit from current lean initiatives.

> *"We believe that the SIBIF offers a great opportunity to cover a lot of ground in a short period of time, in our race to bring the domestic industry on par with foreign builders. In fact, we believe that the advances enabled by this program, in conjunction with our own independent drive toward increased productivity, if applied to a steady and predictable backlog, could put us in a very competitive position with many foreign yards."*
>
> *Dick Vortmann*
> *President of National Steel and Shipbuilding Company (NASSCO)*
> *April 21, 2005*

Lastly, major priority investments in the Organization and Operating Systems thrust area include improvements in shipyard planning, production management information, and production control processes. Investments in shipyard planning and production control processes can start immediately in order to provide benefits in early stages of shipbuilding programs. Investment in production management information systems should flow from and follow the planning system investments.

OUTSOURCING AND SUPPLY

Outsourcing and supply investment priorities account for $28.3 million, or 20 percent, of the total funding recommended for collaborative/industry-wide projects. The major difference between U.S. and international shipyards in this area concerns the make/buy philosophies employed. While international shipyards outsource a high proportion of outfit manufacturing and selected steelwork, U.S. shipyards tend to maintain all capabilities necessary within a single business entity. The U.S. approach exposes the shipyards to expensive workforce fluctuations resulting from variations in demand. Additionally, due to lower volumes, activities such as outfit manufacturing may be carried out in suboptimal facilities at higher cost. Thus the major funded priority in this area concerns developing outsourcing strategies, including regionalization of facilities where appropriate. Significant work and investment will be required in this area. The associated level of effort and scope will be spread over a number of years and requires substantial completion of other priorities, such as establishing common parts and practices. Once best practices for outsourcing are established, significant additional funding may be required to completely implement or to establish necessary facilities.

CUSTOMER FACTOR

At $9.5 million, the investments specified for joint Navy/OSD/industry action is the smallest amount specified for any of the prioritized investments. However, the relatively small investment does not reflect the disproportionately large effect these investments and actions will have. Additionally, these actions reiterate the need for, and importance of, the SIBIF's ability to provide action in areas that are often beyond industry's control. For example, the action that would have the largest effect on industry's performance—Stabilizing the Navy Ship Acquisition Strategy—is a matter of policy not investment. Many of the other prioritized investments in this area also require little funding and are primarily a matter of government policy. The one remedy requiring substantial investment is the Streamlining of Navy Technical Oversight process which will require considerable work to value-stream the design, review, acceptance, change order approval, and construction oversight elements.

A NOTE ABOUT SHIPYARD-SPECIFIC ITEMS

The wide span of benchmarking scores in U.S. shipyards indicates that use of best shipbuilding practices is not consistent across the industry. In the NSRP report, a total of $121 million of shipyard-specific projects were identified in response to FMI's findings. However, these projects will require further prioritization based on the Navy's shipbuilding plan, shipyard work projections, and benefit to ongoing and upcoming shipbuilding programs—and would likely follow after enterprise-wide remedies are implemented. Thus, these projects have not been included in the collaborative projects currently specified for the SIBIF.

THE TIME IS NOW

The SIBIF provides a time-phased investment plan which will address the most important improvement opportunities within the shipbuilding industry. However, SIBIF by itself is not a panacea. Together with stabilization of the naval shipbuilding backlog, the remedies specified in the SIBIF will improve the productivity of the U.S. shipbuilding industry, however the impact will be greatly limited if the designs that are being produced are not optimized to take the greatest advantage of the new processes and practices installed. There is considerable risk that if immature designs, not adequately optimized for production, are allowed to make their way into shipyard production lines, the U.S. shipbuilding industry will be relegated to 20th century productivity standards well into the 21st century.

The U.S. shipbuilding industry produces the most capable warships in the world. However, the emphasis placed on capability over producibility has had a detrimental impact on the industry's performance and has led to cost growth and poor schedule adherence. By optimizing upcoming naval vessel designs for production, the Navy and industry can deliver better value and ensure our warfighters receive the most capable vessels, on cost and on schedule. SIBIF will be a significant enabler towards achieving world-class productivity and cost-effectiveness in the U.S. shipbuilding industrial base.

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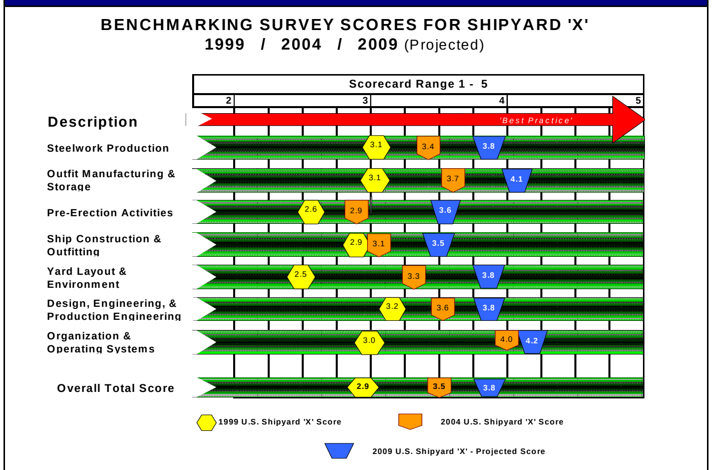
A series of visits to U.S. shipyards since 2000 inspired this study. They made clear the vast differences in productivity among individual U.S. shipyards. These differences have been corroborated by the benchmarking results of this study and, by numerous delivery and cost growth issues in major shipbuilding programs.

At inception, this study was anticipated to generate considerable controversy. Instead, the level of consensus between the independent FMI team, individual shipyards, the NSRP, and this study's assessments is remarkable. In fact, all of the U.S. benchmarked shipyards spoke favorably about what they were able to learn about how to improve their own operations. One shipyard has already used its benchmarking results in its operational planning to set benchmarking goals for 2009, as shown opposite in a notional version.

NOTIONAL BENCHMARKING SCORES & GOALS



Source: Unnamed U.S. Shipyard

It is encouraging, as well, that uniformed Navy leaders and the Congress have embraced this initiative and its findings. This initiative was a catalyst not only for the body of work underlying this study, but also for an associated 80-page report, *First Marine International Findings for the Global Shipbuilding Industrial Base Benchmarking Study, Part I: Major Shipyards,* and the 75-page NSRP report, *Proposed Investment Strategy to Address the Findings of the 2004 Global Shipbuilding Industrial Base Benchmarking Study*. The scope of these combined efforts represented on the order of $1 million expended by the government and NSRP, the efforts of over 100 industry experts, and on the order of 9,000 manhours—all on a very compressed timeline.

> *"Projecting a strong naval presence around the world is crucial to maintaining a strong defense against potential overseas threats. The ability of our military to maintain a robust and capable fleet is extremely important."*
>
> *Representative Gene Taylor (D-MS)*
> *Projection Forces Subcommittee*
> *Ranking Member*
> *May 11, 2005*

This study represents the most analytically rigorous, objective study possible drawing on shipbuilders and shipbuilding expertise from all over the world for one aim: to make the productivity of U.S. military shipbuilding world-class.

Much debate may follow this study and its warning that designs for planned warships must be better optimized for production. Nevertheless, the shipbuilding enterprise must act now, as it is poised to design and produce a number of new ship classes. Failure to do so will waste limited resources over the entire ship series construction cycle. As a maritime power bounded by two oceans and with considerable commercial interests, U.S. standing in the world has always been intimately associated with the superiority of the Navy. Investing in world-class U.S. shipyard productivity is an essential prerequisite to assuring continued U.S. maritime superiority in a century which others may claim as their own "century of oceans."

> *"For many maritime related staffs, January 1st of 2001 is a special day because from this day on, we have marched into an ocean century…We must recognize that the ocean is of great strategic importance to a nation's prosperity, and put our development as a maritime power as the highest priority."*
>
> *Wang Shuguang,*
> *Director, State Oceanic Administration, speaking to PRC Senior Leaders on Navy Modernization, February 2001*

SOURCES & ACRONYMS

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Sources

Ahearn, Dave. "England, Admirals Say Industry Decides If, Where Shipyards Close." *Defense Today,* January 14, 2005.

____. "Navy May Lose as Services Compete for Funds: Analysts." *Defense Today,* October 8, 2004.

____. "Navy Needs Enough Ships, But Capability is Key." *Defense Today,* December 20, 2004.

____. "Tight Times Force Navy to Cut Money for Ships." *Defense Today*, October 8, 2004. Associated Press. "European Shipbuilders Think of Mergers." October 27, 2004.

Bennett, John T. "Analysts Say Navy Unlikely To Achieve Its 375-Ship Fleet Objective." *Inside The Pentagon*, September 23, 2004.

Besselman, Maj. Joseph (USAF); Arora, Ashish; Larkey, Patrick. "Purchasing Performance: A Public Versus Private Sector Comparison of Commodity Buying." *Acquisition Review Quarterly*, Fall 1999, pp.333-353.

Brooke, James. "Korean Shipbuilders See China's Shadow." *The Seoul Times*, January 6, 2005.

Brown, David. "Shipbuilders Ask U.S. to Buy 12 New Vessels This Year." Navytimes.com, January 21, 2004.

Bruno, Michael. "Northrop Grumman Official Calls for Shipbuilding Commitment." *Aerospace Daily*, March 16, 2005.

Cahlink, George. "Boat Buying Business." *Government Executive*. September 15, 2004

"Carrier's Cost Rises $869.9 Million." *Newport News Daily Press*, March 2, 2005.

Castelli, Christopher J. "Collins Warns Navy Not to 'Squander' Shipbuilding Budget Progress." *Inside the Navy,* August 16, 2004.

____. "Navy Leadership Postpones Big Meeting on Seabasing and Shipbuilding – Schedule Conflict Cited." *Inside the Navy,* November 1, 2004.

____. "Rising Costs Drive Navy to Review Major Shipbuilding Programs." *Inside the Navy,* October 25, 2004.

____. "Shipbuilding Hearing Held: Taylor Raises Idea of Subsidizing Ship Manufacturing Improvements." *Inside the Navy*. March 15, 2005.

____. "Young: High Costs Punish Warfighters. Wynne, Navy Continue DD(X) Talks as Senators Seek to Bar Competition." *Inside the Navy,* Vol. 18, No. 14, April 11, 2005.

Cavas, Christopher P. "Northrop Chief Urges Spreading Ship Payments." *Defense News,* November 22, 2004.

____. "U.S. Navy Admiral: Single-Ship Sub Buys 'Stupid'." *Defense News,* November 19, 2004.

____. "U.S. Navy Procurement Seen as Vulnerable." *Defense News,* December 13, 2004.

____. "U.S. Warship Program Details Aired at Conference." *Defense News,* June 29, 2004.

____. Statement of Admiral Vern Clark, U.S. Navy, Chief of Naval Operations before the Senate Armed Services Committee. Unpublished. April 12, 2005.

Coopers & Lybrand. The DoD Regulatory Cost Premium: A Quantitative Assessment. Prepared for Dr. William J. Perry Secretary of Defense, December 1994.

Craggs, John, Bloor, Damien, Tanner, Brian, and Bullen, Hamish. Naval CGT Coefficients and Shipyard Learning. British Crown, 2004.

____ Methodology Used to Calculate Naval CGT Factors. British Crown, 2004.

Dujardin, Peter. "Petters: To Improve, Yard Must Be On Time." *Daily Press*, www.dailypress.com, February 28, 2005.

"Eliminate Disincentives and Improve Incentives." Unpublished paper, Naval Sea Systems Command, August 30, 2000.

Fein, Geoff. "Amid Concern Over Shipbuilding, Navy Facing Backlog of 40 Ships." *Defense Daily*, March 22, 2005, p.3.

General Dynamics Electric Boat. Presentation to Suzanne Patrick, Deputy Under Secretary of Defense (Industrial Policy). April 28, 2004.

Gambrell, Kathy. "Navy Must Look at Requirements, Not Ship Numbers, Analysts Say." *Aerospace Daily & Defense Report*, September 22, 2004.

Hootman, John C. and Tibbits, Barry F. Evolution of U.S. Naval Surface Cambatant Design and Acquisition Policies. Society of Naval Architects and Marine Engineers, 2004.

Hamilton, Robert A. "Adm. Clark Calls for More Effective Shipbuilding Base." Navy/Defense/Electric Boat, January 5, 2005.

Kington, Tom. "U.S. Officials Tour European Yards." *Defense News,* September 6, 2004: 4.

Koenig, Philip C.; Narita, Hitoshi; Baba, Koichi. "Shop-Floor Automation and Market Strategy in Japanese Shipbuilding." *Journal of Ship Production*, Vol. 19, No. 3, August 2003, pp. 131-140.

____. "Strategies and Outcomes in the Two Sectors of the Japanese Shipbuilding Industry." *Journal of Ship Production*, Vol. 17, No. 3, August 2001, pp. 174-182.

____. "Shipbuilding Productivity Rates of Change in East Asia." *Journal of Ship Production*, Vol. 19, No. 1, February 2003, pp. 32-37.

Koenig, Philip C. "Technical and Economic Breakdown of Value Added in Shipbuilding." *Journal of Ship Production*, Vol. 18, No. 1, February 2002, pp. 13-18.

Koenig, Philip C.; Narita, Hitoshi. "An American Perspective on Japanese Shipbuilding Competitiveness." *Techno Marine: Bulletin of the Society of Naval Architects of Japan,* Number 873.

Klamper, Amy. "Navy Officers Suggest Cuts Will Reshape Shipbuilders." *National Journal's Congress Daily*. http://www.govexec.com/dailyfed/0105/011305cdpm1.htm, January 13, 2005.

____. "Outside Influences Ships at Sea." *National Journal's Congress Daily*, September 8, 2004.

Kenny, Elizabeth. "Shipyard is Denied Sub Work." *Portsmouth Herald*, December 11, 2004.

Ma, Jason. “Second Tier and Third Tier Shipyards Should be Allowed to Compete with Larger Shipyards (Foreign Yards Should be Included Also).” *Inside the Navy,* September 20, 2004.

____. “CVN-21 Air Wing Eyed for Reduction: Newport News Chief Skeptical About Entering Commercial Ship Market.” *Inside the Navy,* March 14, 2005.

____. “Bartlett Wants Yards to do Commercial Work: ‘Blue Ribbon’ Panel on Shipbuilding Competitiveness to Stand up Soon.” *Inside the Navy,* February 14, 2005.

Maradia, Hemant. “Steel on Hot Roll…Could Cold Roll Later.” www.indiainfonline.com/nevi/hotr/html. August 4, 2004.

Mullen, Richard. “Pentagon Needs Better Contract Oversight: Thinktanker.” *Defense Today*, November 9, 2004.

Merle, Renae. “Navy Plans to Buy Fewer Ships.” *Washington Post*, September 7, 2004, pg. E1.

McIntire Peters, Katherine. “Charting a Cautious Course.” GovExec.com, August 30, 1999. http://www.govexec.com/features/99top/08a99s9.htm

Nance, Scott. “Clark Calls For Reform in Shipbuilding Practice” *Defense Today*, February 2005.

Odell, Mark. “Naval Orders Signal Seachange for Shipyards.” *London Financial Times*, October 29, 2004.

O’Rourke, Ronald. “Statement of Ronald O’Rourke, Specialist in National Defense Congressional Research Service, Before the Senate Armed Services Committee Subcommittee on Seapower Hearing on Navy Capabilities and Force Structure.” Unpublished. April 12, 2005.

____. “Potential Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress.” Congressional Research Service Report for Congress, January 14, 2005.

____. “Navy Surface Combatant Acquisition Programs: Oversight Issues and Options for Congress.” Congressional Research Service Report for Congress, November 13, 2003.

____. “Navy Littoral Combat Ship (LCS): Background and Issues for Congress.” Congressional Research Service Report for Congress, October 20, 2003.

____. “Statement of Ronald O’Rourke, Specialist in National Defense Congressional Research Service, Before the Senate Armed Services Committee Subcommittee on Seapower Hearing on Ship Procurement and Research and Development Programs.” March 2, 2000.

Panchak, Patricia. “A Failure Of Leadership: Simple lessons from stacks of data and years of reporting.” *Industry Week,* January 1, 2004.

Sherman, Jason. “Shipyard Chief: US Firms Trail Foreign Yards.” *Defense News*, September 29, 2003, p. 16.

“Submarine Construction Changes at Electric Boat Help Keep Costs Down, Official Says.” *Defense Daily*, April 19, 2005.

Thompson, Loren B. “Shipbuilding Work Force on Track to Drop 25 Percent.” *Defense Today*, October 27, 2004.

Truver, Scott C. “U.S. Shipyards: Navigate Between a Rock and a Hard Place.” U.S. Naval Institute *Proceedings*, March 2004, www.navalinstitutes.org.

Tran, Pierre. "Europe's Yards Must Merge to Survive." *Defense News*, August 9, 2004.

U.S. Department of Commerce. "Shipbuilding and Repair" U.S. Industry and Trade Outlook® 2000, http://www.ntis.gov.

Weinberger, Sharon. "Lawmakers to Form New Shipbuilding Caucus." *Defense Daily*, January 5, 2005.

ACRONYMS

AC	Accuracy Control
BIW	Bath Iron Works
CEA	Chief Executive Officer
CGT	Compensated Gross Tonnage
CG(X)	Next-Generation Air Dominance Cruiser
CNO	Chief Naval Operations (N-7)
CVN	Nuclear-Powered Aircraft Carrier
DC	District of Columbia
DDG	Guided Missile Destroyer
DD(X)	Next-Generation Multi-Mission Surface Combatant (Destroyer)
DE/PE	Design, Engineering, and Production Engineering
DFP	Design for Production
DoD	Department of Defense
EB	Electric Boat
FMI	First Marine International
FY	Fiscal Year
GAO	Government Accountability Office
GD	General Dynamics
GSIBBS	Global Shipbuilding Industrial Base Benchmarking Study
GT	Gross Tonnage
IPDE	Integrated Product Data Environment
ISO	International Standards Organization
IT	Information Technology
LHA(R)	Amphibious Assault Ship Replacement
LHD	Amphibious Assault Ship (Multipurpose)
LCS	Littoral Combat Ship
LPD	Amphibious Transport Dock
MMP	Multi-Mission Platform
MoD	Ministry of Defense
MPF(F)	Maritime Prepositioning Forward Future
NASSCO	North American Steel and Shipbuilding Company
NAVSEA	Naval Sea Systems Command
NGSS	Northrop Grumman Ship Systems
NSRP	National Shipbuilding Research Program
ODUSD(IP)	Office of the Deputy Under Secretary of Defense (Industrial Policy)
OPV	Offshore Patrol Vessel
OSD	Office of the Secretary of Defense
OUSD(AT&L)	Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics)
QC	Quality Control
R&D	Research and Development
ROI	Return on Investment
RO-RO	Roll On-Roll Off Vessels

SCN	Shipbuilding and Conversion, Navy
SIBIF	Shipbuilding Industrial Base Investment Fund
SSBN	Nuclear-Powered Ballistic Missile Submarine
SSGN	Nuclear-Powered Cruise Missile Submarine
SSN	Attack Submarine (Nuclear Propulsion)
STEP	Shipboard Technology Evaluation Program
TASC	The Analytic Sciences Corporation
T-AKE	Lewis and Clark Class of Auxiliary Dry Cargo Ships
TOA	Total Obligation Authority
UK	United Kingdom
U.S.	United States
USA	United States of America
USN	United States Navy