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Navy Major Shipbuilding Programs and Shipbuilders: Issues and Options for Congress

Ronald O'Rourke, Foreign Affairs and National Defense Division

Updated September 24, 1996

Abstract. This report focuses on the Navy's major shipbuilding programs and on the six private U.S. shipyards associated with those programs. These six yards are currently highly dependent on Navy shipbuilding programs and are major employers in their home States. The report examines the adequacy of the FY1996-FY2001 shipbuilding plan, the question of how many major shipbuilders the Navy needs, and options for Congress.

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Foreign Affairs and National Defense Division

September 24, 1996

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NAVY MAJOR SHIPBUILDING PROGRAMS AND SHIPBUILDERS: ISSUES AND OPTIONS FOR CONGRESS

SUMMARY

Six shipyards carry out the Navy's major shipbuilding programs: Avondale Shipyards Division of New Orleans, LA; Bath Iron Works Corporation of Bath, ME; Electric Boat Corporation of Groton, CT; Ingalls Shipbuilding, Inc. of Pascagoula, MS; National Steel and Shipbuilding Co. of San Diego, CA; and Newport News Shipbuilding of Newport News, VA. These 6 yards are currently highly dependent on Navy shipbuilding programs. They are also major private employers in their home states.

Under the FY1996-FY2001 Future Years Defense Plan (FYDP), major ships will be procured for the Navy at less than half the rate of the 1980s. This has raised two key policy issues for Congress: Is the FY1996-FY2001 shipbuilding plan adequate? How many major Navy shipbuilders are needed to meet the Navy's needs?

Regarding the first issue, the FY1996-FY2001 shipbuilding plan is sufficient to maintain the planned 346-ship fleet in the short run. As the Administration has acknowledged, however, the planned FY1996-FY2001 shipbuilding rate is well below the rate needed to maintain a 346-ship fleet in the long run. It appears that the FY1996-FY2001 shipbuilding plan will be adequate to keep all 6 shipyards in business through about the turn of the century. As a group, however, the yards will not prosper during the next several years. Prospects for the 6 yards beyond FY2001 are less clear. It appears that the FY1996-FY2001 shipbuilding plan will result in shipyard production rates that are in some respects less efficient than the higher shipyard production rates of earlier years.

Regarding the second issue, anywhere from 2 to 6 yards might be required to provide sufficient capacity solely for future Navy shipbuilding, depending on the future rate of Navy shipbuilding. Having as few as 2 or 3 yards could reduce efficiency and increase costs by depriving the government of the second sources or unused capacity needed to maintain effective competition, or by elevating employment levels at the yards so high that worker productivity is reduced. Having as many as 6 yards, conversely, could reduce efficiency and increase costs by depriving the government of the ability to create enough uncertainty over its contract award decisions to maintain effective competition, or by reducing workloads at each yard to the point where there is limited spreading of fixed costs and reduced learning.

Given the current situation in Navy major shipbuilding and the 6 associated yards, Congress may consider four options: (1) increase the yards' workload, (2) reduce the number of yards, (3) do both, or (4) do neither, at least for now. There are several major Navy shipbuilding programs that might be increased as part of an effort to increase the yards' workload. Neither the Executive Branch nor Congress has shown enthusiasm for reducing the number of shipyards. If policymakers in the future revisit this option, many potential combinations of fewer than 6 yards might be considered.

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NAVY MAJOR SHIPBUILDING PROGRAMS AND SHIPBUILDERS: ISSUES AND OPTIONS FOR CONGRESS

INTRODUCTION AND KEY POINTS

INTRODUCTION

Focus of Report

This report focuses on the Navy's major shipbuilding programs and on the shipyards associated with those programs. The Navy's major shipbuilding programs are those for building submarines and larger surface ships. Larger surface ships have an overall length of more than 400 feet[1] and include aircraft carriers, major surface combatants (cruisers, destroyers, and frigates), amphibious ships, large auxiliaries, and sealift ships.[2]

The Navy's major shipbuilders -- the shipyards associated with these programs -- are:[3]

- Avondale Shipyards Division (ASD) of New Orleans, LA,
- Bath Iron Works Corporation (BIW) of Bath, ME,
- Electric Boat Corporation (EB) of Groton, CT,
- Ingalls Shipbuilding, Inc. (ISI) of Pascagoula, MS,
- National Steel and Shipbuilding Co. (NASSCO) of San Diego, CA, and
- Newport News Shipbuilding (NNS) of Newport News, VA.

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[1] An overall length of more than 400 feet (122 meters) is a commonly used standard for differentiating larger surface ships from smaller ones. For example, the Maritime Administration defines a major shipbuilding and repair facility "as one that is open and has the capability to construct, drydock, and/or topside repair vessels with a minimum length overall of 122 meters, provided that water depth in the channel to the facility is at least 3.7 meters." U.S. Department of Transportation. Maritime Administration. *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995.* Washington, 1995. (Prepared by: Office of Ship Construction, Division of Cost Analysis and Production, December 1995). p. 3; see also p. 42 as well as exhibits 20 and 21 on p. 45 and p. 46.

[2] Sealift ships are built for the Military Sealift Command (MSC) rather than the Navy, and are funded in the defense budget through the National Defense Sealift Fund (NDSF) rather than the Shipbuilding and Conversion, Navy (SCN) appropriation account. In this sense, the sealift shipbuilding program is a DOD rather than Navy shipbuilding program. For purposes of simplicity, however, this report uses the term "Navy major shipbuilding programs" to refer collectively to all the shipbuilding programs listed here, including the sealift program.

[3] BIW, EB, NASSCO, and NNS are commonly used abbreviations. ASD and ISI were created for this report so that all six yards could be referred to with abbreviations.

Two Key Issues for Congress

Under the FY1996-FY2001 Future Years Defense Plan (FYDP), major ships will be procured for the Navy at less than half the rate of the 1980s. As a result, production rates at the 6 above shipyards, which have carried out all of the Navy's major shipbuilding programs since the latter 1980s, will be much lower in total for the next several years than they were during the 1980s. This has raised two key policy issues for Congress:

- Is the FY1996-FY2001 shipbuilding plan adequate?

- How many major Navy shipbuilders are needed to meet the Navy's needs?

Congress' decisions on these two key issues could affect the future size and structure of the Navy, future Navy funding requirements, the structure of the U.S. shipbuilding industry, thousands of shipbuilding-related jobs, and the health of local economies in several U.S. regions.

This report examines these two key issues and discusses options for Congress. Following this introductory chapter, the second chapter of the report provides background information. The third chapter addresses the two key issues. The final chapter discusses options for Congress. Appendices with additional information appear at the end.

Context for the Issues

Total employment in the U.S. shipbuilding industry has been declining since 1981. Declines in employment during the 1980s resulted primarily from the virtual disappearance from U.S. shipyards during these years of ocean-going commercial ship construction work. Continued declines in employment during the first half of the 1990s were due in large part to reductions in Navy ship procurement. The deeper reductions in Navy ship procurement planned for FY1996-FY2001 will thus place continued pressure on an industry that has already experienced more than a decade of contraction.

The 6 shipyards discussed in this report are currently highly dependent on Navy shipbuilding programs. They are also major private employers in their home states, each yard providing thousands of relatively well-paying manufacturing jobs. Decisions that Congress and the Administration reach on the two key issues above can affect the survival of the 6 yards, the jobs of thousands of shipyard workers, and the health of several regional economies. For this reason, the two key issues are politically sensitive.

In part due to the political sensitivity of these questions, the defense oversight committees of Congress in 1995 spent a considerable portion of their time on shipbuilding-related issues. Indeed, one of the most controversial defense acquisition issues debated by Congress in its consideration of the proposed FY1996 defense budget was submarine acquisition. Other shipbuilding-related issues considered by the committees in 1995 included whether to procure one or two destroyers in FY1996 in addition to the two that the Administration had requested for FY1996, and whether to accelerate procurement to FY1996 of two types of amphibious ships that the Administration had planned to procure in later fiscal years.[4] The defense oversight committees in 1996 have continued to devote significant attention to shipbuilding-related issues in their review of the Administration's proposed FY1997 defense budget.[5]

The two key issues discussed in this report arise against a backdrop of events concerning the U.S. defense industry as a whole. Congress and the Administration, for example, continue to examine the issue of overall policy toward the defense industrial base, as well as proposals for reforming defense procurement practices to reduce unit procurement costs.[6] There is concern in Congress and elsewhere over waste and "pork" in defense spending and over a "bow wave" of accumulated defense procurement requirements projected to occur soon after the turn of the century.[7] In the public sector, several government-operated military depots, including five of ten naval shipyards (NSYs) and naval ship repair facilities (SRFs), have been selected for closure under the Base Realignment and Closure (BRAC) process.[8] And in the private sector, there has been a series of consolidations and mergers among U.S. defense aerospace and electronics firms.[9]

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[4] For a discussion of 1995 congressional activity on these issues, see Philpott, Tom. Congressional Watch. *U.S. Naval Institute Proceedings*, May 1996: 134-136; Kitfield, James. Ships Galore! *National Journal*, Feb. 10, 1996: 298-302. See also Bitzinger, Richard A. Living With Less, But Barely Coping. *Armed Forces Journal International*, August 1996.

[5] See, for example, Morgan, Dan. Defense Budget Additions Buoy Sun Belt Shipyards. *Washington Post*, June. 30, 1996: A1, A10.

[6] See *Defense Industry in Transition: Issues and Options for Congress.* CRS Issue Brief 92122, by Gary J. Pagliano. (updated regularly); and *Defense Reinvestment and the Technology Reinvestment Project.* CRS Issue Brief 93078, by John D. Moteff and Michael E. Davey. (updated regularly).

[7] See *Defense Budget for FY1997: Major Issues and Congressional Action.* CRS Issue Brief 96023, by Stephen Daggett. (updated regularly)

[8] See *Military Base Closures Since 1988: Status and Employment Changes at the Community and State Level.* CRS Report 96-562 F, by George H. Siehl and Edward Knight. (June 17, 1996) 60 p.

[9] See Mintz, John. Boeing to Buy Rockwell's Defense, Space Divisions. *Washington Post*, Aug. 2, 1996: F1, F3; Ahles, Andrea, and Vago Muradian. Boeing to Buy Rockwell's Defense and Space Business. *Defense Daily*, Aug. 2, 1996: 181-184; Erlich, Jeff, and Philip Finnegan. DoD: Merger Savings Justify Cost. *Defense News*, Jul. 29-Aug. 4, 1996: 4, 56; Finnegan, Philip. Prices, Politics May Squelch Merger Wave. *Defense News*, Jul. 29-Aug. 4, 1996: 14, 22; Finnegan, Philip. Growth of Lockheed Martin Spurs Industry Adjustment. *Defense News*, Jul. 29-Aug. 4, 1996: 14, 24; Leibstone, Marvin. Corporate Merger-Mania: Good Or Bad For US Defence? *Military Technology*, June 1996: 174-176; Crock, Stan, et al. Defense's New Battlefield. *Business Week*, Jan 22, 1996: 40; Sterngold, James. A 90's Military-Industrial Complex. *New York Times*, Jan.

Limitations on Scope

In the course of discussing the two key issues and options for Congress, the report takes note of potential other sources of business for the 6 shipyards. These include construction of smaller surface ships for the U.S. military; construction of military ships for export; construction of commercial ships; overhaul and repair work now done in the NSYs; and overhaul/repair work now done in other private U.S. shipyards.

The report, however, does not provide an in-depth examination of the policy issues that relate to these other potential sources of work. These include policy regarding the division of government ship construction work between larger and smaller private U.S. yards; the potential for building warships for export and government policy regarding warship exports; the potential for building commercial ships and government policy regarding commercial ship construction; and policy regarding the division of government overhaul and repair work between private shipyards and the NSYs, and between larger and smaller private U.S. yards. Nor does the report discuss issues concerning the supporting supplier industries for the shipbuilding industry. These issues, though important, are beyond the scope of this report.

Sources of Information

Primary sources of information for this report include the Navy and the Department of Defense (DoD) (a questionnaire and specific inquiries), the 6 shipyards (tours, questionnaires and specific inquiries), industry experts (interviews), and the Maritime Administration and the Bureau of the Census (published information on the shipbuilding industry). Much of the information, particularly that provided by the shipyards and the industry experts, was supplied on the condition that sources be identified only in a general way, such as "industry sources."

Shipbuilding is not well represented in the fairly extensive body of published empirical research and modeling on defense production costs and how they vary with respect to changes in variables such as production rate. This

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21, 1996: Sec. 4, p. 4; Study Sees Defense Consolidation Continuing Through 1996. *Defense Daily*, Jan. 18, 1996: 75-76; Starr, Barbara. Mergers becoming a business imperative. *Jane's Defence Weekly*, Jan. 17, 1996: 23; Mintz, John. Adding Loral to the Line. *Washington Post*, Jan. 14, 1996: H1, H4; Pearlstein, Steven. Building Empires In Electronics. *Washington Post*, Jan. 9, 1996: C1; Finnegan, Philip. Analysts Foresee More Industry Consolidation. *Defense News*, Dec. 11-17, 1995: 12; Defense Industry Consolidation 60 Percent Complete -- First Boston. *Defense Daily*, Dec. 4, 1995: 303; Mintz, John. Going Great Guns. *Washington Post*, Oct. 22, 1995: H1, H6, H12; EIA lays out defense industry consolidation scenarios. *Aerospace Daily*, Oct. 11, 1995: 58-59; Watching the mergers. *Jane's Defence Weekly*, May 20, 1995: 36-37; O'Toole, Kevin. A question of scale. *Flight International*, Jan. 4-10, 1995: 22-24; Harbison, John R. and Martin J. Bollinger. *Consolidation in Aerospace/Defense II.* Booz-Allen & Hamilton Inc., 1994. 20 p. See also *Lockheed and Martin Marietta Merger: Potential Concerns for Congress.* CRS Report 94-765, by Gary J. Pagliano. (Oct. 4, 1994) 4 p.

research is based primarily on data from defense aircraft and missile procurement programs and rarely mentions Navy ship procurement.[10]

Major Navy shipbuilding, moreover, differs in two important respects from aircraft and missile manufacturing. First, production rates and total production quantities of shipbuilding programs are one or two orders of magnitude lower than those of aircraft and missile production programs.[11] Second, the percentage of total employees accounted for by production workers is substantially higher in the shipbuilding industry (74 percent as of 1992) than in aircraft (46 percent) or guided missiles and space vehicles (32 percent).[12] In

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[10] Published examples of such research include the following: Rogerson, William P. Economic Incentives and the Defense Procurement Process. *Journal of Economic Perspectives,* v. 8, n. 4, Fall 1991: 65-90; Rogerson, William P. *Overhead Allocation and Incentives for Cost Minimalization in Defense Procurement.* Santa Monica, CA, Rand, 1992. (R-4013-PA&E, Prepared for the Assistant Secretary of Defense (Program Analysis and Evaluation) 107 p.; Rogerson, William P. Excess Capacity in Weapons Production: An Empirical Analysis. *Defence Economics,* v. 2, n. 3: 235-249; Balut, Stephen J., Thomas P. Frazier and James Bui. *Estimating Fixed and Variable costs of Airframe Manufacturers.* Alexandria, VA, Institute for Defense Analyses, 1991. (IDA Paper P-2401, March 1991) 33 p.; McCullough, James D., and Stephen J. Balut. *Trends in a Sample of Defense Aircraft Contractors' Costs.* Alexandria, VA, Institute for Defense Analyses, 1990. (IDA Document D-764, August 1990) 19 p.; Anton, James J., and Dennis A. Yao. Measuring the Effectiveness of Competition in Defense Procurement: A Survey of the Empirical Literature. *Journal of Policy Analysis and Management,* v. 9, n. 1, Winter 1990: 60-79; Balut, Stephen J., Thomas R. Gulledge, Jr., and Norman Keith Womer. A Method for Repricing Aircraft Procurement Programs. *Operations Research,* v. 37, n. 2, March-April 1989: 255-265; U.S. Congress. Congressional Budget Office. *Effects of Weapons Procurement Stretch-Outs on Costs and Schedules.* Washington, Congressional Budget Office, 1987. (CBO Study, November 1987) 63 p.; Rich, Michael, and Edmund Dews. *Improving the Military Acquisition Process, Lessons from Rand Research.* Santa Monica, CA, RAND, 1986. (With C. L. Batten, Jr., R-3373-AF/RC, February 1986) 52 p.; Cox, Larry W., and Jacques S. Gansler. Evaluating the Impact of Quantity, Rate, and Competition. *Concepts,* v. 4, n. 4, Autumn 1981: 29-53; Balut, Steve J. Redistributing Fixed Overhead Costs. *Concepts,* v. 4, n. 2, Spring 1981: 63-76; Bemis, John C. A Model for Examining the Cost Implications of Production Rate. *Concepts,* v. 4, n. 2, Spring 1981: 84-94.

[11] Major Navy shipbuilding programs commonly feature production rates ranging from less than one ship per year to as many as 5 ships per year and total production quantities ranging from a few units to as many as about 50 units. In contrast, aircraft procurement programs commonly feature production rates of more than 10 units per year, and total production quantities in the hundreds, while missile procurement programs can feature production rates of more than 100 units per year and total production quantities in the thousands.

[12] U.S. Department of Commerce. Economics and Statistics Administration. Bureau of the Census. *1992 Census of Manufactures, Ship and Boat Building, Railroad and Miscellaneous Transportation Equipment,* op. cit., and *1992 Census of Manufactures, Aerospace Equipment, Including Parts.* (Preliminary Report Industry Series, Industries 3721, 3724, 3728, 3761, 3764, and 3769, MC92-I-37B(P), Issued December 1994) Table 1, p. 37B-1. Aircraft is Industry 3721; guided missiles and space vehicles is Industry 3761. The higher percentage figure for shipbuilding may reflect the existence of independent naval architectural firms and the Navy's own community of ship designers and engineers, which permit some shipyards to reduce the size of their own in-house design and engineering staffs. It may also reflect the large size of Navy ships and the above-mentioned lower production rates and total production quantities of Navy ship procurement programs, both of which may make the shipbuilding industry intrinsically less amenable to the use of automation as a means of reducing costs. Shipbuilding is sometimes described as more akin to the labor-intensive construction industry than to assembly-line manufacturing operations. See,

view of these differences between shipbuilding and aircraft and missile production, published empirical research on defense production costs and the lessons derived from this research may not be readily applicable to Navy shipbuilding programs.

KEY POINTS

The following are some of the key points made in the report.

From the Chapter on Background Information

Shipbuilding Employment Levels

Since reaching a 35-year peak in 1981, total employment in private-sector U.S. shipyards has fallen about 43 percent, to 106,000. The 6 yards discussed in this report currently account for about 63 percent of employees in all private-sector U.S. yards, and for about 93 percent of employees in the 19 larger private-sector U.S. yards that make up the Major Shipbuilding Base (MSB). Employment at most of the 6 yards has been dropping in recent years, and is projected to drop further over the next few years, in some cases to the lowest levels in more than 20 years.

The Shipbuilding Industry's Dependence on Government Work

In recent years, about 90 percent of all production workers in private-sector U.S. shipyards have been engaged in ship repair or construction work for the Navy and the Coast Guard. Construction of Navy ships currently accounts for about 90 percent of the total dollar value of the work done at the 6 yards discussed in this report. As a result of its dependence on U.S. government work, the shipbuilding industry's fixed overhead costs fall heavily on Navy shipbuilding programs, and the withdrawal of Navy shipbuilding funding could threaten the continued survival of any of these yards.

The 6 Yards' Production Capacities

Most of the 6 yards discussed in this report can build 3 to 5 ships per year of the kinds that they are currently building for the Navy; one of the yards could build more. Achieving and sustaining these maximum rates, however, could require some of the yards to curtail or eliminate other forms of work, such as overhaul and repair of Navy and commercial ships and construction of commercial ships. It could also result in levels of employment that could strain the managerial and supervisory capabilities of some of the yards. Capacity

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for example, *Personnel Requirements for an Advanced Shipyard Technology.* Washington, National Academy of Sciences, 1980. (Prepared by the Committee on Personnel Requirements for an Advanced Shipyard Technology of the Maritime Transportation Research Board Commission on Sociotechnical Systems, National Research Council) p. 51, 63.

limitations in critical supporting supplier industries could also prevent these high rates from being achieved.

There are currently 2 yards involved in the construction of each major category of ship except nuclear-powered aircraft carriers (CVNs), for which there is only one builder. There are also potentially more than 2 sources for most ship types. The exceptions are nuclear-powered submarines, for which there are 2 potential sources, and aircraft carriers. There is only 1 potential builder of CVNs, and 2 or possibly 3 potential sources of conventionally powered carriers (CVs), which are not currently being built.

The Navy's major shipbuilding programs currently divide the 6 yards into 4 paired groups. These are the nuclear-powered shipbuilders (EB and NNS), the major surface combatant shipbuilders (BIW and ISI), the amphibious shipbuilders (ASD and ISI), and the large auxiliary and sealift shipbuilders (ASD and NASSCO). This segmentation of shipbuilding activities, however, is not rigid or fixed. Most yards overlap in current or potential capabilities for building most ship types. The main exception concerns the ability to build nuclear-powered ships, which does appear to strongly divide EB and NNS from the other 4 yards for the production of these ships.

The FY1996-FY2001 Shipbuilding Plan

The Administration plans to procure an average of 6.5 ships per year (including sealift ships) during the FY1996-FY2001 Future Years Defense Plan (FYDP). This is the lowest sustained rate of ship procurement since the post-World War II demobilization of the late 1940s, and is only a small fraction of the combined annual production capacity of the 6 yards.

Key Administration Decisions

Since 1993, the Administration has made four key decisions regarding the Navy's major shipbuilding programs: It reduced the number of new ships to be procured, decided to maintain both EB and NNS as nuclear-capable shipbuilders rather than consolidate construction of all nuclear-powered ships at NNS, decided to maintain both BIW and ISI as builders of DDG-51 class destroyers rather than consolidate DDG-51 construction at one of the yards, and decided to award contracts for the construction of 12 new sealift ships to the two yards not involved in the construction of nuclear-powered ships or surface combatants -- ASD and NASSCO. The effect of these four decisions was to reduce the total amount of shipbuilding work available to the 6 yards while providing at least some work to each of the 6 yards for the next several years, thereby reducing the likelihood for the next several years that the reduction might force any of the yards into bankruptcy and closure.

From the Chapter on Two Key Policy Issues for Congress

The FY1996-FY2001 shipbuilding plan and the resulting relatively low rates of production at the 6 major Navy shipbuilders have raised two key policy issues for Congress:

- Is the FY1996-FY2001 shipbuilding plan adequate?
- How many major Navy shipbuilders are needed to meet the Navy's needs?

Is the FY1996-FY2001 Shipbuilding Plan Adequate?

The issue of whether the FY1996-FY2001 shipbuilding plan is adequate can be viewed from at least three perspectives:

- Is it adequate to maintain the Administration's planned 346-ship Navy?
- Is it adequate to keep all 6 shipyards in business?
- Is it adequate to maintain efficient production rates at the shipyards?

Maintaining the planned 346-ship fleet. The FY1996-FY2001 shipbuilding plan is sufficient to maintain the planned 346-ship fleet in the short run -- that is, for the next few years. As the Administration has acknowledged, however, its planned rate of shipbuilding is well below the rate that would be needed to maintain a 346-ship fleet in the long run.

Maintaining a 346-ship Navy over the long run would require an average procurement rate of about 10 ships per year, not including sealift ships, which are not included in the 346-ship total. Excluding sealift ships, the FY1996-FY2001 shipbuilding plan would procure an average of about 5.2 ships. If maintained over the long run, an average procurement rate of 5.2 ships per year would eventually result in a Navy of about 182 ships -- about 53 percent of the 346-ship goal.

The Administration is aware that, since the relatively low ship procurement rate in its FY1996-FY2001 FYDP would be far from sufficient to maintain a 346-ship Navy in the long run, funding needs to be added to the shipbuilding account in future years so that the ship procurement rate can be increased to a higher level.

Keeping the 6 yards in business. Based on information supplied by shipyard officials and the Navy, it appears that the FY1996-FY2001 shipbuilding plan will be adequate to keep all 6 shipyards in business through about the turn of the century. As a group, however, the yards won't prosper during the next several years. Total employment at the 6 yards will continue to decline, and overall profits will be limited by the relatively small amount of work on order.

Prospects for continuation of all 6 yards after the FY1996-FY2001 FYDP are less clear, because both the volume and distribution of major Navy shipbuilding work after FY2001 are difficult to predict. If the total amount of work does not increase substantially from current levels, then how the work is distributed could become critical in determining whether one or more of the 6 yards falls out of the ranks of the Navy's major shipbuilders.

Maintaining efficient production rates. It appears that the FY1996-FY2001 shipbuilding plan will result in shipyard production rates that are in some respects less efficient than the higher shipyard production rates of earlier years. Changes in cost in recent shipbuilding programs, particularly submarines and surface combatants, suggest that shipyards are experiencing reduced spreading of fixed costs and less economic learning effects, resulting in increased ship costs. Reductions in production efficiency are apparently also occurring at supplier firms, resulting in additional increases in ship costs.

Efficiency, however, is a relative rather than absolute term when applied to manufacturing production rates. Workloads and plant capacities can combine to create production rates of varying levels of efficiency, and observers can come to varying personal judgments as to whether a particular degree of production efficiency is acceptable.

Near-term shipbuilding cost increases, moreover, can be weighed against the potential longer-term benefits of maintaining shipbuilding capacity that may be needed to accommodate a future increased shipbuilding rate, as well as the potential long-term benefits of maintaining competition among shipyards in the future if the shipbuilding rate is increased.

How many major Navy shipbuilders are needed to meet the Navy's needs?

Discussion of the issue of how many major shipbuilders the Navy needs dates to at least 1992. Various perspectives have been expressed on the issue. In assessing the issue, Congress may consider several factors, including the total amount of capacity the Navy will need for shipbuilding and overhaul and repair, shipbuilding economies and diseconomies of scale, competition, shipyard modernization, shipyard disruption, and shipyard reconstitution.

Given uncertainty over the future Navy shipbuilding rate, anywhere from 2 to more than 6 major shipbuilders might be needed to provide enough capacity to meet the Navy's future shipbuilding needs. If the future Navy shipbuilding rate, the future commercial shipbuilding rate, and/or the future amount of Navy ship overhaul and repair work performed by the 6 yards increase from their current values, then all 6 of the yards discussed in this report might be needed (in conjunction with other private-sector yards and the public-sector naval shipyards) to provide sufficient shipyard capacity to meet all of the Navy's needs (i.e., for overhaul and repair work as well as shipbuilding); if, on the other hand, these three variables remain at their current values, then not all of the 6 yards of the yards discussed in this report (in conjunction with other private-sector yards and the public-sector naval shipyards) might be needed to provide sufficient shipyard capacity to meet all of the Navy's needs.

Having as few as 2 or 3 major Navy shipbuilders could reduce efficiency and increase costs by depriving the government of the second sources or unused capacity needed to maintain effective competition, or by elevating employment levels at the yards so high that worker productivity is reduced. Having as many as 6 major Navy shipbuilders, conversely, could reduce efficiency and increase costs by depriving the government of the ability to create enough uncertainty over its contract award decisions to maintain effective competition, or by reducing workloads at each yard to the point where there is limited spreading of fixed costs and reduced learning.

Shipyards can improve their production efficiency and increase their production capacities and capabilities by investing funds to modernize their facilities. Lack of competition could reduce a yard's incentive to modernize. Very strong competitive pressures, however, could also reduce a yard's incentive to modernize, at least in the short term, because avoiding such investments can reduce short-term costs, enabling the yard to bid at a lower price for a highly sought-after contract.

Various events could disrupt operations at the yards, though at least some of these events can be considered unlikely to occur or unlikely to cause disruptions lasting more than a few weeks or months. A capability to build major Navy ships can be established (or reestablished) at a yard that does not currently build them, but this could require significant time and expense.

From the Chapter on Options for Congress

Given the current situation regarding Navy major shipbuilding and the 6 associated yards, which is characterized by a relatively low Navy shipbuilding rate and relatively low workloads at the 6 yards, Congress may consider four general options: (1) increase the major Navy shipbuilders' workload, (2) reduce the number of major Navy shipbuilders, (3) do both, or (4) do neither, at least for now.

The central rationale for increasing the major Navy shipbuilders' workload would be to improve economies of scale and, insofar as such an increase involves increasing the rate of Navy ship procurement, procure Navy ships at a rate closer to that needed to replace the Navy on a steady-state basis and reduce the approaching bow wave of accumulated deferred shipbuilding requirements. Congress can increase the major Navy shipbuilders' workload by increasing either the amount of major Navy shipbuilding work or other forms of shipyard work. Factors to consider in assessing this option include production conditions at each of the 6 yards, Navy force-level requirements and the ages of existing ships, and technological developments that may affect the capabilities and costs of future warships. There are several major Navy shipbuilding programs that might be increased as part of an effort to increase the yards' workload.

The central rationale for reducing the number of yards involved in the Navy's major shipbuilding programs would be to increase and stabilize the workloads at the yards that are maintained as major Navy shipbuilders. Neither the Executive Branch nor Congress has shown enthusiasm for reducing the number of shipyards involved in the construction of major ships for the Navy. If policymakers in the future revisit this option, factors to consider include maintaining enough yards to produce all types of ships that might be built in the future, maintaining enough second sources to support meaningful competition, and maintaining sufficient excess capacity to support meaningful competition, avoid diseconomies of scale due to high workloads, and carry out a potential expanded shipbuilding program in the future.

There are many potential combinations of fewer than 6 yards that might be considered. Given the capabilities of the yards for building various types of ships, these combinations can include or exclude any one of the 6 yards, with the partial exception of NNS, which could not be excluded if a capability for producing nuclear-powered aircraft carriers needs to be preserved. If, however, it is decided that a capability for producing conventionally powered carriers (CVs) is sufficient, then NNS might be excluded, and a potentially CV-capable yard -- ISI or possibly ASD -- would have to be included.

BACKGROUND INFORMATION

This chapter provides background information on the U.S. shipbuilding industry, the 6 shipyards discussed in this report, the FY1996-FY2001 shipbuilding plan, key Administration decisions, and recent shipbuilding-related events.

THE STRUCTURE OF THE U.S. SHIPBUILDING INDUSTRY

Shipyards and Supplier Industries

The U.S. shipbuilding and repair industrial base includes both shipyards and supporting supplier industries.[13] As mentioned in the introductory chapter, this report focuses on shipyards and does not examine issues relating to supporting supplier industries.

Public and Private Sector

The United States has both public- and private-sector shipyards. The public-sector until recently included 8 naval shipyards (NSYs), 2 naval ship repair facilities (SRFs), and one Coast Guard shipyard.[14] Public-sector yards overhaul and repair Navy and Coast Guard ships, particularly nuclear-powered Navy ships.[15] Half of the public-sector Navy yards -- 4 NSYs and 1 SRF --

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[13] In addition to production facilities at the shipyards and supplier firms, the shipbuilding industrial base includes naval architects and designers in the Navy, at the shipyards and supplier firms, and in private naval architectural firms, as well as research and development organizations and laboratories in the Navy, at Federally Funded Research and Development Centers (FFRDCs), at the shipyards and supplier firms, and at a few universities and colleges.

[14] The 4 Atlantic NSYs are Portsmouth NSY at Portsmouth, NH/Kittery ME; Philadelphia NSY; Norfolk NSY, and Charleston NSY. The 4 Pacific NSYs are Puget Sound NSY at Bremerton, WA; Mare Island NSY in the San Francisco Bay area; Long Beach NSY in California, and Pearl Harbor NSY in Hawaii. The 2 SRFs are Guam SRF and Yokosuka SRF at Yokosuka, Japan. The Coast Guard shipyard is at Curtis Bay, MD, near Baltimore; for information on this yard, see Stump, Bill. Curtis Bay looks for work. *Navy Times*, May 22, 1995: 14; and Nolan, Mary I. When and Where the Need Exists. *Sea Power*, March 1995: 45-46. As of October 1995, the NSYs employed a total of 39,484 persons. (U.S. Department of Transportation. Maritime Administration. *Outlook for the U.S. Shipbuilding and Repair Industry 1996.* Washington, 1996. p. 4.)

[15] Six of the NSYs -- Portsmouth, Norfolk, Charleston, Puget Sound, Mare Island, and Pearl Harbor -- are (or until closing were) certified to work on nuclear-powered ships. As a matter of law and Navy policy, the public-sector yards receive 60 to 70 percent of the dollar value of the Navy's ship overhaul and repair work: Section 352 of the FY1993 defense authorization act (P.L. 102-484, Oct. 23 1992, 106 Stat. 2315) amended 10 U.S.C. 2466(a) to in effect require each military service to allocate at least 60 percent of its depot-level maintenance work to public-sector facilities. A separate Navy policy dating to 1970 and supported over the years by Congress requires that at least of 30 percent of the dollar value of overhaul and repair work on Navy ships be awarded to private-sector U.S. shipyards. See also U.S. Congress. Congressional Budget Office. *Public and*

have been selected for closure under the Base Realignment and Closure (BRAC) process; three of these yards have already closed.[16] Since the public-sector yards do not build ships for the Navy,[17] this report does not focus on them.

All of the Navy's major ships are currently built in private-sector U.S. shipyards. (The private-sector yards also receive 30 to 40 percent of the dollar value of the Navy's overhaul and repair work and perform construction and repair work on commercial ships.) Accordingly, this report focuses on the private-sector portion of the U.S. shipbuilding industry.

The Private-Sector Yards (Industry 3731)

The private-sector U.S. shipbuilding and repair industry -- Industry 3731 in the U.S. government's Standard Industrial Classification (SIC) scheme -- contains more than 500 companies. Most of these firms are small -- fewer than half have 20 or more employees[18] -- and focus on building and repairing boats and smaller ships.[19] As of 1995, 92 firms in Industry 3731 had facilities for conducting at least topside repairs on ships 400 feet or more in length. Of these, 19 had at least one position capable of supporting the construction of a ship at least 400 feet long. These 19 shipyards, shown in Figure 1, are referred

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Private Roles in Maintaining Military Equipment at the Depot Level. Washington, Congressional Budget Office, 1995. (A CBO Study, July 1995) p. 7-16.

[16] Philadelphia NSY was selected in the 1991 BRAC round (BRAC 91); Charleston NSY and Mare Island NSY were selected in BRAC 93; and Long Beach NSY and Guam SRF were selected in BRAC 95. Philadelphia NSY was officially closed on Sep. 30, 1995; Charleston and Mare Island NSY were closed on April 1, 1996; Long Beach and Guam will be closed in future years. Three other NSYs at New York, Boston, and San Francisco were closed in 1966, 1974, and 1974, respectively. See also *Military Base Closures Since 1988: Status and Employment Changes at the Community and State Level.* CRS Report 96-562 F, by George H. Siehl and Edward Knight. (June 17, 1996) 60 p.

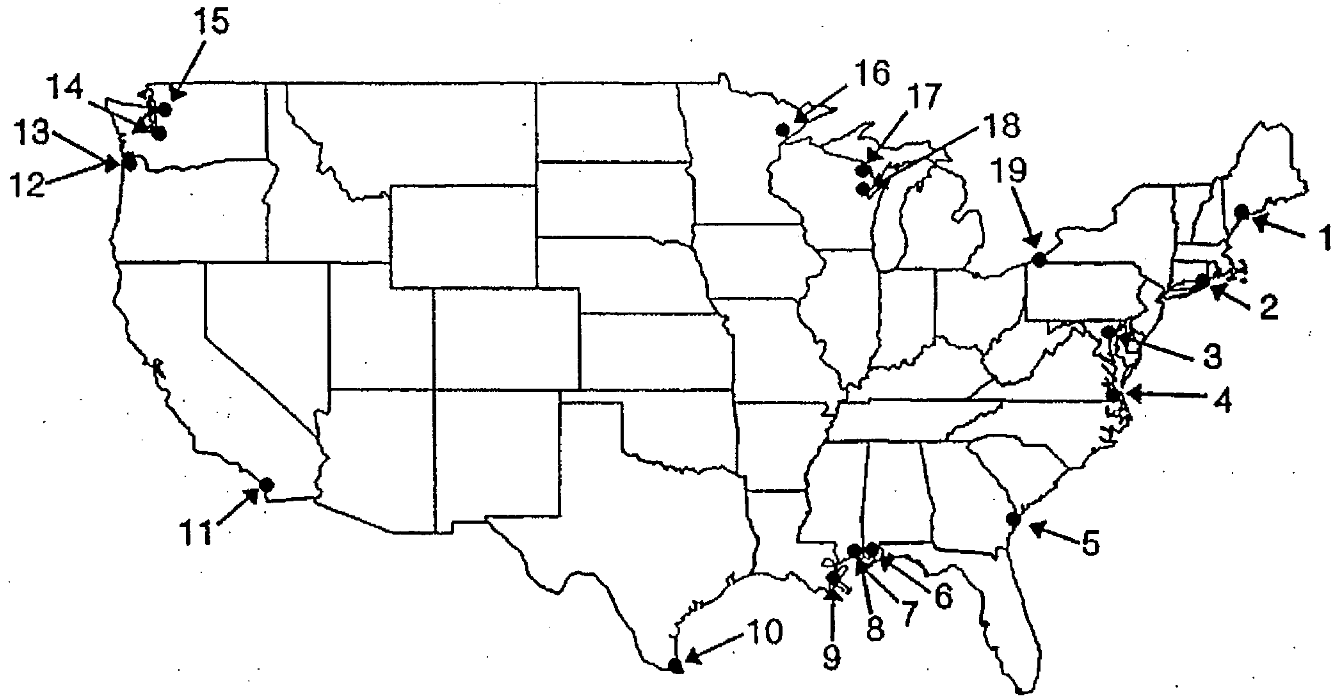
[17] The last NSY-built ships were completed in the early 1970s.

[18] As of 1992, the time of the most recent industry census, Industry 3731 contained 562 firms with at least 10 employees, including 266 with at least 20 employees. U.S. Department of Commerce. Economics and Statistics Administration. Bureau of the Census. *1992 Census of Manufactures, Ship and Boat Building, Railroad and Miscellaneous Transportation Equipment.* (Preliminary Report Industry Series, Industries 3731, 3732, 3743, 3751, 3792, 3795, and 3799, MC92-I-37C(P), Issued July 1994) Table 1, p. 37C-1. The Census of Manufactures occurs every 5 years; the next Census is scheduled for 1997. Less comprehensive Annual Surveys of Manufactures are conducted in the four years between each Census.

[19] For a short discussion of the smaller U.S. private-sector shipyards, see *Outlook for the U.S. Shipbuilding and Repair Industry 1996*, op. cit., p. 22-30 and 43-44.

Figure 1

MAJOR SHIPBUILDING FACILITIES IN THE UNITED STATES



1. Bath Iron Works Corp.
2. General Dynamics - Electric Boat Div.
3. BethShip, Sparrows Point Yard
4. Newport News Shipbuilding
5. Intermarine USA
6. Alabama Shipyard, Inc.
7. Halter Marine, Inc., Moss Point Div.
8. Ingalls Shipbuilding, Inc.
9. Avondale Industries, Inc.
10. AMFELS, Inc.
11. National Steel and Shipbuilding Co.
12. Gunderson, Inc.
13. Portland Ship Yard
14. Tacoma Boatbuilding Co.
15. Todd Pacific Shipyard Corp.
16. Fraser Shipyards, Inc.
17. Marinette Marine Corp.
18. Peterson Builders, Inc.
19. Erie Marine Enterprises, Inc.

1995

Source: Maritime Administration, Report on Survey of U.S. Shipbuilding and Repair Facilities, 1995, p. 44.

to by the Maritime Administration (MARAD) and the Navy as the Major Shipbuilding Base (MSB).[20]

Total employment in Industry 3731 averaged 106,000 through the first 9 months of 1995.[21] As can be seen in Figure 2, this total is about 43 percent below the 1981 peak of 186,700 and is the lowest level since 1955.[22] The 19 yards in the MSB accounted for 71,740 of Industry 3731's employees, or about 68 percent.[23]

Of the 19 shipyards in the MARAD/Navy MSB, only the 6 yards discussed in this report -- ASD, BIW, EB, ISI, NNS, and NASSCO -- are currently building major ships for the Navy. As of mid-1995, these 6 yards employed a total of 66,642 persons[24] -- about 93 percent of all employment in the MSB and about 63 percent of all employment in Industry 3731.

In the final months of 1994, these 6 yards ended their memberships with the Shipbuilders Council of America (SCA), the trade association that had long represented large and small private U.S. shipyards, and formed their own trade association called the American Shipbuilding Association (ASA). The 6 yards' departure from the SCA and their formation of the separate ASA was generally

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[20] *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995,* op. cit. p. 4. The report states that to qualify for the MSB, shipyards also "must own or have in place a long-term lease (1 year or more) on the facility in which they intend to accomplish the shipbuilding work, there must be no dimensional obstructions in the waterway leading to open water (i.e., locks bridges), and the water depth must be a minimum of 3.7 meters."

[21] *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995,* op. cit. p. 56.

[22] Source for data in Figure 2: U.S. Department of Labor. Bureau of Labor Statistics. *Employment, Hours, and Earnings, United States, 1909-90, Volume I.* Washington, 1991. (Establishment Survey Data on the 1987 SIC, March 1991, Bulletin 2370) p. 354, and *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995,* op. cit., p. 56.

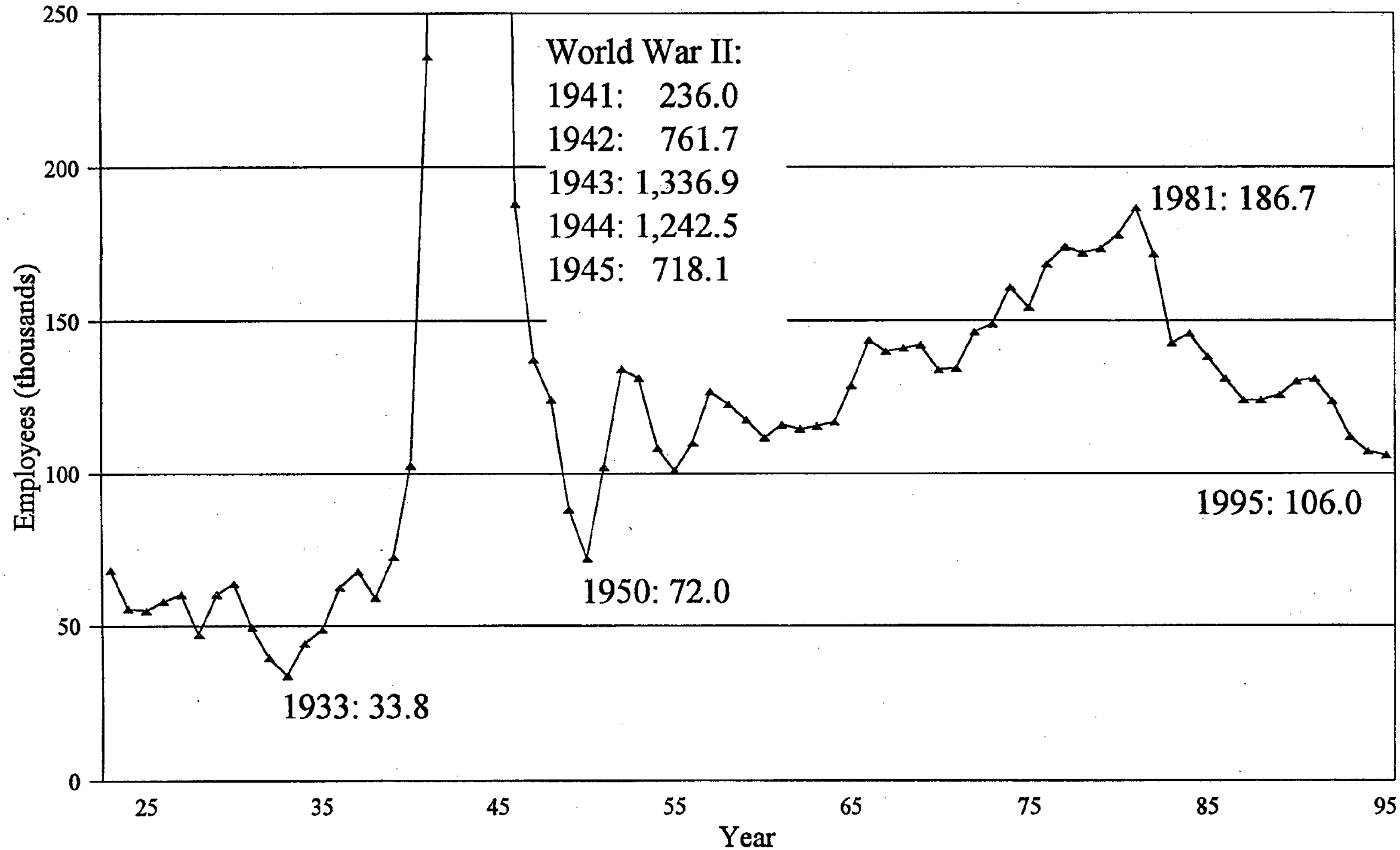
[23] *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995,* op. cit. p. 91, 97, 103, 107.

[24] Ibid., p. 91, 97, 103.

Figure 2

Total employees, 1923-1995

Shipbuilding and repair (SIC 3731)



Source: Prepared by CRS, 7/96, based on U.S. Dept. of Labor data.

viewed as a consequence of a growing divergence of views on shipbuilding-related policy issues between the 6 yards and the other firms that make up the rest of Industry 3731.[25]

Dependence on Government Work

The private U.S. shipbuilding industry at present is highly dependent on U.S. government work. In 1995, 88 percent of all production workers in the industry were engaged in ship repair or construction work for the Navy and the Coast Guard; the figure stayed above 90 percent for the period 1987-1994.[26] Construction of Navy ships currently accounts for about 90 percent of the total dollar value of the work done at the 6 yards discussed in this report.[27]

The industry's current degree of dependence on U.S. government work developed during the 1980s, when ocean-going commercial ship construction work virtually disappeared from the United States. Throughout most of the 1970s, 50 or more ocean-going commercial ships were under construction in U.S. shipyards at any given moment. Following the termination in 1981 of the federal government's Construction Differential Subsidy (CDS), which had supported construction of ocean-going merchant ships in U.S. shipyards, this figure declined rapidly. It reached zero by 1988 and remained close to zero through 1994 before increasing in 1995 to 10 ships -- the highest figure since 1985.[28]

The U.S. shipbuilding industry is attempting to break back into the international market for the construction of ocean-going commercial ships.

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[25] See Schweizer, Roman. Naval Shipbuilders Group to Promote Increased SCN, Industrial Base. *Inside the Navy*, June 12, 1995: 3-4; Statement of Duane D. Fitzgerald, Chairman of the American Shipbuilding Association, March 7, 1995, [at a] Joint Hearing of the Procurement and Research and Development Subcommittees of the House National Security Committee. 5 p.; Fitzgerald, Duane. American Shipbuilding Association. *Maritime Reporter & Engineering News*, January 1995: 8; Top U.S. Shipbuilders Form Group to Preserve Industrial Base. *Defense Daily*, Dec. 13, 1994: 363; Abrams, Alan. 6 Yards That Quit Builders Council Unite to Form Own Association. *Journal of Commerce*, Dec. 9, 1994: 12B; Abrams, Alan. Shipyard Council to Focus On Commercial Issues. *Journal of Commerce*, Oct. 26, 1994: 1B; Sansbury, Tim. 4 Key Shipyards Leave Industry Lobbying Council. *Journal of Commerce*, Oct. 17, 1994: 1A.

[26] *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995,* op. cit., p. 4, and previous editions.

[27] Source: Figure provided to CRS by Paul Magliocchetti Associates, Inc., acting on behalf of the American Shipbuilding Association, in Jan. 25, 1996 telephone conversation. This is a composite figure derived from data solicited from each of the 6 yards.

[28] *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995,* op. cit., Exhibit 23 on p. 48; U.S. Department of Transportation. Maritime Administration. *Report on Survey of U.S. Shipbuilding and Repair Facilities 1984.* Washington, 1984. (Prepared by: Office of Shipbuilding Costs and Production, Division of Production, December 1984). Exhibit 36 on p. 86; and American Shipbuilding Association. *Commercial Shipbuilding and Its Relationship to the U.S. Navy Shipbuilding Industrial Base.* Washington, 1995. (December 1995) 9 p.

Within the last two years, it has received a few orders, including the first order for the construction of an ocean-going commercial ship from a foreign buyer since 1957. At present, however, it is not clear whether the industry's efforts to break back into this market will succeed enough to substantially reduce the industry's dependence on U.S. government work.[29]

The industry's current dependence on U.S. government work has two principal implications for this report. First, the industry's fixed overhead costs fall heavily on Navy shipbuilding programs because there is little commercial ship construction work to which these costs can be partially allocated. Stated more generally, the industry currently has little opportunity to exploit economies of scale by taking advantage of materials and processes that are common to the construction of commercial and military ships. Second, as mentioned in the introduction, the withdrawal of Navy shipbuilding funding could threaten the continued survival of any of these yards, since there is currently little commercial work for the yards to fall back upon.

THE 6 MAJOR NAVY SHIPBUILDERS[30]

The following are brief portraits of the 6 shipyards discussed in this report, followed by summaries of their employment levels and production capabilities. In addition to the shipbuilding work noted in the portraits, the 6 yards also overhaul and repair Navy and commercial ships.

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[29] For discussions of the industry's efforts, results to date, and prospects for the future in the area of ocean-going commercial ship construction, see *Shipbuilding Technology and Education.* Washington, National Academy Press, 1996. (Committee on National Needs in Maritime Technology, Marine Board, Commission on Engineering and Technical Systems, National Research Council) 148 p.; *Commercial Shipbuilding and Its Relationship to the U.S. Navy Shipbuilding Industrial Base*, op. cit.; Blenkey, Nicholas. Title XI powers U.S. yards back into world class competition. *Marine Log*, January 1996; Machalaba, Daniel. Back to the Sea: U.S. Shipbuilders Seek To Regain Some Role in the Global Market. *Wall Street Journal,* Nov. 15, 1995: A1, A14; Abrams, Alan. Buoying a Sagging Sector. *Journal of Commerce*, Aug. 11, 1995: 1A; and *Outlook for the U.S. Shipbuilding and Repair Industry 1996,* op. cit., p. 1-10, 32-44. See also Bath Iron Works: Commercial Goals Were Unrealistic. *Associated Press* wire story, Jan. 29, 1995.

[30] With the exception of EB, information in this section relies primarily on *Report on Survey of U.S. Shipbuilding and Repair Facilities 1995,* op. cit., p. 10, 12, 24, 30, and 32. (EB, as a submarine-only yard, is not covered in detail in this report, which focuses on yards capable of working on surface ships.) Statements regarding each yard's capability to build ship types other than those currently being built by each yard are based on a U.S. Navy data sheet provided to CRS, June 23, 1994.

Avondale Shipyards Division (ASD)[31]

Avondale Shipyards Division of Avondale Industries, Inc. is located on the Mississippi, upriver from New Orleans, LA. It has been employee-owned since 1985. As of mid-1995, ASD employed a total of 5,150 persons, compared to 5,776 in mid-1994. In 1994, ASD received a $17.8 million Title XI federal loan guarantee to help finance its yard modernization efforts.[32]

Since 1938, Avondale has built a variety of Navy, Coast Guard, and commercial ships and other marine structures such as barges and offshore drilling rigs. ASD's past shipbuilding work for the Navy includes 5 of 8 Whidbey Island (LSD-41) class amphibious dock landing ships, all 5 Cimarron (AO-177) class oilers (i.e., large auxiliaries), and 27 of 46 Knox (FF-1052) class frigates (including the final 21 ships in the class). ASD also built all 12 of the Coast Guard's Hamilton (WHEC-715) class high-endurance cutters. The yard is currently building Harpers Ferry (LSD-49) class amphibious dock landing ships, Henry J. Kaiser (TAO-187) class oilers, Bob Hope (TAKR-300) class sealift ships, and Osprey (MHC-51) class mine warfare ships for the Navy. It is also building an icebreaker for the Coast Guard.

ASD recently signed a contract with a Russian ship owner for the construction of seven 42,000-deadweight-ton commercial petroleum product tankers.[33]

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[31] For recent general articles on ASD, see Abrams, Alan. Shipyard Bucks Trend With Cheap Labor, 'Low Tech.' *Journal of Commerce*, Dec. 6, 1995; New "Ship Factory" To Help Avondale Rein In Commercial Business. *Maritime Reporter/Engineering News*, August 1995.

[32] As explained by MARAD, "The Title XI program was established by the Merchant Marine Act of 1936, as amended, and provides for a full faith and credit guarantee by the United States Government for the purpose of promoting the growth and modernization of the U.S. merchant marine and U.S. shipyards. Prior to November 30, 1993, the Title XI program provided for Federal Government guarantees of private sector financing or refinancing obligations for the construction or reconstruction of U.S. flag vessels in U.S. shipyards. . . . On November 30, 1993, Congress passed the National Defense Authorization Act for FY 1994, which contained a section subtitled 'National Shipbuilding and Shipyard Conversion Act of 1993.' This Act provided the Secretary of Transportation with the authority to extent Title XI guarantees for eligible vessels constructed, reconstructed or reconditioned in a U.S. shipyard and for *shipyard modernization and improvement*." (emphasis added) U.S. Department of Transportation. Maritime Administration. *Outlook for the U.S. Shipbuilding and Repair Industry 1995*. Washington, 1995. p. 4. The loan guarantee for Avondale's shipyard modernization project is listed on page 30 at a value of $15.9 million; the 1996 edition of the *Outlook* report updates the value to $17.8 million (see page 41). See also Abrams, Alan. Shipyard Bucks Trend With Cheap Labor, 'Low Tech.' *Journal of Commerce*, Dec. 6, 1995; New 'Ship Factory' To Help Avondale Rein In Commercial Business. *Maritime Reporter/Engineering News, August 1995*.

[33] Abrams, Alan. Russian Tanker Owner Awards Pact to Avondale. *Journal of Commerce*, Aug. 9, 1995: 1B.

With capital improvements, ASD could build major surface combatants (as it did until the early 1970s[34]) and possibly also conventionally powered aircraft carriers.[35]

Bath Iron Works Corporation (BIW)[36]

Bath Iron Works is located in Bath, ME, on the Kennebec River. In September 1995, General Dynamics Corporation purchased BIW from Bath Holding Corporation;[37] reports on negotiations about the purchase first appeared in late April 1995.[38] As of mid-1995, BIW employed a total of 8,300 persons, compared to 8,540 in mid-1994. Employment at BIW is projected to decline through 1998.[39]

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[34] ASD's 27 FF-1052 class frigates entered service between 1969 and 1974.

[35] The Navy states that "Two major physical impediments exist which restrict Avondale's ability to construct or perform a full range of repairs on CV class of ships. The water approach to Avondale and the current channel/dry dock depth are insufficient to accommodate a CV. The Huey P. Long bridge imposes a height restriction of 153 feet, well below that of a CV, and the current channel depth/drydock is only 35 feet." (U.S. Navy information sheet provided to CRS, June 23, 1994, note 4.) Avondale, however, argues that it would be able to build a CV by installing the CV's "island" structure at an Avondale facility downriver from the Huey P. Long bridge. (Interview with Avondale officials, Nov. 15, 1994.)

[36] For a recent general article on BIW, see Wesel, L. Mercedes. Private Contracts No Relief, BIW Says. *Maine Sunday Telegram*, Jan. 28, 1996.

[37] Bath Holding Corporation was an owners group led by the investment firm of Gibbons, Goodwin & van Amerongen and backed by the Prudential Insurance Company. For background on Bath Holding Corporation's ownership of BIW, see Campbell, Steve. Leveraged buyout turned sour for owners. *Maine Sunday Telegram*, Sep. 26, 1993; and Campbell, Steve. BIW charts a new course. *Portland (ME) Press Herald*, Sep. 27, 1993: 1A, 4A.

[38] General Dynamics Finalizes Buy of Maine Shipyard. *Defense Week*, Sep. 18, 1995: 11; Starr, Barbara. GD to create marine group with Bath buy. *Jane's Defence Weekly*, Aug. 26, 1995: 24; Walsh, Mark. GD Won't Take A Bath On Shipyard Acquisition. *Defense Week*, Aug. 21, 1995: 1, 13; Submarine maker buys destroyer yard. *Navy News & Undersea Technology*, Aug. 21, 1995: 5; Campbell, Steve. BIW gains clout under new owner. *Maine Sunday Telegram* (Portland, ME), Aug. 20, 1995; Field, David. Shipbuilder shake-up. *Washington Times*, Aug. 18, 1995: B7, B9; Wesel, L. Mercedes. BIW sale could kill 'teaming' labor pact. *Portland (ME) Press Herald*, July 19, 1995; Finnegan, Philip. General Dynamics' Interest in Bath Yard Represents Shift. *Defense News*, May 8-14, 1995: 24; Pearlstein, Steven. Dynamics May Acquire Shipbuilder. *Washington Post*, May 3, 1995: F1-F2; Rosenberg, Eric. BIW and General Dynamics Discuss A Potential Sale. *Defense Week*, May 1, 1995: 1, 13, 16; Hamilton, Robert A. General Dynamics' interest in Bath hints of politics. *New London Day*, Apr. 28, 1995: A1, A12; Hamilton, Robert A. General Dynamics looks to purchase Bath Iron Works. *New London Day*, Apr. 27, 1995: A1, A8; Lawson, Candace. Buying BIW 'would make sense'. *Times Record* (Bath, ME), Apr. 27, 1995: 1, 16; Wesel, L. Mercedes. Owner of BIW discussing a sale. *Portland (ME) Press Herald*, Apr. 27, 1995.

[39] BIW Plans to Trim up to 300 Workers. *Associated Press* wire story, Dec. 21, 1995. If BIW does not win a share of the LPD-17 shipbuilding program and shipbuilding at BIW is limited to 1.5 destroyers per year, employment at the yard would drop to about 5,000 and remain there

Since 1889, BIW has built a variety of Navy and commercial ships and other marine structures such as barges and dredges. In recent years, BIW has been one of the Navy's two builders of major surface combatants. BIW's past shipbuilding work for the Navy includes 3 of 6 Brooke (FFG-1) class frigates, 24 of 51 Oliver Hazard Perry (FFG-7) class frigates, 4 of 23 Charles F. Adams (DDG-2) class destroyers, 8 of 18 Leahy (CG-16) and Belknap (CG-26) class cruisers, and 8 of 27 Ticonderoga (CG-47) class Aegis cruisers. It is currently one of two yards building Arleigh Burke (DDG-51) class Aegis destroyers.

BIW can also build large auxiliaries, sealift ships, and (with capital improvements) amphibious ships.

Electric Boat Corporation (EB)

The Electric Boat Corporation is located at Groton, CT, with a major additional fabrication facility at Quonset Point, RI. It is a wholly owned subsidiary of General Dynamics Corporation.[40] It is one of two U.S. shipyards capable of building nuclear-powered warships and is the only private U.S. shipyard that focuses exclusively on submarines. As of mid-1995, EB employed a total of 15,111 persons, compared to 16,618 in mid-1994. Employment at EB is projected to decline to about 7,000 by 1998.[41]

Since 1899, EB has designed and built submarines for the Navy. In recent years, EB has been one of the Navy's two builders of nuclear-powered submarines. EB's shipbuilding work for the Navy includes 12 of 37 Sturgeon (SSN-637) class nuclear-powered submarines (SSNs), 33 of 62 Los Angeles (SSN-688) class nuclear-powered submarines (SSNs), all 18 Ohio (SSBN-726) class nuclear-powered ballistic missile submarines (SSBNs; the last of these will enter service in 1997) and all 3 Seawolf (SSN-21) class SSNs (the first of these will enter service in 1996). EB will build the first New Attack Submarine (NSSN), to be funded in FY1998.

As a shipyard that specializes in submarines, EB does not currently build surface ships. With substantial capital investments, the yard could be made capable of building major surface combatants, but EB officials do not emphasize this possibility.

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through 2008. Shipyard's New President Says LPD-17 Program Crucial. Associated Press wire story, Feb. 21, 1996.

[40] Prior to General Dynamics' purchase of BIW (see BIW entry), EB was called the Electric Boat Division. Following the purchase, General Dynamics changed the name to Electric Boat Corporation and formed a marine systems group that includes EB, BIW, and the American Overseas Marine Corporation, which manages the operations of certain DOD sealift ships.

[41] Electric Boat to Lay Off 1,500 in 1996; Renew Lease In Rhode Island. *Associated Press* wire story, Jan. 19, 1996.

Ingalls Shipbuilding, Inc. (ISI)

Ingalls Shipbuilding is located at Pascagoula, MS, where the Pascagoula River meets the Gulf of Mexico. It is a division of Litton Industries, Inc. Its main West Bank facility, built to support modular construction of ships, was completed in 1970. As of mid-1995, ISI employed a total of 14,081 persons, compared to 14,733 in mid-1994. Employment at ISI is projected to decline to about 9,600 by 1997.[42]

Since 1938, Ingalls has built a variety of Navy and commercial ships. In recent years, ISI has built amphibious assault ships and major surface combatants for the Navy. ISI's past shipbuilding work for the Navy includes all 5 Tarawa (LHA-1) class amphibious assault ships, all 31 Spruance (DD-963) class destroyers, all 4 Kidd (DDG-993) class destroyers, and 19 of 27 CG-47 class Aegis cruisers. ISI currently is building Wasp (LHD-1) class amphibious assault ships and is one of two yards building DDG-51 class Aegis destroyers. It is also building 5 corvettes for Israel and might build 2 German-designed diesel-electric submarines for Egypt.[43]

ISI could also build large auxiliaries and sealift ships, and with capital improvements could be made capable of building conventionally powered aircraft carriers as well.

National Steel and Shipbuilding Company (NASSCO)

NASSCO is located in San Diego, CA. It has been employee-owned since 1989. It is the only West Coast shipyard building major ships for the Navy. As of mid-1995, NASSCO employed a total of 4,500 persons, compared to 3,271 in mid-1994. In 1994, NASSCO received a $15.9 million Title XI federal loan guarantee to help finance its yard modernization efforts.[44]

Since 1945, NASSCO has built a variety of Navy and commercial ships and boats. In recent years, it has built and converted[45] large auxiliaries and sealift ships for the Navy. NASSCO's past work for the Navy includes the construction of several large auxiliaries -- all 4 Yellowstone (AD-41) class destroyer tenders,

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[42] Ingalls President Confident Ingalls Will Remain Key Build[er] For Navy. *Associated Press* wire story, Feb. 7, 1995.

[43] The project to build the two submarines would be funded partly by the U.S. Foreign Military Sales (FMS) program, and partly by the Egyptian government. The project is awaiting the Egyptian share of funding and has not yet been finalized. See Sub Deal With Egypt May Be Taking Shape. *Navy News & Undersea Technology*, Aug. 12, 1996: 4-5. ISI built nuclear-powered submarines for the U.S. Navy until the early 1970s at its older East Bank facility, but ISI is no longer certified to build nuclear-powered warships.

[44] *Outlook for the U.S. Shipbuilding and Repair Industry 1995,* op. cit., p. 30.

[45] Conversion is a major modification or reconstruction of an existing ship that permits the ship to be used in a new way.

1 of 7 Wichita (AOR-1) class underway replenishment ships, and a cable repair ship -- and 17 of 20 Newport (LST-1179) class amphibious tank landing ships. NASSCO also converted 2 cargo ships into hospital ships and 6 other cargo ships into sealift ships. It is currently building Supply (AOE-6) class underway replenishment ships (i.e., large auxiliaries) and new TAKR-310 class sealift ships for the Navy. It is also converting 3 older cargo ships into sealift ships.

NASSCO could also build amphibious ships and (with capital improvements) major surface combatants.

Newport News Shipbuilding and Dry Dock Company (NNS)[46]

Newport News Shipbuilding is located at Newport News, VA. Since 1968, it has been a subsidiary of Tenneco, Inc. In March 1996, however, Tenneco announced that it will spin off the shipyard as an independent company; the spin off is to be completed by the end of 1996.[47] NNS is the largest shipbuilding complex in the United States. It currently is one of two yards building nuclear-powered warships and is the only U.S. shipyard that can build nuclear-powered aircraft carriers (CVNs). As of mid-1995, NNS employed a total of 19,500 persons, compared to 20,900 in mid-1994. Employment at NNS is projected to decline to about 16,500 by the end of 1996.[48]

Since 1886, NNS has built a variety of Navy and commercial ships. NNS's past shipbuilding work for the Navy includes 14 of 18 aircraft carriers funded since World War II (including all 12 funded since FY1958), all 6 California (CGN-36) and Virginia (CGN-38) class nuclear-powered cruisers (CGNs), 9 of 37 SSN-637 class submarines, and all 5 Charleston (LKA-113) class amphibious cargo ships. It is currently building Nimitz (CVN-68) class CVNs and completing work on the last of 29 SSN-688 class submarines. It is also converting 2 older cargo ships into sealift ships. It will build the second New Attack Submarine, to be funded in FY1999.

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[46] For recent general articles on NNS, see Donlan, Thomas G. Anchors Aweigh. *Barron's*, Aug. 5, 1996; *Trimming the Sails*. Naval Forces, No. 3, 1996: 57; Bi[e]secker, Calvin. Newport News Looks to Expand Navy Business. *Defense Daily*, Apr. 5, 1996: 35-36.

[47] Dinsmore, Christopher. What's Next? Yard Should Thrive, But Future Not Totally Secure. *Virginian-Pilot*, Mar. 24, 1996: D1, D4; Barboza, David. Tenneco to Spin Off Newport News Shipbuilding. *New York Times*, Mar. 22, 1996: D1, D4; Southerland, Daniel. Tenneco to Spin Off Virginia Shipyard. *Washington Post*, Mar. 22, 1996: F1, F8. Earlier in 1996, Tenneco announced that is was considering selling the shipyard to another company or spinning it off. See Shipyard President Says Sale Could Mean Independence. *Associated Press* wire story, Feb. 21, 1996; Sterngold, James. Tenneco's Big Shipyard May Soon Sail Off Solo. *New York Times*, Feb. 18, 1996: Sec. 3, p. 3; Newport News Shipbuilding May Be Sold. *Washington Post*, Jan. 31, 1996: F2; Tenneco preparing to sell shipyard. *Navy News & Undersea Technology*, Feb. 12, 1996: 4.

[48] Associated Press. Virginia Yard's New Chief Says Slide In Jobs Not as Steep as First Thought. *Journal of Commerce*, Nov. 6, 1995.

In 1994, NNS signed a contract with a Greek shipowner for the construction of two 46,000-deadweight-ton "Double Eagle" petroleum product tankers, with an option (since exercised) for two more. This was the first time since 1957 that a foreign buyer had contracted with a U.S. shipyard for the construction of an ocean-going commercial ship. Together with a contract since signed with another buyer, NNS now has contracts to build up to 14 Double Eagle tankers.[49]

NNS can build submarines and surface ships of any kind. Its last major surface combatants -- the 6 nuclear-powered cruisers -- were completed between 1974 and 1980.

Summary of Past, Current and Projected Employment Levels

Table 1 below summarizes employment levels at the 6 yards for the years 1973-1994 and compares these historical employment levels to mid-1995 levels and to levels projected for future years. (See Appendix A for year-by-year data on employment at the 6 yards.)

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[49] NNS at one time had an agreement with a third buyer for an additional 6 Double Eagle tankers, but the buyer later canceled its planned purchase. Tanker Operator's Marad Move Costs Newport News Yard an Order. *Journal of Commerce*, Jan. 18, 1995. See also Dinsmore, Christopher. Commercial Work is Back at Newport News Shipbuilding. *Virginian-Pilot* (via Associated Press), Apr. 25, 1996; Newport News Shipyard Celebrates Construction of Commercial Ship. *Associated Press* wire story, Sep. 18, 1995; Huber, Lisa. Newport News Shipyard to Start 1st Commercial Contract Since '79. *Journal of Commerce*, Sep. 14, 1995; Abrams, Alan. Eletson to Purchase 2 More Tankers From US Shipyard. *Journal of Commerce*, July 11, 1995; Shorrock, Tim. Virginia Yard Homes In On Five-Ship Contract. *Journal of Commerce*, May 17, 1995; Newport News Shipbuilding Wins Commercial Tanker Order. *Associated Press* wire story, Mar. 14, 1995; Abrams, Alan. Newport News Yard Poised to Secure Second Tanker Deal. *Journal of Commerce*, Dec. 15, 1994: 8B; Taylor, Joe. As Navy Work Dwindles, Va. Yard Turns to Commercial Construction. *Journal of Commerce*, Nov. 22, 1994; Abrams, Alan. Shipyard Pins Commercial Hopes On Military Gear, Modular Technique. *Journal of Commerce*, June 23, 1994; Needham, Marjorie. Tenneco Unit Obtains Order to Build Two Tankers for Greek Shipping Firm. *Wall Street Journal*, May 23, 1994: A4; Abrams, Alan. Ship Order Is US' First Export Sale Since 1957. *Journal of Commerce*, May 23, 1994.

TABLE 1. EMPLOYMENT LEVELS[a]

	ASD	BIW	EB	ISI	NASSCO	NNS	Total
Past employment: 1973-1994							
Avg.	6,288	6,655	21,680	15,171	4,538	25,269	79,601
High (year)	7,782 (1989)	10,516 (1990)	28,513 (1977)	24,900 (1977)	6,775 (1981)	30,000 (1985)	95,793 (1977)
Low (year)	4,342 (1984)	2,245 (1973)	13,588 (1973)	9,760 (1984)	2,015 (1988)	20,900 (1994)	69,838 (1994)
1995 employment							
	5,150	8,300	15,111	14,081	4,500	19,500	66,642
1995 employment: % difference from 1973-1994 figures							
Avg.	-18%	+25%	-30%	-7%	-0%	-23%	-16%
High	-34%	-21%	-47%	-43%	-34%	-35%	-30%
Low	+19%	+270%	+11%	+44%	+123%	-7%	-5%
Projected employment (EB 1998, ISI 1997, NNS 1996)							
	n/a	n/a	7,000	9,600	n/a	16,500	n/a
Projected employment: % difference from 1973-1994 figures							
Avg.	n/a	n/a	-68%	-37%	n/a	-35%	n/a
High	n/a	n/a	-75%	-61%	n/a	-45%	n/a
Low	n/a	n/a	-48%	-2%	n/a	-21%	n/a

Source: Report on Survey of U.S. Shipbuilding and Repair Facilities, editions for 1973-1994, and Electric Boat Corporation (for EB figures for 1973-1984).

[a] Figures are mid-year levels. The high and low figures shown for each shipyard occur in various years during the period 1973-1994 and do not add to the figures shown in the total column, which are figures for the years in which *total* employment at the six yards was highest and lowest.

As can be seen in the table, total employment at the 6 yards in mid-1995 (66,642) was 16 percent below the average combined level of employment for the 6 yards for 1973-1994 (79,601), and 30 percent below the peak combined figure of 95,793, which occurred in 1977. Mid-1995 employment levels at each of the yards except BIW were below respective averages for the period 1973-1994. (As mentioned earlier, employment levels at BIW are expected to drop between now and 1998.) For NNS, employment in mid-1995 was lower than for any year during the period 1973-1994.

As can also be seen in the table, employment levels at EB, ISI, and NNS are projected to drop considerably from mid-1994 levels. By 1998, employment at EB is projected to be about two-thirds below EB's 1973-1994 average, and almost one-half below EB's previous low figure during this period of 13,588, which occurred in 1973. By 1997, employment at ISI is projected to be 37 percent below ISI's 1993-1994 average, and slightly below ISI's previous low figure of 9,760, which occurred in 1984. And in 1996, employment at NNS is projected to be more than one-third below NNS's 1973-1994 average, and more than 20 percent below NNS's mid-1995 level.

Summary of Production Capacity

Table 2 below presents the maximum annual production capacities of the 6 yards, measured in the principal kinds of ships that they are currently building for the Navy. As can be seen in the table, most of the yards each year could build 3 to 5 ships of the kinds they are currently building; ISI could build more.

Caution should be exercised in using the figures in Table 2 to judge the comparative capacities of the yards, because these figures do not adjust for the differing sizes and levels of complexity of the various types of ships listed. A shipyard that is listed as being able to build a given number of large, complex ships may have more capacity than a yard that is listed as being able to build a larger number of smaller or less complex ships.[50]

It is important to note that achieving and sustaining these maximum rates could require some of the yards to curtail or eliminate other forms of work, such as overhaul and repair of Navy and commercial ships and construction of commercial ships. It could also result in levels of employment that could strain the managerial and supervisory capabilities of some of the yards. The figures in the table also do not take into account possible capacity limitations in critical supporting supplier industries that could prevent these high rates from being achieved.

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[50] Other things held equal, a larger ship can require larger facilities and more worker-hours to build, while a more complex ship can require both more worker-hours to build and a greater range of worker and project-management skills and shipyard equipment and facilities. Ship combat systems (i.e., sensors, computers, and weapons) and nuclear propulsion are key contributors to ship complexity. CVNs are the largest type of Navy ship and include a nuclear propulsion plant. Nuclear-powered submarines are much smaller than CVNs but, ton-for-ton, are probably more complex to build than any other ship type. Major surface combatants are fairly complex because of their extensive and integrated ship combat systems. Amphibious ships are larger than major surface combatants but are generally less complex in their combat systems. Large auxiliaries are even less complex in their combat systems. Sealift ships are generally the least complex type.

TABLE 2. ANNUAL PRODUCTION CAPACITIES

Yard	Maximum capacity: Number of ships completed per year
ASD	4 Harpers Ferry (LSD-49) class amphibious ships
BIW	3.5 Arleigh Burke (DDG-51) class destroyers
EB	3 nuclear-powered attack submarines (SSNs)[a]
ISI	11 DDG-51 class destroyers *or* 8 DDG-51 class destroyers + 1 Wasp (LHD-1) class amphibious ship
NASSCO	4 or 5 Supply (AOE-6) class underway replenishment ships *or* 5 or 6 TAKR-310 class sealift ships
NNS	4 SSNs[b] + 1 nuclear-powered aircraft carrier (CVN)

Source: Interviews with shipyard officials.

[a] Capacity of EB's Land Level Submarine Construction Facility (LLSCF). Additional submarines could be built in EB's older inclined building ways.

[b] Capacity of NNS Modular Outfitting Facility (MOF). Additional submarines could be built in NNS's graving docks.

Table 3 below summarizes the current and potential production capabilities of the 6 yards in terms of the kinds of ships they are currently building or could build.

TABLE 3. PRODUCTION CAPABILITIES BY TYPE

Yard	Nuclear		Conventional					
	Sub-marines	Aircraft carriers		Major surface combatants	Amphibious ships[b]		Large auxiliaries	Sealift ships
		CVN	CV[a]		LHD	LSD/ LPD		
ASD			o--?[c]	o-	o	●[d]	●	●
BIW				●	o--[e]	o-	o	o
EB	●			o--[e]				
ISI			o--[f]	●	●	o	o	o
NASSCO				o-	o--[g]	o	●	●
NNS	●[h]	●	o	o	o	o	o	o[i]

Source: U.S. Navy data sheet to CRS, June 23, 1994, and interviews with shipyard officials. The Navy data sheet states: "Capability categorizations on [this table] are rough estimates of facility capital equipment and do not include substantial cost in establishing appropriation organizations and required personnel training/qualification. The specific facilities and Rough Order of Magnitude (ROM) costs for [o- and o--] are generally not available without extensive evaluation."

● Current construction work.
o Yard capable of building this type.
o- Yard could be made capable of building this type with up to $100 million in capital improvement.
o-- Yard could be made capable of building this type with $100 million to $500 million in capital improvement.

a The Navy is not currently building CVs. Ship shown here is a modified repeat of the last CV, the John F. Kennedy (CV-67), or a non-nuclear variant of the Nimitz (CVN-68) class design.
b The Wasp (LHD-1) class amphibious assault ship, with a full-load displacement of about 40,500 tons, is considerably larger than the Harpers Ferry (LSD-49) class amphibious dock landing ship (about 16,700 tons) or the LPD-17 class amphibious transport ship (about 25,000 tons).
c The Navy believes physical impediments restrict ASD's potential ability to build CVs; ASD officials are more optimistic. See background section on ASD. The Navy did not give a o-- rating to ASD for CVs; the o--? rating shown here was inserted to reflect the apparent difference of views between the Navy and ASD on this issue.
d Type being constructed is LSD-49 class.
e Although the Navy lists the potential for the yard to be made capable of building this type of ship, officials from the yard in question do not emphasize this possibility.
f Shipyard officials state that the principal capital improvement would be the enlargement of the yard's floating drydock; they estimate the cost of this at less than $100 million.
g The Navy provided a ROM cost estimate of $400 million for this capital improvement.
h NNS is currently building SSNs. The Navy states that NNS would require a minor capital improvement to build SSBNs.
i NNS currently is not building new sealift ships but is converting 2 older cargo ships into sealift ships.

As can be seen in the table, there are currently 2 yards involved in the construction of each major category of ship except CVNs, for which there is only one builder. There are also potentially more than 2 sources for most ship types. The exceptions are nuclear-powered submarines, for which there are 2 potential sources, and aircraft carriers. There is only 1 potential builder of CVNs, and 2 or possibly 3 potential sources of CVs, which are not currently being built.[51]

Table 3 shows that the Navy's major shipbuilding programs currently divide the 6 yards into 4 paired groups. These are the nuclear-powered shipbuilders (EB and NNS), the major surface combatant shipbuilders (BIW and ISI), the amphibious shipbuilders (ASD and ISI), and the large auxiliary and sealift shipbuilders (ASD and NASSCO).

As can also be seen in the table, however, this segmentation of shipbuilding activities is not rigid or fixed. Most yards overlap in current or potential capabilities for building most ship types. The main exception concerns the ability to build nuclear-powered ships, which does appear to be a strong divide: The time, expense, and regulatory approvals needed to qualify a shipyard for the construction of nuclear-powered ships appear to form a strong barrier to any non-nuclear-capable yard that might wish to enter the nuclear-powered shipbuilding business. This applies even to ISI, which built nuclear-powered submarines until the early 1970s.

THE FY1996-FY2001 SHIPBUILDING PLAN

Table 4 below shows the Administration's amended plan for building Navy ships in the FY1996-FY2001 Future Years Defense Plan (FYDP). The amended plan reflects Congressional action on the FY1996 defense budget. The sealift ships are funded in the National Defense Sealift Fund (NDSF); the other ships are funded in the Shipbuilding and Conversion, Navy (SCN) appropriation account.

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[51] The last CV, the John F. Kennedy (CV-67), was funded in FY1963 and commissioned in 1968.

TABLE 4. ADMINISTRATION'S AMENDED FY1996-FY2001 SHIPBUILDING PLAN
New-construction ships[a]

Ship type	Fiscal Year						Total	Avg
	96	97	98	99	00	01		
SCN-funded ships								
Submarines[b]	1	0	1	(1)	1	(1)	3	0.5
Aircraft carriers	0	0	0	0	0[c]	0[c]	0	0
Major surface combatants	2[d]	4	2	3	3	3	17	2.8
LHD amphibious ship	1[e]	0	0	0	0	0	1	0.2
LPD-17 amphibious ship	1[f]	0	1	1	2	2	7	1.2
Large auxiliaries	0	0	0	0	1[g]	0	1	0.2
Smaller ships[h]	0	0	0	2	0	0	2	0.3
Subtotal: SCN ships	5	4	4	6	7	5	31	5.2
NDSF-funded sealift ships	2	2	2	2	0	0	8	1.3
Total ships	**7**	**6**	**6**	**8**	**7**	**5**	**39**	**6.5**

Source: U.S. Department of the Navy. *Highlights of the Department of the Navy FY 1997 Budget.* Washington, 1996. (March 1996) p. 3-4.

[a] In addition to the new-construction ships shown, the Administration's SCN plan also includes conversion work on 4 large auxiliaries in FY1996, conversion work on another 2 large auxiliaries in FY1997, conversion work on 2 large auxiliaries and a refueling complex overhaul of a CVN in FY1998, a service life extension program (SLEP) overhaul of a large auxiliary in FY1999, and a refueling complex overhaul of a CVN in FY2001.

[b] The FY1996 SSN is SSN-23, the third Seawolf (SSN-21) class SSN. The FY1998-FY2001 SSNs are to be based on the New Attack Submarine design. The FY1999 and FY2001 SSNs, shown in parentheses, were inserted by Congress under Sec. 131 of the FY1997 defense authorization act but are not funded in the Administration's amended FY1996-FY2001 FYDP.

[c] Advanced procurement funding is programmed in FY2000 and FY2001 for a CVN tentatively scheduled to be fully funded in FY2002.

[d] Congress authorized 3 DDG-51s in FY1996 but did not fully fund a 3-ship buy.

[e] Congress funded this ship -- LHD-7, the seventh ship Wasp (LHD-1) class amphibious assault ship -- in FY1996 rather than FY2001 as planned by the Administration.

[f] Congress funded this ship -- the first of 12 planned class of 12 LPD-17s -- in FY1996 rather than FY1998 as planned by the Administration.

[g] This is the lead ship of a new class of dry cargo ships currently designated ADC(X).

[h] These SCN-funded ships of less than 400 feet in length are an ocean surveillance ship and an oceanographic ship.

As can be seen in the table, the Administration plans to procure 39 ships during the FYDP, or an average of 6.5 major ships per year. This figure includes 2 smaller ships less than 400 feet in length. Excluding the 8 NDSF-funded sealift ships, the average number of SCN-funded ships is 5.2 per year. This is the lowest sustained rate of ship procurement since the post-World War II demobilization of the late 1940s, and is only a fraction of the combined maximum production capacity of the 6 yards (about 30 ships per year) as presented in Table 2.

The following are brief descriptions of the shipbuilding programs listed in Table 4 above.

Submarines

Congress funded the last of 18 Ohio (SSBN-726) class nuclear-powered ballistic missile submarines (SSBNs) in FY1991. EB is the builder of all 18. The 18th is scheduled to enter service in 1997. Congress funded the last of 62 Los Angeles (SSN-688) class nuclear-powered attack submarines (SSNs) in FY1990. EB is the builder of 33 and NNS is the builder of 29. The 62nd boat, being built by NNS, is scheduled to enter service in 1996.

Congress funded SSN-21, the first Seawolf (SSN-21) class SSN, in FY1989, and SSN-22, the second Seawolf-class SSN, in FY1991. The FY1996 submarine is SSN-23, the third and final Seawolf-class SSN. EB is the builder of all 3 Seawolf-class SSNs. SSN-21 will enter service in 1996.

The FY1998-FY2001 submarines are to be based on the New Attack Submarine design. The FY1999 and FY2001 SSNs were inserted by Congress under Sec. 131 of the FY1997 defense authorization act but are not funded in the Administration's amended FY1996-FY2001 FYDP. EB is to be the builder of the FY1998 and FY2000 submarines; NNS is to be the builder of the FY1999 and FY2001 submarines. Additional NSSNs are to be procured in later years.[52]

Aircraft Carriers

Congress funded two Nimitz (CVN-68) class nuclear-powered aircraft carriers (CVNs) -- the John C. Stennis (CVN-74) and the Harry S. Truman (CVN-75) -- in FY1988. The Stennis entered service in December 1995; the Truman will enter service in 1998. Congress funded its most recent Nimitz-class CVN, the Ronald Reagan (CVN-76), in FY1995; it is scheduled to enter service in 2003. NNS is the builder of these and all other aircraft carriers procured for the Navy since FY1958.[53]

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[52] For a discussion of issues relating to procurement of attack submarines, see CRS Issue Brief 91098, *Navy Attack Submarine Programs: Issues for Congress*, by Ronald O'Rourke. Washington, 1996. (updated regularly) 15 p.

[53] For a review of aircraft carrier procurement through CVN-76, see CRS Issue Brief 92042, *Navy Nuclear-Powered Aircraft Carrier (CVN-76)*, by Ronald O'Rourke. Washington, 1995. (archived Feb. 3, 1995) 14 p.

The FY1996-FY2001 plan contains advanced procurement funding in FY2000 and FY2001 for a tenth and final Nimitz-class ship (CVN-77) tentatively scheduled for procurement in FY2002. After CVN-77, the Navy is planning to shift aircraft carrier procurement from the Nimitz-class design to a new design. The first ship of the new class, CV(X)-78, is currently planned for procurement in FY2006. The Navy has said that Project 78, the study effort that will explore design options for CV(X)-78, will reexamine all issues relating to aircraft carrier design, including overall ship size, flight deck configuration, and whether the ship should be nuclear- or conventionally powered.[54]

Major Surface Combatants

Congress procured the last of 27 Ticonderoga (CG-47) class Aegis[55] cruisers in FY1988. ISI is the builder of 19, BIW is the builder of 8. The 27th ship entered service in 1994. Congress began procuring Arleigh Burke (DDG-51) class Aegis destroyers in FY1985. Including 2 ships in FY1996,[56] a total of 34 DDG-51s have been procured through FY1996. Of the 32 ships funded through FY1995, BIW is the builder of 18 and ISI the builder of 14. The first DDG-51 entered service in 1991. An additional 23 DDG-51s are to be procured between FY1997 and about FY2004, bringing the planned total procurement to 57 ships.[57]

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[54] With Kaminski's Approval, Navy Sets Up Future Carrier Office. *Inside the Navy*, Apr. 8, 1996: 2; Robinson, John. Kaminski Approves Preliminary Plan for Next Generation Carrier. *Defense Daily*, Apr. 5, 1996: 36-37; Truver, Scott C., and Edward H. Feege. From Paper Ships To Reality? *Armed Forces Journal International*, April 1996: 55-57; Lopez, Ramon. Future Flat-Top. *Flight International*, Mar. 20-26, 1996: 35; Starr, Barbara. USN Studies Ski Jumps and Radical Catapults. *Jane's Defence Weekly*, Feb. 14, 1996: 5; Blazar, Ernest. How Will Future Carriers Look? Sky's the Limit. *Navy Times*, Feb. 5, 1996: 26; Jannery, Beth. Navy to Brief Senior Pentagon Official on Future Aircraft Carrier Plans. *Inside the Navy*, Dec. 11, 1995: 1, 18-19; Eisman, Dale. The Carrier Evolves. *Virginian-Pilot*, Nov. 26, 1995: A1, A14; Holzer, Robert. U.S. Navy To Blend Technologies in New Carrier. *Defense News*, Oct. 30-Nov. 5, 1995: 16; Jannery, Beth. Navy Begins Planting Seed Money in Budget for Next-Generation Carrier. *Inside the Navy*, Oct. 9, 1995: 1, 8; Navy Carrier Study to Feed Into 1998 Program Objective Memorandum. *Inside the Navy*, July 17, 1995: 3; Huber, Lisa. Navy's Carrier of the Future. *Daily Press* (Newport News, VA), Jun. 18, 1995; Holzer, Robert. U.S. Navy Seeks Funding for Carrier Review. *Defense News*, Mar. 13-19, 1995: 23.

[55] The Aegis system is a highly integrated ship combat system that gives U.S. Navy surface combatants much more capability than their non-Aegis predecessors. For this reason, cruisers and destroyers equipped with the Aegis system are often referred to as Aegis cruisers and Aegis destroyers. For background information on the Aegis system and installation aboard Navy cruisers and destroyers, see CRS Report 84-180 F, *The Aegis Anti-Air Warfare System: Its Principal Components, Its Installation on the CG-47 and DDG-51 Class Ships, and Its Predecessors*, by Ronald O'Rourke. Washington, 1984. (Oct. 24, 1984) 18 p.

[56] As noted in the table above, Congress authorized 3 DDG-51s in FY1996 but did not fully fund a 3-ship buy.

[57] For additional background information on the DDG-51 program, see CRS Report 94-343 F, *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress*, by Ronald O'Rourke. Washington, 1994. (Apr. 25, 1994) 67 p.

In FY2003, the Navy plans to begin procurement of a new family of surface combatant designs currently referred to collectively as SC-21, meaning surface combatant for the 21st Century.[58] The Navy also wants to procure over the next several years about half a dozen specialized "arsenal" ships that might each carry about 500 missiles.[59]

Amphibious Ships

Department of the Navy plans call for a fleet of 36 amphibious ships -- 12 Tarawa (LHA-1) or Wasp (LHD-1) class "big deck" amphibious assault ships of about 40,000 tons full load displacement each, 12 Whidbey Island (LSD-41) or Harpers Ferry (LSD-49) class amphibious dock landing ships of about 17,000 tons full load displacement each, and 12 LPD-17 class amphibious transport ships of about 25,000 tons full load displacement each.

Congress funded LHD-7, the last of the 12 amphibious assault ships, in FY1996 rather than in FY2001 as planned by the Administration. ISI is the builder of all 12 of these ships.

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[58] SC 21 gets fleet modernization back on track. *Navy News & Undersea Technology*, Oct. 30, 1995: 5; Grimes, Vincent P. Surface Navy Faces Heavy Weather on Budget Ocean. *National Defense*, October 1995: 36-37; Holzer, Robert. Super Warship Shows Promise in Computer Trials. *Defense News*, Aug. 28-Sep. 3, 1995: 3; Holzer, Robert. JAST Tactic May Aid Vessel Design. *Defense News*, June 12-18, 1995: 4; Walsh, Edward J. A Bold Move in a New Direction. *Sea Power*, April 1995: 31, 33-34, 37-38, 41; 21st Century Surface Combatant COEA Outlines Alternatives, Costs. *Inside the Navy*, Feb. 6, 1995: 15-17.

[59] For information on the arsenal ship, see the forthcoming CRS Report, *Navy Arsenal Ship Program: Issues and Options for Congress,* by Ronald O'Rourke. (title tentative). See also Blazar, Ernest. Future Shock. *Navy Times*, July 29, 1996: 12-14; Truver, Scott C. Floating Arsenal To Be 21st Century Battleship. *Jane's International Defense Review*, July 1996: 44-47; Mintz, John. New Ship Could Be Next Wave in Warfare. *Washington Post*, June 23, 1996: A1, A22; Holzer, Robert. Commanders May Share Arsenal Ship Assets. *Defense News*, June 17-23, 1996: 10; Arsenal Ship Sails a Fast Track as Contractors Weight Ideas. *Navy News & Undersea Technology*, May 20, 1996: 1, 3; Schweizer, Roman. Navy, DARPA Pitch Arsenal Ship Concept to Hungry Defense Industry. *Inside the Navy*, May 13, 1996: 1, 24-26; Robinson, John. Navy Wants to Forward Deploy Arsenal Ships. *Defense Daily*, Apr. 25, 1996: 145-146; Holzer, Robert. U.S. Navy's New Arsenal Ship Takes Shape. *Defense News*, April 8-14, 1996: 4, 28; Landay, Jonathan S. New Post-Cold-War Vessel Would Pack Huge Punch. *Christian Science Monitor*, Apr. 4, 1996: 1; Grimes, Vincent P. Arsenal Ships Steaming Toward Budget Decision. *National Defense*, April 1996: 32-34; Robinson, John. Navy, DARPA Ink Agreement for Arsenal Ship. *Defense Daily*, Mar. 21, 1996: 429-430; Starr, Barbara. US Navy to Seek Funding for Radical Arsenal Ship. *Jane's Defence Weekly*, Mar. 6, 1996: 3; Navy, DARPA Will Sign Agreement for Co-Development of Arsenal Ship. *Inside the Navy*, Mar. 4, 1996: 1, 12-13; Holzer, Robert. U.S. Navy Eyes Options as Arsenal Ship Takes Shape. *Defense News*, Feb. 5-11, 1996: 20; Jannery, Beth. Navy Drafts Performance Specifications for Arsenal Ship Capabilities. *Inside the Navy*, Jan. 8, 1996: 1, 8-11; Polmar, Norman. More Bang for the Buck. *U.S. Naval Institute Proceedings*, January 1996: 87-88; Lasswell, James A. Why the Arsenal Ship Concept Is Gaining Momentum. Marine Corps Gazette, January 1996: 31-32.

LSD-52, the last of the 12 LSD-41/49 class dock landing ships, was funded in FY1993 and will enter service in 1998. ASD is the builder of the final 9 ships in this group.[60]

Congress funded the first of 12 planned LPD-17 class amphibious transport ships in FY1996 rather than in FY1998 as planned by the Administration.[61]

Large Auxiliaries

AOE-10, the last of four Supply (AOE-6) class underway replenishment ships, was funded in FY1993 and is scheduled to enter service in 1997. NASSCO is the builder of all four ships. The first ship in a planned class of dry cargo ships currently designated ADC(X) is planned for procurement in FY2000.[62]

Sealift Ships

In response to the 1992 Mobility Requirements Study (MRS), which established new military airlift and sealift objectives, the Defense Department is acquiring 19 large, medium-speed, roll-on/roll-off (LMSR) sealift ships. Unlike the other ship types discussed above, which are funded in the Shipbuilding and Conversion, Navy (SCN) appropriation account, these ships are funded in the National Defense Sealift Fund. Five of the 19 LMSRs will be converted commercial cargo ships; the other 14 will be new-construction ships.

The five conversions were funded in FY1993; NASSCO was awarded 3 and NNS was awarded 2. The last of these five ships will enter service in 1997. Of the 14 new-construction ships, 8 have been funded through FY1996. The remaining 6 ships are to be funded between FY1997 and FY1999. NASSCO and ASD have each been awarded a contract to build up to 6 of the new-construction ships. (Each contract is for 1 ship with options to build up to 5 additional ships.) The Defense Department has not yet decided who will build the final 2 new-construction LMSRs. The last of these 14 ships will enter service in 2001.[63]

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[60] The builder of the first 3 ships was Lockheed Shipbuilding Company of Seattle, WA, which was effectively closed in 1987.

[61] For additional background information on the LPD-17 program, see CRS Report 96-346F, *Navy LPD-17 Amphibious Shipbuilding Program: Background and Funding Options for Congress*, by Valerie Bailey Grasso. (April 17, 1996) 6 p.

[62] For additional information on the ADC(X) program, see Navy to Start Work on Next Generation Combat Force Logistics Ship. *Inside the Navy*, Dec. 11, 1995: 11-12.

[63] For additional background information on the LMSR program, see CRS Report 96-257F, *Sealift (LMSR) Shipbuilding and Conversion Program: Backgrounds and Status*, by Valerie Bailey Grasso. (March 19, 1996) 6 p.

KEY ADMINISTRATION DECISIONS

The Administration since 1993 has made four key decisions regarding the Navy's major shipbuilding programs.

Reduce Ship Procurement

One of these decisions was to reduce the number of new SCN-funded ships to be procured. The FY1994-FY1999 defense budget outline submitted by the outgoing Bush Administration in January 1993 called for an average of 6.2 new SCN-funded ships per year.[64] This figure was reduced to 5.3 new SCN-funded ships per year in the FY1994-FY1999 FYDP submitted by the Clinton Administration in February 1994, and to 5.2 new SCN-funded ships per year in the amended FY1996-FY2001 FYDP submitted by the Clinton Administration in March 1996.[65]

The DDG-51 and LPD-17 programs were the primary programs involved in this reduction. The Bush Administration planned a procurement rate of 3.5 DDG-51s per year during the period FY1994-FY1999. The Clinton Administration reduced this to 3 ships per year in its FY1994-FY1999 FYDP, and to 2.8 ships per year in its amended FY1996-FY2001 FYDP. The Bush Administration planned to procure the first LPD-17 in FY1996. The Clinton Administration maintained the FY1996 procurement date in its FY1994-FY1999 FYDP, but deferred procurement of the ship to FY1998 in the original version of its FY1996-FY2001 FYDP submitted in February 1995. Congress funded the first LPD-17 in FY1996, but the Clinton Administration in its amended FY1996-FY2001 FYDP submitted in March 1996 plans to procure follow-on ships in the class at a one-per-year rate in FY1998 and FY1999, rather than the two-per-year rate planned by the Bush Administration.

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[64] Package of briefing slides provided to Congress by the Defense Department in January 1993, page entitled "Shipbuilding." The cover sheet of this package of slides stated: "Enclosed is a proposed Department of Defense budget for fiscal year 1994 and the outyears through 1999. It is based on the overall budget levels set by President Bush and is consistent with previous budget arrangements. This was approved by Secretary of Defense [Dick] Cheney and is the budget that would have been submitted to the Congress had the outcome of the [1992 Presidential] election been different."

[65] These figures are for SCN-funded ships only because specific numbers of NDSF-funded sealift ships to be procured were not shown in the budget outline submitted by the outgoing Bush Administration. The outline did show $306 million in NDSF funding for shipbuilding in FY1994, and an average of about $822 million per year in NSDF funding for shipbuilding in FY1995-FY1999. The figures cited do, however, include a few SCN-funded ships of less than 400 feet in length. Excluding such ships, which are often built by shipyards other than the 6 yards discussed in this report, the Bush Administration outline would procure an average of 5.3 (rather than 6.2) new SCN-funded ships per year, the February 1994 Clinton Administration plan would procure an average of new 4.7 (rather than 5.3) SCN-funded ships per year, and the March 1996 Clinton Administration plan would procure an average of 4.8 (rather than 5.2) new SCN-funded ships per year.

This reduction in the number of major ships to be procured resulted partly from the Clinton Administration's decision to reduce the planned size of the military, including the Navy. The Bush Administration's "Base Force" plan for the future of the U.S. military called for a Navy of about 416 ships.[66] The Clinton Administration's Bottom-Up Review (BUR) plan for the future of the military calls for a Navy of 346 ships, a reduction of 70 ships or about 17 percent. Clinton Administration officials stated in 1994 and 1995 that a reduction in equipment procurement rates for a few years would be acceptable in light of the Clinton Administration's decision to maintain a smaller military than the one planned by the Bush Administration, the higher equipment procurement rates of the 1980s, and the relatively low average ages of equipment currently in service. They also acknowledged that starting a few years from now, funding will have to be added to the procurement accounts so that procurement rates can be increased to levels needed to maintain planned BUR force levels in the longer run.[67]

The reduction also reflected a decision announced by the Clinton Administration in December 1994 to defer, reduce, or terminate certain weapon acquisition programs so as to release funding for application to near-term military readiness programs. Among other things, this decision reduced the planned DDG-51 procurement rate to less than 3 ships per year and deferred procurement of the third New Attack Submarine from FY2001 to FY2002.[68]

Maintain 2 Nuclear Shipbuilders (EB and NNS)

A second decision, announced by the Administration in its September 1993 Bottom-Up Review (BUR) of U.S. defense policy, was to maintain both EB and NNS as nuclear-capable shipbuilders rather than consolidate construction of all

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[66] U.S. Department of Defense. *Annual Report to the President and the Congress*. Washington, 1993. (Dick Cheney, Secretary of Defense, January 1993) Table 14 on p. 82. The Navy in the Bush Administration's Base Force plan was often referred to as a 450-ship Navy. Table 14, however, shows the size of the Navy declining from 448 ships in FY1993 to 416 ships in FY1999.

[67] See, for example, Statement of The Secretary of Defense, William J. Perry, Before the House Armed Services Committee in Connection With The Fiscal Year 1996 Budget for the Department of Defense, February 22, 1995, p. 5; and Statement of the Secretary of Defense, William J. Perry, Before the House National Security Committee In Connection With The FY 1996-97 Department of Defense Budget, February 8, 1995, p. 7 and accompanying briefing charts 16, 17, and 18.

[68] For a review of the Defense Department's December 1994 program reductions, see Blazar, Ernie, and Gidget Fuentes. A few guns for butter. *Navy Times*, Dec. 19, 1994: 3; Glashow, Jason, and Robert Holzer. DoD Weapon Cuts May Boomerang as Price Hikes. *Defense News*, Dec. 12-18, 1995: 1, 44; Navy Not Crippled by Pentagon Modernization Cuts. *Inside the Navy*, Dec. 12, 1994: 3; Navy bears brunt of DOD weapons cuts. *Navy News & Undersea Technology*, Dec. 12, 1994: 1; Robinson, John. $8 Billion in Cuts Claims TSSAM, Slows Comanche. *Defense Daily*, Dec. 12, 1994: 348-350; Biesecker, Calvin, and Richard Lawson. DDG-51 Reduction Could Be Troubling for Bath Iron Works. *Defense Daily*, Dec. 12, 1994: 354; and Lovece, Joseph. Republicans Warn Perry About Modernization Cuts. *Defense Week*, Dec. 12, 1994: 1, 9-10.

nuclear-powered ships at NNS. This decision followed previous examination of the issue by the Bush Administration. In support of its decision, the Clinton Administration decided to fund SSN-23 in FY1996 for construction at EB, assign EB as the builder of the first (i.e., FY1998) NSSN, and proceed with procurement of CVN-76 in FY1996 for construction at NNS.[69]

Maintain DDG-51 Production at 2 Yards (BIW and ISI)

A third decision, announced by the Administration in November 1995, was to maintain both BIW and ISI as builders of DDG-51 class ships, rather than consolidate DDG-51 production at one of the yards.[70] The decision followed the recommendation of a Navy study on the future DDG-51 acquisition strategy. In June 1994, the Navy announced that it would begin the study and -- as an interim measure to preserve both yards while the study was being conducted -- allocate the 6 DDG-51s funded in FY1994 and FY1995 evenly between BIW and ISI rather than award the ships on the basis of competitive bidding, which had been used in the DDG-51 program until that time.[71]

Build Sealift Ships at 2 Remaining Yards (ASD and NASSCO)

A fourth decision, announced in 1993, was to award contracts for the construction of the first 12 new LMSRs to two shipyards rather than one. The contracts were awarded, after a competition involving all 5 of the yards capable of building surface ships, to the two yards not involved in production of nuclear-powered ships or surface combatants -- ASD and NASSCO.[72]

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[69] U.S. Department of Defense. *Report on the Bottom-Up Review.* Washington, 1993. (Les Aspin, Secretary of Defense, October 1993) p. 53 and 57.

[70] Aegis to remain a two-yard affair. *Navy Times*, Dec. 4, 1995: 30; Wesel, L. Mercedes. BIW, Ingalls both assured a share of destroyer work. *Portland (ME) Press Herald*, Nov. 14, 1995; Navy Will Split Aegis Contracts Between Maine, Miss. Yards. *Associated Press* wire story, Nov. 14, 1995; Study Says Compete Aegis Destroyer Job. *Defense News*, June 12-18, 1995: 2.

[71] Under the Navy's decision, each yard would receive 3 of the 6 ships: BIW was allocated 2 of the FY1994 ships and 1 of the FY1995 ships, while ISI was allocated 1 of the FY1994 ships and 2 of the FY1995 ships. Holzer, Robert. Is It Salvation or Starvation? *Defense News*, June 13-19, 1994: 4, 36; Concerned Shipyards Were Underbidding, Navy Split DDG-51 Work. *Inside the Navy*, June 13, 1994: 3-4; Burkes parcelled out. *Navy News & Undersea Technology*, June 13, 1994: 1-2; Rosenberg, Eric. The Navy Is Sailing On A Sea Of Industrial Policy. *Defense Week*, June 13, 1994: 2-3; DDG-51 Split 'Buys Time' For New Acquisition Strategy. *Defense Daily*, June 10, 1994: 385-386; Ricks, Thomas E. Navy Allocates Ship Contracts In Policy Shift. *Wall Street Journal*, June 9, 1994: 16; Navy Divides DDG 51 Buy to Keep Industrial Base Healthy. *Defense Daily*, June 9, 1994: 381.

[72] ISI and NNS, two of the other bidders on the program, filed protests against the awards, but the General Accounting Office rejected the protest and upheld the awards. Holzer, Robert. Major U.S. Shipyards Question Navy Awards. *Defense News*, Sep. 20-26, 1993: 6; Holzer, Robert. GAO Ruling To Fuel U.S. Navy Ship Plan. *Defense News*, Feb. 7-13, 1994.

Effect of These 4 Decisions

The effect of these four decisions was to reduce the total amount of shipbuilding work available to the 6 yards while providing at least some work to each of the 6 yards for the next several years, thereby reducing the likelihood for the next several years that the reduction might force any of the yards into bankruptcy and closure.

OTHER RECENT SHIPBUILDING-RELATED EVENTS

In addition to the events listed in the above section, there are other recent shipbuilding-related events of note.

In October 1993, the Administration issued a report outlining its 5-part plan for assisting the U.S. shipbuilding industry in its efforts to break back into the international market for construction of commercial ships.[73] A month later, Congress passed the National Shipbuilding and Shipyard Conversion Act of 1993 as a section of the FY1994 defense authorization bill to help promote merchant ship construction in U.S. shipyards and the modernization of U.S. shipyard facilities.[74]

In August 1995, while General Dynamics Corporation's purchase of BIW was being negotiated, it was reported that NNS had earlier sought help from DOD in financing a planned purchase of EB. DOD reportedly turned down NNS's request and the purchase did not go through. NNS reportedly had intended to close down EB's main facility at Groton, CT after purchasing EB while leaving open EB's facility at Quonset Point, RI.[75]

At the end of August 1995, ASD and BIW announced that they had formed a team along with Hughes Aircraft of southern California to bid on the LPD-17 program.[76] In October 1995, ISI, NASSCO, and NNS announced that they had formed an opposing team along with Lockheed Martin Government Electronic Systems of New Jersey to bid on the program.[77] In June and July 1996, it was

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[73] *Strengthening America's Shipyards: A Plan for Competing in the International Market.* Washington, 1994. (The White House, October 1, 1993) 18 p.

[74] For a short discussion of the National Shipbuilding and Shipyard Conversion Act, see *Outlook for the U.S. Shipbuilding and Repair Industry 1995*, op. cit., p. 28-30.

[75] Mintz, John. Torpedoing a $100 Million Favor. *Washington Post*, Aug. 26, 1995: C1-C2.

[76] Bath Forms an Alliance To Bid on Navy Ships. *Journal of Commerce*, Sep. 7, 1995; BIW Forms Alliance To Compete For New Contract. *Associated Press* wire story, Sep. 1, 1995; Shipbuilder Joins Two Companies to Seek Contracts. *Associated Press* wire story, Aug. 31, 1995.

[77] Ingalls forms team to compete for LPD 17. *Jane's Defence Weekly*, Nov. 4, 1995: 8; Walsh, Mark. Second Team Will Bid for LPD-17. *Defense Week*, Oct. 30, 1995: 3; Ingalls To Team With Other Companies To Bid For New Navy Ship Contract. *Associated Press* wire story, Oct. 24, 1995;

reported that ISI and NNS had joined one team to compete for the arsenal ship program, while BIW and EB had joined another.[78] The formation of bidding teams involving more than one shipyard breaks with the yards' traditional pattern of bidding separately on shipbuilding programs and is analogous to the trend in recent years among aircraft manufacturers to form teams to bid jointly on U.S. military aircraft programs. For both the shipyards and the aircraft manufacturers, the advent of team bidding appears to reflect the relative scarcity of new defense procurement programs in the 1990s, and the consequent need among defense firms to take steps to increase the likelihood of winning at least a share of each new program.[79]

Newport News Shipyard to Bid as Team for Navy Contract. *Associated Press* wire story, Oct. 24, 1995.

[78] Five Industry Teams Compete in Arsenal Ship Program. *Navy News & Undersea Technology*, July 22, 1996: 3-4; Holzer, Robert. Teams Are New Shipbuilding Wave. *Defense News*, June 10-16, 1996: 22; Shifting Alliances Mark Navy Bidding Wars. *Associated Press* wire story, June 14, 1996; DARPA Picks Winners for Arsenal Ship Concept Exploration Work. *Aerospace Daily*, July 12, 1996: 58. ASD has joined a third team, while NASSCO has joined a fourth. There is also a fifth team that involves shipyards other than the 6 involved in this report; see Dinsmore, Christopher. Metro Machine Looking to Build Ships. *Virginian-Pilot*, July 18, 1996: D1-D2. All these teams include defense electronics and consulting/analysis companies as well as shipyards.

[79] See Shipyards Must Learn to Team. *Navy News & Undersea Technology*, July 22, 1996: 1, 3; Teams Are New Shipbuilding Wave, op. cit.; and Finnegan, Philip, and Robert Holzer. U.S. Shipbuilders Team Up in Tough Times. *Defense News*, Feb. 12-18, 1996: 3, 37. For the aircraft manufacturers, teaming arrangements may also reflect the large out-of-pocket corporate expenditures now required to develop certain new aircraft designs.

TWO KEY ISSUES FOR CONGRESS

This chapter discusses two key issues for Congress concerning the Navy's major shipbuilding programs and shipbuilders. As stated in the introductory chapter, these two issues are:

- Is the FY1996-FY2001 shipbuilding plan adequate?

- How many major Navy shipbuilders are needed to meet the Navy's needs?

IS THE FY1996-FY2001 SHIPBUILDING PLAN ADEQUATE?

The issue of whether the FY1996-FY2001 shipbuilding plan is adequate can be viewed from at least three perspectives:

- Is it adequate to maintain the Administration's planned 346-ship Navy?

- Is it adequate to keep all 6 shipyards in business?

- Is it adequate to maintain efficient production rates at the shipyards?

Each of these questions is discussed below.

Adequate to Maintain the Planned 346-Ship Navy?

The Navy currently has more than 346 ships, and is not projected to drop down to the 346-ship level until the end of the decade.[80] To reduce down to the 346-ship figure, the Navy is retiring a variety of ships years before they reach the end of their expected service lives.

Thus, in the short run -- that is, for the next few years -- the Navy could maintain a 346-ship Navy without procuring any additional ships at all,

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[80] The Navy had 435 ships at the end of FY1993, 387 ships at the end of FY1994, and 372 at the end of FY1995. It is projected to decline to 359 ships by the end of FY1996, and to 358 ships by the end of FY1997. *Highlights of the FY 1995 Department of the Navy Budget*, op. cit., Table 3 on p. 15; and U.S. Department of the Navy. *Highlights of the Department of the Navy FY 1997 Budget.* Washington, 1996. (March 1996) p. Table 3 on p. 2-2 and Table 5 on p. 2-4. The total number of battle force ships in the Navy includes active and Naval Reserve Force (NRF) battle force ships. The narrative on page 2-1 of the FY1997 budget highlights document can lead to confusion regarding the projected size of the Navy relative to the 346-ship goal because it does not take into account the 18 NRF ships discussed on page 2-4. Previous editions of the budget highlights document present the situation more clearly by showing the active and NRF battle force ships in the same table. See, for example, U.S. Department of the Navy. *Highlights of the Department of the Navy FY 1996/FY 1997 Biennial Budget.* Washington, 1995. (February 1995) p. 2-1 and Table 3 on p. 2-3.

particularly if ships now planned for early retirement are instead kept in service until the end of their expected service lives. The resulting fleet would have a higher average age and be less modernized than the fleet that would result from the FY1996-FY2001 plan.[81] But the overall goal of 346-ships could be maintained, as could most or all major component goals within that total for various major categories of ships.[82]

As the Administration has acknowledged, however, the rate of shipbuilding in the FY1996-FY2001 shipbuilding plan is well below the rate that would be required to maintain a 346-ship fleet in the long run, and is adding to a downstream "bow wave" of deferred procurement requirements that Congress and DOD will face after the turn of the century. Maintaining a Navy of a given size over the longer run requires an average ship procurement rate equal to the planned fleet size divided by average service life. Assuming a fleet-wide average service life of about 35 years,[83] maintaining a 346-ship Navy would require an average procurement rate of about 10 ships per year for a period of 35 years.[84]

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[81] For example, the Navy's goal of achieving a surface combatant force that included about 80 higher-capability surface combatants by about 2005 would be delayed, as would the goal of achieving an attack submarine force that included 10 to 12 SSNs with Seawolf-level stealth by the year 2012. For a discussion of these goals, see *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress*, op. cit., p. 4-5, 12-13, 35, 45-46, and 54-57; and Statement of Ronald O'Rourke, Specialist in National Defense, Congressional Research Service, Before the Senate Armed Services Committee Subcommittee on Seapower Hearing on Submarine Acquisition Issues, May 16, 1995, p. 1-2 and 4.

[82] The 346-ship plan calls for an attack submarine force of 45 to 55 boats; an aircraft carrier force of 11 fully active ships and 1 training/reserve carrier; a surface combatant force of 120 to 126 major surface combatants (including 10 in the Naval Reserve Force), and an amphibious force capable of lifting the assault echelons of 2.5 Marine Expeditionary Brigades (MEBs).

[83] This is a frequently used figure for fleet-wide average service life. A 346-ship fleet composed of 14 SSBNs (as called for in the Administration's Nuclear Posture Review), 55 SSNs, 12 aircraft carriers, 126 surface combatants, 36 amphibious ships, and 103 other ships (mostly auxiliaries, plus patrol and mine warfare ships), in which service lives were 30 to 40 years for SSBNs, 30 years for SSNs, 50 years for aircraft carriers, 30 to 35 years for surface combatants, 35 to 40 years for amphibious ships, and 35 to 45 years for other ships would have a fleet-wide average service life of 32.7 to 38.4 years, or about 35 years on average.

[84] Though frequently used, a fleet-wide average service life of 35-years may be somewhat on the high side: Although the Navy is studying the idea of extending the service lives of its SSBNs to 40 years, they are currently certified only for 30 years. And although surface combatants are certified for 30 or 35 years, in practice, many surface combatants have been retired in their twenties due to obsolescence of their combat systems. (For a discussion of ship service lives, see *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress*, op. cit., p. 13-15.) If the fleet-wide average service life turns out to be closer to 30 years, then maintaining a 346-ship fleet would require a long-term (i.e., 30-year) average procurement rate of about 11.5 ships per year.

This figure excludes sealift ships, which are not included in the 346-ship total.[85]

As shown in Table 4 above, including two SCN-funded ships less than 400 feet in length, the FY1996-FY2001 plan would procure a total of 31 SCN-funded ships over six years, or an average of about 5.2 SCN-funded ships per year. The difference between this rate and the required long-term average rate of about 10 SCN-funded ships per year is about 5 ships per year, or about 30 ships over the 6 years of the FY1996-FY2001 FYDP. Deferring the procurement of these 30 ships beyond FY2001 would increase the required long-term average procurement rate for the 29 remaining years in the 35-year period by about 1 ship per year. Stated differently, the FY1996-FY2001 shipbuilding plan would add about 30 ships to the post-FY2001 "bow wave" of required ship procurement.

Another way to examine the issue would be to project the size of the Navy that would result if the shipbuilding rate in the FY1996-FY2001 FYDP were maintained over the long run. Again assuming a fleet-wide average service life of 35 years, an average procurement rate of 5.2 ships per year would in the long run result in a Navy of about 182 ships -- about 53 percent of the 346-ship goal.[86] As discussed earlier, the Administration is aware that the relatively low ship procurement rate in its FY1996-FY2001 FYDP is far from sufficient to maintain a 346-ship Navy in the long run, and that funding needs to be added to the SCN account in future years so that the ship procurement rate can be increased to a higher level.

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[85] The 346-ship total refers to the number of battle force ships in the Navy. Battle force ships are ships that can deploy overseas and contribute to the combat capability of the Navy either directly (in the case of combat ships) or indirectly (in the case of ships that rearm, resupply, or repair combat ships). Sealift ships are intended primarily to transport equipment and supplies for the Army and Air Force and thus are not counted in the total number of battle force ships. For a summary presentation of the kinds of ships that are included in the total number of battle force ships, and how sealift ships are listed separately from battle force ships, see *Highlights of the Department of the Navy FY 1996/FY 1997 Biennial Budget*, op. cit., p. 2-3. For discussions of the method used for counting the Navy's ships, see U.S. Congress. Senate. Committee on Armed Services. *[Hearings on] Department of Defense Authorization for Appropriations for Fiscal Year 1991*, 101st Cong., 2nd Sess., Part 4. Washington, U.S. Govt. Print. Off., 1991. p. 179-182; U.S. Congress. House. Committee on Appropriations. Subcommittee on the Department of Defense. *[Hearings on] Department of Defense Appropriations for [Fiscal Year] 1984*, 98th Cong., 1st Sess., Part 1. Washington, U.S. Govt. Print. Off., 1983. p. 573-574; U.S. Congress. House. Committee on Appropriations. Subcommittee on the Department of Defense. *[Hearings on] Department of Defense Appropriations for [Fiscal Year] 1983*, 97th Cong., 2nd Sess., Part 2. Washington, U.S. Govt. Print. Off., 1982. p. 178-181; U.S. Congress. Senate. Committee on Armed Services. *[Hearings on] Department of Defense Authorization for Appropriations for Fiscal Year 1983*, 97th Cong., 2nd Sess., Part 6. Washington, U.S. Govt. Print. Off., 1982. p. 3692-3693; U.S. Congress. Senate. Committee on Armed Services. *[Hearings on] Department of Defense Authorization for Appropriations for Fiscal Year 1983*, 97th Cong., 2nd Sess., Part 2. Washington, U.S. Govt. Print. Off., 1982. p. 1140-1142, 1162-1164.

[86] The procurement rate times the service life equals the long-term force size. 5.2 ships per year times 35 years equals 182 ships. If the fleet-wide average service life turns out to be closer to 30 years, then the result in the long run would be a Navy of 156 ships (5.2 times 30 equals 156).

Adequate to Keep All 6 Yards in Business?

Keeping all 6 of the yards discussed in this report in business may or may not be an appropriate policy goal; this policy issue is addressed later in this chapter in the section on how many major shipbuilders the Navy needs. Independent of this policy issue, however, policymakers may simply have an informational interest in understanding the effect of the FY1996-FY2001 shipbuilding plan on the continued health of the 6 yards discussed in this report.

Based on information supplied by shipyard officials and the Navy,[87] it appears that the FY1996-FY2001 shipbuilding plan will be adequate to keep all 6 shipyards in business through the turn of the century. As noted earlier, the Administration's recent decisions regarding nuclear warship programs, the DDG-51 program, and the sealift ship program had the effect of distributing the limited amount of shipbuilding work available for the next several years in a way that reduced the likelihood that any of the 6 yards will be forced into bankruptcy and closure.

As a group, however, the yards won't prosper during the next several years. Total employment at the 6 yards will continue to decline, and overall profits will be limited by the relatively small amount of work on order. The planned FY1996-FY2001 shipbuilding rate appears to be at or near the minimum needed to keep all 6 yards in the shipbuilding business for the next few years.

- To remain viable as a full capability submarine construction yard for the next several years, EB needed SSN-23 (or a roughly equivalent amount of submarine construction work) in FY1996, and will need another submarine around FY1998.[88]

- Even with recent contracts for construction of commercial tankers, the total workload and employment level at NNS is likely to remain considerably below levels of previous years.

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87 In reviewing this section, it should be remembered that sources might sometimes perceive an interest in shading the information that they provide to researchers regarding their current or potential future financial health, particularly if that information is to be used in a public report. A firm, for example, might describe its own financial condition in an optimistic or best-case manner, so as to strengthen investor or policymaker confidence in the firm, while describing the financial condition of its competitors in a pessimistic or worst-case manner, so as to weaken investor or policymaker confidence in them. Conversely, a firm that derives a significant share of its business from the government, and which is important to policymakers because of what it makes for government or because of the number of people it employs, might describe its own financial condition in a pessimistic or worst-case manner, so as to encourage policymakers to take steps, such as increasing or accelerating procurement of items made by the firm, that would increase the firm's business base and profitability.

88 See Statement of Ronald O'Rourke, Specialist in National Defense, Congressional Research Service, Before the Senate Armed Services Committee Subcommittee on Seapower Hearing on Submarine Acquisition Issues, May 16, 1995, p. 14-15, 17-18.

- The planned DDG-51 procurement rate of 2.8 ships per year appears close to the minimum needed to sustain both BIW and ISI as DDG-51 builders, after taking into account other forms of work currently at the 2 yards.[89] Congress' decision to fund LHD-7 in FY1996 will help bolster work levels at ISI over the next few years.[90] Even so, as discussed earlier, employment at ISI is projected to drop considerably below levels of previous years.

- ASD and NASSCO need the remaining options in their sealift shipbuilding contracts to be exercised to maintain work levels through the end of the FYDP.

Prospects for continuation of all 6 yards after the FY1996-FY2001 FYDP are less clear, because both the volume and distribution of major Navy shipbuilding work after FY2001 are difficult to predict. If the total amount of work does not increase substantially from current levels, then how the work is distributed could become critical in determining whether one or more of the 6 yards falls out of the ranks of the Navy's major shipbuilders. The distribution of work after FY2001 will be affected by decisions on which yard or yards will build LPD-17s (first ship procured FY1996), attack submarines (first ship to be procured FY1998), arsenal ships (first ship to be procured possibly in FY1998), ADC(X)s (first ship to be procured FY2000), and SC-21s (first ship to be procured about FY2003).

A 1994 Defense Department report on the current and future adequacy of the shipbuilding industrial base that took into account the FY1994-FY1999 shipbuilding plan (rather than the amended FY1996-FY2001 shipbuilding plan shown in Table 4, which reflects congressional action in FY1996) concluded the following regarding the U.S. shipbuilding industrial base as a whole:

> The current Navy shipbuilding plan (reflecting the downsized force structure of the future) will not sustain the U.S. shipbuilding industry at present levels. Absent new commercial orders, employment in the private sector industrial base supporting ship construction is expected to decline from over 120,000 in 1980 to less than 60,000 in 1999.
>
> In the near future, some of the remaining major shipyards could be forced into financial restructuring and/or closure. They may experience cash flow crises, reduced profitability, and increased overhead rates due to reduced business levels ....

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[89] See *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress*, op. cit., p. 59-62.

[90] Ingalls Gets Contract For Seventh Assault Ship. *Associated Press* wire story, Dec. 28, 1995.

> The U.S. shipbuilding industry is, and will continue to be, adequate to meet military requirements (including sealift) during the period 1994 through 1999.
>
> The U.S. shipbuilding industrial base is a product of the buildup of Navy force structure in the 1980's coupled with the virtual loss of commercial shipbuilding orders during that same period. Shipbuilding sector "downsizing" will continue over the next several years due to declining Navy requirements and the continued absence of commercial contracts.
>
> For the longer term, the ability of the U.S. shipbuilding industry to meet military requirements is more problematic. Forecasted Navy requirements (again including sealift) are insufficient to sustain the shipbuilding base as it exists today. A healthy, responsive, cost-effective domestic shipbuilding industry requires commercial, not just Navy, workload.[91]

With regard to the future viability of the country's "major shipyards" (a term which the report used to refer not just to the 6 yards discussed in this report, but at least 6 other yards then involved mostly in building smaller ships for the Navy), the report stated that

> the shipbuilding industry will decline as the industry reduces the orderbook created during the Navy's [1980s] expansion program. Employment levels could decline as much as 40 percent by the year 2000 if commercial shipbuilding is not revitalized to offset reductions in Navy work. Employment levels required to support projected Navy shipbuilding programs, including sealift requirements, are expected to drop to a low of approximately 45,000 shipyard employees in the year 1998 and then should return to approximately 70,000 employees by the year 2007, based on current productivity levels and anticipated force level requirements.
>
> Forecasts of the financial viability of the major shipyards, as performed by the Navy, are based on the current financial situation at each of the shipyards as well as the Navy Fiscal Year 1994-1999 shipbuilding plan. These forecasts take into account such factors as annual "fixed" cost payments (e.g., interest and principal payments on debt), estimated profitability on existing and future contracts, and the overhead structure at each of the shipyards. Based on this analysis of the shipbuilding industry's viability, the following evaluations are provided:
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> *Near-term (1 - 3 years).* Over the next three years, one or more of the major shipyards could be forced into financial restructuring.

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[91] U.S. Department of Defense. Undersecretary of Defense (Acquisition & Technology). *Adequacy of the Shipbuilding Industrial Base.* Washington, 1994. (March 1994) p. i, ii.

Shipyards could experience cash flow crises, reduced profitability and increased overhead rates due to reduced business. For shipyards to remain viable, they will need some combination of the following events to occur: access to additional financing, development of profitable new business, and/or reduction in existing overhead structures.

Mid-term 3 - 5 years. The likelihood of two or more major shipyards facing restructuring is greatly increased over the mid-term. As the shipyards weak in financial condition seek to remedy their current woes with new business, some shipyards may bid too aggressively. Given the industry's already weakened state, such aggressive bids could drive these shipyards into some type of restructuring. Furthermore, to the extent that the financially weaker shipyards are given work at the expense of the more financially sound shipyards via aggressive bids, the health of the stronger shipyards could also be diminished. This condition may be corrected through evaluation of the quality and executability of future offers presented to the Department.

Long-term (Over 5 years). Over the long-term, several shipyards may be on the verge of failing. The surviving shipyards should be well adjusted to a reduced Navy business base and will have effectively reduced their fixed costs (for example, depreciation and maintenance) associated with these assets and thereby have reduced their overhead levels. However, the adjustment process will involve reducing levels of property, plant, and equipment in order to bring them in line with lower revenue levels precipitated by reduced SCN funding. The alternative is for these shipyards to substantially re-engineer their entire operation and business practices towards the best commercial practices. This should lead to a condition where not only are their overhead levels reduced, but also the design and ship production processes and facilities are brought into line with world class shipbuilders and related manufacturers.[92]

Adequate to Maintain Efficient Production Rates?

During the 1970s and 1980s, the Navy procured an average of about 14.2 new major ships per year, or more than 1.5 new major ships each year for each of the roughly 9 shipyards that on average were engaged in the construction of major Navy ships during this period.[93] In contrast, the planned rate of ship

[92] Ibid, p. 13-14.

[93] This calculation *excludes* surface ships less than 400 feet in length and is based on data on numbers of ships and shipyards from Polmar, Norman. *Ships and Aircraft of the U.S. Fleet.* Annapolis, MD, Naval Institute Press, 1993. (15th edition) p. 614-615 (for SCN-funded ships from FY1970 through FY1992); *Highlights of Department of the Navy FY1996/FY1997 Biennial Budget,* op. cit., and previous editions (for SCN-funded ships from FY1993-FY1995); and supplementary data provided by the Navy (for new-construction sealift ships from FY1970 onward).

procurement during the FY1996-FY2001 FYDP -- about 6.2 new major ships per year[94] -- equates to an average of about 1 new major ships per year for each of the 6 shipyards currently engaged in the construction of major Navy ships. This reduction in the number of new major Navy ships per year per yard raises the question of whether the FY1996-FY2001 shipbuilding plan is adequate to maintain efficient production rates at the 6 shipyards.

It appears that the FY1996-FY2001 shipbuilding plan will result in shipyard production rates that are in some respects less efficient than the higher shipyard production rates of earlier years. Changes in cost in recent shipbuilding programs, particularly submarines and surface combatants (see Appendix D), suggest that shipyards are experiencing reduced spreading of fixed costs (see Appendix B) and less economic learning effects (see Appendix C), resulting in increased ship costs. Reductions in production efficiency are apparently also occurring at supplier firms, resulting in additional increases in ship costs. These increases in shipyard and supplier costs are reflected in higher Navy funding requests to Congress for ship procurement and higher negotiated shipbuilding contract prices between the Navy and the shipyard.[95]

Efficiency, however, is a relative rather than absolute term when applied to manufacturing production rates. Workloads and plant capacities can combine to create production rates of varying levels of efficiency, and observers can come to varying personal judgments as to whether a particular degree of production efficiency is acceptable.

Near-term shipbuilding cost increases, moreover, can be weighed against the potential longer-term benefits of maintaining shipbuilding capacity that may be needed to accommodate a future increased shipbuilding rate, as well as the

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[94] This figure excludes the 2 surface ships less than 400 feet in length to be procured in FY1999 under the Administration's amended FY1996-FY2001 FYDP (see Table 4).

[95] When the Administration is preparing to request funding for the procurement of a new ship, the Navy's cost analysts estimate the cost to build that ship using data on the cost to build previous ships of that type (or a similar type) and their judgment of how that data should be adjusted to account for, among other things, likely changes in spreading of fixed costs and learning effects at shipyards and suppliers. The analysts' estimated cost helps determine the amount of funding that the Administration requests in the Shipbuilding and Conversion, Navy (SCN) appropriation account to procure the ship. Congress, if it decides to approve the procurement of the ship, can adopt the Administration's requested funding figure or adjust it upward or downward. Congress' decision on this issue determines the amount of funding the Navy has available as it seeks bids to build the ship from competing shipyards and negotiates with the selected shipyard on the contract to build the ship. The Navy uses various contract types in shipbuilding, but typically uses fixed-price incentive (FPI) contracts that have a target price (which is the sum of a target cost and a target profit), a government/shipyard share ratio (also called a share line) for sharing differences between target and final cost (typically a 50/50 ratio), and a ceiling price, which is the highest amount that the government is required to pay under the contract, regardless of the share ratio.

potential long-term benefits of maintaining competition among shipyards in the future if the shipbuilding rate is increased.[96]

HOW MANY MAJOR NAVY SHIPBUILDERS ARE NEEDED?

Recent Perspectives

The issue of how many major shipbuilders are needed to meet the Navy's needs dates to at least February 1992, when a panel on the structure of the U.S. defense industrial base of the then-House Armed Services Committee (now the House National Security Committee) held a hearing on the U.S. shipbuilding and repair industry. At this hearing, John J. Stocker, President of the Shipbuilders Council of America, which then represented the 6 shipyards discussed in this report along with other U.S. shipyards,[97] testified on the implications for the U.S. shipbuilding industry of the Bush Administration's Navy shipbuilding plan, which was designed to support a planned fleet of more than 400 ships:

> The six year [FY1992-FY1997] Navy Shipbuilding Plan submitted with the President's Fiscal Year 1992 budget planned for the construction of [an average of] 9.7 ships per year. The FY 1993 budget requests six ships and we understand that in Fiscal Year 1994 there will be only five ships. In July of 1990 the Navy presented a briefing to the Congress [in] which [the Navy] expressed its belief that a ten ship per year Navy construction program would sustain only two or three large shipyards and two or three smaller yards. The Navy surmised that the construction of thirty commercial ships a year would be required to sustain the industry at its 1990 level of employment.
>
> The Shipbuilders Council believes that a five to six [ships] a year Navy construction program will sustain only one or two major shipyards and one or two smaller yards.[98]

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[96] Weighing near-term cost increases against longer-term cost benefits generated by future competition can involve use of net present value (NPV) analysis using constant dollars that are discounted using an appropriate discount rate. For a brief discussion of discount rates and an example of their application in a shipbuilding NPV cost comparison, see Statement of Ronald O'Rourke, Specialist in National Defense, Congressional Research Service, before the Senate Armed Services Committee Subcommittee on Seapower Hearing on Submarine Acquisition Issues, May 16, 1995, p. 33-34.

[97] See the background section for a discussion of the subsequent decision by the 6 shipyards to leave the Shipbuilders Council of America and form their own association, the American Shipbuilding Association.

[98] U.S. Congress. House. Committee on Armed Services. *[Hearings on] Defense Industrial Base.* Hearings Before the Structure of U.S. Defense Industrial Base Panel, 102nd Congress, H.A.S.C. No. 102-54. Washington, U.S. Govt. Print. Off., 1992. p. 511.

Later at this hearing, W. R. Phillips, Jr., then President and Chief Executive Officer of NNS, testified:

> Mr. Chairman,[99] you have asked for suggestions for avoiding an unacceptable reduction of the naval industrial base. There are three major actions that we think should be taken: 1. Increase commercial shipbuilding in the United States .... 2. Approve the President's shipbuilding budget .... 3. Finally, Mr. Chairman, the country does have an alternative. A rationalization of the shipbuilding industrial base *now* would enable the country to extend our ability to reconstitute this base. As [House Armed Services Committee] Chairman [Les] Aspin said last Wednesday: "We've got to plan now so that the industrial base we have left will provide us the defense we need for the future." Considering the reductions in the shipbuilding budget, and the size of the Navy fleet in the future, this country will face considerable excess capacity in both ship repair and construction. In my opinion, Mr. Chairman, this situation must be rationalized now to maintain the most capable and efficient operations. Regrettably, this will reduce the number of shipyards, but those remaining should be more robust. Uniquely, this involves both private and public facilities.[100]

The issue was raised again at an April 1994 hearing on Navy recapitalization (i.e., procurement) issues before the Military Acquisition Subcommittee of the then-House Armed Services Committee. At this hearing, Representative John Spratt asked the witnesses about the future of the 6 shipyards discussed in this report in light of the Navy's reduced shipbuilding program:

> There is also an industrial base structure question raised by your testimony. As I quickly understand what you are talking about, you are proposing about three DDGs a year, about a carrier every 4 years, about a submarine or a submarine and a half every year, which is a pretty lean procurement schedule for the foreseeable future that you have laid out here .... What happens to the six major shipyards that we have, who have been fairly busily engaged for the last dozen years? That is somewhere below the surface of this particular briefing, but certainly it is an implication that has to be considered.

Admiral William Owens, then the Vice Chairman of the Joint Chiefs of Staff, responded:

> I think that is an excellent issue for us. As we made the decision to recapitalize, we were also looking at what happened with our facilities.

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99 Representative Dave McCurdy, chairman of the panel.

100 *[Hearings on] Defense Industrial Base*, op. cit., p. 573-574. See also p. 563. Emphasis as in the original.

> It would have been very easy in this 5-year period to say we have got some relatively young ships. If you take the oldest 150 of those 590 ships we had in the end of the 1980's, you could still keep about 450 ships alive and they would last for a long time. We can keep them for 10 years and not build any ships, essentially.
>
> So the industrial base in that situation would have been allowed to dry up. Frankly, sir, there are many who would argue that that is the right thing to do, that at the time when we are faced with world danger, that we maintain [existing force] structure [i.e., existing ships] and that we not put money into building new ships .... We decided that if we could put at least a reasonable amount of money into the recapitalization scheme for aircraft, for ships of a variety of sorts and for the submarine industrial base, that we would be able to best support the industrial base, so that when it came time at the end of the century to increase a little bit, that that industrial base would be there ....
>
> Our approach here was to try to generate enough money to recapitalize, and that means to keep industrial facilities alive, as well, albeit it at a smaller level.

Representative Spratt responded: "That was the point I was trying to extract. Realistically, there is going to be a shakeout among [the] six major shipyards, is there not?" Admiral Owens apparently misinterpreted this as a question about the public-sector naval shipyards and responded with a discussion about the then-approaching 1995 round of the Base Realignment and Closure (BRAC) process. Representative Spratt then restated the question, asking: "Does the Navy have an industrial base strategy as a complement to its recapitalization strategy? For example, are you considering picking [which of the] two shipyards that would be the DDG yard, or combining the carrier and the SSN yard?" Admiral Owens responded:

> We do not have a specific list of places that we like and do not like, sir. We are very much into the business of trying to develop a total capacity requirement and, of course, we have to compete ships, new ships with private yards, and so we would very much, at least at our level, we would very much like to stay away from the designation of which particular places we like.
>
> But our approach is to say what we need for the long term and how many ships we need to build per year, given the world conditions and budget levels we have, and then have our political system deal with the issues through the established procedures, BRAC and the established procedures of competition and the established procedures of testifying and getting authorizations.

Vice Admiral T. Joseph Lopez, who had succeeded Admiral Owens as the Deputy Chief of Naval Operations for Resources, Warfare Requirements, and Assessments, then added:

> We certainly would feel most comfortable with a viable industrial base. We worry about those sorts of things. But, as Admiral Owens says, our first and foremost worry is: can we meet the requirements today and still build the Navy of the future, so that we can also meet the requirements of the future[?]
>
> We will be successful in recapitalization by building three DDG-51s a year, CVN-76, the new attack submarine and the SSN-23, and also the Navy is, of course, in the business of building 19 sealift ships to carry our army, should they be needed in the future. So I think that will support a reasonable industrial base. How many shipyards, I really do not know, to tell you the truth. We will have to see how that falls out. But our plan will keep our Navy strong and we believe it will also support a viable industrial base.[101]

A 1995 report from the now-disestablished congressional Office of Technology Assessment, based in part on workshops held in 1993, stated:

> The size of the Navy fleet is currently projected to fall from over 500 [ships] in 1993, to between 300 and 400 ships under *DOD's Bottom-Up Review* ....
>
> Given reasonable assumptions about service life, new Navy construction for a force of this size might range from 10 to 13 ships per year. This new construction might be supplemented with the overhaul and repair of 44 to 67 vessels, but overhaul and repair work is also decreasing as the Navy moves away from its past practice of allowing 35 percent of a ship's service life to be spent out of commission in major repair and overhaul, and toward the commercial industry's figure of about 5 percent.
>
> Participants in OTA's shipbuilding workshops concluded that three building yards might be the minimum necessary to meet anticipated Navy shipbuilding needs for a force of this size. Participants argued, however, that five to six yards were preferred. Building yards and overhaul and repair docks are important not only to provide normal peacetime support but also to handle unforeseen peacetime accidents or combat damage that might disable a vessel. A

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[101] U.S. Congress. House. Committee on Armed Services. *Hearings on National Defense Authorization Act for Fiscal Year 1995 -- S. 2182 (H.R. 4301) and Oversight of Previously Authorized Programs*, 103rd Cong., 2nd Sess., Military Acquisition Subcommittee Hearings on Title I -- Procurement, H.A.S.C. No. 103-33. Washington, U.S. Govt. Print. Off., 1994. p. 208, 209-210. (The cover of this volume of hearings mistakenly says that it includes hearings held in 1993 rather than 1994.)

> future shipbuilding defense base might include the following types and numbers of building yards: one carrier yard, one submarine yard, two surface combatant yards, [and] two auxiliary yards. Some of these yards could, of course, build more than one type of ship.[102]

At a May 1995 hearing on submarine acquisition issues before the Seapower subcommittee of the Senate Armed Services Committee, W. P. ("Bill") Fricks, the current President of NNS, testified:

> The excess capacity presently existing in the United States shipbuilding industry and the resultant higher costs per ship mandate that the industrial base must be rationalized. We have entered a new era; the industrial base must change with it or the Country will not be able to afford the ships it needs. I believe if the Navy continues with the outdated strategy of parcelling out work to maintain all the shipyards, the costs will be staggering.[103]

A February 1996 magazine article on the FY1996 Navy shipbuilding budget quoted a shipyard official on the issue:

> "In many ways, the Navy's shipbuilding industrial base is also its political base, and that political support is critical to the Navy in its competition with the Air Force and Army," a senior shipbuilding executive said. "In the Navy's view, it would be much better to have six yards employing 10,000 workers each, rather than two yards employing 30,000 apiece."[104]

An additional perspective on the issue was presented in a trade press article that also appeared in February 1996:

> "The general sense is the Navy is going to be about 340-odd ships," Tom Bowler, President of the Arlington, Va.-based American Shipbuilding Association, said Feb. 9. "If that is the case you are going

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[102] U.S. Congress. Office of Technology Assessment. *Assessing the Potential for Civil-Military Integration: Selected Case Studies.* Washington, U.S. Govt. Print. Off., 1995. (September 1995, OTA-BP-ISS-158) p. 58-59. The workshops were held in June and August 1993 and included mostly Navy, DOD, and industry officials. The clause "one carrier yard ... two auxiliary yards" appeared in the original as a list of four separate items, each preceded by a "bullet" and lacking punctuation afterward. It is retyped here as a continuous clause, with commas and a final period inserted, for ease of reading as an excerpt.

[103] Statement of W. P. ("Bill") Fricks, President, Newport News Shipbuilding, Before the Seapower Subcommittee of the Senate Armed Services Committee on May 16, 1995, p. 2.

[104] Kitfield, James. *Ships Galore!* National Journal, Feb. 10, 1996: 300.

to build 10 to 12 ships a year and six yards is not a bad number for that."[105]

Factors to Consider

In assessing how many major shipbuilders the Navy will need in the future, Congress may consider several factors, including the total amount of capacity the Navy will need for shipbuilding and overhaul and repair, shipbuilding economies and diseconomies of scale, competition, shipyard modernization, shipyard disruption, and shipyard reconstitution. Each of these is discussed below.

Capacity

The Navy requires shipyard capacity for both building new Navy ships and overhauling and repairing existing Navy ships. As discussed in the background section, since the 1970s private-sector shipyards have built all of the Navy's new ships and have performed 30 percent to 40 percent of the Navy's overhaul and repair work. (The remaining 60 percent to 70 percent of the overhaul and repair work is performed in the public-sector naval shipyards.) Since construction of new Navy ships currently accounts for about 90 percent of the total dollar value of the work done at the 6 yards discussed in this report, the discussion below begins by focusing on the number of major Navy shipbuilders needed to provide sufficient capacity to build new Navy ships. It then briefly factors in the question of Navy overhaul and repair work.

The future Navy shipbuilding rate may be influenced by several factors, including the international security environment; the size of the defense budget; technological developments and their effects on warship requirements, capabilities, and costs; and the priority given to shipbuilding as opposed to other defense funding priorities. The table below shows the potential number of shipyards needed for the future Navy shipbuilding rate, given various potential future Navy shipbuilding rates and various potential average rates of ship construction at the shipyards.

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[105] Finnegan, Philip, and Robert Holzer. U.S. Shipbuilders Team Up in Tough Times. *Defense News*, Feb. 12-18, 1996: 3, 37.

TABLE 8. NAVY SHIP CONSTRUCTION: POTENTIAL RATES AND NUMBER OF YARDS REQUIRED

Shipbuilding plan or objective[a]	Rate (ships per year)	Number of yards required, given number of Navy ships per year per yard (s/y/y)				
		1 s/y/y	1.5 s/y/y	2 s/y/y	3 s/y/y	4 s/y/y
FYDP FY96-FY01	6.5[b]	6.5	4.3	3.3	2.2	1.6
CBO FY00-FY10	7.5[c]	7.5	5.0	3.8	2.5	1.9
346-ship steady-state replace	10[d]	10	6.7	5.0	3.3	2.5
29-yr bow wave	11[d]	11	7.3	5.5	3.7	2.8
10-yr bow wave/buildup	13[d]	13	8.7	6.5	4.3	3.3
6-yr bow wave/buildup	15[d]	15	10.0	7.5	5.0	3.8

[a] FY1996-FY2001 plan includes construction of 8 LMSR sealift ships; other lines include construction of no sealift ships.

[b] 6-year plan with a total of 39 ships, including 2 smaller ships less than 400 feet in length (see Table 4) that could be built by shipyards other than the 6 yards discussed in this report.

[c] 11-year plan with a total of 83 ships, including 2 smaller ships less than 400 feet in length (not the same as the two ships in the FY1996-FY2001 FYDP shipbuilding plan) that could be built by shipyards other than the 6 yards discussed in this report.

[d] Approximate rate; includes a small fraction (less than 10 percent) of smaller ships less than 400 feet in length that could be built by shipyards other than the 6 yards discussed in this report.

The first line in the table shows a future shipbuilding rate equal to the currently planned FY1996-FY2001 rate of 6.5 ships of all kinds per year.[106] The second line shows a November 1994 CBO projection of the shipbuilding rate required for the 11-year period FY2000-FY2010 to maintain a 330-ship fleet -- about 7.5 ships per year.[107] The third line shows the average shipbuilding rate required to maintain the planned 346-ship fleet over the long run, assuming a 35-year fleet wide average service life for Navy ships -- about 10 ships per year.

As discussed earlier in the section on the adequacy of the FY1996-FY2001 shipbuilding plan, the FY1996-FY2001 shipbuilding plan in effect defers the procurement of about 30 Navy ships to the "bow wave" period that starts beyond

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[106] See Table 4 in the background section for a detailed breakdown.

[107] U.S. Congress. Congressional Budget Office. *The Costs of the Administration's Plan for the Navy Through the Year 2010.* Washington, 1994. (CBO Memorandum, November 1994) p. 4-5. Although the 1993 BUR calls for maintaining a 346-ship Navy, the Navy was planning on maintaining a 330-ship Navy at the time this report was prepared.

the 6-year period of the FYDP. The fourth line adjusts upward the 10-ships-per-year steady-state replacement rate by procuring these 30 or so deferred ships over the remaining 29 years of the 35-year procurement period. This results in an increase of about 1 ship per year in the required rate, to 11 ships per year.

The fifth line shows the effects of procuring these 30 or so deferred ships more quickly -- over a ten-year period. This results in a 3-ships-per-year increase over the steady-state replacement rate for the period FY2002-FY2011, to 13 ships per year. The final line on the table further accelerates the procurement of these 30 ships by procuring them over the subsequent 6-year period. This results in a 5-ships-per-year increase over the steady-state replacement rate for the period FY2002-FY2007, to 15 ships per year. The 13- and 15-ships-per-year rates can also be viewed as rates that might result from a decision to rapidly increase the size of the Navy in response to the emergence of a major foreign threat to U.S. interests.

Of the columns showing the average number of Navy ships built per yard each year, the first -- 1 Navy ship per yard per year (s/y/y) -- is the approximate per-yard Navy shipbuilding rate that will result from the FY1996-FY2001 shipbuilding plan. The second column -- 1.5 Navy s/y/y -- is about equal to the per-yard rate of major Navy shipbuilding in the 1970s and early 1980s, when there was also a fairly significant amount of commercial shipbuilding work. The third column -- 2 Navy s/y/y -- is about equal to the per-yard rate of major Navy shipbuilding in the late 1980s, when there was relatively little commercial shipbuilding work.

The fourth column -- 3 Navy s/y/y -- would be a higher per-yard rate of major Navy shipbuilding than has been experienced in recent years. It would appear to be within the capacities of the 6 yards discussed in this report, as presented earlier in Table 2, but would leave relatively little additional capacity available for other forms of work, including overhaul and repair of Navy ships. The fifth column -- 4 Navy s/y/y -- would be twice as high as the per-yard rate experienced during the late 1980s. It would appear to be just within the capacities of most of the 6 yards discussed in this report, but could strain the capacities of some of the yards and leave little or no additional capacity available for other forms of work.

As can be seen in the table, depending on the combination of the total and the per-yard rates of shipbuilding, anywhere from about 2 major Navy shipbuilders to more than 6 major Navy shipbuilders might be required to have sufficient capacity solely for future Navy shipbuilding.

- If the total Navy shipbuilding rate in the future is at or below the CBO-projected rate of 7.5 ships per year, and if the per-yard rate is at least 1.5 s/y/y, then 2 to 5 major Navy shipbuilders would be needed.

- If the total Navy shipbuilding rate in the future is above the steady-state replacement rate of 10 ships per year, and if the per-yard rate goes no higher than 2 s/y/y, then 6 or more major Navy shipbuilders would be needed.

- If the total Navy shipbuilding rate is about equal to the steady-state replacement rate of 10 ships per year and the per-yard rate is 1.5 to 2 s/y/y, then 5 to 7 major Navy shipbuilders would be needed.

Beyond the capacity required for building new major Navy ships, additional shipyard capacity is required to overhaul and repair Navy ships. This work can be done in either the 6 yards discussed in this report, other private-sector U.S. shipyards, or the public-sector naval shipyards.

In arriving at an overall assessment of how many major Navy shipbuilders will be needed (in conjunction with other private-sector yards and the public-sector naval shipyards) to provide a total shipyard capacity adequate for all of the Navy's needs (i.e., not just for shipbuilding, but for overhaul and repair work as well), the most important variables to consider appear to be the future Navy shipbuilding rate, the future commercial shipbuilding rate, and the future amount of Navy ship overhaul and repair work performed by the 6 yards. These are the forms of work that are most frequently mentioned by Navy officials, industry officials, and elected officials in discussions about the future of the 6 yards, primarily because they have the potential to generate large and continuing workloads for the yards.

Other forms of work -- such as construction of warships for export to foreign countries, overhaul and repair of commercial ships, and construction, overhaul and repair of barges and other marine structures such as oil platforms -- are also mentioned sometimes. But the potential workloads that can be generated by these other forms of work, particularly over a sustained period of time, appear to be less significant.

If the future Navy shipbuilding rate, the future commercial shipbuilding rate, and the future amount of Navy ship overhaul and repair work performed by the 6 yards do dominate the calculation, then the following might be concluded: If one or more of these three variables increase from their current values, then all 6 of the yards discussed in this report might be needed (in conjunction with other private-sector yards and the public-sector naval shipyards) to provide sufficient shipyard capacity to meet all of the Navy's needs; if, on the other hand, these three variables remain at their current values, then not all of the 6 yards of the yards discussed in this report (in conjunction with other private-sector yards and the public-sector naval shipyards) might be needed to provide sufficient shipyard capacity to meet all of the Navy's needs.[108]

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[108] Another potential factor to consider is the possibility of building major Navy ships in foreign shipyards. 10 U.S.C. 7309 states that "no vessel to be constructed for any of the armed forces, and no major component of the hull or superstructure of any such vessel, may be constructed in a foreign shipyard." The President may authorize exceptions to this prohibition "when the President determines that it is in the national security interest of the United States

Economies and Diseconomies of Scale

Production costs at shipyards can be affected by traditional manufacturing economies and diseconomies of scale. While various factors contribute to manufacturing economies and diseconomies of scale,[109] discussions with industry officials and analysts and Navy officials suggest that three factors are of particular significance for shipyards -- spreading of fixed costs, learning effects, and labor productivity. As production at a yard increases from relatively low levels to higher levels, spreading of fixed costs and learning effects can contribute to economies of scale. As production at the yard increases to still higher levels, reduced labor productivity can after a certain point contribute to diseconomies of scale. The discussion below briefly examines each of these three factors.

Spreading of fixed costs.[110] A manufacturing facility's fixed costs (also called fixed overhead costs) are those that are relatively insensitive (i.e., do not change very much in response) to changes in the level of production, particularly over the shorter run. A firm's fixed costs are spread over -- that is, charged to and thereby incorporated into the cost of -- the various work projects that make up the total workload underway at the firm.

Although a firm's total fixed costs can be changed in the longer run, the change is often less than fully proportional to the change in workload. As a result, as workload at the yard decreases, fixed costs often decrease more slowly, becoming larger in relation to workload. Economies of scale are thereby reduced and production becomes less efficient, increasing the cost of each ship. As workload increases, fixed costs often increase more slowly, becoming smaller in relation to workload. Economies of scale are thereby increased and production becomes more efficient, reducing the cost of each ship.

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to do so. The President shall transmit notice to Congress of any such determination, and no contract may be made pursuant to the exception authorized until the end of the 30-day period beginning on the date on which the notice of the determination is received by Congress." Very few ships intended for the U.S. Navy or other U.S. armed forces have ever been built in foreign shipyards. Among these are two 393-foot-long Chauvenet (TAGS-29) class ocean surveying ships ordered in FY1965 and FY1966 from a shipyard in the United Kingdom (these were the first ships since World War II built in the United Kingdom for U.S. naval service) and three 283-foot-long Edenton (ATS-1) class salvage and rescue ships ordered in FY1966 and FY1967 from another U.K. shipyard. (Sources: Consultations with the U.S. Navy's Naval Historical Center and the American Shipbuilding Association, July 23, 1996, and *The Ships and Aircraft of the U.S. Fleet,* op. cit., p. 251, 272.) Some auxiliary and sealift ships in service with the Navy and the MSC today were originally built in foreign shipyards for foreign users, and were then later purchased by the U.S. government and converted by U.S. shipyards for use by the U.S. Navy and the MSC.

[109] For a general treatment on the sources of economies and diseconomies of scale at industrial production facilities, see Scherer, F. M. (Frederic M.), and David Ross. *Industrial Market Structure and Economic Performance.* Boston, Houghton Mifflin Company, 1990. (Third Edition) p. 97-106.

[110] For a more detailed discussion of spreading of fixed costs, see Appendix B.

On the basis of estimated shipyard fixed costs (see Appendix B) and cost changes in recent Navy shipbuilding programs (see Appendix D), it appears that changes in spreading of shipyard fixed costs can change the cost of a major Navy ship by millions or tens of millions of dollars. Cost changes of this magnitude can be viewed as significant in absolute terms, particularly when added together across several ships. For ships costing several hundred millions of dollars each, however, such changes might represent a relatively small percentage change in total ship cost.

Learning effects.[111] Shipbuilding, like many traditional manufacturing activities, exhibits the phenomenon of learning through repetition: As workers at a given production facility repeatedly perform the same production-related task or series of tasks, they learn to do it in increasingly less time. Since labor-related costs account for 20 percent to 40 percent of the total cost of major Navy ships, learning effects can have a noticeable effect on the total cost of major Navy ships.

On the basis of typical shipyard learning curves (see Appendix C) and cost changes in recent Navy shipbuilding programs (see Appendix D), it appears that learning effects, like spreading of fixed costs, can change the cost of a major Navy ship by millions or tens of millions of dollars -- a potentially significant change in absolute terms, but a relatively small one in percentage terms for a ship costing several hundred million dollars.

Labor productivity. Beyond a certain point, increases in workload can lead to shipyard employment levels that are high enough that worker density may become a problem: Workers and their materials may get in each other's way, slowing operations down. (If the yard can build new facilities or increase its size, this effect can be reduced over time.)[112] Perhaps more important, if employment levels or the variety of shipbuilding programs at the yard grows beyond a certain point, the ability of yard management to effectively plan yard operations and guide and supervise workers may be overtaxed, causing efficiency losses. For example, according to a 1991 Defense Department study on the submarine construction industrial base,

> A Navy study of NNS productivity completed in 1989 stated that "one of the key factors affecting all CVN and SSN-688 new construction efforts, has been high levels of manpower necessary to meet the increasing shipyard work load. The high employment levels have resulted in a drop in productivity across all programs at NNS."

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[111] For a more detailed discussion of learning effects, see Appendix C.

[112] Increases in workload can also lead to reduced average productivity in the shorter term due to the lower productivity of newly hired workers who need training and practice in their basic skills. If the workload at the yard stabilizes at the higher level, this effect can be reduced over time if the new workers stay with the yard, become more seasoned in their jobs, and consequently attain productivity levels comparable to workers with more seniority.

> The report concluded that ... "productivity at NNS declines as total shipyard manpower employment exceeds 25,000 to 26,000."[113]

The 6 yards discussed in this report have different maximum efficient employment levels above which worker productivity may begin to decline, reflecting differences between the yards in factors such as size and layout, the type of ships being built, and management and supervision practices. The maximum efficient employment level at a given yard, moreover, can change over time as these factors change, and the figure quoted above for NNS, if accurate in 1989, may not be accurate today.

Summary. For any industrial production facility, including a shipyard,

> At some critical point, the diseconomies of large-scale management overpower the economies of scale, and unit costs begin rising with output, giving the long-run average total cost curve its U-shape familiar to readers of microeconomic theory texts. The downward segment of the U is governed by orthodox scale economies, the upward thrust by managerial diseconomies.[114]

Competition

Among policymakers, it is a widely shared premise that competition in defense acquisition can generate benefits in restraining cost, improving product quality, encouraging adherence to scheduled delivery dates, and promoting innovation.[115] For major Navy shipbuilding, the role of competition can be broken down into two questions:

- How many major Navy shipbuilders are needed for effective competition at the shipyard level?

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[113] Report on Submarine Construction Base, January 1991, Prepared by OASD (Production and Logistics), as reprinted in *Inside the Pentagon*, Nov. 7, 1991: 11. Ellipse as in the reprinted version.

[114] *Industrial Market Structure and Economic Performance*, op. cit., p. 104.

[115] The potential and actual results of competition in defense procurement is a topic of discussion among economists, policy analysts, public officials, and leaders of industry. See, for example, Kovacic, William E., and Dennis E. Smallwood. Competition Policy, Rivalries, and Defense Industry Consolidation. *Journal of Economic Perspectives*, Fall 1994: 91-110; Rogerson, William P. Economic Incentives and the Defense Procurement Process. *Journal of Economic Perspectives*, Fall 1994: 65-90; Anton, James J., and Dennis A. Yao. Measuring the Effectiveness of Competition in Defense Procurement: A Survey of the Empirical Literature. *Journal of Policy Analysis and Management*, Winter 1990: 60-79; Burnett, William B., and William E. Kovacic. Reform of United States Weapons Acquisition Policy: Competition, Teaming Agreements, and Dual Sourcing. *Yale Journal on Regulation*, Summer 1989: 249-317; Pyatt, Everett. Procurement Competition at Work: The Navy's Experience. *Yale Journal on Regulation*, Summer 1989: 319-331; Augustine, Norman R., and Robert F. Trimble. Procurement Competition at Work: The Manufacturer's Experience. *Yale Journal on Regulation*, Summer 1989: 333-347.

- To what degree can competition be applied below the shipyard level to achieve these benefits?

Competition at the shipyard level. From the perspective of the government, competition is effective (or meaningful) if it generates bargaining leverage for the government. For the government to have bargaining leverage in its dealings with shipyards, bidding yards must have some uncertainty as to whom the government will award the contract. For bidding yards to face such uncertainty, it would appear that three conditions must me met:

- ***More than one source.*** There must be two yards capable of building the type of ship in question, or, at a minimum, one yard capable of building that type, plus a second yard that can be made capable of building that type relatively quickly and at acceptable cost. (A shipyard need not fear that the government will award the work to another shipyard if there is no other shipyard that can or easily could build that type of ship.)

- ***Unused capacity.*** The bidding yards must have sufficient unused capacity to carry out the work for which they are bidding. (Shipyard A need not fear that the government will award the work to Shipyard B if Shipyard B lacks sufficient unused capacity to carry out the work.)

- ***Yard survival.*** Either the contract to build the ships must not be critical to the survival of the bidding yards, or the bidders must believe that the government may be willing to let one or more yards go out of the shipbuilding business. (Shipyard A will not fear that the government will award the work to Shipyard B if the work is critical to Shipyard A's survival as a shipbuilder and Shipyard A believes that the government will not permit Shipyard A to go out of the shipbuilding business.)

More than one source. Given the capabilities of the 6 yards discussed in this report (see Table 3), a minimum of 3 shipyards -- EB, NNS, and a third yard -- would be required to have two yards capable of building any type of major Navy ship (except CVNs). EB and NNS would compete on submarines, and NNS and the third yard would compete on surface ships other than CVNs.

The yard currently most capable of acting as the third yard without additional investment would be ISI. ASD would need some investment to resume construction of major surface combatants. BIW would need some investment to enter into production of smaller (LSD- or LPD-type) amphibious ships, and significant investment to enter into production of large-deck amphibious ships (LHDs). NASSCO would need some investment to enter into production of major surface combatants, and significant investment to enter into production of LHDs. If building CVs is acceptable as an alternative to building CVNs, then ISI or possibly ASD might be made capable of competing with NNS on aircraft carriers.

Policy changes could permit different 3-yard solutions, or even 2-yard solutions, to the problem of maintaining 2 sources for most ship types. If sole-sourcing large-deck amphibious ships (LHDs) is acceptable, then NASSCO or BIW could serve as the third yard without a need for major investment. If sole-sourcing submarines is deemed acceptable at some point in the future (Congress in 1995 in effect determined that it would not be, at least for the next few years), then including EB among the 3 yards would not be necessary. If sole-sourcing subs and building CVs rather than CVNs is deemed acceptable, then only one of the two nuclear-capable yards (either EB or NNS) need be included among the 3 yards. If NNS is not included, then either ISI or ASD would have to be included and made capable of building CVs.

Solutions with more than 3 yards would provide more than 2 potential sources for most ship types. Excluding instances where major investment would be needed to make yards capable of building particular ship types, there are 5 actual or potential sources of major surface combatants, smaller amphibious ships, large auxiliaries, and sealift ships, as well as 3 potential sources of large-deck amphibious ships.

Unused capacity. As discussed in the background chapter, there is at present substantial unused capacity among the 6 yards discussed in this report. In the future, the amount of unused capacity would depend on the total amount of military and commercial shipbuilding and repair work available to the yards.

Yard survival. As discussed earlier in the section on the adequacy of the FY1996-FY2001 shipbuilding plan, prospects for continuation of all 6 yards after the FY1996-FY2001 FYDP are not clear, because both the volume and distribution of major Navy shipbuilding work after FY2001 are difficult to predict. If the total amount of work does not increase substantially from current levels, then how the work is distributed could become critical in determining whether one or more of the 6 yards falls out of the ranks of the Navy's major shipbuilders. Yard survival might thus be at stake in future shipbuilding competitions.

At present, however, the yards may have reason to doubt the willingness of the government to allow any of the yards to go out of the shipbuilding business. In particular, the Administration's decisions regarding nuclear warship construction and the DDG-51 program as well as Congress' recent actions to increase the FY1996-FY2001 shipbuilding plan (see background chapter) suggest a strong unwillingness on the part of policymakers in both branches of government to permit any of the 6 yards to go out of the shipbuilding business against its will.

This may be limiting the ability of the government to sustain meaningful competition: If, as discussed earlier in the section on the adequacy of the FY1996-FY2001 shipbuilding plans, the total workload available to the 6 yards is at or near the minimum needed to keep them all in the shipbuilding business, and if the yards do not believe that the government is willing to let any of the yards go out of the shipbuilding business against its will, then the government may have limited options for how the work can be awarded to the yards over the longer run, and the yards consequently will face only limited uncertainty in the longer run about the government's possible award decisions.

To help illustrate the potential competition-limiting effects of having too many shipyards relative to the amount of available shipbuilding work, consider a simplified hypothetical case in which there are 6 yards, with each yard needing an average of 1 ship per year to remain viable as a shipbuilder, a shipbuilding program that provides an average of 6 ships per year, and reasons for the yards to doubt the willingness of the government to allow a yard to go out of the shipbuilding business against its will. In such a case, the yards will be able to anticipate that they will each receive an average of one ship per year over the long run. In any given year, a yard may face the possibility of being awarded no ships. If that occurs, however, the yard will be able to anticipate a future year in which it is awarded more than 1 ship, so that the required average rate of one ship per year is maintained over the long run.

The current situation, in which there are 6 yards and a shipbuilding plan that provides an average of about 6 major Navy ships per year (including sealift ships), is in some respects similar to this simplified hypothetical situation. Due to differences in facility sizes, cost structures, and types of ships being built, some of the 6 yards may need more than 1 ship per year to remain viable as shipbuilders, while others may need less. But since the 6-per-year rate appears to be at or near the minimum needed to keep all 6 yards in the shipbuilding business, the government's options for awarding this work in some cases appear limited. As a consequence, the government's ability to present the yards with uncertainty regarding contract awards and thereby generate bargaining leverage over the yards may also in some cases be limited.

Summary. Taking these three factors into account, it is clearly possible to have either too few or too many major Navy shipbuilders to sustain effective competition. The following can be concluded:

- Beyond the end of the FY1996-FY2001 FYDP, if the number of shipyards building major Navy ships is reduced to as few as 2 or 3, depending on which yards remain as major Navy shipbuilders, maintaining effective competition for certain ship types may be precluded due to lack of second sources; the potential for maintaining effective competition may also be limited due to lack of sufficient unused capacity among the remaining yards, particularly if the total workload for the remaining shipyards increases from current levels;

- On the other hand, if the number of shipyards building major Navy ships is not reduced from the current figure of 6, and if total workload for the yards does not increase from current levels, then the potential for maintaining effective competition may be limited by the government's inability to maintain substantial uncertainty among the yards over the long run regarding the government's options for awarding shipbuilding contracts.

Competition below the shipyard level. Even if the government cannot maintain effective competition at the shipyard level, it can seek to maintain effective competition below the shipyard level, among firms that supply materials and components to the shipyards. These materials and components, which are either purchased by the government and delivered to the shipyard (government-furnished equipment or GFE) or purchased directly by the shipyard (in some cases called contractor-furnished equipment or CFE), can account for a substantial portion of the total cost of the ship.[116]

The government can use competition in its purchases of GFE. The government can also require shipyards to use competition in their own purchases of materials and components. Shipyards may perceive a strong interest in using competition in their purchases so as to hold down total ship price and thereby maximize the number of ships the Navy can procure. And in the absence of competition at the shipyard level, the government can seek to minimize costs at the shipyards through audits of the shipyards' expenses. All these mechanisms have been employed in recent major Navy shipbuilding programs that for various reasons were limited to a single shipyard.[117]

It may be preferable for the government to employ competition at both the shipyard and supplier levels, since this maximizes the use of competition in ship procurement. But if competition is not possible at the shipyard level, it might still be possible to apply it at the supplier level to generate benefits in the areas of cost, product quality, schedule adherence, innovation. Lack of second sources, however, may preclude effective competition at the supplier level in some cases. This may be particularly the case with regard to submarine components and certain surface-ship combat system equipment.

Modernization

Shipyards can improve their production efficiency and increase their production capacities and capabilities beyond those shown in Tables 2 and 3 by investing funds to purchase more modern production equipment and implement improved production processes and practices. A shipyard's decisions regarding

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[116] For example, combat system materials may account for 42 percent of the total cost of a "typical destroyer," while shipyard materials may account for another 20 percent. (The remainder of the ship's cost is accounted for by shipyard labor [21 percent] and Navy-related costs [17 percent].) Rains, Dean A. Naval Ship Affordability. *Naval Engineers Journal*, July 1996: 20 (figure 1).

[117] Examples of single-yard shipbuilding programs where these mechanisms were used include the 31 Spruance (DD-963) class destroyers and the 5 Tarawa (LHA-1) and 7 Wasp (LHD-1) class amphibious assault ships (all built by ISI), the 18 Ohio (SSBN-726) class Trident ballistic missile submarines and 3 Seawolf (SSN-21) class attack submarines (all built by EB), and the 9 Nimitz (CVN-68) class aircraft carriers (all built by NNS). Provisions for government competition of GFE purchases, a government requirement for the shipyard to compete its purchases, and government audits of shipyard expenses "are inherent in all [Naval Sea Systems Command] contracts for ship platforms." Source: U.S. Navy information paper provided to CRS by U.S. Navy Office of Legislative Affairs, June 7, 1996.

facility modernization can be influenced by its perceived competitive position relative to other U.S. shipyards, foreign shipyards, and other U.S. defense contractors (whose non-shipbuilding defense programs may compete against major Navy ships for limited U.S. defense procurement dollars). The yard's modernization strategy can also be influenced by the amount of financial resources available for investment.

With regard to competition among U.S. yards, as discussed earlier, the balance between the number of U.S. shipyards and the available workload for these yards will affect the potential for sustaining meaningful competition among them. Lack of competition could reduce a yard's incentive to modernize. Very strong competitive pressures, however, could also reduce a yard's incentive to modernize, at least in the short term, because avoiding such investments can reduce short-term costs, enabling the yard to bid at a lower price for a highly sought-after contract.

With regard to availability of financial resources, a yard's ability to finance modernization of its facilities can depend on its overall financial health, which in turn can reflect the size and stability of its business base. Some industry officials and analysts have suggested that reducing the number of yards involved in building major Navy ships would increase the size and stability of the business base for the yards that are retained as major Navy shipbuilders, thereby improving their financial health and making yard modernization more possible.

Availability of financing for yard modernization, however, can also be affected by the government, which can approve or reject applications that yards may file for Title XI government-backed loan guarantees for yard modernization efforts. As mentioned in the background chapter, the government recently has approved loan guarantees for yard modernization projects at ASD and NASSCO.

Disruption

Shipyards can have their operations disrupted by natural disasters, industrial accidents, worker strikes, employee sabotage, terrorist attacks, or severe financial difficulties. Issues to address include the likelihood of such events and the length of time for which they might disrupt a yard's operations.

Natural disasters such as hurricanes[118] or earthquakes[119] are possible but unlikely in any given year, and yards can take steps to mitigate the potential consequences of such events.[120] Yards similarly can take actions to

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[118] The Gulf and Atlantic coast yards (ASD, BIW, EB, ISI and NNS) face a risk from hurricanes. The National Hurricane Center provided the following mean return periods (the average number of years between occurrences) for hurricanes of varying strengths passing within 75 nautical miles (about 86 statute miles) of five Gulf and Atlantic Coast sites: New Orleans, LA (about 14 miles downriver from ASD), Pascagoula, MS (the site of ISI), Norfolk, VA (a few miles from NNS), Newport, RI (about 40 miles from Groton, CT, the main site of EB), and Portland, ME (about 30 miles from Bath, ME, the site of BIW):

Mean return periods in years for hurricanes passing within 75 nm

Hurricane category	New Orleans, LA	Pascagoula, MS	Norfolk, VA	Newport, RI	Portland, ME
1	8	9	19	16	34
2	18	19	50	38	130
3	31	30	95	69	330
4	66	57	230	150	>500
5	170	130	>500	420	>500

Source: National Hurricane Center data provided to CRS by Office of Legislative Affairs, National Oceanographic and Atmospheric Administration, Sep. 12, 1996. ">" means greater than.

The Saffir-Simpson scale divides hurricanes into 5 categories according to their sustained wind speeds. Category 1 hurricanes (sustained winds of 74 to 95 miles per hour [mph]) cause no real damage to building structures, but can cause some coastal road flooding and minor pier damage. Category 2 hurricanes (96 to 110 mph) cause some roofing material, door and window damage to buildings, and considerable damage to piers. Category 3 hurricanes (111 to 130 mph) cause some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. Terrain continuously lower than 5 feet above sea level (ASL) may be flooded. Category 4 hurricanes (131-155 mph) cause more extensive curtainwall failures with some complete roof structure failure on small residences. Structures near the shore sustain major damage to their lower floors. Terrain continuously lower than 10 feet ASL may be flooded. Category 5 hurricanes (greater than 155 mph) cause complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All structures located less than 15 feet ASL and within 500 yards of the shoreline sustain major damage to their lower floors. (U.S. Department of Commerce. National Oceanic and Atmospheric Administration. National Weather Service. "Hurricane!" A Familiarization Booklet. Washington, U.S. Govt. Print. Off., 1993. (Revised April 1993, NOAA PA 91001) p. 28.

[119] NASSCO in San Diego, CA, faces a risk from earthquakes. Compared to most other parts of the country, California faces an elevated risk of earthquakes. Compared to other parts of California, San Diego faces a moderate or roughly average risk of earthquakes -- not as high as the San Francisco Bay or Los Angeles areas, but higher than locations such as Fresno or Bakersfield. Sources: Consultations on Sept. 5, 1996, with the Southern California (Pasadena) office of the U.S. Geological Service's Earthquake Hazards Program, and on Sep. 4, 1996 with the California Department of Insurance, a California state government agency that studies earthquake and other risks posed to various parts of the state. See also the seismic probability maps on the Internet that can be found through http://geohazards.cr.usgs.gov.

[120] For example, shipyards can strengthen their buildings and other structures to withstand the effects of earthquakes and hurricanes, and can prepare for approaching hurricanes by taking actions such as mooring ships securely or moving them out of the area, securing outdoor materials and equipment to the ground or moving them indoors, covering all building window and door openings with shielding materials, and evacuating personnel.

reduce the likelihood of industrial accidents.[121] Worker strikes and apparent employee sabotage have occurred on occasion at some of the shipyards discussed in this report.[122] But while disasters, accidents, strikes, and sabotage appear capable of disrupting a yard's operations for periods of days, weeks, or perhaps months, it is not clear that they could disrupt operations for longer periods of time.

In 1995 congressional hearings on future submarine acquisition, the Navy cited natural disaster as a secondary reason for supporting the maintenance of two nuclear shipbuilders rather than consolidating construction of nuclear-powered warships at a single yard;[123] EB cited both natural disaster and "economic work stoppage."[124] NNS, in disagreeing with the need to maintain two nuclear shipbuilders, argued that the possibility of a natural disaster was "a very unlikely hypothetical" and that "the physical plant of a shipyard ruined by a natural disaster can be repaired far more quickly than a skilled work force lost through attrition can be reconstituted."[125]

Break-ins at major Navy shipbuilders have been a cause for concern from time to time since the early 1980s.[126] Previous break-ins have mostly involved

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121 Shipyards can have accidents with things such as cranes, large metal-working tools, chemicals, electrical equipment, and (in the case of yards that work on nuclear-powered ships) radioactive materials. The likelihood of such accidents can be reduced by instituting and adhering to safety programs, including (for yards that work on nuclear-powered ships) the very strict safety standards and procedures of the naval nuclear propulsion program.

122 For press reports on recent examples of worker strikes and apparent employee sabotage, see Anderson, Sarah. Talks Set in NASSCO Strike. *Defense Daily*, July 25, 1996: 136; Fordhall, Matthew. Shipyard Workers Strike Over Union Rules. Associated Press wire story, July 19, 1996; Union Laborers Strike At Ingalls Over Wages, Benefits. Associated Press wire story, Aug. 15, 1996; Rabb, William. Sabotage at the Shipyard. *Navy Times*, Aug. 26, 1996.

123 Statement of the Honorable Nora Slatkin, Assistant Secretary of the Navy (Research, Development and Acquisition) and Admiral Bruce DeMars, USN, Director, Naval Nuclear Propulsion and Vice Admiral T. Joseph Lopez, USN, Deputy Chief of Naval Operations, Resources Warfare Requirements and Assessments, Before the Subcommittee on Seapower of the Senate Armed Services Committee on [the] FY 1996 Navy Submarine Modernization Plan, May 16, 1995, p. 15-16.

124 James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. Senate Armed Services Committee Sea Power Subcommittee, May 16, 1995, p. 8.

125 Statement of W. P. ("Bill") Fricks, President, Newport News Shipbuilding, Before the Seapower Subcommittee of the Senate Armed Services Committee on May 16, 1995, p. 7-8.

126 For early examples, see U.S. Congress. Senate. *[Hearing on] Security at Shipyards, Naval Bases and Related Facilities*, 97th Cong., 2nd Sess., August 2, 1982. Washington, U.S. Govt. Print Off., 1983. 31 p.; U.S. Congress. House. *[Hearing on] Break-Ins at the Electric Boat Shipyard, Groton, Conn*, 97th Cong., 2nd Sess., December 1, 1982. Washington, U.S. Govt. Print Off., 1983. 40 p. See also U.S. Congress. House. Committee on Appropriations. *[Hearings on] Department of Defense Appropriations for [Fiscal Year] 1986*, 99th Cong., 1st Sess., Part 7.

anti-war protestors who in some cases caused relatively superficial damage to Navy ships, but they raise the possibility that terrorists may attempt to break into a yard with the intent of carrying out a larger-scale attack against a yard's facilities or workers. Improved security measures can reduce the vulnerability of a yard to such attacks.

Severe financial difficulties can cause delays and cost increases to ships under construction at a yard due to the yard's inability to purchase materials or hire or pay workers. These delays and cost increases can continue until the underlying financial difficulties of the yard are resolved through financial restructuring or closure. If a yard is closed, ships under construction at the yard might be transferred to another yard for completion or, if transfer and completion costs are high enough, simply canceled (i.e., left unfinished). Financial difficulties have forced some shipyards out of the Navy shipbuilding business in recent years, and in at least one case, involving the construction of two Navy oilers (i.e., large auxiliaries), yard closure has led to significant disruption of a shipbuilding effort.[127] In the longer run, however, the closure of one yard can strengthen the business base and thus the financial health of the yards that remain, perhaps reducing the risk of future disruptions due to financial problems.

Reconstitution

A capability for building major Navy ships can be established (or reestablished) at a facility that does not currently build such ships. This potential could mitigate against some of the risks of reducing the number of yards currently involved in major Navy shipbuilding programs. For example, if at some point in the future there is reason to believe that the Navy shipbuilding rate will increase to a level that would stress or exceed the maximum potential capacity of the yards currently building major Navy ships, it might be possible for the government to take steps to encourage the establishment or reestablishment of one or more additional major Navy shipbuilding facilities.

One option would be to establish a major Navy shipbuilding capability at a facility that has not previously built major Navy ships, but has the potential for doing so. Potential candidates in this category include several of the shipyards in the Major Shipbuilding Base (see Figure 1) other than the 6 yards discussed in this report.

Washington, U.S. Govt. Print. Off., 1985. p. 388-390. For a more recent example, see Peace Activists Sentenced For Damaging Submarine. Associated Press wire story, Sep. 7, 1996; Huber, Lisa. Primitive Break-in Prompts Yard to Tighten Security -- Again. *Journal of Commerce*, Sep. 25, 1995.

[127] See, for example, Burney, Teresa. Senate Panel Closes the Book On Probe of Unfinished Ships. *Journal of Commerce*, Sep. 26, 1995; After a Dozen Years, Incomplete Oilers Still Haunt Navy. *Navy News & Undersea Technology*, May 8, 1995: 1, 8; Mintz, John. Hearings to Examine Why Navy Tankers Left to Rust. *Washington Post*, May 2, 1995: A1; TA-O [sic] "Yard Killers" Strike Again. *Navy News & Undersea Technology*, Aug. 30, 1993: 6.

Alternatively, a major Navy shipbuilding capability could be reestablished at a facility that built major Navy ships at some earlier point but subsequently fell out of the ranks of the Navy's major shipbuilders. Such a yard might still be operating (as a builder of commercial ships or smaller Navy ships or as a ship repair and overhaul facility) or might have closed down completely following the end of its major Navy shipbuilding work. Potential candidates in this category include the public-sector naval shipyards (NSYs), some of which built major Navy ships until the early 1970s. At some point in the future, this category conceivably could also include one or more of the 6 yards discussed in this report.

Establishing or reestablishing a major Navy shipbuilding capability at a shipyard, however, could require significant time and investment, particularly if the shipyard is to construct complex combatant ships. Assembling a skilled work force of a few or several thousand workers and a complementary staff of waterfront supervisors, project managers, and executives could take several years. Enlarging or building new dry dock capacity and purchasing new construction equipment and tools could cost tens or hundreds of millions of dollars.

The time and investment required to reestablish a major shipbuilding capability at a fully closed shipyard could be particularly significant. In some cases, it might not be possible at all if some or all of the yard's land -- particularly its waterfront property -- was sold following closure. Sale of a closed yard's land could be a significant possibility: Depending on the location of the yard in question, waterfront property might be in high demand for other industrial uses or for construction of waterfront housing.

Reestablishing a capability for building nuclear-powered ships at EB, NNS, ISI (which built nuclear-powered submarines until the early 1970s) or a naval shipyard could be a very lengthy and difficult process. Special nuclear-related construction skills would have to be regained, and special equipment for handling nuclear materials might have to be purchased. Perhaps most important, regaining certification for the shipyard to once again handle nuclear materials could prove very difficult, given the nuclear-related regulatory issues involved.[128]

Reestablishing a capability for building major Navy ships at one or more NSYs would involve reversing the policy in effect since the early 1970s of

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[128] For a discussion of potential costs and other issues relating to restarting construction of nuclear-powered submarines at a shipyard where there previously has been a "smart shutdown" of production of such ships, see Birkler, John, et al. *The U.S. Submarine Production Base: An Analysis of Cost, Schedule, and Risk for Selected Force Structures.* RAND Institution, Santa Monica, CA, 1994. (National Defense Research Institute, Prepared for the Office of the Secretary of Defense, MR-456-OSD) 183 p.

building new Navy ships solely in private-sector shipyards and having the NSYs focus exclusively on overhaul and repair of Navy ships.[129]

Summary

Discussion of the issue of how many major shipbuilders the Navy needs dates to at least 1992. Various perspectives have been expressed on the issue.

Given uncertainty over the future Navy shipbuilding rate, anywhere from 2 to more than 6 major shipbuilders might be needed to provide enough capacity to meet the Navy's future shipbuilding needs. If the future Navy shipbuilding rate, the future commercial shipbuilding rate, or the future amount of Navy ship overhaul and repair work performed by the 6 yards increase from their current values, then all 6 of the yards discussed in this report might be needed (in conjunction with other private-sector yards and the public-sector naval shipyards) to provide sufficient shipyard capacity to meet all of the Navy's needs (i.e., for overhaul and repair work as well as shipbuilding); if, on the other hand, these three variables remain at their current values, then not all of the 6 yards of the yards discussed in this report (in conjunction with other private-sector yards and the public-sector naval shipyards) might be needed to provide sufficient shipyard capacity to meet all of the Navy's needs.

Having as few as 2 or 3 major Navy shipbuilders could reduce efficiency and increase costs by depriving the government of the second sources or unused capacity needed to maintain effective competition, or by elevating employment levels at the yards so high that worker productivity is reduced. Having as many as 6 major Navy shipbuilders, conversely, could reduce efficiency and increase costs by depriving the government of the ability to create enough uncertainty over its contract award decisions to maintain effective competition, or by reducing workloads at each yard to the point where there is limited spreading of fixed costs and reduced learning.

Yard modernization can increase the capacities and capabilities of the yards discussed in this report. Lack of competition against other U.S. shipyards could reduce a yard's incentive to modernize. Very strong competitive pressures, however, could also reduce a yard's incentive to modernize, at least in the short term, because avoiding such investments can reduce short-term costs, enabling the yard to bid at a lower price for a highly sought-after contract.

Various events could disrupt operations at the yards, though at least some of these events can be considered unlikely to occur or unlikely to cause disruptions lasting more than a few weeks or months. A capability to build major Navy ships can be established (or reestablished) at a yard that does not currently build them, but this could require significant time and expense.

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[129] Another factor to consider is the potential for building major Navy ships in foreign shipyards. As discussed in an earlier footnote (see the section on the number of major Navy shipbuilders needed to provide adequate capacity), current law prohibits the construction of Navy ships in foreign shipyards without a Presidential waiver, and very few Navy ships have ever been built in foreign yards.

OPTIONS FOR CONGRESS

This chapter discusses four general options for Congress (and the Executive Branch) regarding the Navy's major shipbuilding programs and the 6 shipyards associated with those programs. The options are intended as possible responses to the current situation regarding Navy major shipbuilding and the 6 associated yards. As discussed in earlier parts of the report, this situation is characterized by a relatively low Navy shipbuilding rate and relatively low workloads at the 6 yards. The options are: (1) increase the major Navy shipbuilders' workload, (2) reduce the number of major Navy shipbuilders, (3) do both, and (4) do neither, at least for now. Each of these options is discussed below.

INCREASE THE MAJOR NAVY SHIPBUILDERS' WORKLOAD

The central rationale for increasing the major Navy shipbuilders' workload would be to improve economies of scale and, insofar as such an increase involves increasing the rate of Navy ship procurement, procure Navy ships at a rate closer to that needed to replace the Navy on a steady-state basis and reduce the approaching bow wave of accumulated deferred shipbuilding requirements. Congress can increase the major Navy shipbuilders' workload by increasing either the amount of major Navy shipbuilding work or other forms of shipyard work. The discussion here focuses primarily on increasing the amount of major Navy shipbuilding work.[130] As discussed in the background chapter, Congress has already increased the amount of major Navy shipbuilding work in the short run by accelerating procurement of LHD-7 from FY2001 to FY1996, by accelerating the first ship in the LPD-17 class from FY1998 to FY1996, and by adding an additional attack submarine in FY1999 and possibly FY2001 as well.

Factors to Consider

If Congress decides to further increase the amount of major Navy shipbuilding work available to the 6 yards, the central question that would arise would be: Which shipbuilding programs should be increased? Potential factors to consider in assessing this question include the following:

- **Shipyard/production conditions.** Do some of the major Navy shipbuilders need additional work more than others? Are some better

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[130] With regard to increasing other forms of shipyard work, Congress may consider various options, such as promoting the construction of commercial ships; promoting the construction of warships for export; shifting construction of smaller surface ships (i.e., those less than 400 feet in length) from smaller shipyards to the 6 yards involved in this report; and giving the private-sector yards, and particularly the 6 yards involved in this report, a greater share of Navy ship overhaul and repair work. In considering these options, Congress may wish to explore various issues, such as the potential size of the international markets for commercial ships and warships and the feasibility of penetrating them, as well as the potential impact of these options on the cost of major Navy ships and on the business bases of the 6 yards, smaller private-sector U.S. shipyards, and the naval shipyards.

positioned than others to absorb additional work? What would be the impact on unit costs of increasing or accelerating procurement of various types of ships?

- **Force-level considerations.** Given stated force-level requirements for various types of ships, current inventories, and projected retirements, which ship types most need to have their procurement accelerated or increased? How might future reviews of U.S. defense strategy alter current requirements for various ship types?

- **Technological/mission considerations.** Independent of simple (i.e., purely numerical) force-level considerations, are some elements of the fleet more in need of technological modernization than others? What is the ability of various components of the fleet to perform their mission against the forces of potential adversaries now and in the future?

Specific Options

Beyond actions taken in FY1996, Congress could further increase the amount of major Navy shipbuilding work available to the yards by taking one or more approaches.

- **Increase the DDG-51 procurement rate to more than 3 ships per year.** A 1994 CRS report noted that a DDG-51 procurement rate of more than 3 ships per year is needed to replace the Navy's planned surface combatant force on a steady-state basis.[131]

- **Increase the eventual attack submarine procurement rate to more than 2 ships per year.** CRS testimony to Congress in 1995 noted that, due to the relatively low number of attack submarines planned for procurement in the 1990s, an attack submarine procurement rate of more than 2 ships per year starting around FY2000 will be needed to maintain the Navy's planned attack submarine force level after 2020.[132]

- **Increase the eventual LPD-17 procurement rate to more than 2 ships per year.** This option would accelerate the date by which the Navy's amphibious force would reach its stated goal of having enough

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[131] *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress.* CRS Report 94-343 F, by Ronald O'Rourke. (April 25, 1994) p. 4, 33-34.

[132] Statement of Ronald O'Rourke, Specialist in National Defense, Congressional Research Service, before the House National Security Committee Subcommittee on Military Procurement Hearing on Submarine Acquisition Issues, March 16, 1995, p. 8-11, and Statement of Ronald O'Rourke, Specialist in National Defense, Congressional Research Service, before the Senate Armed Services Committee Subcommittee on Seapower Hearing on Submarine Acquisition Issues, May 16, 1995, p. 9-11.

amphibious lift for 2.5 Marine Expeditionary Brigades. At the currently planned eventual rate of 2 ships per year, this goal will be reached around 2010. The Navy's FY1997 "wish list" -- its list of programs on which it would prefer to spend any additional funding that the Congress might add to the Navy's proposed FY1997 budget -- included, as a high-priority item, the option of procuring an additional LPD-17 in FY1997.[133]

- **Accelerate procurement of CVN-77 from FY2002 to perhaps FY1999 or FY2000.** This option would reduce the amount of time between the funding of CVN-76 (funded in FY1995) and CVN-77 and thereby avoid some of the loss of learning and reduce the need for a compressed construction schedule that could occur on CVN-77 as a result of the currently planned 7-year funding gap between the two ships. An expanded version of the Navy's FY1997 wish list included the option of providing advanced procurement funding for CVN-77 in FY1997 so as to accelerate procurement of CVN-77 to FY1999.[134]

- **Add procurement of arsenal ships to the current shipbuilding plan.** This option may materialize as part of the FY1998-FY2003 shipbuilding plan that the Administration submits to Congress in early 1997.

- **Add procurement of additional large auxiliaries or sealift ships to the current shipbuilding plan.** Congress, for example, is currently examining options for acquiring 3 converted or new-construction sealift ships to enhance the capabilities of the Marine Corps' Maritime Prepositioning Force (MPF).

Arguments For and Against

Proponents of increasing the amount of major Navy shipbuilding work could argue that doing so could:

- Improve economies of scale at both the 6 shipyards and supplier firms,

- Increase the potential for maintaining effective competition by avoiding situations where there is so little work relative to the number

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[133] For the wish lists of the various services, see the attachments to U.S. House. Fiscal Year 1997 Defense Budget: The Need to Revitalize. Washington, 1996. (Floyd D. Spence, Chairman, House National Security Committee and C.W. Bill Young, Chairman, Subcommittee on National Security, House Appropriations Committee, April 22, 1996). See also Blazar, Ernest. If Navy's Wish Came True. *Navy Times*, Apr. 29, 1996: 28; Duffy, Thomas. Navy Sends $3 Billion, 11 Program 'Wish List' For FY-97 to Capitol Hill. *Inside the Navy*, Apr. 8, 1996: 1, 7-8.

[134] Holzer, Robert. U.S. Navy Pushes for Speedier Buy of Carrier. *Defense News*, Apr. 29-May 5, 1996: 26.

of yards that the government cannot present the yards with sustained uncertainty regarding its contract award decisions,

- Improve the financial health of the yards and thus their ability to finance yard modernization efforts,

- Reduce and thereby make more affordable the post-FY2001 "bow wave" of accumulated deferred ship procurement requirements,

- Accelerate modernization of the fleet in areas where modernization is required, and

- Promote a shift to a next-generation fleet structure by acquiring new-concept ship types such as the arsenal ship.

Opponents of increasing the amount of major Navy shipbuilding work could argue that doing so could:

- Add significantly to defense funding requirements,

- Expend funding on fleet modernization for which there is little need, in view of the fact that the Navy, as a result of recent downsizing, currently consists of relatively new and modern ships,

- Prematurely reduce a shipbuilding "bow wave" that may not materialize if Navy force-level requirements are reviewed and reduced between now and FY2001, and

- Retard the shift to a next-generation fleet structure by increasing the sunk investment in today's ship designs.

REDUCE THE NUMBER OF MAJOR NAVY SHIPBUILDERS

The central rationale for reducing the number of yards involved in the Navy's major shipbuilding programs would be to increase and stabilize the workloads at the yards that are maintained as major Navy shipbuilders. As discussed earlier in the report, neither the Executive Branch nor Congress has shown enthusiasm for the option of taking action to reduce the number of shipyards involved in the construction of major ships for the Navy. To the contrary, the Administration's decisions regarding shipbuilding will have the effect of maintaining the involvement of all 6 yards in the Navy's major shipbuilding programs out to the turn of the century, while Congress last year rejected the option of consolidating construction of nuclear-powered warships into a single yard, at least for the time being, and increased the 6 yards' near-term business base by adding ships to the Administration's proposed shipbuilding budget.

Factors to Consider

If policymakers in the future revisit the option of reducing the number of yards involved in major Navy shipbuilding programs, the central question that would arise would be: Which yards should be retained as major Navy shipbuilders, and which should not? Potential factors to consider in assessing this question include the following:

- **Coverage of ship types.** Do the retained yards have the capacity to produce all ship types that might be built in the future?

- **Second sources.** Among the retained yards, are there current or potential second sources for all ship types for which competition might be desirable in the future?

- **Excess capacity.** Do the retained yards have sufficient excess capacity to support meaningful competition, avoid diseconomies of scale due to high workloads, and carry out an expanded shipbuilding program if needed to respond to a significant future threat to U.S. interests?

Another factor to consider is the potential for establishing (or reestablishing) a capability for building major Navy ships at a facility that does not currently build such ships. As discussed in the previous chapter, this potential could mitigate against some of the risks of reducing the number of yards currently involved in major Navy shipbuilding programs, but could take significant time and investment.

Specific Options

Many potential combinations of fewer than 6 yards might meet the three criteria highlighted above. These combinations can include or exclude any one of the 6 yards, with the partial exception of NNS, which could not be excluded if a capability for producing CVNs needs to be preserved. If, however, it is decided that a capability for producing CVs (as opposed to CVNs) is sufficient, then NNS might be excluded, and a potentially CV-capable yard -- ISI or possibly ASD -- would have to be included. Potential approaches to selecting which yards to retain include the following:

- **Dispersion or concentration by coast.** Congress may wish to preserve at least one major Navy shipbuilder on each of the three coasts (West, Gulf, and Atlantic). This would favor NASSCO, since it is the only West Coast major Navy shipbuilder. Conversely, Congress may wish to consolidate major Navy shipbuilding into two coasts or one coast. This could favor the East Coast yards, since the East Coast could not be eliminated unless it were considered acceptable to eliminate the capability for building both submarines and CVNs.

- **Location relative to other industries.** Another approach would involve taking into account the location of other defense or non-defense industrial facilities. For example, Congress may seek to distribute defense industrial facilities, or industrial facilities generally, around the country, or concentrate them into a limited number of areas. If so, Congress may wish to retain major Navy shipbuilders that are either far from other defense or non-defense industrial facilities, or close to them, respectively.

- **Yard versatility or specialization.** Another approach would be to favor the retention of major Navy shipbuilders that are capable of building the greatest variety of ships, on the theory that such yards could maximize the number of second sources and more easily handle shifts in the composition of the Navy's shipbuilding program. This approach would favor NNS, the only yard that can build all ship types, and perhaps ISI, which can build a broad array of surface ships including surface combatants and large-deck amphibious ships, and which could be made capable of building CVs.

  Conversely, one could favor the retention of more specialist major Navy shipbuilders, on the theory that such yards could reduce shipbuilding costs by optimizing their production facilities for the production of a specific type of ship. This approach could favor EB, which has long specialized in the construction of submarines, NASSCO, which has specialized in the construction of non-combatant Navy ships (i.e., large auxiliaries and sealift ships), and possibly BIW, which in recent years has specialized in the construction of surface combatants.

- **Market segmentation.** An additional possible approach, and one that is perhaps the most often mentioned in debates over the future of the 6 yards, is to consolidate within the various current market segments. Under this approach, one would retain one of the two current yards that currently build nuclear-powered warships (EB or NNS), or one of the two yards that currently build surface combatants (BIW or ISI), or one of the two yards that currently build large auxiliaries and sealift ships (ASD and NASSCO). A choice that overlaps with these would be to retain one of the two yards that currently build amphibious ships (ASD or ISI). This approach would not necessarily favor any one yard, with the partial exception of the desirability of maintaining a capability for building CVNs vs. CVs, which could favor the retention of NNS or (if NNS is excluded), ISI or possibly ASD.

- **Cost or value.** A final alternative would be to retain the lowest-cost or best-value major Navy shipbuilders. Identifying which yards best fit this criterion, however, would likely be a difficult and controversial undertaking, since each yard is prepared to argue that it is a lowest-cost or best-value yard, either generally or for certain ship types.

Arguments For and Against

Proponents of taking actions to reduce the number of yards involved in major Navy shipbuilding programs could argue that doing so could:

- Improve economies of scale at the retained shipyards and perhaps some suppliers,[135]
- Increase the potential for maintaining competition by avoiding situations where there are so many yards relative to the amount of available work that the government cannot present the yards with sustained uncertainty regarding its contract award decisions, and
- Improve the financial health of the retained yards and thus their ability to finance yard modernization efforts, and
- Preempt the risk that market forces will lead to decisions by the shipyards themselves to close or consolidate their facilities in ways that are undesirable from the government's perspective.

Opponents of taking actions to reduce the number of yards involved in major Navy shipbuilding programs could argue that doing so could:

- Eliminate capacity that may be needed to handle either the post-FY2001 bow wave or an expanded shipbuilding program for responding to a significant future threat to U.S. interests,
- Do nothing to improve economies of scale at supplier firms that are sole sources of what they make for Navy ships, even though diseconomies at these firms contribute to current diseconomies in Navy shipbuilding,
- Increase the risk of future diseconomies of scale due to very high workloads at the yards,
- Reduce the potential for maintaining effective competition by reducing the number of yards capable of building certain types of ships or the unused capacity that a given yard needs to show that it can take on additional work that it is attempting to win away from another yard, and
- Deprive the shipyards, at least for now, of the freedom to determine their own futures in reaction to market forces.

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[135] Suppliers that are associated with some shipyards more than others may have improved economies of scale if their associated shipyard is retained. Suppliers that are not associated with specific shipyards, particularly suppliers that are sole sources for what they produce, may not experience improved economies of scale because the number of ships being produced has not been increased.

DO BOTH

The two options above are not mutually exclusive; Congress can consider both increasing the amount of work available to the yards and reducing the number of yards involved in major Navy shipbuilding programs. In general, the factors to consider for each of two previous options would apply in combination here. The arguments for and against the two previous options would also apply. Arguments relating to the potential affects of increased average shipyard workload -- such as economies or diseconomies of scale and increased or reduced potential for sustaining meaningful competition -- could apply in accentuated form, since the average workload at each yard could be increased more under this combined option than under the previous two options.

DO NEITHER, AT LEAST FOR NOW

One potential rationale for neither increasing the work available to the yards nor reducing the number of yards involved in major Navy shipbuilding programs, at least for now, might be a view that the current situation involving the rate of major Navy shipbuilding and the workloads at the 6 yards is, all factors considered, acceptable, if perhaps not ideal. An additional primary reason for not reducing the number of shipyards involved in major shipbuilding programs might be a preference for permitting the yards to determine their own futures in reaction to market forces, rather than have government encourage or compel a particular solution. The arguments for and against this option are essentially the obverse of those made in relation to the first two options.

Proponents can argue that doing nothing, at least for now, would:

- Avoid the cost of acting on the uncertain premise of an approaching bow wave of deferred shipbuilding requirements that in fact may not materialize due to potential future changes in the planned size of the Navy,

- Preserve yards that may be needed to have sufficient shipbuilding capacity to handle either the post-FY2001 bow wave or an expanded shipbuilding program for responding to a significant future threat to U.S. interests,

- Avoid the risks of diseconomies of scale due to excessively high workloads at the yards,

- Avoid unneeded modernization of the fleet,

- Facilitate a shift to a next-generation fleet structure by not increasing the sunk investment in today's ship designs, and

- Permit the shipyards, at least for now, the freedom to determine their own futures in reaction to market forces.

Opponents can argue that doing nothing, at least for now, would:

- Not reduce the size of the approaching bow wave of shipbuilding requirements,
- Forego the opportunity to reduce average ship costs by improving economies of scale at the yards,
- Limit the potential for modernizing the parts of the fleet that may need modernization,
- Forego the opportunity to accelerate the shift to a next-generation fleet structure by accelerating procurement of new-concept ship types such as the arsenal ship, and
- risk having market forces lead to decisions by the shipyards themselves to close or consolidate their facilities in ways that are undesirable from the government's perspective.

APPENDIX A: EMPLOYMENT LEVELS AT THE 6 YARDS

The table below shows mid-year employment levels at the 6 yards discussed in this report for the period 1973-1995, as collected by the Maritime Administration for its annual *Report on Survey of U.S. Shipbuilding and Repair Facilities*. Data on employment levels at EB for 1973-1984 were provided by EB.

TABLE 9. SHIPYARD EMPLOYMENT LEVELS, 1973-1995

Year	ASD	BIW	EB	ISI	NASSCO	NNS	Total
1973	7,330	2,245	13,588	17,000	3,310	26,600	70,073
1974	6,350	3,840	17,440	18,890	4,700	24,000	75,220
1975	6,440	3,675	20,064	22,500	5,230	22,400	80,309
1976	6,300	3,330	23,874	23,760	6,300	23,600	87,164
1977	6,900	3,430	28,513	24,900	6,050	26,000	95,793
1978	6,180	4,460	21,968	20,750	5,430	25,000	83,788
1979	7,494	5,311	21,812	16,926	6,356	22,400	80,299
1980	7,507	6,119	23,274	11,170	6,600	22,900	77,570
1981	7,300	6,565	23,689	12,700	6,775	24,000	81,029
1982	5,360	7,300	24,097	12,350	6,180	25,000	80,287
1983	5,188	7,720	25,553	10,200	3,463	28,260	80,384
1984	4,342	6,800	25,297	9,760	4,770	28,112	79,081
1985	4,600	6,795	24,400	11,550	4,630	30,000	81,975
1986	5,600	6,680	24,527	12,700	3,920	28,500	81,927
1987	6,450	7,500	19,808	11,850	2,145	25,350	73,103
1988	6,650	8,524	23,220	11,650	2,015	27,000	79,059
1989	7,782	9,600	21,827	10,500	2,650	26,000	78,359
1990	6,512	10,516	22,247	12,978	3,950	25,945	82,148
1991	7,211	9,504	18,001	15,531	3,931	27,000	81,178
1992	6,008	9,298	19,222	16,072	4,085	24,442	79,127
1993	5,045	8,663	17,912	15,289	4,085	22,501	73,495
1994	5,776	8,540	16,618	14,733	3,271	20,900	69,838
1995	5,150	8,300	15,111	14,081	4,500	19,500	66,642

APPENDIX B: SPREADING OF SHIPYARD FIXED COSTS

FIXED vs. VARIABLE COSTS

A manufacturing facility's fixed costs (also called fixed overhead costs) are those that are relatively insensitive (i.e., do no change very much in response) to changes in the level of production, particularly over the shorter run. Some fixed costs would continue to be incurred even if the level of production at the facility falls to zero. A manufacturing facility's other main type of costs are its variable costs, which are those incurred in proportion to the level of production. Variable costs include expenses for labor and materials. A firm's fixed costs are spread over -- that is, charged to and thereby incorporated into the cost of -- the various work projects that make up the total workload underway at the firm.

TYPES OF SHIPYARD FIXED COSTS

Shipyards, like other firms, differ in the particulars of what they include under the category of fixed overhead costs. Some of these differences might reflect differences in corporate structure, differing methods of cost accounting developed at each yard, or variations in the mix of work at the yards. A shipyard that is a subsidiary of a larger corporation or one that focuses on the production of a particular kind of ship, for example, may define fixed overhead costs differently than an independently owned shipyard or one that builds a variety of ship types. Shipyards with relatively large in-house design and engineering staffs may have greater design- and engineering-related fixed costs than yards with relatively small in-house design and engineering staffs. EB and NNS, the shipyards capable of building nuclear-powered ships, may have nuclear-related fixed overhead costs that the other yards lack.

The following is a representative but by no means definitive or exhaustive list of the kinds of costs that can be included in a shipyard's fixed overhead costs. While all of these costs are to some degree insensitive to changes in production level, some are more completely insensitive than others:[136]

- Facilities-related costs
    - Depreciation
    - Insurance
    - Tax
    - Rent
    - Waste removal
    - Oil and steam
    - Water
    - Electricity

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[136] This list was developed in consultation with the American Shipbuilding Association, July 23, 1996.

  - Cleaning services and material
  - Maintenance material
  - Security

- Centralized expenditures
  - Actuarial services
  - Computers and data processing (including computer-aided design [CAD] costs)
  - Manufacturing and production engineering
  - Independent research and development (IRAD)

- Costs for headquarters/central administrative personnel
  - Salaries, wages, and lump sums
  - Benefits (e.g., vacation, holidays, sick leave, other paid absences, pensions, stock option plans, health care, Social Security (FICA), unemployment tax)

- Corporate allocation costs
  - Corporate office allocation
  - Franchise tax

- Self-insurance costs
  - Workers' compensation
  - Group insurance for retirees.

ESTIMATING SHIPYARD FIXED COSTS

Precise data on the fixed costs of private U.S. shipyards generally is proprietary and not available in the public domain. Rough estimates of shipyard fixed costs, however, can be developed on the basis of generalized information provided by shipyard officials, industry analysts, and the Navy. As detailed below, on the basis of this information, a smaller shipyard capable of building major Navy ships (i.e., one whose facilities are adjusted to support a total employment of a few thousand people) might have fixed costs range from a few to several tens of millions of dollars per year, while a larger shipyard capable of building major Navy ships (i.e., one whose facilities are adjusted to support a total employment ranging from several thousand people to more than 10,000 people) might have fixed costs ranging from several tens of millions of dollars per year to more than $100 million dollars per year.

Sources for this report described the fixed costs of shipyards primarily as a percentage of total (i.e., both fixed and variable) overhead costs. (Variable overhead costs, which rise and fall with the level of production, include overhead associated with direct labor and materials.) Total shipyard overhead costs in turn were usually expressed as an equivalent percent of direct labor costs.

Total overhead costs at shipyards, like total overhead costs of many U.S. firms, have been rising in recent years, due in large part to increases in labor-related overhead costs (i.e., benefits). Older studies on shipyards with data dating back to the 1970s state that total overhead costs at the time were 60 percent or more of direct labor costs and growing.[137]

As shown in the table below, sources now estimate total shipyard overhead costs at 100 percent to 140 percent of direct labor costs. As also shown in the table, sources estimate that fixed overhead costs currently account for 30 percent to 50 percent of total overhead costs, with fixed costs consequently being equivalent to 35 percent to 62.5 percent of direct labor costs.

TABLE 10. SHIPYARD OVERHEAD COSTS

Source	Total overhead as percent of direct labor costs	Fixed overhead as percent of total overhead	Fixed overhead as percent of direct labor costs
Navy[a]	136%	n/a	n/a
CNA[b]	140%	n/a	n/a
CNA[c]	110%	n/a	n/a
EB[d]	114%-122%	30%	35%-37%
A[e]	100%-125%	50%	50%-62.5%
B[e]	100%-120%	40%-45%	40%-54%
C[e]	120%	50%	60%
D[e]	n/a	50%	n/a

n/a = Not available.

137 A 1980 National Academy of Sciences report used a 71 percent total overhead rate in estimating the costs to build a commercial tanker in a U.S. shipyard. (*Personnel Requirements for an Advanced Shipyard Technology.* Washington, National Academy of Sciences, 1980. (Prepared by the Committee on Personnel Requirements for an Advanced Shipyard Technology of the Maritime Transportation Research Board Commission on Sociotechnical Systems, National Research Council) p. 41.) A 1977 report prepared for the Naval Sea Systems Command states: "There was no systematic or thorough method of determining overhead rates for shipyards prior to 1972. Cost estimators applied a standard 70 percent rate to all labor estimates since that figure was representative for at least several shipyards .... The latest national overhead average for the principal yards doing Navy work is 105 percent, with a range of 70-144 percent and the trend is upward ...." (*A Study of Ship Acquisition Cost Estimating in the Naval Sea Systems Command.* Washington, 1977. (Prepared under Contract No. N00024-77-C-2013 for [the] Naval Sea Systems Command, Department of the Navy, Washington, D.C. 20362, [by] International Maritime Associates, Inc., Washington, D.C.) p. III-64, III-66.) An appendix to the report states: "Over the past ten years, the overheads in the shipbuilding industry have risen from a range of 60 to 80 percent of direct labor dollars to a range of 90 to 120 percent." It also states that "overhead as a % of direct labor grew from 60.5% in 1969 to 81.9% in 1975 but in 1980 it could be back to 76%." p. D-229/D-451, and D-454-a.)

a Information paper provided to CRS on Jan. 9, 1995 by U.S. Navy Office of Legislative Affairs. Percentage figure based on a composite direct labor rate ($15.21 per hour) and a composite wrap around rate ($35.90 per hour) "reflecting direct labor rates and overhead rates for the major private shipyards currently performing Navy new construction or ship conversion work in 1995." The composite direct labor rate "includes a rate for production and a rate for engineering appropriately weighted." The composite wrap around rate "includes an average yard-wide overhead cost per hour of direct labor." The overhead cost of $20.69 per hour (35.90 - 15.21 = 20.69) is 136 percent of 15.21 per hour (20.69/15.21 = 1.36).

b A 1993 Center for Naval Analyses Report states: "In the U.S. most yards associate overhead with a fixed percentage of direct labor payroll. For them, overhead equals a constant k times direct man-hours times the wage rate (net of fringes). The Shipbuilders Council [of America] and an individual shipyard recommended k = 140 percent for U.S. yards." (Rost, Ronald F., and Carla Tighe. *Shipyard Costs and Capabilities (U).* Alexandria, Center for Naval Analyses, 1992. (CRM [Center for Naval Analyses Research Memorandum] 92-13, May 1992, Confidential.) p. 12. Page 12 is unclassified; material from this page is used here with the permission of Navy Office of Legislative Affairs, Feb. 10, 1995.)

c Approximate percentage figure derived from figures presented for labor and overhead costs for constructing a 54,000 deadweight ton product tanker and a 70,000 deadweight ton dry bulk carrier in a U.S. shipyard. *Shipyard Costs and Capabilities (U)*, op. cit., Tables 1 and 2 (p. 6, 8). Pages 6 and 8 are unclassified; material from these pages is used here with the permission of Navy Office of Legislative Affairs, Feb. 10, 1995.)

d James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. Senate Armed Services Committee Sea Power Subcommittee, May 16, 1995, p. 21-22. The testimony on page 21 states that of the combined direct labor and total overhead costs to build five submarines, direct labor accounts for about 45 percent. Total overhead therefore accounts for the remaining 55 percent. 55 divided by 45 is about 1.22. The testimony also states that about 70 percent of total overhead costs are "people-related" costs, particularly benefits, that "are assumed to be variable overhead costs associated with the labor to construct the ship ...." Fixed costs therefore account for the remaining 30 percent of total overhead costs. 1.22 times 0.3 is about 0.37. Figures provided on page 22 show total overhead costs for the five boats would be $1.6 billion while total direct labor costs would be $1.4 billion. 1.6 divided by 1.4 is about 1.14. The testimony separately shows that fixed costs for the five boats would be $500 million. This equates to about 31 percent of the total overhead costs of $1.6 billion. 1.14 times 0.31 is about 0.35.

e Not-for-attribution interviews with industry officials and analysts.

If fixed costs can be expressed as an equivalent percent of direct labor costs, then estimated dollar figures for fixed costs can be derived using data for direct labor costs. Average hourly earnings for production workers in the private-sector U.S. shipbuilding and repair industry (SIC 3731) are currently $14.04 an hour.[138] Combining this figure with a roughly 2,080-hour work year (52 weeks times 5 workdays a week times 8 working hours a day), shipyard production workers currently earn on average about $29,200 per year in wages.

If a shipyard's fixed costs are equal to 35 percent to 62.5 percent of these direct labor costs, then fixed costs would come to about $10,200 to $18,300 per production worker per year, or about $10.2 million to $18.3 million per 1,000 production workers per year. Since, as mentioned in the background chapter,

[138] Source: U.S. Bureau of Labor Statistics, Division of Monthly Industry Employment Statistics, July 8, 1996. For May 1996, the most recent month for which a figure was available, the preliminary figure was $14.04 per hour. The figure for April 1996 was $14.26 per hour.

about 74 percent of the shipbuilding industry's employees are production workers, a shipyard's fixed costs might therefore range from about $7.5 million to about $13.5 million per 1,000 *total employees* per year.[139] A shipyard with 5,000 total employees and a production plant and headquarters/central administrative organization adjusted to that employment level might thus have fixed costs of about $38 million to $68 million per year, while a yard with 10,000 total employees and a production plant and headquarters/central administrative organization adjusted to that employment level might have fixed costs of $75 million to $135 million per year.

It should be remembered that although this model estimates shipyard fixed costs on the basis of the number of production workers at the yard, fixed costs by definition are relatively insensitive to the level of production and thus to the number of production workers at the plant. The estimating method here simply uses the size of the work force as a rough proxy for the size of the firm's production plant and headquarters/central administrative organization and thus for the costs associated with maintaining that plant and organization, independent of production rate. It assumes, in other words, that the per capita amount of production plant and headquarters/central administrative organization for each production worker usually falls within a certain range.[140]

It should also be noted that because this model estimates shipyard fixed costs on the basis of the number of production workers at the yard, it implies that fixed costs would be zero if production was zero and there were no production workers, and that fixed costs would rise in perfect proportion with the number of production workers. As discussed earlier, however, fixed costs would be incurred even if production is zero and would likely rise less than proportionately as production (and the associated number of production workers) increases above zero. For this reason, this model for estimating shipyard fixed costs may underestimate fixed costs for relatively small yards (i.e., those with less than perhaps 3,000 or 5,000 total employees) and overestimate fixed costs for relatively large yards (i.e., those with more than perhaps 10,000 or 15,000 total employees).

Estimates derived from this model are comparable to a 1994 RAND Institution estimate of the fixed costs of a generic submarine construction

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[139] Seventy-four percent of $10.2 million to $18.3 million is about $7.5 million to $13.5 million.

[140] Since the time needed to change the number of production workers through hiring or layoff decisions may differ from the time needed to change the size of the production plant and headquarters/central administrative organization, the ratio between the number of workers and the size of the production plant and headquarters/central administrative organization could temporarily depart from this range while the yard brings the size of its production plant and headquarters/central administrative organization into line with its new level of production workers.

facility of $50 million to $150 million per year in FY1992 dollars.[141] This equates to about $56 million to $167 million in FY1996 dollars.

Estimates derived from this model might also be compared to a 1994 Defense Science Board task force report on DOD's "organic" (i.e., government-operated public-sector) repair depots, of which naval shipyards are one example. This report cited an estimate that "an organic depot with several thousand employees incurs fixed overhead costs in the range of $50-100 million annually."[142] The cost structures of government-operated depots, however, can differ from those of private-sector firms such as the 6 shipyards discussed in this report.

SPREADING OF SHIPYARD FIXED COSTS

If the fixed costs of a single shipyard capable of building major Navy ships are in the tens of millions of dollars per year, then the combined fixed costs of the 6 shipyards discussed in this report might be in the range of $300 million dollars per year (assuming an average of $50 million per yard per year) to $600 million per year (assuming an average of $100 million per yard per year). Since, as mentioned in the background chapter, construction of Navy ships accounts for about 90 percent of the total dollar value of the work done at the 6 yards, about 90 percent of the yards' combined fixed costs, or perhaps $270 million to $540 million per year, might be charged to construction of new Navy ships. This is equivalent to about 5 to 11 percent of the roughly $5 billion that the Administration requested in FY1996 for procurement of major Navy ships,[143] or about 4 to 9 percent of the roughly $6.5 billion that Congress appropriated in FY1996 for procurement of major Navy ships.[144]

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[141] Birkler, John, et al. *The U.S. Submarine Production Base: An Analysis of Cost, Schedule, and Risk for Selected Force Structures.* RAND Institution, Santa Monica, CA, 1994. (National Defense Research Institute, Prepared for the Office of the Secretary of Defense, MR-456-OSD) p. 183. See also Table F.5 on p. 184, and Figures F.7, F.8, and F.9 on p. 185-186. The notional submarine facility in the RAND report could produce up to 3 submarines a year. Such a facility, RAND estimated, would have a production work force of up to 17,045 persons (5,682 per boat). Ibid., p. 173. As noted in the background section, about 74 percent of Industry 3731's workers in 1992 were production workers. Using this figure, a production work force of 17,045 persons would equate to a total shipyard employment level of about 23,034 persons.

[142] U.S. Department of Defense. Office of the Under Secretary of Defense for Acquisition & Technology. *Report of the Defense Science Board Task Force on Depot Maintenance Management.* Washington, 1994. (April 1994) p. 17.

[143] This includes about $4.4 billion in the Shipbuilding and Conversion, Navy (SCN) appropriation account for procurement of SSN-23 and two DDG-51 destroyers, and advanced procurement for a submarine to be procured in FY1998, plus about $600 million in the National Defense Sealift Fund for procurement of two sealift ships.

[144] This includes about $5.9 billion in the Shipbuilding and Conversion, Navy (SCN) appropriation account for procurement of SSN-23, three DDG-51 destroyers, LHD-7, and LPD-17, and advanced procurement for submarines to be procured in FY1998 and FY1999, plus about $600

Some of a firm's fixed costs, such as the costs associated with the size of its production plant, can be altered over time to match recent or expected changes in workload. For example, a firm could respond to a recent or expected reduction in workload by reducing the size and associated fixed costs of its physical plant. A firm's fixed costs are thus completely fixed (that is, completely unchangeable) only in the short run. Over the longer run -- over the course of a few months or a few years -- a firm's fixed costs can be altered to some degree in response to a changing workload.

Some fixed costs, however, are less sensitive to changes in workload, even in the longer run. For example, whether workload is relatively low or high, a particular firm may still need one top executive, one chief financial officer, one head personnel specialist, one chief engineer, one central computer facility, etc.

In addition, although some actions for changing fixed costs might be possible in theory, the firm may view them as undesirable. For example, a firm might be able to reduce its fixed costs to respond to a reduction in workload by selling a portion of its land and facilities, but might choose not to do this out of a desire to preserve the option of using the property at some later point either to expand its production capacity in response to a subsequent increase in workload, or to build a more modern replacement production facility.

As a result, although a firm's total fixed costs can be changed in the longer run, the change is often less than fully proportional to the change in workload. A firm that experiences a reduction in workload may not be able or willing to achieve an equally large percentage reduction in fixed costs, while a firm that experiences an increase in workload may be able to expand its production capacity to meet that increase without incurring a proportionately large increase in its fixed costs.

Fixed costs in this way can contribute to economies of scale and thereby affect relative efficiency in shipbuilding. As workload at the yard decreases, fixed costs often decrease more slowly, becoming larger in relation to workload. Economies of scale are thereby reduced and production becomes less efficient, increasing the cost of each ship. As workload increases, fixed costs often increase more slowly, becoming smaller in relation to workload. Economies of scale are thereby increased and production becomes more efficient, reducing the cost of each ship.

HYPOTHETICAL CASES

For purposes of illustration, consider the simplified hypothetical case of a shipyard with annual fixed costs of $50 million, 90 percent of whose total workload consists of the construction of 2 Navy ships per year (i.e., the yard's workload consists of 9 parts Navy ship construction and 1 part other forms of work), each ship taking 5 years to construct. If 90 percent ($45 million) of the

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million in the National Defense Sealift Fund for procurement of two sealift ships.

yard's annual fixed costs are charged to the construction of Navy ships, and 10 Navy ships are in various stages of construction at the yard (2 ships each in the first, second, third, fourth, and fifth years of construction), then each ship would be charged an average of $4.5 million per year in fixed costs each year that it is under construction, or a total of $22.5 million per ship over the course of its 5-year construction period.

Assume now that Navy ship construction at the yard falls to 1 ship per year and other factors remain unchanged. Within five years, the yard's total workload will drop 45 percent from the previous level, the share of total workload accounted for by Navy ship construction will drop to 81.8 percent (4.5 parts Navy construction, 1 part other work), and the number of Navy ships in various stages of construction at the yard will drop to 5 (1 ship each in the first, second, third, fourth, and fifth years of construction). If 81.8 percent ($40.9 million) of the yard's fixed costs are charged to the construction of Navy ships, then each of the 5 ships in the yard would be charged an average of $8.18 million per year in fixed costs, or a total of $40.9 million (instead of $22.5 million) over the course of its 5-year construction period. The result is an $18.4 million increase in the cost of each ship.

This $18.4 million cost increase can be avoided if the shipyard takes adequate steps to reduce its total fixed costs, increase other forms of work at the yard, or both. For example, reducing the yard's fixed costs by 45 percent (to $27.5 million) to match the percentage reduction in total workload would eliminate the $18.4 million increase. Alternatively, increasing the amount of other forms of work at the yard by 450 percent -- which would maintain the yard's total workload at the original level and reduce the share accounted for by Navy ship construction to 45 percent (4.5 parts Navy ship construction, 5.5 parts other work) -- would also eliminate the $18.4 million increase. Simultaneously reducing fixed costs by 25 percent (to $37.5 million) and tripling other forms of work -- so that the yard's total workload would drop only 25 percent from the original level and Navy ship construction accounted for 60 percent (4.5 parts Navy ship construction, 3 parts other work) -- would do the same.

As discussed earlier, however, it might be difficult for the yard to reduce its fixed costs by a percentage equal to the percentage reduction in its total workload. Similarly, it might be difficult for the shipyard to increase other forms of work as much as suggested in the above hypothetical example, since this could involve competing successfully for this work against other yards that have competed successfully for it in the past and are experienced in doing this work.

If fixed costs and other forms of work cannot be changed enough, then the increase in the cost of each new Navy ship would not be completely avoided. For example, if the yard can reduce its fixed costs by 25 percent (rather than 45 percent) but cannot increase other forms of work, the cost of each ship would increase by about $8.2 million. Alternatively, if the yard can reduce its fixed costs by 15 percent (rather than 25 percent) while doubling (rather than tripling) its other forms of work, then the cost of each ship would increase by about $6.9 million.

For a ship costing a few hundred million dollars, a cost increase of $6.9 million to $18.4 million would equate to an increase of a few percent.

The above hypothetical example examines spreading of fixed costs from the perspective of a single yard. The issue can also be viewed from a multiple-yard perspective. If changes in fixed costs are less than fully proportional to changes in workload, then the fixed costs associated with the capacity to produce a certain number of ships per year can be minimized if that capacity is organized into a smaller rather than larger number of yards.

To again use a simplified hypothetical example for purposes of illustration, consider a case involving shipyards whose only form of work is construction of major Navy ships, and whose annual fixed costs in the long run are, say, $30 million per yard plus $10 million for each major Navy ship per year that each yard is capable of producing, up to a maximum capacity of 6 ships per year per yard. The $30 million figure represents the portion of each yard's fixed costs that are fixed even in the long run (i.e., the costs associated with the need to have one top executive, one chief financial officer, etc.). The $10 million figure represents the portion of each yard's fixed costs that can be altered over the longer run (i.e., the costs associated with the size of the yard's production plant). Using these figures, a yard with a production capacity of 2 ships per year would have annual fixed costs of $50 million, a yard with a capacity of 3 ships per year would have annual fixed costs of $60 million, and a yard with a capacity of 6 ships per year would have annual fixed costs of $90 million.

Consider now a situation where production of major Navy ships drops from 14 per year (roughly the average number procured each year during the 1970s and 1980s) to 6 per year (the approximate number under the Administration's amended FY1996-FY2001 FYDP). Since a single yard in this example can produce a maximum of 6 ships per year, a production rate of 14 ships would require a minimum of 3 yards, while a production rate of 6 ships per year would require a minimum of 1 yard. The reduction from 14 ships per year to 6 ships per year thus raises the question of whether production should be maintained at 3 yards, or consolidated into 2 yards or 1.

If the yard or yards involved reduce their combined production capacity to equal the new production rate of 6 ships per year, then producing the 6 ships per year in 1 yard would incur total annual fixed costs of $90 million; producing the 6 ships in 2 yards would result in total annual fixed costs of $120 million; producing them in 3 yards would result in total annual fixed costs of $150 million. Compared to the 1-yard arrangement, the additional fixed costs of the 2-yard arrangement are $30 million per year or $5 million per ship, while the additional fixed costs of the 3-yard arrangement are $60 million per year or $10 million per ship.

As discussed earlier, however, shipyards may not always be willing to reduce their production capacity to meet current production rates. For example, they may wish to preserve additional production capacity because they intend to bid for and win a greater share of the annual 6-ship Navy workload. If so, then the additional fixed costs of a 2- or 3-yard arrangement compared to a 1-yard arrangement will be greater than $5 million or $10 million per ship, respectively.

If, for example, the yards decide to retain an average capacity of 4 ships per year per yard (two-thirds of their maximum potential capacities), then the annual fixed costs of the 2-yard arrangement would be $140 million (rather than $120 million) for the 2-yard arrangement, while the annual fixed costs of the 3-yard arrangement would be $210 million (rather than $150 million). Compared to the 1-yard arrangement, the additional fixed costs of the 2-yard arrangement would now be about $8.3 million (rather than $5 million) per ship, while the additional fixed costs of the 3-yard arrangement would be $20 million (rather than $10 million) per ship.

Similarly, if the yards decide to maintain their maximum potential capacities of 6 ships per year per yard, then the annual fixed costs of the 2-yard arrangement would be $180 million (rather than $120 million) for the 2-yard arrangement, while the annual fixed costs of the 3-yard arrangement would be $270 million (rather than $150 million). Compared to the 1-yard arrangement, the additional fixed costs of the 2-yard arrangement would now be $15 million (rather than $5 million) per ship, while the additional fixed costs of the 3-yard arrangement would $30 million (rather than $10 million) per ship.

For a ship costing several hundred million dollars, an increase of up to $30 million would equate to an increase in cost of a few or several percent. This figure could be reduced if one or more of the yards start to perform forms of work other than construction of major Navy ships. As noted earlier, however, it may be difficult for the yards to substantially increase their other forms of work.

In summary, although a decline in production rate need not result in an increase in the amount of fixed costs charged to Navy ship construction work, in practice this is often the result. Reductions in workload can lead to reduced efficiency -- that is, higher total ship costs -- as a result of reduced spreading of shipyard fixed costs. But the increase in cost due to reduced spreading of shipyard fixed costs, while amounting to millions or tens of million of dollars per ship, may not be particularly significant in terms of percentage increase in total ship cost.

The above discussion applies to spreading of fixed costs at the shipyard. Changes in production profile can also affect spreading of fixed costs at suppliers, producing additional changes in the total cost of the ship. The total procurement cost of a Navy ship, moreover, includes government overhead costs for things such as the Navy's substantial in-house shipbuilding design and engineering community and Navy shipbuilding program management activities.

Some of these government overhead costs may be relatively insensitive to changes in production rate and may thus be subject to spreading effects analogous to those that apply to shipyard and supplier fixed costs.

APPENDIX C: SHIPYARD LEARNING EFFECTS

LEARNING CURVES IN SHIPBUILDING

Shipbuilding, like many traditional manufacturing activities, exhibits the phenomenon of learning through repetition: As workers at a given production facility repeatedly perform the same production-related task or series of tasks, they learn to do it in increasingly less time. As a result, items produced in a series to a common design can be produced with increasingly less labor and, consequently, increasingly lower labor-related costs.

Labor-related costs[145] account for 20 percent to 40 percent of the total cost of major Navy ships; for more complex ships such as submarines and major surface combatants, the figure is closer to 20 percent, while for less complex ships such as sealift ships, the figure is closer to 40 percent.[146] Learning

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[145] Labor-related costs include both direct labor costs (i.e., wages) and indirect labor costs (e.g., fringe benefits, employer-paid social security taxes, etc.).

[146] Information provided Feb. 21, 1996, to CRS by American Shipbuilding Association. EB officials testified in 1995 that total labor-related costs (both direct labor costs and labor-related overhead) would account for about $2.5 billion, or about 23 percent, of the $11.1 billion combined cost of the first five New Attack Submarines planned by the Administration. (James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. Senate Armed Services Committee Sea Power Subcommittee, May 16, 1995, p. 22.) Shipyard labor accounts for about 21 percent of the total cost of a "typical destroyer." (Rains. Dean A. Naval Ship Affordability. *Naval Engineers Journal*, July 1996: 20 (figure 1).) A 1990 Maritime Administration report estimated that labor-related costs would account for about $35 million, or about 39 percent, of the roughly $89 million construction cost (excluding profit) of a U.S.-built 89,000-deadweight-ton commercial tanker. (U.S. Department of Transportation. Maritime Administration. *Relative Cost of Shipbuilding; A Report to the Congress on the Relative Cost of Shipbuilding in the Various Coastal Districts of the United States.* Washington, 1990. (October 1990) p. 18. Figures cited are averages of separate figures supplied for the Atlantic, Pacific, and Gulf coasts.) Sealift ships are comparable in overall complexity to commercial cargo ships but include military systems and equipment not found on commercial cargo ships. The percentage figure for a sealift ship might thus be lower than the 39 percent figure calculated for the commercial tanker.

Another way to understand the contribution of labor-related costs to total ship cost is to examine the billable labor rate -- also known as the "wrap around rate" or simply the "wrap rate" -- which includes not just direct and indirect labor costs, but an additional charge for fixed overhead costs as well. For the six shipyards involved in this report, the 1995 composite wrap rate was $35.90 per hour. (Source: U.S. Navy Office of Legislative Affairs information sheet provided to CRS, Jan. 9, 1995.) This figure includes a direct labor cost figure of $15.21 per hour (this is a composite figure for both production and engineering workers, appropriately weighted; a figure for production workers only would be lower) plus an additional overhead cost per hour of direct labor. Using this composite figure, each million labor hours required to build the ship would add $35.9 million to its cost. Most kinds of major Navy ships require a few million to several million labor hours to build. According to one press report, for example, a destroyer might require 3 million to 5 million hours. (Wesel, L. Mercedes. Private Contracts No Relief, BIW Says. *Maine Sunday Telegram*, Jan. 28, 1996.) Submarines may require several million to more than 10 million labor hours. The first Ohio (SSBN-726) class Trident SSBN required 24.7 million hours;

effects can thus have a noticeable effect on the total cost of major Navy ships.

The pattern of reduction in the amount of labor required to produce each unit in a series, when presented in graph form, is called a learning curve.[147] The basic learning curve used in shipbuilding and many other traditional manufacturing industries -- the Crawford or logarithmic-linear learning curve model -- is derived from empirical studies of traditional manufacturing activities[148] and refers to the percentage reduction in labor required for each unit produced in a series in a given production facility that is achieved with each doubling of production quantity at that facility. For example, with a 90 percent learning curve, the second unit built at that production facility can be built with 90 percent as much labor as the first, the fourth with 90 percent as much as the second, the eighth with 90 percent as much labor as the fourth, and so on.[149]

Most traditional manufacturing activities demonstrate learning curves between 70 percent (significant learning) and 100 percent (no learning). For the shipbuilding industry, learning curves appear to fall generally between 80 percent and 95 percent. More complex ships, such as submarines and major surface combatants, may exhibit greater learning (since they are more complex,

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the first Los Angeles (SSN-688) class SSN required 11.3 million hours, and the first Seawolf (SSN-21) class SSN was originally budgeted for 12.5 million hours. (U.S. Congress. House. Committee on Appropriations. *[Hearings on] Department of Defense Appropriations for [Fiscal Year] 1989*, 100th Cong., 2nd Sess., Part 6. Washington, U.S. Govt. Print. Off., 1988. p. 292.) (According to one press report, the first Seawolf will actually require 21.5 million hours, while the second will require 14.1 million hours. Electric Boat Official: Quonset Point Layoffs Definite, Closure Possible. Associated Press wire story, Mar. 14, 1995.) Aircraft carriers, which are much larger than other Navy ships, require about 40 million labor hours. (U.S. Navy on-line Fact File, page entitled "The Building of an Aircraft Carrier," [http://www.navy.mil/homepages/jcs/cvbuild.html], updated July 6, 1996.)

147 Other terms that are used include cost-improvement curve, progress curve, experience curve, or learning by doing.

148 For early empirical discussions, see Conway, R. W., and Andrew Schultz. The Manufacturing Progress Function. *Journal of Industrial Engineering*, January-February, 1959: 39-54; Rapping, Leonard. Learning and World War II Production Functions. *The Review of Economics and Statistics*, February 1965 (v. 47): 81-86. See also Argote, Linda, and Dennis Epple. Learning Curves in Manufacturing. *Science*, Feb. 23, 1990 (v. 247): 920-924.

149 For general discussions of learning curves, see Teplitz, Charles J. *The Learning Curve Deskbook, A Reference Guide to Theory, Calculations, and Applications.* New York, Quorum Books, 1991. 288 p.; Smith, Jason. *Learning Curves for Cost Control.* Norcross, GA, Industrial Engineering and Management Press, Institute of Industrial Engineers, 1989. 84 p.; and Riahi-Belkaoui. *The Learning Curve: A Management Accounting Tool.* Westport, CT, Quorum Books, 1986. 245 p.

there is more to learn), while less complex ships, such as sealift ships, may exhibit less learning (since they are less complex, there is less to learn).[150]

Figure 3 displays 80, 85, 90, and 95 percent learning curves. As can be seen in the figure, the amount of labor required to build a given ship, expressed in terms of a percentage of the amount of labor required to build the first ship of that class, can vary greatly depending on the facility-specific sequence number of the ship in question and the rate of learning for the program to build ships of that class. For example, the fourth ship produced at a given facility in a shipbuilding program with a 90 percent learning curve will require about 81 percent as much labor as the first ship of that class, while the 16th ship produced at a given facility in a shipbuilding program with an 85 percent learning curve will require about 52 percent as much labor as the first ship of that class.

SPLITTING THE LEARNING CURVE

Decisions regarding the acquisition strategy for a class can alter both a ship's facility-specific sequence number and the program's rate of learning. Facility-specific sequence number can be significantly altered by a decision on the number of shipyards to include in a shipbuilding program. For purposes of discussion, assume a shipbuilding program with a 90 percent learning curve to build a class of 15 ships. If one shipyard (call it Yard A) builds all 15 ships,

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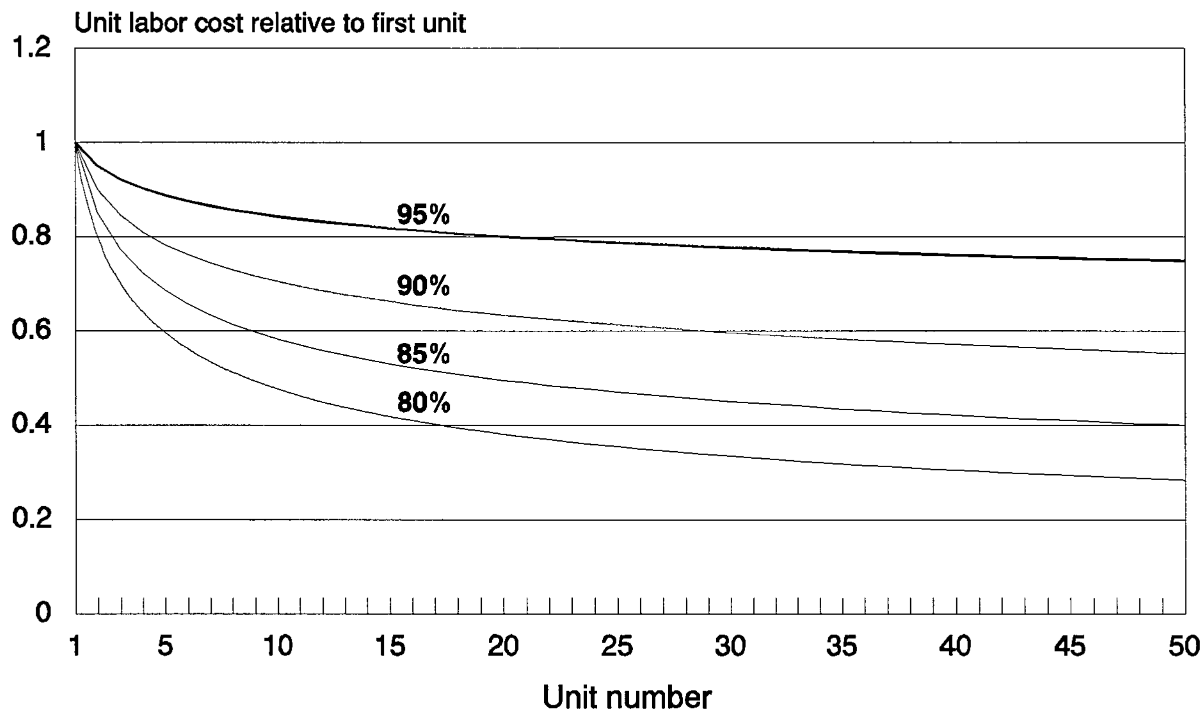
[150] EB officials testified in 1995 that the 15th Ohio (SSBN-726) class ballistic missile submarine was built with one-half of the recurring labor hours as the first ship; this equates to a learning curve rate of about 84 percent. They also stated that the number of labor hours required to complete an identical portion of work on SSN-22, the second Seawolf (SSN-21) class submarine, averages 85 percent of the amount required on SSN-21, the first Seawolf submarine. This equates to a learning curve of 85 percent, which they testified equates to the learning curve of the Trident program. (James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. House of Representatives Committee on National Security Military Procurement Subcommittee, March 16, 1995, p. 10, 12). A 1992 report from the Center for Naval Analyses stated that learning curve rates for Liberty- and Victory-class cargo ships built during World War II were 78 percent to 84 percent and 76 percent to 90 percent, respectively; that the learning curve rate for Knox (FF-1052) class frigates built from the mid-1960s to the early 1970s has been estimated at 88 percent; that the learning curve rate for Spruance (DD-963) class destroyers built from the mid-1970s to the early 1980s has been estimated at 78 percent; and that a learning curve rate of 88 percent for a commercial cargo ship was suggested by the Shipbuilders Council of America and seemed reasonable. (Rost, Ronald F., and Carla Tighe. *Shipyard Costs and Capabilities (U).* Alexandria, Center for Naval Analyses, 1992. (CRM [Center for Naval Analyses Research Memorandum] 92-13, May 1992, Confidential.) p. 11-12. Pages 11 and 12 are unclassified; material from them is used here with the permission of Navy Office of Legislative Affairs, Feb. 10, 1995.) A text on ship production states that the percent improvement realized in the *average cost* of all units each time the accumulated unit production is doubled (known as the Wright learning curve model) has generally been 5 percent to 10 percent. This equates to a *unit cost* (Crawford) learning curve of about 87 percent to 93 percent. (Storch, Richard Lee, Colin P. Hammon, and Howard M. Bunch. *Ship Production.* Centreville, MD, Cornell Maritime Press, 1988. p. 31.) Older sources generally cite similar figures.

Figure 3. **Learning curves: unit labor costs**

For 80%, 85%, 90%, and 95% curves



Source: Prepared by CRS, 9/95, based on standard tables.

there is only one learning curve to move down, and there is no difference between a ship's position in the program's overall sequence and its position in the yard's learning curve: The eighth ship in the program is the eighth ship on Yard A's learning curve, and requires 72.9 percent as much labor to build as the first ship in the class, while the thirteenth ship in the program is the thirteenth on Yard A's curve, and requires 67.7 percent as much labor to build as the first ship in the class.

Assume now that the 15 ships are to be built by two yards (Yard A and Yard B) rather than one, that each yard builds half of the ships, that individual ships are built by alternate yards, and that both yards achieve a 90 percent learning curve. Now there are two learning curves to move down -- a situation sometimes referred to as a "split" learning curve -- and a resulting difference between a ship's position in the program's overall sequence and its position in a yard's learning curve. The eighth ship in the program is now the fourth ship on a yard's learning curve (Yard B's), and requires 81 percent as much labor to build as the first ship in the class, while the thirteenth ship is now the seventh ship on a yard's learning curve (Yard A's), and requires 74.4 percent as much labor to build as the first ship in the class.

Compared to the single-yard production strategy, labor costs have been increased by 11.1 percent for the eighth ship in the program and by 9.9 percent for the thirteenth ship in the program.[151] Since labor-related costs constitute 20 percent to 40 percent of total ship cost, splitting the learning curve between Yards A and B, all other factors held equal, has increased the total cost of the eighth and thirteenth ships by about 2 to 4 percent.

Figure 4 shows the additional labor costs of a two-yard acquisition strategy relative to a one-yard strategy for various learning curve rates and total production quantities. As can be seen in the figure, dividing a shipbuilding program between two yards rather than building all the ships in the program in one yard can increase labor-related costs by roughly 5 percent to 20 percent, depending mostly on the rate of learning. For example, the figure shows that splitting a 22-ship program with an 85 percent learning curve between two yards, all other factors held equal, would increase the labor-related costs for producing all 22 ships by about 15 percent. For more complex ships, where labor costs might account for about 25 percent of total ship costs and the learning curve might be about 85 percent, the increase in the total cost of the shipbuilding program might be about 4 percent (about 25 percent of a 15 percent increase in labor-related costs). For less complex ships, where labor costs might account for about 35 percent of total ship costs and the learning curve might be 95 percent, the increase in the total cost of the shipbuilding program might be about 2 percent (about 35 percent of a 5 percent increase in labor-related costs).

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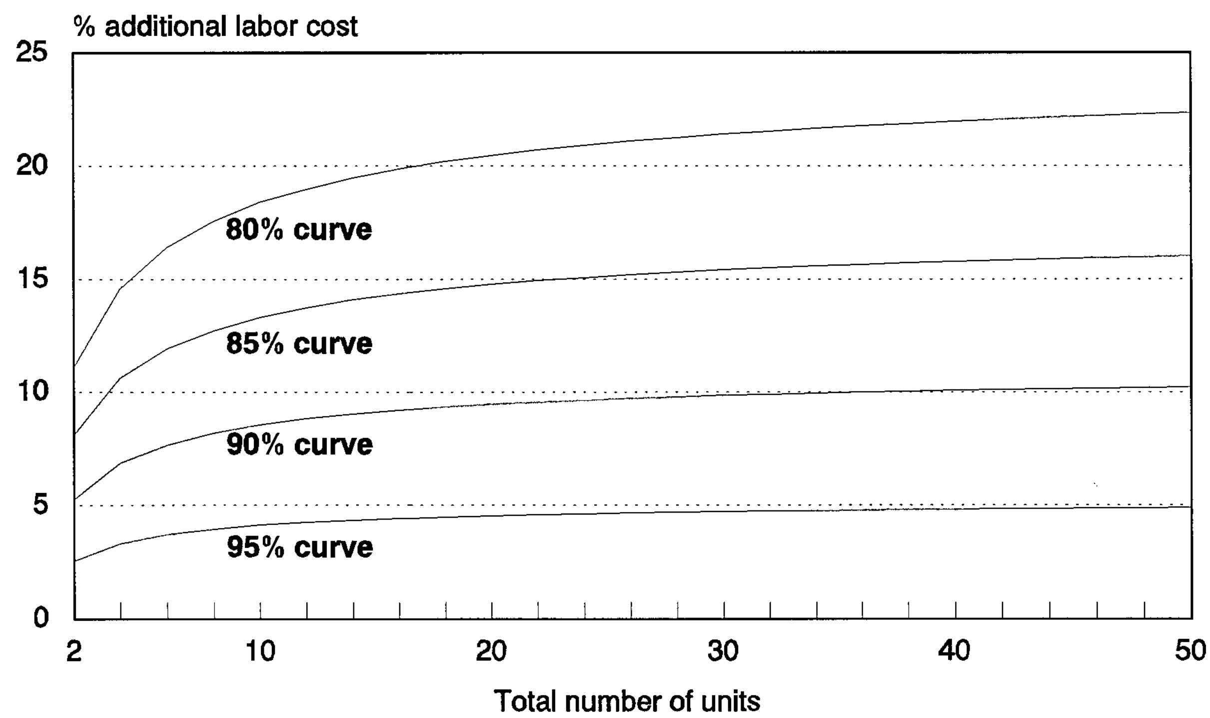
[151] 81 percent is 8.1 *percentage points* -- but 11.1 *percent* -- greater than 72.9 percent; 74.4 percent is 6.7 *percentage points* -- but 9.9 *percent* -- greater than 67.7 percent.

Figure 4. Add'l labor cost of split learning curve

Relative to unified learning curve



Source: Prepared by CRS, 9/95, based on standard tables.

Splitting a shipbuilding program between 3 yards rather than 2 would further increase labor-related costs due to additional splitting of the learning curve. Returning to the hypothetical 15-ship program discussed above, under a 3-yard strategy where the shipyards rotate production of individual ships (one ship to Yard A, one to Yard B, one to Yard C, then another to Yard A, and so on), the eighth ship in the program would now be the third ship on a yard's learning curve (Yard B's), and would require 84.6 percent as much labor to build as the first ship in the class (as opposed to 72.9 percent for a 1-yard strategy or 81 percent for a 2-yard strategy), while the thirteenth ship in the program would now be the fourth ship on a yard's learning curve (Yard A's), and would require 81 percent as much labor to build as the first ship in the class (as opposed to 67.7 percent for a 1-yard strategy or 74.4 percent for a 2-yard strategy).

LOSS OF LEARNING

A program's rate of learning might also be affected by the rate of production at a shipyard. In a shipbuilding program, if the production rate falls low enough, the amount of time between ships can be so great that the rate of learning is reduced below what it could be if the rate of production at the yard were higher and the ships were spaced more closely together. The effect is analogous to a piano student whose rate of learning is reduced because practice sessions were reduced from one per day to one every other day.[152]

Interviews with industry officials suggest that reduced learning can occur at a shipyard if the production rate of a given kind of ship falls below one ship per year at the shipyard;[153] one industry official suggested that reducing the production rate at a yard of a given class of ships might add roughly three percentage points to the program's learning curve. An 88 percent learning curve, for example, might be achieved, rather than an 85 percent curve.

Figure 5 shows the additional labor-related costs associated with a 1-, 3-, or 5-percentage point reduction in the rate of learning. As can be seen in the figure, the increase in labor-related costs depends mostly on the extent of the reduction in learning and the total numbers produced. The resulting absolute learning rate, in contrast, has relatively little impact. For example, the figure shows that, for a program involving the construction of 5 ships at a given shipyard, a 3-percentage-point reduction in the rate of learning can increase the total labor-related costs for the 5 ships produced at that shipyard by about 5 percent; whether the resulting learning curve is 83 percent or 98 percent makes little difference. Since labor-related costs account for 20 percent to 40 percent

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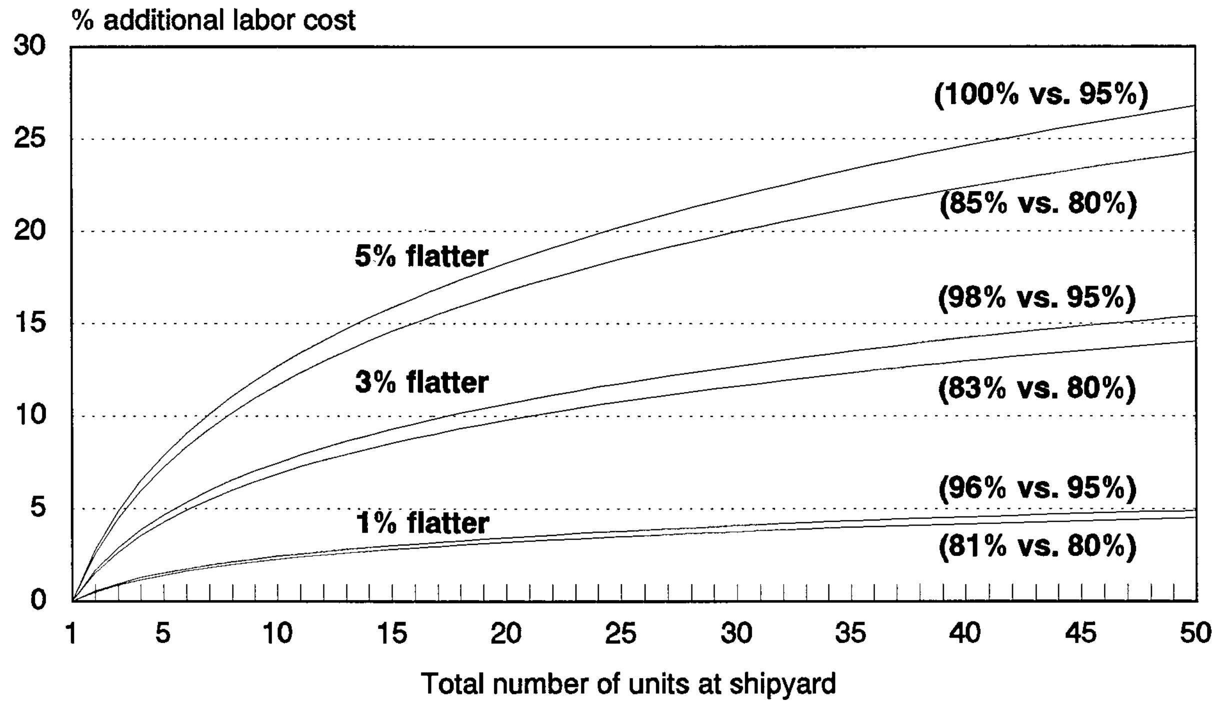
[152] For short discussions of the effect of production rate on the rate of learning, see *The Learning Curve Deskbook*, op. cit., p. 133; and Bemis, John C. A Model for Examining the Cost Implications of Production Rate. *Concepts,* v. 4, n. 2, Spring 1981: 84-94.

[153] For aircraft carriers, which in recent decades have been funded at an average rate of less than one ship per year, but which take several years to build, loss of learning may occur if individual carriers are built more than a few years apart from one another.

Figure 5. Add'l labor cost of reduced learning

Result of 1%, 3%, or 5% flatter curve



Source: Prepared by CRS, 9/95, based on standard tables of total ship costs, the resulting increase in the total cost of the 5 ships produced at that yard would be 1 percent to 2 percent.

As the total number of ships of a certain class produced at the yard increases above 5 ships, the increase in labor-related costs due to reduced learning rises, but likelihood of reduced learning due to a very low production rate declines because the increasing total number of ships to be produced makes it less likely that the production rate at a shipyard will fall to less than one ship per year. For this reason, although Figure 5 shows the additional labor-related costs of reduced learning for a shipyard producing as many as 50 ships of a certain class, the most likely scenarios are for cases where the shipyard produces 10 or fewer ships of a given class.

Compared to a very low rate of production at a shipyard, a break in production at a shipyard can result in even more significant loss of learning at that shipyard. If production of a certain class of ships is suspended at a shipyard and then restarted years later, the shipyard might have to return to a higher point on the learning curve for that class, and then move down the learning curve a second time. In general, the greater the length of the production break, the greater will be the loss in learning.[154]

CLASS SIZE AND AVERAGE COST

Independent of splitting the learning curve or causing a loss of learning, the total number of units produced can result in a learning-related effect on average production costs. The reduction in *unit* labor-related costs shown in Figure 3 leads to a similar though more gentle reduction in *average* labor-related costs shown in Figure 6.

A decision made to reduce the size of a planned class of ships to a smaller number than originally planned can thus lead to an increase in the average cost of the ships, because the class will now include only the earlier ships in the originally planned program, with their relatively higher labor-related costs, and will no longer include the later ships in the originally planned program, with their relatively low labor-related costs. For example, in a 1-yard shipbuilding program with a 90 percent learning curve, a decision to reduce the total number of ships produced from 20 to 10 will increase the average amount of labor

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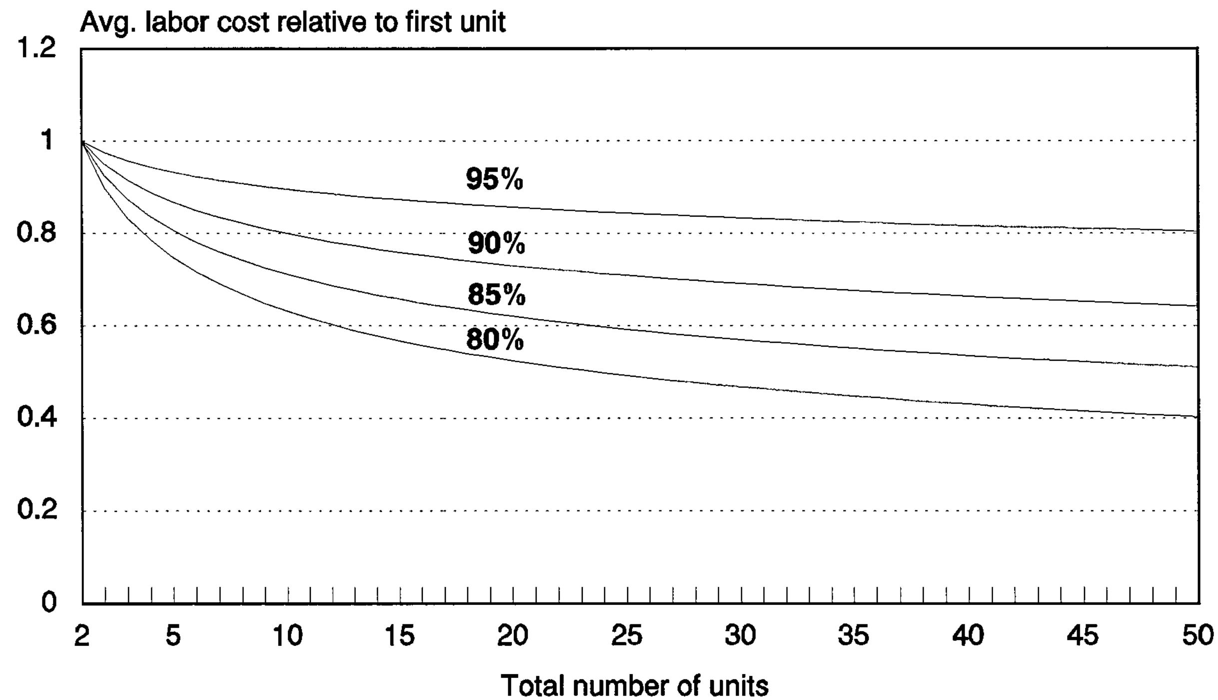
[154] For short discussions of loss of learning resulting from a break in production, see *The Learning Curve Deskbook*, op. cit., p. 144-150; *Learning Curve for Cost Control*, op. cit., p. 49-54; and Mukherjee, Mrinal K., and Richard J. Baker. Impact of Closing and Reopening a Production Line. *Program Manager*, March-April 1990: 19-23.

Figure 6. Learning curves: average labor costs

For 80%, 85%, 90%, and 95% curves



Source: Prepared by CRS, 9/95, based on standard tables.

required to produce each from 73 percent of the labor required for the first ship to 79.9 percent -- a 9.5 percent increase.[155]

As with the discussion of spreading of fixed costs, the discussion here of learning effects focused on effects at the shipyard only. Learning effects due to splitting of the learning curve or reduced learning rates can also occur at the supplier level, creating additional effects on total ship cost.

LEARNING CURVE TABLES

The tables below show unit (U), cumulative total (T), and cumulative average (A) values for the learning-influenced (i.e., labor-related) costs of units 1 through 65 for production programs with 80 to 99 percent unit cost (i.e., Crawford model) learning curves, as presented in Appendix D of Teplitz, Charles J. *The Learning Curve Deskbook, A Reference Guide to Theory, Calculations, and Applications.* New York, Quorum Books, 1991. 288 p. (Reproduced here with permission of the publisher.).

The tables show, for example, that for a production program with an 80 percent learning curve, the 6th unit will have 56.2 percent as much labor-related costs as the first unit, and the first 6 units will have cumulative labor-related costs equal to about 4.3 times the labor costs of the first unit, or an average for each of the 6 units of 71.7 percent as much labor-related costs as the first unit.

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[155] 79.9 percent is 6.9 *percentage points*, but about 9.5 *percent*, greater than 73 percent. Reduced average learning can also occur in a numerically large class if the design of the class is periodically modified. Such periodic modifications, which are usually intended to update the technology incorporated into the design, have the effect of splitting the class into a series of groups known as baselines or flights. The SSN-688, CG-47, and DDG-51 programs are recent examples of numerically large classes that are divided into sub-groups as a result of periodic design modifications. For a shipyard building ships of a class that experiences such periodic modifications, the first ship that the yard builds to a modified design may require an increased amount of labor for the parts of the ship affected by the design modification. The resulting pattern of learning at the shipyard, when graphed, could be a saw-toothed line (with periodic increases each time a design modification was introduced) rather than a classic (i.e., smoothly descending) learning curve. Such a saw-toothed pattern would equate to a reduced average rate of learning for all the ships of that class built at the shipyard. For a discussion of reduced learning due product design changes, see *The Learning Curve Deskbook*, op. cit., p. 150-154.

Unit	80			81			82			83		
i	U	T	A	U	T	A	U	T	A	U	T	A
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.800	1.800	0.900	0.810	1.810	0.905	0.820	1.820	0.910	0.830	1.830	0.915
3	0.702	2.502	0.834	0.716	2.526	0.842	0.730	2.550	0.850	0.744	2.574	0.858
4	0.640	3.142	0.786	0.656	3.182	0.796	0.672	3.223	0.806	0.689	3.263	0.816
5	0.596	3.738	0.748	0.613	3.795	0.759	0.631	3.853	0.771	0.649	3.912	0.782
6	0.562	4.299	0.717	0.580	4.375	0.729	0.599	4.452	0.742	0.618	4.530	0.755
7	0.534	4.834	0.691	0.553	4.929	0.704	0.573	5.025	0.718	0.593	5.122	0.732
8	0.512	5.346	0.668	0.531	5.460	0.683	0.551	5.576	0.697	0.572	5.694	0.712
9	0.493	5.839	0.649	0.513	5.973	0.664	0.533	6.109	0.679	0.554	6.248	0.694
10	0.477	6.315	0.632	0.497	6.469	0.647	0.517	6.627	0.663	0.538	6.787	0.679
11	0.462	6.777	0.616	0.482	6.952	0.632	0.503	7.130	0.648	0.525	7.312	0.665
12	0.449	7.227	0.602	0.470	7.422	0.618	0.491	7.621	0.635	0.513	7.824	0.652
13	0.438	7.665	0.590	0.459	7.880	0.606	0.480	8.101	0.623	0.502	8.326	0.640
14	0.428	8.092	0.578	0.448	8.329	0.595	0.470	8.570	0.612	0.492	8.818	0.630
15	0.418	8.511	0.567	0.439	8.768	0.585	0.461	9.031	0.602	0.483	9.301	0.620
16	0.410	8.920	0.558	0.430	9.198	0.575	0.452	9.483	0.593	0.475	9.776	0.611
17	0.402	9.322	0.548	0.423	9.621	0.566	0.444	9.927	0.584	0.467	10.242	0.602
18	0.394	9.716	0.540	0.415	10.036	0.558	0.437	10.365	0.576	0.460	10.702	0.595
19	0.388	10.104	0.532	0.409	10.444	0.550	0.430	10.795	0.568	0.453	11.155	0.587
20	0.381	10.485	0.524	0.402	10.847	0.542	0.424	11.219	0.561	0.447	11.602	0.580
21	0.375	10.860	0.517	0.396	11.243	0.535	0.418	11.637	0.554	0.441	12.043	0.573
22	0.370	11.230	0.510	0.391	11.634	0.529	0.413	12.050	0.548	0.436	12.479	0.567
23	0.364	11.594	0.504	0.386	12.019	0.523	0.408	12.458	0.542	0.430	12.910	0.561
24	0.359	11.954	0.498	0.381	12.400	0.517	0.403	12.860	0.536	0.426	13.335	0.556
25	0.355	12.309	0.492	0.376	12.776	0.511	0.398	13.258	0.530	0.421	13.756	0.550
26	0.350	12.659	0.487	0.371	13.147	0.506	0.393	13.651	0.525	0.417	14.173	0.545
27	0.346	13.005	0.482	0.367	13.514	0.501	0.389	14.041	0.520	0.412	14.585	0.540
28	0.342	13.347	0.477	0.363	13.877	0.496	0.385	14.426	0.515	0.408	14.993	0.535
29	0.338	13.685	0.472	0.359	14.237	0.491	0.381	14.807	0.511	0.404	15.398	0.531
30	0.335	14.020	0.467	0.356	14.592	0.486	0.378	15.185	0.506	0.401	15.798	0.527
31	0.331	14.351	0.463	0.352	14.944	0.482	0.374	15.559	0.502	0.397	16.196	0.522
32	0.328	14.679	0.459	0.349	15.293	0.478	0.371	15.930	0.498	0.394	16.590	0.518
33	0.324	15.003	0.455	0.345	15.638	0.474	0.367	16.297	0.494	0.391	16.980	0.515
34	0.321	15.324	0.451	0.342	15.981	0.470	0.364	16.662	0.490	0.388	17.368	0.511
35	0.318	15.643	0.447	0.339	16.320	0.466	0.361	17.023	0.486	0.385	17.752	0.507
36	0.315	15.958	0.443	0.336	16.656	0.463	0.358	17.381	0.483	0.382	18.134	0.504
37	0.313	16.271	0.440	0.334	16.990	0.459	0.356	17.737	0.479	0.379	18.513	0.500
38	0.310	16.581	0.436	0.331	17.321	0.456	0.353	18.090	0.476	0.376	18.889	0.497
39	0.307	16.888	0.433	0.328	17.649	0.453	0.350	18.440	0.473	0.374	19.262	0.494
40	0.305	17.193	0.430	0.326	17.975	0.449	0.348	18.788	0.470	0.371	19.633	0.491
41	0.303	17.496	0.427	0.323	18.298	0.446	0.345	19.133	0.467	0.369	20.002	0.488
42	0.300	17.796	0.424	0.321	18.619	0.443	0.343	19.476	0.464	0.366	20.368	0.485
43	0.298	18.094	0.421	0.319	18.938	0.440	0.341	19.817	0.461	0.364	20.732	0.482
44	0.296	18.390	0.418	0.317	19.255	0.438	0.338	20.156	0.458	0.362	21.094	0.479
45	0.294	18.684	0.415	0.314	19.569	0.435	0.336	20.492	0.455	0.359	21.453	0.477
46	0.292	18.975	0.413	0.312	19.881	0.432	0.334	20.826	0.453	0.357	21.810	0.474
47	0.290	19.265	0.410	0.310	20.192	0.430	0.332	21.158	0.450	0.355	22.165	0.472
48	0.288	19.552	0.407	0.308	20.500	0.427	0.330	21.488	0.448	0.353	22.519	0.469
49	0.286	19.838	0.405	0.306	20.806	0.425	0.328	21.816	0.445	0.351	22.870	0.467
50	0.284	20.122	0.402	0.304	21.111	0.422	0.326	22.143	0.443	0.349	23.219	0.464
51	0.282	20.404	0.400	0.303	21.413	0.420	0.324	22.467	0.441	0.348	23.567	0.462
52	0.280	20.684	0.398	0.301	21.714	0.418	0.323	22.790	0.438	0.346	23.913	0.460
53	0.279	20.963	0.396	0.299	22.013	0.415	0.321	23.110	0.436	0.344	24.256	0.458
54	0.277	21.239	0.393	0.297	22.310	0.413	0.319	23.430	0.434	0.342	24.599	0.456
55	0.275	21.515	0.391	0.296	22.606	0.411	0.317	23.747	0.432	0.341	24.939	0.453
56	0.274	21.788	0.389	0.294	22.900	0.409	0.316	24.063	0.430	0.339	25.278	0.451
57	0.272	22.060	0.387	0.293	23.193	0.407	0.314	24.377	0.428	0.337	25.615	0.449
58	0.271	22.331	0.385	0.291	23.484	0.405	0.313	24.690	0.426	0.336	25.951	0.447
59	0.269	22.600	0.383	0.290	23.773	0.403	0.311	25.001	0.424	0.334	26.285	0.446
60	0.268	22.868	0.381	0.288	24.061	0.401	0.310	25.311	0.422	0.333	26.618	0.444
61	0.266	23.134	0.379	0.287	24.348	0.399	0.308	25.619	0.420	0.331	26.949	0.442
62	0.265	23.399	0.377	0.285	24.633	0.397	0.307	25.926	0.418	0.330	27.279	0.440
63	0.263	23.662	0.376	0.284	24.917	0.396	0.305	26.231	0.416	0.328	27.607	0.438
64	0.262	23.924	0.374	0.282	25.199	0.394	0.304	26.535	0.415	0.327	27.934	0.436
65	0.261	24.185	0.372	0.281	25.481	0.392	0.303	26.838	0.413	0.326	28.260	0.435

Unit	84			85			86			87		
i	U	T	A	U	T	A	U	T	A	U	T	A
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.840	1.840	0.920	0.850	1.850	0.925	0.860	1.860	0.930	0.870	1.870	0.935
3	0.759	2.599	0.866	0.773	2.623	0.874	0.787	2.647	0.882	0.802	2.672	0.891
4	0.706	3.304	0.826	0.723	3.345	0.836	0.740	3.387	0.847	0.757	3.429	0.857
5	0.667	3.971	0.794	0.686	4.031	0.806	0.705	4.092	0.818	0.724	4.153	0.831
6	0.637	4.608	0.768	0.657	4.688	0.781	0.677	4.769	0.795	0.698	4.850	0.808
7	0.613	5.221	0.746	0.634	5.322	0.760	0.655	5.423	0.775	0.676	5.527	0.790
8	0.593	5.814	0.727	0.614	5.936	0.742	0.636	6.060	0.757	0.659	6.185	0.773
9	0.575	6.389	0.710	0.597	6.533	0.726	0.620	6.679	0.742	0.643	6.828	0.759
10	0.560	6.950	0.695	0.583	7.116	0.712	0.606	7.285	0.729	0.630	7.458	0.746
11	0.547	7.497	0.682	0.570	7.686	0.699	0.593	7.879	0.716	0.618	8.076	0.734
12	0.535	8.032	0.669	0.558	8.244	0.687	0.582	8.461	0.705	0.607	8.683	0.724
13	0.525	8.557	0.658	0.548	8.792	0.676	0.572	9.034	0.695	0.597	9.280	0.714
14	0.515	9.072	0.648	0.539	9.331	0.667	0.563	9.597	0.685	0.588	9.868	0.705
15	0.506	9.578	0.639	0.530	9.861	0.657	0.555	10.151	0.677	0.580	10.449	0.697
16	0.498	10.075	0.630	0.522	10.383	0.649	0.547	10.698	0.669	0.573	11.022	0.689
17	0.490	10.566	0.622	0.515	10.898	0.641	0.540	11.238	0.661	0.566	11.588	0.682
18	0.483	11.049	0.614	0.508	11.405	0.634	0.533	11.771	0.654	0.559	12.147	0.675
19	0.477	11.526	0.607	0.501	11.907	0.627	0.527	12.298	0.647	0.553	12.701	0.668
20	0.471	11.997	0.600	0.495	12.402	0.620	0.521	12.819	0.641	0.548	13.248	0.662
21	0.465	12.462	0.593	0.490	12.892	0.614	0.516	13.335	0.635	0.542	13.791	0.657
22	0.460	12.921	0.587	0.484	13.376	0.608	0.510	13.845	0.629	0.537	14.328	0.651
23	0.454	13.376	0.582	0.479	13.856	0.602	0.505	14.351	0.624	0.533	14.861	0.646
24	0.450	13.825	0.576	0.475	14.331	0.597	0.501	14.852	0.619	0.528	15.389	0.641
25	0.445	14.270	0.571	0.470	14.801	0.592	0.496	15.348	0.614	0.524	15.913	0.637
26	0.441	14.711	0.566	0.466	15.267	0.587	0.492	15.840	0.609	0.520	16.432	0.632
27	0.436	15.147	0.561	0.462	15.728	0.583	0.488	16.328	0.605	0.516	16.948	0.628
28	0.432	15.580	0.556	0.458	16.186	0.578	0.484	16.813	0.600	0.512	17.460	0.624
29	0.429	16.008	0.552	0.454	16.640	0.574	0.481	17.293	0.596	0.508	17.968	0.620
30	0.425	16.434	0.548	0.450	17.091	0.570	0.477	17.770	0.592	0.505	18.473	0.616
31	0.422	16.855	0.544	0.447	17.538	0.566	0.474	18.244	0.589	0.502	18.975	0.612
32	0.418	17.273	0.540	0.444	17.981	0.562	0.470	18.714	0.585	0.498	19.473	0.609
33	0.415	17.688	0.536	0.441	18.422	0.558	0.467	19.182	0.581	0.495	19.969	0.605
34	0.412	18.100	0.532	0.437	18.859	0.555	0.464	19.646	0.578	0.492	20.461	0.602
35	0.409	18.509	0.529	0.434	19.294	0.551	0.461	20.107	0.574	0.490	20.951	0.599
36	0.406	18.915	0.525	0.432	19.725	0.548	0.459	20.566	0.571	0.487	21.437	0.595
37	0.403	19.318	0.522	0.429	20.154	0.545	0.456	21.022	0.568	0.484	21.921	0.592
38	0.401	19.719	0.519	0.426	20.580	0.542	0.453	21.475	0.565	0.482	22.403	0.590
39	0.398	20.117	0.516	0.424	21.004	0.539	0.451	21.925	0.562	0.479	22.882	0.587
40	0.395	20.512	0.513	0.421	21.425	0.536	0.448	22.374	0.559	0.477	23.358	0.584
41	0.393	20.905	0.510	0.419	21.844	0.533	0.446	22.819	0.557	0.474	23.833	0.581
42	0.391	21.296	0.507	0.416	22.260	0.530	0.443	23.263	0.554	0.472	24.305	0.579
43	0.388	21.684	0.504	0.414	22.674	0.527	0.441	23.704	0.551	0.470	24.774	0.576
44	0.386	22.070	0.502	0.412	23.086	0.525	0.439	24.143	0.549	0.468	25.242	0.574
45	0.384	22.454	0.499	0.410	23.496	0.522	0.437	24.580	0.546	0.465	25.707	0.571
46	0.382	22.835	0.496	0.408	23.903	0.520	0.435	25.014	0.544	0.463	26.171	0.569
47	0.380	23.215	0.494	0.405	24.309	0.517	0.433	25.447	0.541	0.461	26.632	0.567
48	0.378	23.593	0.492	0.403	24.712	0.515	0.431	25.878	0.539	0.459	27.091	0.564
49	0.376	23.969	0.489	0.402	25.113	0.513	0.429	26.306	0.537	0.458	27.549	0.562
50	0.374	24.342	0.487	0.400	25.513	0.510	0.427	26.733	0.535	0.456	28.005	0.560
51	0.372	24.714	0.485	0.398	25.911	0.508	0.425	27.158	0.533	0.454	28.459	0.558
52	0.370	25.084	0.482	0.396	26.307	0.506	0.423	27.582	0.530	0.452	28.911	0.556
53	0.368	25.453	0.480	0.394	26.701	0.504	0.422	28.003	0.528	0.450	29.361	0.554
54	0.367	25.819	0.478	0.392	27.094	0.502	0.420	28.423	0.526	0.449	29.810	0.552
55	0.365	26.184	0.476	0.391	27.484	0.500	0.418	28.841	0.524	0.447	30.257	0.550
56	0.363	26.548	0.474	0.389	27.873	0.498	0.416	29.258	0.522	0.445	30.702	0.548
57	0.362	26.909	0.472	0.388	28.261	0.496	0.415	29.672	0.521	0.444	31.146	0.546
58	0.360	27.269	0.470	0.386	28.647	0.494	0.413	30.086	0.519	0.442	31.588	0.545
59	0.359	27.628	0.468	0.384	29.031	0.492	0.412	30.498	0.517	0.441	32.029	0.543
60	0.357	27.985	0.466	0.383	29.414	0.490	0.410	30.908	0.515	0.439	32.468	0.541
61	0.356	28.341	0.465	0.381	29.796	0.488	0.409	31.317	0.513	0.438	32.906	0.539
62	0.354	28.695	0.463	0.380	30.176	0.487	0.407	31.724	0.512	0.436	33.343	0.538
63	0.353	29.047	0.461	0.379	30.554	0.485	0.406	32.130	0.510	0.435	33.778	0.536
64	0.351	29.399	0.459	0.377	30.931	0.483	0.405	32.535	0.508	0.434	34.211	0.535
65	0.350	29.749	0.458	0.376	31.307	0.482	0.403	32.938	0.507	0.432	34.643	0.533

Unit	88			89			90			91		
I	U	T	A	U	T	A	U	T	A	U	T	A
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.880	1.880	0.940	0.890	1.890	0.945	0.900	1.900	0.950	0.910	1.910	0.955
3	0.817	2.697	0.899	0.831	2.721	0.907	0.846	2.746	0.915	0.861	2.771	0.924
4	0.774	3.471	0.868	0.792	3.513	0.878	0.810	3.556	0.889	0.828	3.599	0.900
5	0.743	4.214	0.843	0.763	4.276	0.855	0.783	4.339	0.868	0.803	4.403	0.881
6	0.719	4.933	0.822	0.740	5.016	0.836	0.762	5.101	0.850	0.784	5.186	0.864
7	0.698	5.631	0.804	0.721	5.737	0.820	0.744	5.845	0.835	0.767	5.954	0.851
8	0.681	6.313	0.789	0.705	6.442	0.805	0.729	6.574	0.822	0.754	6.707	0.838
9	0.667	6.980	0.776	0.691	7.133	0.793	0.716	7.290	0.810	0.742	7.449	0.828
10	0.654	7.634	0.763	0.679	7.812	0.781	0.705	7.994	0.799	0.731	8.180	0.818
11	0.643	8.276	0.752	0.668	8.481	0.771	0.695	8.689	0.790	0.722	8.901	0.809
12	0.632	8.909	0.742	0.659	9.139	0.762	0.685	9.374	0.781	0.713	9.615	0.801
13	0.623	9.532	0.733	0.650	9.789	0.753	0.677	10.052	0.773	0.705	10.320	0.794
14	0.615	10.146	0.725	0.642	10.431	0.745	0.670	10.721	0.766	0.698	11.018	0.787
15	0.607	10.753	0.717	0.634	11.065	0.738	0.663	11.384	0.759	0.692	11.710	0.781
16	0.600	11.353	0.710	0.627	11.692	0.731	0.656	12.040	0.752	0.686	12.396	0.775
17	0.593	11.946	0.703	0.621	12.313	0.724	0.650	12.690	0.746	0.680	13.076	0.769
18	0.587	12.533	0.696	0.615	12.928	0.718	0.644	13.334	0.741	0.675	13.751	0.764
19	0.581	13.114	0.690	0.610	13.538	0.713	0.639	13.974	0.735	0.670	14.421	0.759
20	0.576	13.689	0.684	0.604	14.142	0.707	0.634	14.608	0.730	0.665	15.086	0.754
21	0.570	14.260	0.679	0.599	14.742	0.702	0.630	15.237	0.726	0.661	15.747	0.750
22	0.565	14.825	0.674	0.595	15.336	0.697	0.625	15.862	0.721	0.657	16.403	0.746
23	0.561	15.386	0.669	0.590	15.927	0.692	0.621	16.483	0.717	0.653	17.056	0.742
24	0.556	15.942	0.664	0.586	16.513	0.688	0.617	17.100	0.713	0.649	17.705	0.738
25	0.552	16.495	0.660	0.582	17.095	0.684	0.613	17.713	0.709	0.645	18.350	0.734
26	0.548	17.043	0.656	0.578	17.673	0.680	0.609	18.323	0.705	0.642	18.992	0.730
27	0.545	17.588	0.651	0.575	18.248	0.676	0.606	18.929	0.701	0.639	19.631	0.727
28	0.541	18.128	0.647	0.571	18.819	0.672	0.603	19.531	0.698	0.635	20.266	0.724
29	0.537	18.666	0.644	0.568	19.386	0.668	0.599	20.131	0.694	0.632	20.899	0.721
30	0.534	19.200	0.640	0.564	19.951	0.665	0.596	20.727	0.691	0.630	21.528	0.718
31	0.531	19.731	0.636	0.561	20.512	0.662	0.593	21.320	0.688	0.627	22.155	0.715
32	0.528	20.258	0.633	0.558	21.071	0.658	0.590	21.911	0.685	0.624	22.779	0.712
33	0.525	20.783	0.630	0.556	21.626	0.655	0.588	22.498	0.682	0.621	23.401	0.709
34	0.522	21.305	0.627	0.553	22.179	0.652	0.585	23.084	0.679	0.619	24.020	0.706
35	0.519	21.824	0.624	0.550	22.729	0.649	0.583	23.666	0.676	0.616	24.636	0.704
36	0.516	22.341	0.621	0.547	23.276	0.647	0.580	24.246	0.674	0.614	25.250	0.701
37	0.514	22.854	0.618	0.545	23.821	0.644	0.578	24.824	0.671	0.612	25.862	0.699
38	0.511	23.366	0.615	0.543	24.364	0.641	0.575	25.399	0.668	0.610	26.472	0.697
39	0.509	23.874	0.612	0.540	24.904	0.639	0.573	25.972	0.666	0.607	27.079	0.694
40	0.506	24.381	0.610	0.538	25.442	0.636	0.571	26.543	0.664	0.605	27.684	0.692
41	0.504	24.885	0.607	0.536	25.978	0.634	0.569	27.111	0.661	0.603	28.288	0.690
42	0.502	25.387	0.604	0.533	26.511	0.631	0.567	27.678	0.659	0.601	28.889	0.688
43	0.500	25.887	0.602	0.531	27.042	0.629	0.565	28.243	0.657	0.599	29.489	0.686
44	0.498	26.384	0.600	0.529	27.572	0.627	0.563	28.805	0.655	0.598	30.086	0.684
45	0.496	26.880	0.597	0.527	28.099	0.624	0.561	29.366	0.653	0.596	30.682	0.682
46	0.494	27.373	0.595	0.525	28.624	0.622	0.559	29.925	0.651	0.594	31.276	0.680
47	0.492	27.865	0.593	0.523	29.148	0.620	0.557	30.482	0.649	0.592	31.868	0.678
48	0.490	28.355	0.591	0.522	29.669	0.618	0.555	31.037	0.647	0.591	32.459	0.676
49	0.488	28.843	0.589	0.520	30.189	0.616	0.553	31.590	0.645	0.589	33.047	0.674
50	0.486	29.329	0.587	0.518	30.707	0.614	0.552	32.142	0.643	0.587	33.635	0.673
51	0.484	29.813	0.585	0.516	31.224	0.612	0.550	32.692	0.641	0.586	34.220	0.671
52	0.483	30.295	0.583	0.515	31.738	0.610	0.548	33.241	0.639	0.584	34.805	0.669
53	0.481	30.776	0.581	0.513	32.251	0.609	0.547	33.787	0.637	0.583	35.387	0.668
54	0.479	31.256	0.579	0.511	32.763	0.607	0.545	34.333	0.636	0.581	35.968	0.666
55	0.478	31.733	0.577	0.510	33.272	0.605	0.544	34.877	0.634	0.580	36.548	0.665
56	0.476	32.209	0.575	0.508	33.781	0.603	0.542	35.419	0.632	0.578	37.126	0.663
57	0.474	32.683	0.573	0.507	34.287	0.602	0.541	35.960	0.631	0.577	37.703	0.661
58	0.473	33.156	0.572	0.505	34.793	0.600	0.539	36.499	0.629	0.576	38.279	0.660
59	0.471	33.628	0.570	0.504	35.296	0.598	0.538	37.037	0.628	0.574	38.853	0.659
60	0.470	34.098	0.568	0.502	35.799	0.597	0.537	37.574	0.626	0.573	39.426	0.657
61	0.469	34.566	0.567	0.501	36.300	0.595	0.535	38.109	0.625	0.572	39.997	0.656
62	0.467	35.033	0.565	0.500	36.800	0.594	0.534	38.643	0.623	0.570	40.568	0.654
63	0.466	35.499	0.563	0.498	37.298	0.592	0.533	39.176	0.622	0.569	41.137	0.653
64	0.464	35.964	0.562	0.497	37.795	0.591	0.531	39.708	0.620	0.568	41.705	0.652
65	0.463	36.427	0.560	0.496	38.290	0.589	0.530	40.238	0.619	0.567	42.271	0.650

Unit	92			93			94			95		
i	U	T	A	U	T	A	U	T	A	U	T	A
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.920	1.920	0.960	0.930	1.930	0.965	0.940	1.940	0.970	0.950	1.950	0.975
3	0.876	2.796	0.932	0.891	2.821	0.940	0.907	2.847	0.949	0.922	2.872	0.957
4	0.846	3.643	0.911	0.865	3.686	0.922	0.884	3.730	0.933	0.903	3.774	0.944
5	0.824	4.467	0.893	0.845	4.531	0.906	0.866	4.596	0.919	0.888	4.662	0.932
6	0.806	5.273	0.879	0.829	5.360	0.893	0.852	5.449	0.908	0.876	5.538	0.923
7	0.791	6.064	0.866	0.816	6.176	0.882	0.841	6.289	0.898	0.866	6.404	0.915
8	0.779	6.843	0.855	0.804	6.980	0.873	0.831	7.120	0.890	0.857	7.261	0.908
9	0.768	7.610	0.846	0.794	7.775	0.864	0.822	7.942	0.882	0.850	8.111	0.901
10	0.758	8.368	0.837	0.786	8.560	0.856	0.814	8.756	0.876	0.843	8.954	0.895
11	0.749	9.118	0.829	0.778	9.338	0.849	0.807	9.563	0.869	0.837	9.792	0.890
12	0.742	9.860	0.822	0.771	10.109	0.842	0.801	10.364	0.864	0.832	10.624	0.885
13	0.735	10.594	0.815	0.764	10.874	0.836	0.795	11.159	0.858	0.827	11.451	0.881
14	0.728	11.322	0.809	0.759	11.632	0.831	0.790	11.950	0.854	0.823	12.274	0.877
15	0.722	12.044	0.803	0.753	12.386	0.826	0.785	12.735	0.849	0.818	13.092	0.873
16	0.716	12.760	0.798	0.748	13.134	0.821	0.781	13.516	0.845	0.815	13.907	0.869
17	0.711	13.472	0.792	0.743	13.877	0.816	0.777	14.292	0.841	0.811	14.717	0.866
18	0.706	14.178	0.788	0.739	14.616	0.812	0.773	15.065	0.837	0.807	15.525	0.862
19	0.702	14.880	0.783	0.735	15.351	0.808	0.769	15.834	0.833	0.804	16.329	0.859
20	0.697	15.577	0.779	0.731	16.081	0.804	0.765	16.599	0.830	0.801	17.130	0.857
21	0.693	16.270	0.775	0.727	16.808	0.800	0.762	17.361	0.827	0.798	17.929	0.854
22	0.689	16.960	0.771	0.724	17.532	0.797	0.759	18.120	0.824	0.796	18.724	0.851
23	0.686	17.646	0.767	0.720	18.252	0.794	0.756	18.876	0.821	0.793	19.517	0.849
24	0.682	18.328	0.764	0.717	18.969	0.790	0.753	19.629	0.818	0.790	20.307	0.846
25	0.679	19.007	0.760	0.714	19.683	0.787	0.750	20.379	0.815	0.788	21.095	0.844
26	0.676	19.683	0.757	0.711	20.394	0.784	0.748	21.127	0.813	0.786	21.881	0.842
27	0.673	20.355	0.754	0.708	21.102	0.782	0.745	21.872	0.810	0.784	22.665	0.839
28	0.670	21.025	0.751	0.705	21.808	0.779	0.743	22.614	0.808	0.781	23.446	0.837
29	0.667	21.692	0.748	0.703	22.510	0.776	0.740	23.355	0.805	0.779	24.226	0.835
30	0.664	22.356	0.745	0.700	23.211	0.774	0.738	24.093	0.803	0.777	25.003	0.833
31	0.662	23.018	0.743	0.698	23.909	0.771	0.736	24.829	0.801	0.776	25.779	0.832
32	0.659	23.677	0.740	0.696	24.605	0.769	0.734	25.563	0.799	0.774	26.553	0.830
33	0.657	24.334	0.737	0.693	25.298	0.767	0.732	26.295	0.797	0.772	27.325	0.828
34	0.654	24.988	0.735	0.691	25.989	0.764	0.730	27.025	0.795	0.770	28.095	0.826
35	0.652	25.640	0.733	0.689	26.678	0.762	0.728	27.753	0.793	0.769	28.864	0.825
36	0.650	26.290	0.730	0.687	27.366	0.760	0.726	28.479	0.791	0.767	29.631	0.823
37	0.648	26.937	0.728	0.685	28.051	0.758	0.724	29.203	0.789	0.766	30.396	0.822
38	0.646	27.583	0.726	0.683	28.734	0.756	0.723	29.926	0.788	0.764	31.160	0.820
39	0.644	28.227	0.724	0.681	29.416	0.754	0.721	30.647	0.786	0.763	31.923	0.819
40	0.642	28.868	0.722	0.680	30.095	0.752	0.719	31.367	0.784	0.761	32.684	0.817
41	0.640	29.508	0.720	0.678	30.773	0.751	0.718	32.084	0.783	0.760	33.444	0.816
42	0.638	30.146	0.718	0.676	31.449	0.749	0.716	32.801	0.781	0.758	34.202	0.814
43	0.636	30.782	0.716	0.674	32.124	0.747	0.715	33.516	0.779	0.757	34.959	0.813
44	0.634	31.416	0.714	0.673	32.797	0.745	0.713	34.229	0.778	0.756	35.715	0.812
45	0.633	32.049	0.712	0.671	33.468	0.744	0.712	34.941	0.776	0.755	36.469	0.810
46	0.631	32.680	0.710	0.670	34.138	0.742	0.711	35.651	0.775	0.753	37.222	0.809
47	0.629	33.309	0.709	0.668	34.806	0.741	0.709	36.360	0.774	0.752	37.975	0.808
48	0.628	33.937	0.707	0.667	35.473	0.739	0.708	37.068	0.772	0.751	38.725	0.807
49	0.626	34.563	0.705	0.665	36.138	0.738	0.707	37.775	0.771	0.750	39.475	0.806
50	0.625	35.187	0.704	0.664	36.802	0.736	0.705	38.480	0.770	0.749	40.224	0.804
51	0.623	35.811	0.702	0.663	37.464	0.735	0.704	39.184	0.768	0.748	40.971	0.803
52	0.622	36.432	0.701	0.661	38.126	0.733	0.703	39.887	0.767	0.746	41.718	0.802
53	0.620	37.053	0.699	0.660	38.786	0.732	0.702	40.588	0.766	0.745	42.463	0.801
54	0.619	37.671	0.698	0.659	39.444	0.730	0.700	41.289	0.765	0.744	43.208	0.800
55	0.618	38.289	0.696	0.657	40.101	0.729	0.699	41.988	0.763	0.743	43.951	0.799
56	0.616	38.905	0.695	0.656	40.758	0.728	0.698	42.686	0.762	0.742	44.693	0.798
57	0.615	39.520	0.693	0.655	41.412	0.727	0.697	43.383	0.761	0.741	45.435	0.797
58	0.614	40.134	0.692	0.654	42.066	0.725	0.696	44.079	0.760	0.740	46.175	0.796
59	0.612	40.746	0.691	0.653	42.719	0.724	0.695	44.774	0.759	0.740	46.915	0.795
60	0.611	41.357	0.689	0.651	43.370	0.723	0.694	45.468	0.758	0.739	47.653	0.794
61	0.610	41.967	0.688	0.650	44.020	0.722	0.693	46.161	0.757	0.738	48.391	0.793
62	0.609	42.575	0.687	0.649	44.669	0.720	0.692	46.853	0.756	0.737	49.128	0.792
63	0.608	43.183	0.685	0.648	45.318	0.719	0.691	47.543	0.755	0.736	49.864	0.791
64	0.606	43.789	0.684	0.647	45.964	0.718	0.690	48.233	0.754	0.735	50.599	0.791
65	0.605	44.395	0.683	0.646	46.610	0.717	0.689	48.922	0.753	0.734	51.333	0.790

Unit	96			97			98			99		
I	U	T	A	U	T	A	U	T	A	U	T	A
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.960	1.960	0.980	0.970	1.970	0.985	0.980	1.980	0.990	0.990	1.990	0.995
3	0.937	2.897	0.966	0.953	2.923	0.974	0.968	2.948	0.983	0.984	2.974	0.991
4	0.922	3.819	0.955	0.941	3.864	0.966	0.960	3.909	0.977	0.980	3.954	0.989
5	0.910	4.729	0.946	0.932	4.795	0.959	0.954	4.863	0.973	0.977	4.931	0.986
6	0.900	5.628	0.938	0.924	5.720	0.953	0.949	5.812	0.969	0.974	5.906	0.984
7	0.892	6.520	0.931	0.918	6.638	0.948	0.945	6.757	0.965	0.972	6.878	0.983
8	0.885	7.405	0.926	0.913	7.550	0.944	0.941	7.698	0.962	0.970	7.848	0.981
9	0.879	8.283	0.920	0.908	8.458	0.940	0.938	8.636	0.960	0.969	8.817	0.980
10	0.873	9.157	0.916	0.904	9.362	0.936	0.935	9.571	0.957	0.967	9.784	0.978
11	0.868	10.025	0.911	0.900	10.262	0.933	0.932	10.504	0.955	0.966	10.750	0.977
12	0.864	10.889	0.907	0.897	11.159	0.930	0.930	11.434	0.953	0.965	11.714	0.976
13	0.860	11.749	0.904	0.893	12.052	0.927	0.928	12.362	0.951	0.963	12.678	0.975
14	0.856	12.605	0.900	0.891	12.943	0.924	0.926	13.288	0.949	0.962	13.640	0.974
15	0.853	13.457	0.897	0.888	13.830	0.922	0.924	14.212	0.947	0.961	14.602	0.973
16	0.849	14.307	0.894	0.885	14.716	0.920	0.922	15.134	0.946	0.961	15.562	0.973
17	0.846	15.153	0.891	0.883	15.599	0.918	0.921	16.055	0.944	0.960	16.522	0.972
18	0.843	15.996	0.889	0.881	16.479	0.916	0.919	16.974	0.943	0.959	17.481	0.971
19	0.841	16.837	0.886	0.879	17.358	0.914	0.918	17.892	0.942	0.958	18.439	0.970
20	0.838	17.675	0.884	0.877	18.235	0.912	0.916	18.808	0.940	0.957	19.397	0.970
21	0.836	18.511	0.881	0.875	19.109	0.910	0.915	19.724	0.939	0.957	20.354	0.969
22	0.834	19.345	0.879	0.873	19.982	0.908	0.914	20.637	0.938	0.956	21.310	0.969
23	0.831	20.176	0.877	0.871	20.854	0.907	0.913	21.550	0.937	0.956	22.265	0.968
24	0.829	21.006	0.875	0.870	21.723	0.905	0.912	22.462	0.936	0.955	23.220	0.968
25	0.827	21.833	0.873	0.868	22.592	0.904	0.910	23.372	0.935	0.954	24.175	0.967
26	0.825	22.658	0.871	0.867	23.458	0.902	0.909	24.281	0.934	0.954	25.129	0.966
27	0.824	23.482	0.870	0.865	24.323	0.901	0.908	25.190	0.933	0.953	26.082	0.966
28	0.822	24.304	0.868	0.864	25.187	0.900	0.907	26.097	0.932	0.953	27.035	0.966
29	0.820	25.124	0.866	0.862	26.050	0.898	0.907	27.004	0.931	0.952	27.987	0.965
30	0.818	25.942	0.865	0.861	26.911	0.897	0.906	27.909	0.930	0.952	28.939	0.965
31	0.817	26.759	0.863	0.860	27.771	0.896	0.905	28.814	0.929	0.951	29.890	0.964
32	0.815	27.574	0.862	0.859	28.629	0.895	0.904	29.718	0.929	0.951	30.841	0.964
33	0.814	28.388	0.860	0.858	29.487	0.894	0.903	30.621	0.928	0.951	31.792	0.963
34	0.812	29.201	0.859	0.856	30.343	0.892	0.902	31.524	0.927	0.950	32.742	0.963
35	0.811	30.012	0.857	0.855	31.199	0.891	0.902	32.425	0.926	0.950	33.692	0.963
36	0.810	30.822	0.856	0.854	32.053	0.890	0.901	33.326	0.926	0.949	34.641	0.962
37	0.808	31.630	0.855	0.853	32.906	0.889	0.900	34.226	0.925	0.949	35.590	0.962
38	0.807	32.437	0.854	0.852	33.759	0.888	0.899	35.125	0.924	0.949	36.539	0.962
39	0.806	33.243	0.852	0.851	34.610	0.887	0.899	36.024	0.924	0.948	37.487	0.961
40	0.805	34.048	0.851	0.850	35.460	0.887	0.898	36.922	0.923	0.948	38.435	0.961
41	0.804	34.851	0.850	0.849	36.310	0.886	0.897	37.820	0.922	0.948	39.383	0.961
42	0.802	35.654	0.849	0.849	37.158	0.885	0.897	38.716	0.922	0.947	40.330	0.960
43	0.801	36.455	0.848	0.848	38.006	0.884	0.896	39.613	0.921	0.947	41.277	0.960
44	0.800	37.255	0.847	0.847	38.853	0.883	0.896	40.508	0.921	0.947	42.223	0.960
45	0.799	38.055	0.846	0.846	39.699	0.882	0.895	41.403	0.920	0.946	43.170	0.959
46	0.798	38.853	0.845	0.845	40.544	0.881	0.894	42.298	0.920	0.946	44.116	0.959
47	0.797	39.650	0.844	0.844	41.388	0.881	0.894	43.191	0.919	0.946	45.061	0.959
48	0.796	40.446	0.843	0.844	42.232	0.880	0.893	44.085	0.918	0.945	46.007	0.958
49	0.795	41.241	0.842	0.843	43.075	0.879	0.893	44.977	0.918	0.945	46.952	0.958
50	0.794	42.035	0.841	0.842	43.917	0.878	0.892	45.870	0.917	0.945	47.897	0.958
51	0.793	42.829	0.840	0.841	44.758	0.878	0.892	46.761	0.917	0.945	48.841	0.958
52	0.792	43.621	0.839	0.841	45.599	0.877	0.891	47.653	0.916	0.944	49.786	0.957
53	0.792	44.413	0.838	0.840	46.438	0.876	0.891	48.543	0.916	0.944	50.730	0.957
54	0.791	45.203	0.837	0.839	47.278	0.876	0.890	49.434	0.915	0.944	51.674	0.957
55	0.790	45.993	0.836	0.839	48.116	0.875	0.890	50.323	0.915	0.944	52.617	0.957
56	0.789	46.782	0.835	0.838	48.954	0.874	0.889	51.213	0.915	0.943	53.560	0.956
57	0.788	47.570	0.835	0.837	49.791	0.874	0.889	52.101	0.914	0.943	54.503	0.956
58	0.787	48.357	0.834	0.837	50.628	0.873	0.888	52.990	0.914	0.943	55.446	0.956
59	0.787	49.144	0.833	0.836	51.464	0.872	0.888	53.878	0.913	0.943	56.389	0.956
60	0.786	49.930	0.832	0.835	52.299	0.872	0.888	54.765	0.913	0.942	57.331	0.956
61	0.785	50.715	0.831	0.835	53.134	0.871	0.887	55.652	0.912	0.942	58.273	0.955
62	0.784	51.499	0.831	0.834	53.968	0.870	0.887	56.539	0.912	0.942	59.215	0.955
63	0.783	52.282	0.830	0.834	54.802	0.870	0.886	57.425	0.912	0.942	60.157	0.955
64	0.783	53.065	0.829	0.833	55.635	0.869	0.886	58.311	0.911	0.941	61.098	0.955
65	0.782	53.847	0.828	0.832	56.467	0.869	0.885	59.197	0.911	0.941	62.040	0.954

APPENDIX D: RECENT SHIPBUILDING PROGRAMS

Recent cases involving procurement of major Navy ships help illustrate how changes in spreading of fixed costs (see Appendix B) and learning effects (see Appendix C) can lead to changes in production efficiency and resulting ship cost. In reviewing these cases, it should be remembered that some of the cost figures below reflect cost effects not only at the shipyard level, but at the supplier level as well. They may also reflect changes in spreading of government overhead costs.

It should also be remembered that shipyard and supplier fixed costs and government overhead costs can change over time and might differ from what they were a few years ago. As a consequence, changes in spreading of shipyard and supplier fixed costs and government overhead costs today may result in changes in total ship cost that differ from those reflected in these recent cases.

SUBMARINES

The table below shows the average cost of the final 14 Improved Los Angeles (Improved SSN-688 or 688I) class submarines, which were procured in FY1986-FY1990. As can be seen in the table, as the annual quantity procured dropped from 3 or 4 boats to 1, the average unit cost in constant FY1996 dollars increased from about $838 million (the average for the 11 boats procured in FY1986-FY1988) to $1,170 million (the cost of the FY1990 boat). This is an increase of about 40 percent. Given the maturity of the 688I procurement program and the relative lack of major shipyard difficulties in building these boats, much of this increase appears due to the reduction spreading of fixed costs at the shipyards and supplier firms that occurred as a result of the reduction in procurement rate.[156]

TABLE 5. 688I UNIT COSTS
(millions of constant FY1996 dollars)

	FY1986	FY1987	FY1988	FY1989	FY1990
Number procured	4	4	3	2	1
Average cost	828.9	858.0	823.2	941.0	1,170.0

Source: Department of Defense information paper provided to CRS by U.S. Navy Office of Legislative Affairs, Aug. 13, 1996. See also U.S. Congress. House. Committee on Appropriations. [Hearings on] Department of Defense Appropriations for [Fiscal Year] 1991, 101st Cong., 1st Sess., Part 6. Washington, U.S. Govt. Print. Off., 1990. p. 415, 431. Figures converted to constant FY1996 dollars using Jan. 23, 1995 Department of Defense deflator for SCN Total Obligational Authority.

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156 An additional source of increased cost could be design changes implemented on the final 688Is, which could have reduced overall learning benefits for those boats.

Even the FY1989 and FY1990 688Is benefitted during the earlier years of their construction from spreading of fixed costs with the relatively large number of submarines procured in the second half of the 1980s. The backlog of submarines ordered in previous years, however, is now much smaller than it was in FY1989 and FY1990. As a result, submarines procured today would benefit even less from spreading of fixed costs than the FY1989 and FY1990 688Is. This further reduction in spreading of fixed costs is apparently a major reason why the Navy estimates that 688Is procured today at a rate of about 1.5 to 2 boats per year would cost about $1.49 billion in constant FY1996 dollars[157] -- an increase of about 27 percent over the cost of the FY1990 688I and about 78 percent over the average cost of the FY1986-FY1988 688Is.

The Navy estimates that the New Attack Submarine would cost about $1.59 billion in constant FY1996 dollars if procured at a rate of 1.5 to 2 boats per year.[158] This is about 7 percent more than a 688I. Given the procurement costs of 688Is procured in FY1986-FY1988, and the fact that the New Attack Submarine design is estimated to be only marginally more expensive to build than the 688I design, it would appear that New Attack Submarines would cost substantially less than $1.59 billion in constant FY1996 dollars if they were procured at a rate of 3 to 4 boats per year rather than 1.5 to 2 boats per year.

Substantial increases in the procurement cost of the Seawolf (SSN-21) attack submarine design also demonstrate the effect that reduced spreading of fixed costs and learning effects can have on total ship cost. The original unit procurement cost goal for follow-on SSN-21s (defined as the fifth and following boats in the class) was $1.0 billion in FY1985 dollars. This would equate to about $1.4 billion in FY1996 dollars. Today, however, the unit procurement cost

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[157] Source for 688I cost figure: Department of Defense information paper provided to CRS by U.S. Navy Office of Legislative Affairs, Aug. 13, 1996. The paper noted that a March 1995 report to Congress on the New Attack Submarine program estimated that a 688I would cost $1.45 billion in FY1995 dollars to procure today. This equates to about $1.49 billion in constant FY1996 dollars using a Jan. 23, 1995 DOD deflator for SCN total obligational authority (TOA). An information paper provided to CRS on May 14, 1996 by the Navy Office of Legislative Affairs, which provided figures in FY1996 dollars, states that "the cost to build a new 688I today would be $1.4B [billion] to $1.8B [billion]." In 1994 the Navy estimated the cost of the 688I in FY1998 dollars at about $1.4 billion; this figure was used in *Navy New Attack Submarine (NSSN) Program: Is It Affordable?* CRS Report 94-643 F, by Ronald O'Rourke. Washington, 1996. (August 9, 1994) 6 p. The Navy does not plan to procure any additional 688Is; as discussed in the background chapter, the Navy plans to procure New Attack Submarines (NSSNs) instead. The estimated cost to build a 688I today is used here simply to maintain an "apples-to-apples" comparison with the 688Is procured in FY1987-FY1990.

[158] Source: Department of Defense information paper, op. cit. The paper notes that the March 1995 report to Congress on the New Attack Submarine program estimates the procurement cost of the fifth New Attack Submarine at $1.55 billion in constant FY1995 dollars. This equates to about $1.59 billion in constant FY1996 dollars using the Jan. 23, 1995 DOD deflator for SCN total obligational authority (TOA).

of the SSN-21 is estimated at about $2.16 billion in constant FY1996 dollars[159] -- a real increase of more than 50 percent over the inflation-adjusted goal of about $1.4 billion.

Some of this increase reflects the fact that the SSN-21 design turned out to be intrinsically more expensive to build than originally estimated. At least some of the increase, however, appears related to reductions in the planned SSN-21 procurement rate and the consequent effects on spreading of fixed costs and learning. The original cost goal of about $1.4 billion per boat in FY1996 dollars assumed an eventual SSN-21 procurement rate of about 3.3 boats per year (to maintain a planned 100-boat SSN force). It also assumed, during the earlier years of the Seawolf program, the simultaneous procurement of a few more Ohio (SSBN-726) class ballistic missile submarines at a rate of one per year.

The planned SSN-21 planned procurement rate, however, was reduced to 3 boats every 2 years (i.e., 1.5 boats per year) in 1990, and to about 1 boat per year in 1991. Procurement of Trident submarines was also ended with the 18th boat in FY1991. At the new rate of 1 boat per year, and without additional procurement of Trident submarines, the unit procurement cost for the SSN-21 rose in the FY1992 budget submission to about $2.0 billion in FY1992/FY1993 dollars.[160] This equates to about $2.2 billion in FY1996 dollars -- an increase of roughly 55 percent over the inflation-adjusted cost goal of $1.4 billion.[161] When questioned in 1990 about the potential impact of a decision to reduce Seawolf and Trident procurement, the Navy stated:

> Based on one SSN-21 per year vice [rather than] the proposed building rate in the FY1991 timeframe, the SSN-21 unit cost will increase by 40 to 60 percent. Additional significant cross program impacts will occur on the TRIDENT and CVN programs. The magnitude of the cost impacts on these programs is largely affected by which shipyard the single SSN-21 is awarded to. Cost impacts are

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[159] Source: Department of Defense information paper, op. cit. The paper notes that the March 1995 report to Congress on the New Attack Submarine estimates that SSN-21s would cost about $2.1 billion in FY1995 dollars. This equates to about $2.16 billion in constant FY1996 dollars using the Jan. 23, 1995 DOD deflator for SCN total obligational authority (TOA).

[160] Source: DOD P-1 (Procurement) document for FY1993.

[161] It should also be noted that the FY1992 and FY1993 SSN-21s in the FY1992 budget submission were the third and fourth boats in the SSN-21 program. As pointed out earlier, the inflation-adjusted cost goal of about $1.4 billion in FY1997 dollars was not to be reached until the fifth boat in the class. Earlier boats would be somewhat more expensive, in large part due to their earlier position on the learning curve.

> driven by the industry's ability to control overhead costs and productivity during very low rates of production.[162]

In response to a similar question, the Navy also stated:

> Finally, reducing SEAWOLF and TRIDENT procurements would significantly increase the cost of both programs. These cost increases would be due to the combined effects of spreading of shipyard overhead over fewer units, higher material prices stemming from the shrinking submarine vendor base, higher government-furnished equipment (GFE) costs resulting from cancellation of quantity buys, and additional man-hours of labor due to the loss of learning from breaks in production. In addition, as a result of lower total shipyard production rates, substantial cost increases would be realized in both the SSN-688 and CVN programs.[163]

The Navy in 1990 also testified that deferring procurement of the 18th Ohio (SSBN-726) class Trident SSBN from FY1991 to FY1992 would increase the cost of that submarine by $115 million and subsequent submarines by lesser amounts due in large part to loss of learning at EB.[164]

In 1991, EB argued that SSN-22, the second Seawolf submarine, should be awarded to EB rather than NNS because awarding it to NNS would cause a break in Seawolf production at EB that would lead to increased costs due to reduced spreading of overhead costs and loss of learning at the shipyard, and increased material costs from suppliers. Awarding SSN-22 to NNS, EB testified, would create

> at least a three-year gap from the start of lead-ship [SSN-21] construction [at EB] to the first Electric Boat follow ship [i.e., SSN-23 or a later submarine]. At our Groton shipyard the impact of this production break would result in a severe workforce reduction beginning in 1992. Moreover, Electric Boat has projected that a break in SEAWOLF production at Electric Boat would result in an immediate negative cost impact of about $230 million. These costs include:

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162 U.S. Congress. House. Committee on Appropriations. *[Hearings on] Department of Defense Appropriations for [Fiscal Year] 1991.* 101st Cong., 1st Sess., Part 6. Washington, U.S. Govt. Print. Off., 1990. p. 423.

163 Ibid., p. 422.

164 Ibid., p. 396. The Navy also testified in 1989 on the potential cost effects of deferring the 17th Trident SSBN from FY1990 to FY1991; see U.S. Congress. House. Committee on Armed Services. *Hearings on National Defense Authorization Act for Fiscal Year 1990 -- H.R. 2461 and Oversight of Previously Authorized Programs*, 101st Cong., 1st Sess., Seapower and Strategic and Critical Materials Subcommittee Hearings on Seapower. Washington, U.S. Govt. Print. Off., 1990. p. 1011 and 336-337. See also p. 240.

-- $84 million in unabsorbed overhead, which directly impacts existing construction contracts.

-- $126 million due to loss of savings, resulting from the inability to efficiently roll over trades from the lead ship to the next follow ship. Key experience developed on the lead ship would be lost due to at least a three-year production gap.

-- $20 million in increased vendor material costs, resulting from a break in production as well as additional certification.[165]

At 1995 congressional hearings on future submarine procurement, NNS argued that consolidating construction of submarines and carriers at NNS would be significantly less expensive than building submarines at EB and carriers at NNS in part because consolidation would enable the fixed costs of NNS to be spread over a larger volume of work while avoiding the need to pay additional fixed costs at EB.[166] EB argued in return that it had launched a comprehensive corporate "reengineering" effort to reduce its costs, including its fixed costs, so that EB could build affordable submarines at low production rates.[167] EB also testified that its fixed costs would constitute about $500 million, or about 4.5 percent of the $11.1 billion combined cost of the first five New Attack Submarines planned by the Administration for construction at EB.[168]

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165 James E. Turner, Jr., Executive Vice President -- Marine, Land Systems and Services, General Dynamics Corporation, Testimony before the U.S. Senate Appropriations Committee Defense Subcommittee, Mar. 19, 1991. p. 14.

166 Statement of W. P. ("Bill") Fricks, President, Newport News Shipbuilding, Before the Military Procurement Subcommittee of the House National Security Committee; March 16, 1995, p. 4-5; Testimony of W. P. ("Bill") Fricks, President & Chief Operating Officer, Newport News Shipbuilding, Before the House Appropriations Subcommittee on National Security, April 5, 1995, p. 8-9, 12-13; Statement of W. P. ("Bill") Fricks, President, Newport News Shipbuilding, Before the Seapower Subcommittee of the Senate Armed Services Committee on May 16, 1995, p. 12-13, 16-17.

167 James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. House of Representatives Committee on National Security Military Procurement Subcommittee, March 16, 1995, p. 13-17; James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. House of Representatives Committee on Appropriations National Security Subcommittee, April 5, 1995, p. 14-18; James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. Senate Armed Services Committee Sea Power Subcommittee, May 16, 1995, p. 14-17. See also Holzer, Robert. Electric Boat Pushes Operations Overhaul. *Defense News*, October 24-30, 1994: 48.

168 James E. Turner, Jr., Corporate Executive Vice President, General Dynamics Corporation, President, Electric Boat Division, Testimony before the U.S. Senate Armed Services Committee Sea Power Subcommittee, May 16, 1995, p. 22.

The Navy in its testimony stated that not funding SSN-23 for construction at EB would increase the cost of other work performed at EB by hundreds of millions of dollars due to, among other things, the reallocation of overhead costs, including fixed overhead costs, that would have been charged to SSN-23. The Navy agreed with NNS that consolidating nuclear-warship production at NNS would save money, but the Navy's estimate of the savings from consolidation -- about 3 percent of the combined cost of the submarines and carriers to be built -- was much smaller than NNS's estimate.[169]

The General Accounting Office agreed that consolidation at NNS would save money but stated that it did not have enough time and information to validate fully NNS's estimates.[170] The Congressional Budget Office cited the avoidance of fixed costs at the second shipyard as one source of savings and stated that its own estimate of the total savings from consolidation would probably fall between the NNS and Navy estimates.[171]

The Congressional Research Service noted that the Navy's estimated savings from consolidation would amount to $60 million to $130 million per year in FY1996 dollars.[172] These savings were largely the result of the avoidance

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169 Statement of the Honorable Nora Slatkin, Assistant Secretary of the Navy (Research, Development and Acquisition) Before the Subcommittee on Procurement of the House National Security Committee on the FY 1996 Navy Submarine Modernization Plan, March 16, 1995, p. 13; Statement of the Honorable Nora Slatkin, Assistant Secretary of the Navy (Research, Development and Acquisition), and Admiral Bruce DeMars, USN, Director, Naval Nuclear Propulsion, and Vice Admiral T. Joseph Lopez, USN, Deputy Chief of Naval Operations, Resources, Warfare Requirements and Assessments, Before the Subcommittee on National Security of the House Appropriation Committee on the FY 1996 Navy Submarine Modernization Plan, April 5, 1995, p. 13; Statement of the Honorable Nora Slatkin, Assistant Secretary of the Navy (Research, Development and Acquisition), and Admiral Bruce DeMars, USN, Director, Naval Nuclear Propulsion, and Vice Admiral T. Joseph Lopez, USN, Deputy Chief of Naval Operations, Resources, Warfare Requirements and Assessments, Before the Subcommittee on Seapower of the Senate Armed Services Committee on the FY 1996 Navy Submarine Modernization Plan, May 16, 1995, p. 13-14, 17-18, and attachment, Report on Navy Submarine Acquisition Plan and Assessment of Shipbuilder Proposed Alternative Plan, 1 May 1995, Prepared for The Assistant Secretary of the Navy (Research, Development, and Acquisition), Admiral B. DeMars, Director, Naval Nuclear Propulsion, Vice Admiral G. R. Sterner, Commander, Naval Sea Systems Command, Rear Admiral R. E. Frick, Program Executive Officer for Submarines, p. 3-4 and Attachment A.

170 U.S. Congress. General Accounting Office. Navy Shipbuilding Programs: Nuclear Attack Submarine Issues; Statement by Richard Davis, Director, National Security Analysis, National Security and International Affairs Division. Washington, 1995. (Testimony Before the Subcommittee on Seapower, Committee on Armed Services, U.S. Senate, May 16, 1995, GAO/T-NSIAD-95-162) p. 2, 8-10.

171 Statement of Cindy Williams, Assistant Director, National Security Division, Congressional Budget Office, on Attack Submarine Programs before the Subcommittee on Seapower, Committee on Armed Services, United States Senate, May 16, 1995. p. 8, 18.

172 Statement of Ronald O'Rourke, Specialist in National Defense, Foreign Affairs and National Defense Division, Congressional Research Service, Before the Senate Armed Services Committee Subcommittee on Seapower Hearing on Submarine Acquisition Issues, May 16, 1995.

of fixed costs at the second yard.[173] CRS concluded on the basis of its analysis of the Navy and NNS estimates that the difference between the NNS and Navy regarding the total savings of consolidation resulted primarily not from differences in NNS and Navy estimates of shipyard fixed costs, but rather from differences in other shipbuilding cost elements.[174]

AIRCRAFT CARRIERS

CVN-77, an aircraft carrier planned for procurement in FY2002, is projected to cost about $5.0 billion in constant FY96 dollars, or about $700 million more than CVN-76, which was funded in FY1995 and is projected to cost about $4.3 billion in FY1996 dollars. Of the estimated $700 million increase in cost between CVN-76 and CVN-77, the Navy attributes about $200 million to reduced workload at the shipyard and consequent reduced spreading of fixed costs.[175] Loss of learning may also be involved: The president of NNS reportedly stated that accelerating procurement of CVN-77 to FY1999 of FY2000 could reduce the cost of the ship by as much as $1 billion, in part because "You would be able to take that [CVN-76] labor group and apply it to [CVN]-77." Accelerating procurement of CVN-77, he reportedly said, would "prevent a drop off in those years. Otherwise you have a gap."[176]

In 1992, when Congress was considering whether to provide about $830 million in FY1993 advanced procurement funding for CVN-76 so as to support procurement of CVN-76 in FY1995 at a total cost of about $4.4 billion, it was argued that deferring procurement of CVN-76 by one, two or three years (i.e., to FY1996, FY1997, or FY1998) would increase the cost of the ship by about $400 million, $750 million, or $1.2 billion, respectively.[177] A Navy

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p. 35-36.

[173] In a May 15, 1995 telephone conversation, the Navy Office of Legislative Affairs informed CRS that although some other cost effects were involved in the calculation, the primary factor in the Navy's calculation of estimated savings was the avoidance of fixed costs at the second yard. The Navy provided this information for CRS to use in its spoken testimony at the May 16, 1995 hearing before the Seapower subcommittee of the Senate Armed Services Committee.

[174] Statement of Ronald O'Rourke, op. cit., p. 36.

[175] Source: U.S. Navy information paper on aircraft carrier costs provided to CRS, May 10, 1996. The remaining components of the $700 million cost increase were compression of the construction schedule for CVN-77 to 6 years compared to the 8-year period for CVN-76 ($150 million), incorporation of new technologies into the ship's design ($250 million), and increased costs for Government-furnished equipment due to an assumed lack of refurbished GFE for the ship ($100 million).

[176] Robinson, John. Extra Carrier Funds Would Plug Gap in Development, NNS Says. *Defense Daily*, Apr. 30, 1996: 173.

[177] See, for example, the remarks of Senator John McCain in *Congressional Record*, daily edition, July 2, 1992: S9584.

memorandum to Congress estimated the cost of a one-year delay more precisely at $398 million. Of this, $180 million was due to additional inflation. The remaining real cost increase of $218 million was due to loss of learning ($65 million), reduced spreading of overhead ($22 million), and increased material costs due to "the shrinking vendor base" ($131 million).[178]

In 1987, when Congress was considering whether to accelerate the procurement of CVN-74 and CVN-75 and procure the two ships together rather than separately, the Navy estimated that accelerating their procurement would reduce their combined cost by about $700 million by avoiding a break in aircraft carrier production continuity at NNS after completion of CVN-73. Of this $700 million reduction in cost, about $300 million was due to avoided start-up and non-recurring costs at NNS, while about $400 million was due to avoiding a 5-percent loss of learning at NNS and a consequent 6-million-hour increase in the amount of labor required to build the two ships. The Navy also estimated that procuring CVN-74 and CVN-75 together as a two-ship package rather than separately would reduce their combined cost by an additional $1.1 billion by permitting the government and NNS to purchase materials for both ships at once and thereby take advantage of economies of scale at supplier firms.[179]

Similarly, in 1982, when Congress was considering whether to fund CVN-72 and CVN-73 together in FY1983 rather than separately, the Navy estimated that procuring the ships together would reduce their combined cost by about $220 million by maintaining production continuity at NNS following completion of CVN-71. Of this $220 million reduction in cost, about $100 million was due to avoided start-up and non-recurring costs at NNS, while about $100 million was due to "improved planning, manpower utilization and productivity," which included avoided loss of learning. The Navy also estimated that procuring CVN-72 and CVN-73 together as a 2-ship package would reduce their combined

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[178] Memorandum from Sean O'Keefe, Acting Secretary of the Navy, to "Interested Members of Congress" on the Aircraft Carrier Procurement Program, Sep. 19, 1992, Tab B.

[179] The potential savings of the proposed accelerated and joint procurement of CVN-74 and CVN-75 were the subject of a debate involving the Navy, the General Accounting Office (GAO), and Congress. In addition to $700 million in savings from maintaining production continuity and $1.1 billion in savings from procuring materials for both ships at once, the Navy argued that accelerating procurement of the ships would avoid about $700 million in inflation and $500 million in design modifications that would have been implemented had the ships been procured at a later date. Adding all these sources of savings together, the Navy argued that accelerating procurement of the ships and procuring them together rather than separately would reduce their combined cost by about $3 billion, to about $7 billion. GAO agreed that maintaining production continuity would produce savings but disputed the Navy's other argued sources of savings. See, for example, U.S. Congress. Senate. Committee on Armed Services. *[Hearings on] Department of Defense Authorization for Appropriations for Fiscal Years 1988 and 1989,* 100th Cong., 1st Sess., Part 6. Washington, U.S. Govt. Print. Off., 1987. p. 3101-3156. See also U.S. Congress. Senate. Committee on Appropriations. *[Hearings on] Department of Defense Appropriations for Fiscal Year 1988,* 100th Cong., 1st Sess., Part 1. Washington, U.S. Govt. Print. Off., 1987. p. 123-126. Congress decided to procure the two ships together and accelerate their procurement to FY1998 -- a greater acceleration than the Navy had proposed. Congress funded their procurement at a combined cost of about $6.3 billion.

cost by an additional $230 million by permitting the government and NNS to purchase materials for both ships at once.[180]

MAJOR SURFACE COMBATANTS

A June 1996 Navy point paper states that building 5 rather than 6 DDG-51s during the 2-year period FY1996-FY1997 (i.e., an average of 2.5 ships per year rather than 3 ships per year) would increase average ship cost by $44 million per ship due to higher per-ship overhead and engineering services costs.[181]

More generally, as can be seen in the table below, in constant FY1996 dollars, recent DDG-51s appear to cost more than $1 billion each when procured at a rate of 2 ships per year, about $900 million to $950 million each when procured at a rate of 3 ships per year, and about $850 million to $900 million each when procured at a rate of 4 ships per year.[182]

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[180] The Navy also estimated that the plan would reduced the combined cost of the two ships by another $304 million due to avoided inflation resulting from earlier delivery of the ships. Adding all these sources of savings together, the Navy thus estimated that the proposed two-ship buy would reduce the combined cost of the two ships by $754 million, to about $7.3 billion. See U.S. Congress. House. *Hearings on Military Posture and H.R. 5968 [H.R. 6030], Department of Defense Authorization for Appropriations for Fiscal Year 1983*, 97th Cong., 2nd Sess., Part 4 of 7 Parts. Washington, U.S. Govt. Print. Off., 1982. p. 317, 319, 348-376, particularly 363. Congress decided to fund the procurement of the two ships in FY1983 at a combined cost of about $7.1 billion.

[181] Holzer, Robert. U.S. Navy, Shipyards To Lobby Against Destroyer Cuts. *Defense News*, June 24-30, 1996: 55. The article on this point was quoting a figure in a June 18, 1996, Navy point paper entitled Proposed Deletion of $750M [million] and One Ship From FY[19]97 DDG-51 Class Procurement.

[182] Similarly, cost figures in DOD Procurement (P-1) documents from the early 1990s suggest that DDG-51s today might cost $800 million to $850 million each in constant FY1996 dollars when procured at a rate of 5 ships per year.

TABLE 6. DDG-51 UNIT PROCUREMENT COSTS

Source	Unit procurement cost ($FY1996 millions) and fiscal year procured, given annual procurement quantity of		
	2 ships	3 ships	4 ships
FY1997 DOD Procurement (P-1) document	1,041 (FY1996)	907 (FY1995)	852 (FY1997)
1995 briefing slides: "Split Funding for DDG-51"[a]	1,081 (FY1996)	951 (FY1996)	895 (FY1996)

[a] Briefing slides apparently prepared to support Congressional consideration of the FY1996 Navy shipbuilding budget, provided to CRS, July 1995, by a defense trade publication.

Although the data from the FY1997 P-1 document is for ships procured in different fiscal years and thus at different points along the shipyards' learning curves, given the maturity of this program -- a total of 34 DDG-51s have been procured through FY1996 -- it would appear that different positions along the learning curve account for relatively small shares of the differences in unit procurement costs. Most of the difference appears to be due to changes in spreading of fixed costs at both the shipyards and suppliers.

Cost effects at suppliers may account for a significant share of the effect. Systems, components and materials from supplier firms make up a significant share of the total cost of DDG-51s,[183] and as shown in the table below, changes in annual procurement quantities of DDG-51s can have a significant effect on the cost of these items.

[183] As noted earlier in the section on competition, combat system materials may account for 42 percent of the total cost of a "typical destroyer," while shipyard materials may account for another 20 percent. (The remainder of the ship's cost is accounted for by shipyard labor [21 percent] and Navy-related costs [17 percent].) Rains, Dean A. Naval Ship Affordability. *Naval Engineers Journal*, July 1996: 20 (figure 1) 22. The article states on page 22 that "The DDG 51 is the destroyer baseline used in the model results presented in this paper."

TABLE 7. PERCENT CHANGE IN UNIT PROCUREMENT COST FOR DDG-51 COMPONENTS

Procurement rate	Percent change in cost	
	Combat system[a]	Other ship systems[b]
3.5 per year	---	---
3.0 per year	10%-20%	10%-20%
2.5 per year	15%-25%	15%-20%
2.0 per year	20%-30%	15%-25%
1.5 per year	35%-40%	20%-30%
1.0 per year	50%	30%-40%

Source: U.S. Navy Office of Legislative Affairs briefing slides provided to CRS, Feb. 28, 1994.

a Includes items such as weapon launchers, radars, sonars, and associated electronics.

b Includes items such as propulsion equipment and general hull, mechanical and electrical (HM&E) equipment.

AMPHIBIOUS SHIPS

Congress' decision last year to fund LHD-7 in FY1996 rather than in FY2001 as planned by the Administration provided an example of the potential cost effects caused by an extended break in a shipbuilding program. Accelerating procurement of LHD-7 to FY1996 reduced the estimated cost of LHD-7 by about $737 million, to $1,352 million. Of the $737 million in estimated savings, about $315 million was simply avoided inflation; the remaining real (i.e., inflation-adjusted) savings resulting from the accelerated procurement was about $422 million. Of this $422 million in real savings, about $96 million is for Government-furnished equipment; the remaining savings of about $325 million are related to the shipyard.[184]

Some of the $325 million in shipyard-related savings are due to reduced costs for materials and components purchased by the shipyard from supplier firms. A significant share, however, is related to the cost effects at the shipyard of avoiding a several-year break in production between LHD-6 (funded in FY1993/FY1994) and LHD-7. This would include avoidance of both reduced spreading of shipyard fixed costs and shipyard loss of learning.

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184 U.S. Navy information paper on LHD-7 costs provided to CRS, May 13, 1996. For somewhat similar overall and real savings figures, see Hastened Ship Buy Saves $700 million. *Defense News*, Dec. 4-10, 1995: 2.

SEALIFT SHIPS

The decision to procure the first 12 new-construction LMSR sealift ships at two shipyards rather than at a single yard split the learning curve for these 12 ships and, other things held equal, thereby increased the labor-related costs of building these ships. According to one industry source, the increase due to split learning is about $100 million. This is equal to about 2.7 percent of the $3,751 million projected total cost of these 12 ships.[185]

If shipyard labor-related costs account for about 35 percent (about $1,313 million) of the cost of the 12 new-construction LMSRs, and if the LMSR program is experiencing a learning curve of between 90 and 91 percent, then splitting the learning curve between two shipyards would increase shipyard labor-related costs by about $100 million. If, on the other hand, the LMSR program is experiencing about a 95 percent learning curve, which might be more appropriate for a program to build relatively less complex ships like LMSRs, then the increase in shipyard labor-related costs resulting from splitting the learning curve would be closer to $50 million, or about 1.3 percent of the projected total cost of these 12 ships.[186]

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[185] For information on the projected cost of the first 12 new-construction LMSRs, see *Sealift (LMSR) Shipbuilding and Conversion Program: Background and Status*, op. cit., p. 6.

[186] Each yard is building its six ships to its own design. The Administration's decision to award construction contracts for the 12 ships to two yards rather than one thus divided the 12 ships into two distinct classes. Since each class has its own design and engineering costs, the Administration's decision to award construction contracts for the 12 ships to two yards rather than one thus resulted in a program that included two sets of design and engineering costs rather than one. These design and engineering costs are included in the cost of the first ship in each class. The difference in projected cost between the first and second ship at each yard suggests that the total design and engineering costs for each class are roughly $85 million. The Administration's decision to award contracts to two yards rather than one thus further increased the total projected cost of the 12 ships by about $85 million, or about 2.3 percent.

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APPENDIX F: ABBREVIATIONS AND ACRONYMS

AD	destroyer tender (large auxiliary ship)
ADC(X)	dry cargo ship (projected) (large auxiliary ship)
AO	oiler (large auxiliary ship)
AOE	replenishment ship (large auxiliary ship)
AOR	replenishment ship (large auxiliary ship)
ASA	American Shipbuilding Association
ASD	Avondale Shipyards Division
BIW	Bath Iron Works
BRAC	Base Realignment and Closure
BUR	Bottom-Up Review
CDS	Construction Differential Subsidy
CFE	contractor-furnished equipment
CG	guided missile cruiser
CGN	nuclear-powered guided missile cruiser
CV	conventionally powered aircraft carrier
CVN	nuclear-powered aircraft carrier
DARPA	Defense Advanced Research Projects Agency
DD	destroyer
DDG	guided missile destroyer
EB	Electric Boat Corporation
FF	frigate
FFG	guided missile frigate
FMS	Foreign Military Sales
FY	fiscal year
FYDP	Future Years Defense Plan
GFE	government-furnished equipment
ISI	Ingalls Shipbuilding, Inc.
LHA	amphibious assault ship (large-deck amphibious ship)
LHD	amphibious assault ship (large-deck amphibious ship)
LKA	amphibious cargo ship (smaller amphibious ship)
LMSR	large, medium-speed RO/RO ship (sealift ship)
LPD	dock landing ship (smaller amphibious ship)
LSD	dock landing ship (smaller amphibious ship)
LST	tank landing ship (smaller amphibious ship)
MARAD	Maritime Administration
MHC	coastal mine hunter (mine warfare ship)
MPF	Maritime Prepositioning Force
MRS	Mobility Requirements Study
MSB	Major Shipbuilding Base
MSC	Military Sealift Command
NASSCO	National Steel and Shipbuilding Company
NDSF	National Defense Sealift Fund
NNS	Newport News Shipbuilding
NSSN	New Attack Submarine (alternate abbreviation: NAS)
NSY	naval shipyard
ROM	rough order of magnitude

RO/RO	roll-on/roll-off
SCA	Shipbuilders Council of America
SC-21	surface combatant for the 21st Century
SCN	Shipbuilding and Conversion, Navy (appropriation account)
SIC	Standard Industrial Classification
SLEP	Service Life Extension Program
SRF	ship repair facility
SSBN	nuclear-powered ballistic missile submarine
SSN	nuclear-powered attack submarine
s/y/y	ships (produced) per yard per year
TAKR	MSC-operated RO/RO cargo ship (sealift ship)
TAO	MSC-operated oiler (large auxiliary)
WHEC	Coast Guard high-endurance cutter