United States Government Accountability Office

GAO

Report to Congressional Committees

May 2009

BEST PRACTICES

High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding

GAO

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GAO-09-322

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High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding

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Highlights

Highlights of GAO-09-322, a report to congressional committees

Why GAO Did This Study

Cost growth is a prevalent problem in Navy shipbuilding programs, particularly for the first ships in new classes. In response to a mandate in the conference report accompanying the Defense Appropriations Act for Fiscal Year 2008, GAO undertook this review to (1) identify key practices employed by leading commercial ship buyers and shipbuilders that ensure satisfactory cost, schedule, and ship performance; (2) determine the extent to which Navy shipbuilding programs employ these practices; and (3) evaluate how commercial and Navy business environments incentivize the use of best practices. To address these objectives, GAO visited leading commercial ship buyers and shipbuilders, reviewed its prior Navy work, and convened a panel of shipbuilding experts.

What GAO Recommends

GAO suggests Congress consider refining required reporting to include additional design stability metrics. GAO is also making recommendations to the Secretary of Defense aimed at improving shipbuilding programs by balancing requirements and resources early, retiring technical risk and stabilizing design at key points, moving to fixed-price contracts for lead ships, evaluating in-house management capability, and assessing if the desired fleet size sufficiently constrains the cost and technical content of new ships. The Department of Defense agreed with five recommendations and partially agreed with two. GAO believes all recommendations remain valid.

To view the full product, including the scope and methodology, click on GAO-09-322. For more information, contact Paul Francis at (202) 512-4841 or francisp@gao.gov.

What GAO Found

Delivering ships on time and within budget are imperatives in commercial shipbuilding. To ensure design and construction of a ship can be executed as planned, commercial shipbuilders and buyers do not move forward until critical knowledge is attained. Before a contract is signed, a full understanding of the effort needed to design and construct the ship is reached, enabling the shipbuilder to sign a contract that fixes the price, delivery date, and ship performance parameters. To minimize risk, buyers and shipbuilders reuse previous designs to the extent possible and attain an in-depth understanding of new technologies included in the ship design. Before construction begins, shipbuilders complete key design phases that correspond with the completion of a three-dimensional product model. Final information on the systems that will be installed on the ship is needed to allow design work to proceed. During construction, buyers maintain a presence in the shipyard and at key suppliers to ensure the ship meets quality expectations and is delivered on schedule.

Navy programs often do not employ these best practices. Ambitious requirements are set and substantial investments made in technology development, but often the Navy does not afford sufficient time to fully mature technology. New designs often make little use of prior ship designs. As a result, a full understanding of the effort needed to execute a program is rarely achieved at the time a design and construction contract is negotiated. This in turn leads the Navy and its shipbuilders to rely on cost-reimbursable contracts (rather than fixed-price contracts) that largely leave the Navy responsible for cost growth. Complete information on the systems that will be installed on the ship may not be available, leading to changes that ripple through the design as knowledge grows. Starting construction without a stable design is a common practice and the resulting volatility leads to costly out-of-sequence work and rework. These inefficient practices cause Navy ships to cost more than they otherwise should, reducing the number of ships that can be bought under constrained budgets. The Navy's in-house capability to oversee design and construction has eroded, and it has been slow to build capacity to support new programs. Congress has recently encouraged greater technology maturity and design stability at key points, but required reporting does not directly address completion of a three-dimensional product model.

Differences in commercial and Navy practices reflect the incentives of their divergent business models. Commercial shipbuilding is structured on shared priorities between buyer and shipbuilder, a healthy industrial base, and maintaining in-house expertise. The need to sustain profitability incentivizes disciplined practices in the commercial model. In Navy shipbuilding, the buyer favors the introduction of new technologies on lead ships—often at the expense of other competing demands—including fleet size. This focus—along with low volume, a relative lack of shipyard competition, and insufficient expertise—contributes to high-risk practices in Navy programs. Further, the consequences of delayed deliveries and cost growth are not as severe in Navy programs because of the use of cost-reimbursable contracts.

Contents

Figures

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United States Government Accountability Office
Washington, DC 20548

May 13, 2009

The Honorable Daniel K. Inouye
Chairman
The Honorable Thad Cochran
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable John P. Murtha
Chairman
The Honorable C.W. Bill Young
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

The U.S. Navy builds the most sophisticated, technologically advanced ships in the world, but pays too high a premium for this capability. Since fiscal year 2002, Congress has appropriated over $74.1 billion[1] for new construction of aircraft carriers, nuclear submarines, surface combatants, and amphibious vessels. This investment, however, has included over $8.3 billion[2] to cover cost growth associated with ships funded in prior years, subsequently reducing the overall buying power of the Navy and constraining the Department of Defense as a whole.

Lead ships—the first to be built in a class—have proven the most problematic. In fact, the Navy's six most recent lead ships[3] have

[1]Total excludes funding appropriated for conversions, nuclear aircraft carrier and submarine refuelings, modernizations, service life extension programs, service and special purpose craft, outfitting, post-delivery work, first destination transportation, and canceled ships.

[2]Total includes approximately $4.8 billion in prior year completion funding, $2.6 billion in supplemental funding related to the effects of Gulf Coast hurricanes, $667.6 million in cost growth for the first and second Littoral Combat Ships funded outside of procurement accounts, and $251.2 million in incrementally funded cost growth for the eighth Wasp-class amphibious assault ship (LHD 8).

[3]Includes the second Virginia-class submarine, which was constructed in a different shipyard than the first submarine in the class.

experienced cumulative cost growth over $2.4 billion above their initial budgets. This cost growth has been accompanied by delays in delivering capability totaling 97 months across these new classes. Together, these outcomes have required the Navy to increasingly reshape its long-range ship procurement plans, placing its goal of a minimum 313-ship fleet in jeopardy.

In light of these developments, you directed that we conduct a review of shipbuilding-specific best practices to identify measures that could improve outcomes in Navy shipbuilding programs.[4] Specifically, we (1) identified key practices employed by leading commercial ship buyers and shipbuilders that ensure satisfactory cost, schedule, and quality performance; (2) determined the extent to which Navy shipbuilding programs employ these practices; and (3) evaluated how effectively the business environments that exist in commercial and Navy shipbuilding incentivize the use of best practices.

To identify key practices used by commercial ship buyers and shipbuilders, we met with representatives of leading ship buyers from the cruise, oil and gas, and commercial shipping industries, including Royal Caribbean, Exxon Mobil, and A.P. Moller-Maersk, respectively. We also met with officials from high-performing commercial shipyards responsible for building a variety of complex ships: Meyer Werft (Germany); Odense Steel Shipyard (Denmark); Aker Yards (Finland);[5] and Samsung Heavy Industries, Hyundai Heavy Industries, Daewoo Shipbuilding and Marine Engineering, and STX Shipbuilding (South Korea). To determine the extent to which Navy shipbuilding programs employ best practices, we drew from our prior work on programs, including the San Antonio-class amphibious transport dock ship (LPD 17), Littoral Combat Ship, Zumwalt-class destroyer (DDG 1000), Ford-class aircraft carrier (CVN 21), Virginia-class submarine (SSN 774), and Lewis and Clark-class dry cargo and ammunition ship (T-AKE 1), among others. To supplement this analysis, we held discussions with a number of Navy offices responsible for shipbuilding programs. We also met with representatives from General Dynamics and Northrop Grumman Shipbuilding and visited the National

[4] H.R. Rep. No. 110-434, at 190 (2007).

[5] In August 2008, Aker Shipyards was purchased by STX Shipbuilding, a Korean company, and is now known as STX Europe. This report will refer to Aker Yards because this was the name of the individual Turku, Finland, yard at the time of our visit, and to distinguish it from other shipyards in the STX Europe portfolio.

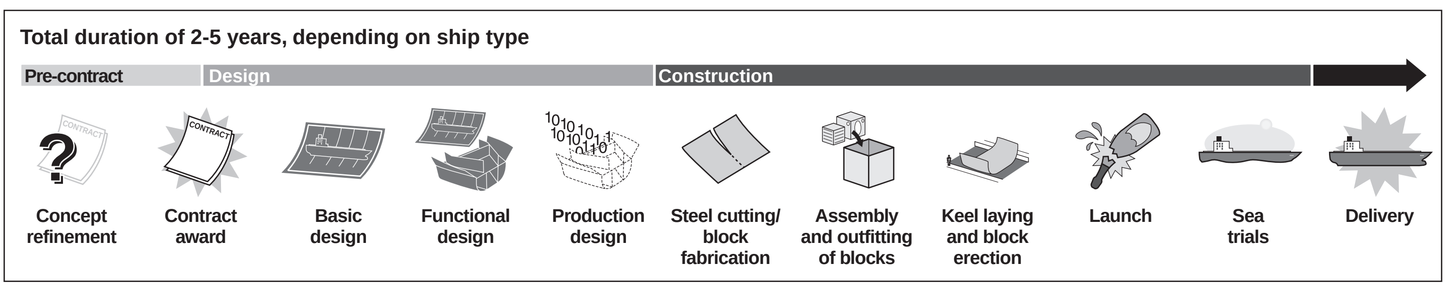
Steel and Shipbuilding Company (NASSCO) and Electric Boat shipyards. To evaluate how effectively the business environments that exist in commercial and Navy shipbuilding incentivize the use of best practices, we convened a panel of shipbuilding experts representing both the Navy and industry to discuss factors that compel behaviors in different shipbuilding programs. A more detailed description of our scope and methodology is presented in appendix I.

We conducted this performance audit from January 2008 to May 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Shipbuilding is a complex, multistage industrial activity that includes a number of key events that are common regardless of the type of ship constructed or nature of the buyer (Navy or commercial). As figure 1 shows, these events are sequenced among three primary phases: pre-contract,[6] design, and construction. Each phase builds upon work completed in earlier stages.

Figure 1: Typical Shipbuilding Process



Source: GAO.

Note: Though this graphic depicts generic shipbuilding phases, Navy shipbuilding programs may use different terms to describe design phases.

[6] "Pre-contract phase" refers to the activities that occur before award of a contract for design and construction.

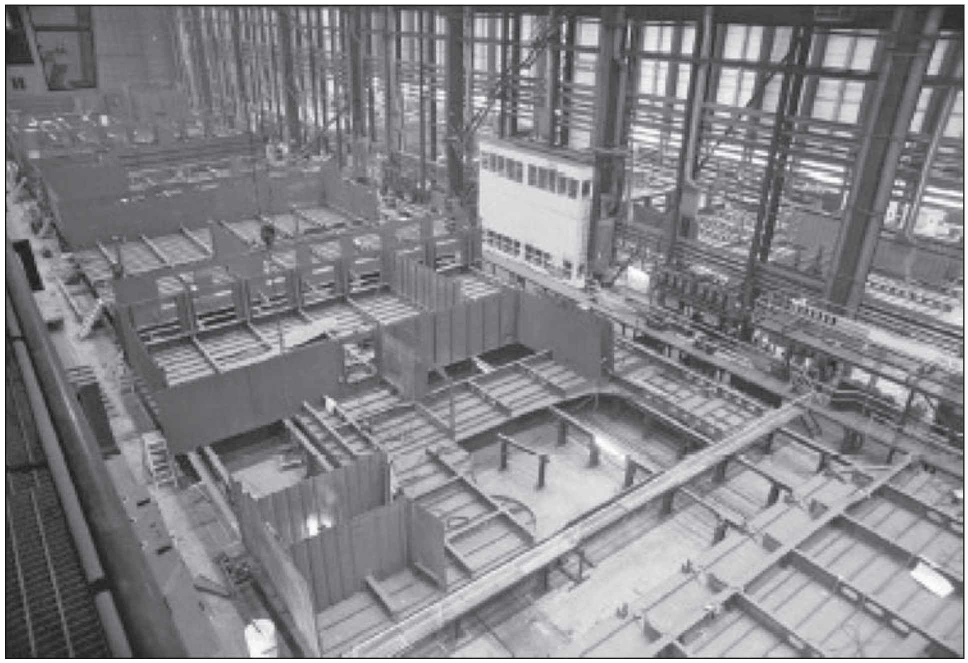
In the pre-contract phase, the buyer may work with different shipbuilders to refine its ship concept. This stage concludes with the buyer selecting its desired concept and agreeing to a design and construction contract with the chosen shipbuilder(s). In commercial shipbuilding, firm, fixed-price contracts are almost always used. This type of contract (1) provides for a price that is not subject to any adjustment on the basis of the contractor's experience in performing the contract and (2) places upon the contractor maximum risk and full responsibility for all costs and resulting profit or loss.[7]

Though some design work occurs in the pre-contract phase, the design phase continues in earnest after contract signing. The design phase encompasses three activities: basic design, functional design, and production design. Basic design serves to outline the steel structure of the ship, whereas functional design routes distributive systems—such as electrical or piping systems—throughout the ship. Production design furnishes the work instructions used to construct elements of the ship. During this phase, all aspects of the ship are defined, a three-dimensional (3D) computer-aided design (CAD) model is often generated, and two-dimensional paper drawings are created that shipyard workers will use to build the ship.

The construction phase includes several steps: steel cutting and block fabrication, assembly and outfitting of blocks, keel laying, block erection, launch, dock and sea trials, and delivery. The first milestone in production is steel cutting, which involves cutting large steel plates into appropriately sized pieces. This task often involves computerized cutting machinery, laser etching of steel plates based on the computerized ship design, and robotics to ensure accuracy and minimize future rework. Figure 2 illustrates the next step in the construction sequence, block fabrication, where steel plates are welded together into elements called blocks. Blocks are the basic building units for a ship, and when completed they will form completed or partial compartments, including accommodation space, engine rooms, and storage areas.

[7]See, for example, 48 C.F.R. § 16.202-1 (Title 48 of the *Code of Federal Regulations* is the Federal Acquisition Regulation).

Figure 2: Cruise Ship Block Fabrication

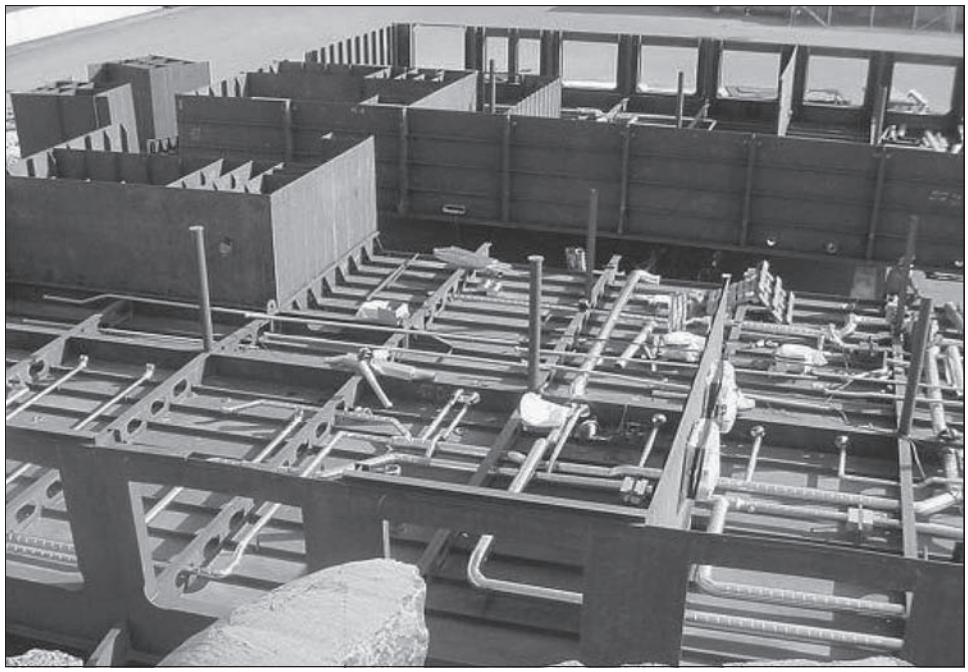


Source: Aker Yards.

Once any planned doorways or holes are cut into the block units, the blocks are ready for equipment installation, a process called block outfitting.[8] Block outfitting is partially performed while the block is positioned upside down, as figure 3 shows. This approach enables shipyard workers to install equipment more efficiently by lowering it into the block instead of hoisting the equipment into place. Building blocks in the inverted (upside down) position also enables more down-head welding, rather than less efficient overhead welding.

[8]Industry differentiates between outfitting at the block stage and outfitting in the drydock—the floodable basin that provides the platform for ship construction. Equipment such as piping and cable trays is typically outfitted at the block stage, whereas equipment of heavy machinery, such as engines and generators, is outfitted in the drydock.

Figure 3: Cruise Ship Block Outfitting



Source: Aker Yards.

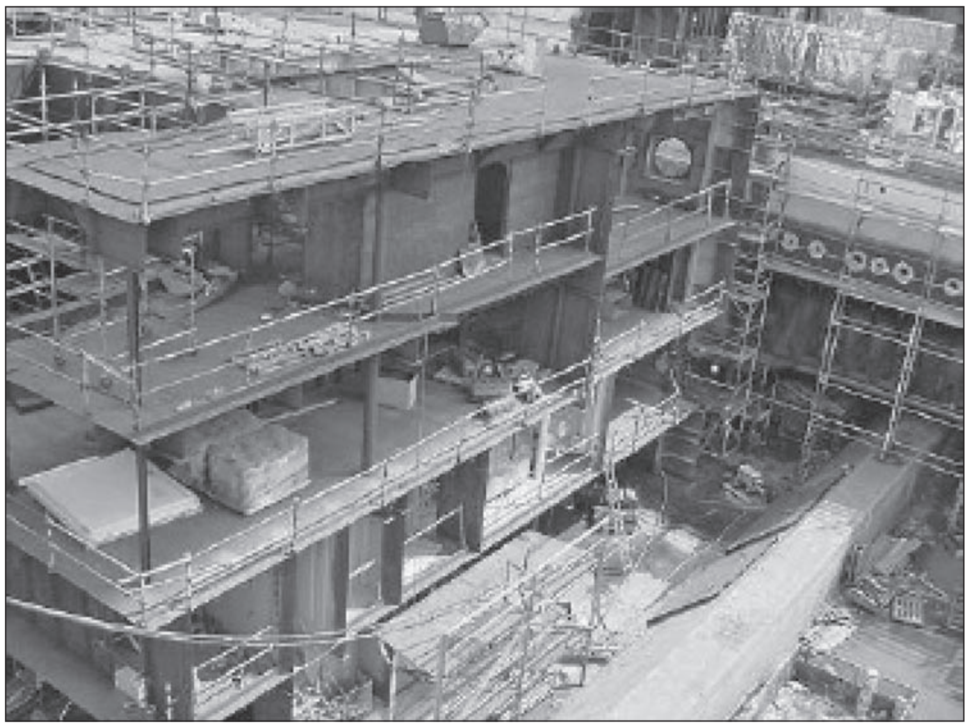
Blocks are generally outfitted with pipes, brackets for machinery or cabling, ladders, and any other equipment that may be available for installation at this early stage of construction. This allows a block to be installed as a completed unit with connectors to adjacent blocks. Installing equipment at the block stage of construction is preferable because access to spaces is not limited by doors or machinery, unlike at later phases. Shipbuilders often describe a "1-3-8 rule," where work that takes 1 hour to complete in a workshop takes 3 hours to complete once the steel panels have been welded into blocks, and 8 hours to complete after a block has been erected and/or after the ship has been "launched," or conveyed from its building site to the water.[9]

As figure 4 illustrates, each block is ultimately welded together with other blocks to form larger sections, which are known as grand blocks and

[9]Some shipbuilders identify slightly different numbers of hours for the second and third phases (block and post-erection/post-launch construction) cited in the rule. These numbers of hours tend to increase as the complexity and outfitting density of a ship increase.

compose the ship's structure. These blocks and grand blocks are moved around the shipyard by wheeled block transporter vehicles and are lifted by large gantry cranes suspended over the drydocks.

Figure 4: Cruise Ship Grand Block

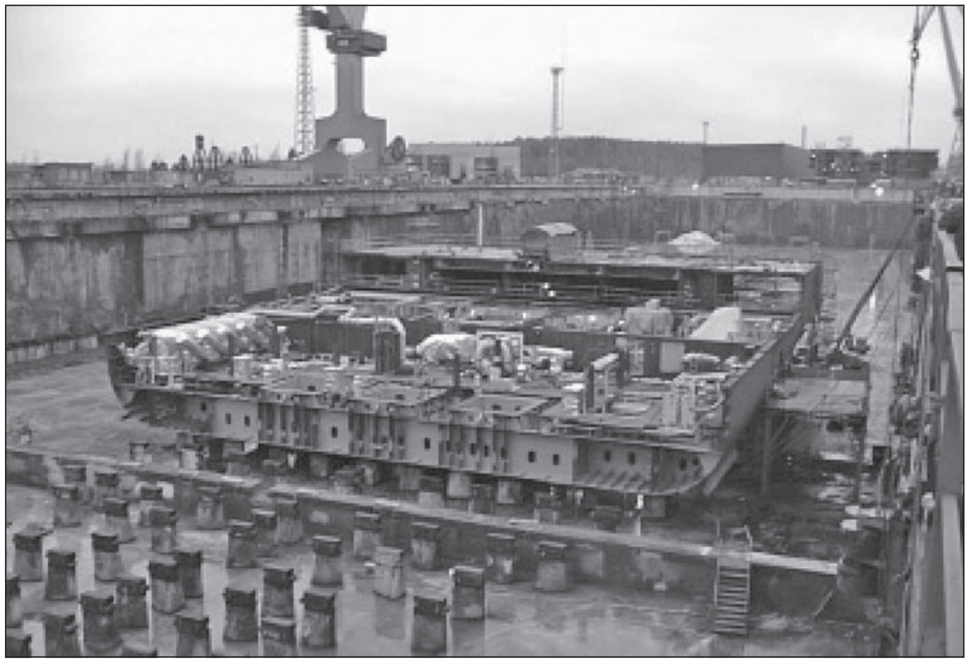


Source: Aker Yards.

Once the shipyard has enough blocks and grand blocks completed based on its internal work sequencing, the yard lays the keel into the drydock, which is where the ship will be erected.[10] After the keel is laid, other grand blocks are placed in the drydock and welded to the surrounding grand blocks, and the outfitting of machinery, engines, propeller shafts, and other large items requiring the use of overhead cranes occurs. Ships are typically built from the center-bottom up. Figure 5 illustrates how blocks are assembled in the drydock.

[10]Historically, keel laying coincided with laying the main timber of the ship hull, or keel. Today, keel laying generally means landing the first grand block into the drydock.

Figure 5: Cruise Ship Blocks in Drydock after Keel Laying



Source: Aker Yards.

Finally, once the ship is watertight and the decision is made to launch—or float the ship in water—the drydock is flooded and the ship, now afloat for the first time, is towed into a quay or dock area where final outfitting and testing of machinery and equipment like main engines will occur.[11] Different shipyards apply different criteria to assess if or when a ship is ready to launch. One factor that contributes to these decisions is shipyard facilities, including the capability to efficiently outfit the ship dockside once it has been launched. Shipyards we visited tended to have a high degree of outfitting completed prior to launch, and one Korean shipyard typically has close to 95 percent of the ship completed at the time of launch. One European shipyard we visited that builds cruise ships sometimes chooses to launch ships with less outfitting—about 50 percent—of the ship completed because cabin insertion—a major aspect of cruise ship construction—can efficiently take place pierside. Most shipyards agreed, however, that launching a ship at a lower level of

[11]Some shipyards launch ships by sliding them backwards or sideways into the water.

outfitting than planned should be avoided because it is generally more expensive to perform work on a ship after it is launched.

Once final outfitting activities and planned dock trials are completed, and the shipyard is satisfied that the ship is seaworthy, the ship buyers are brought aboard and the ship embarks on sea trials where performance is evaluated against the contractually required specifications and overall quality will be assessed.[12] Following successful sea trials, the shipyard delivers the ship to the ship owner.

The International Maritime Organization requires a ship's design and construction to be approved by ship classification societies, including the American Bureau of Shipping and Lloyd's Register.[13] These societies (1) establish and maintain standards for the construction and classification of ships and offshore structures, (2) supervise construction in accordance with these standards, and (3) carry out regular surveys of ships in service to ensure the compliance with these standards.

Commercial ships range from more basic vessels—such as cargo carriers, tankers, and product carriers—to ships that are highly complex and densely outfitted and incorporate technological advances vital to improving business operations. These ships include floating production storage and offloading (FPSO) vessels, which are able to collect, process, and store oil from undersea oil fields; large cruise ships, some of which exceed the size of a Ford-class aircraft carrier; and liquefied natural gas (LNG) carriers. Each of these ship types generally takes longer to build than simpler commercial ships with construction times lasting up to 3 years. Further, these ships are very dense, meaning that unlike a bulk carrier or an oil tanker that has large, empty voids to hold cargo, these ships have equipment and accommodation spaces tightly packed throughout. Similar to the mission equipment for certain Navy ships, FPSO vessels have oil refining equipment that may be built by a separate contractor and provided to the shipyard for installation.

[12]Liquefied natural gas ships also have a gas trial where the gas containment systems are tested.

[13]There are 10 classification societies worldwide that have been approved and recognized by the International Maritime Organization. The Navy recently partnered with one of these societies, the American Bureau of Shipping, to develop new design guidelines for its ships, which are referred to as Naval Vessel Rules.

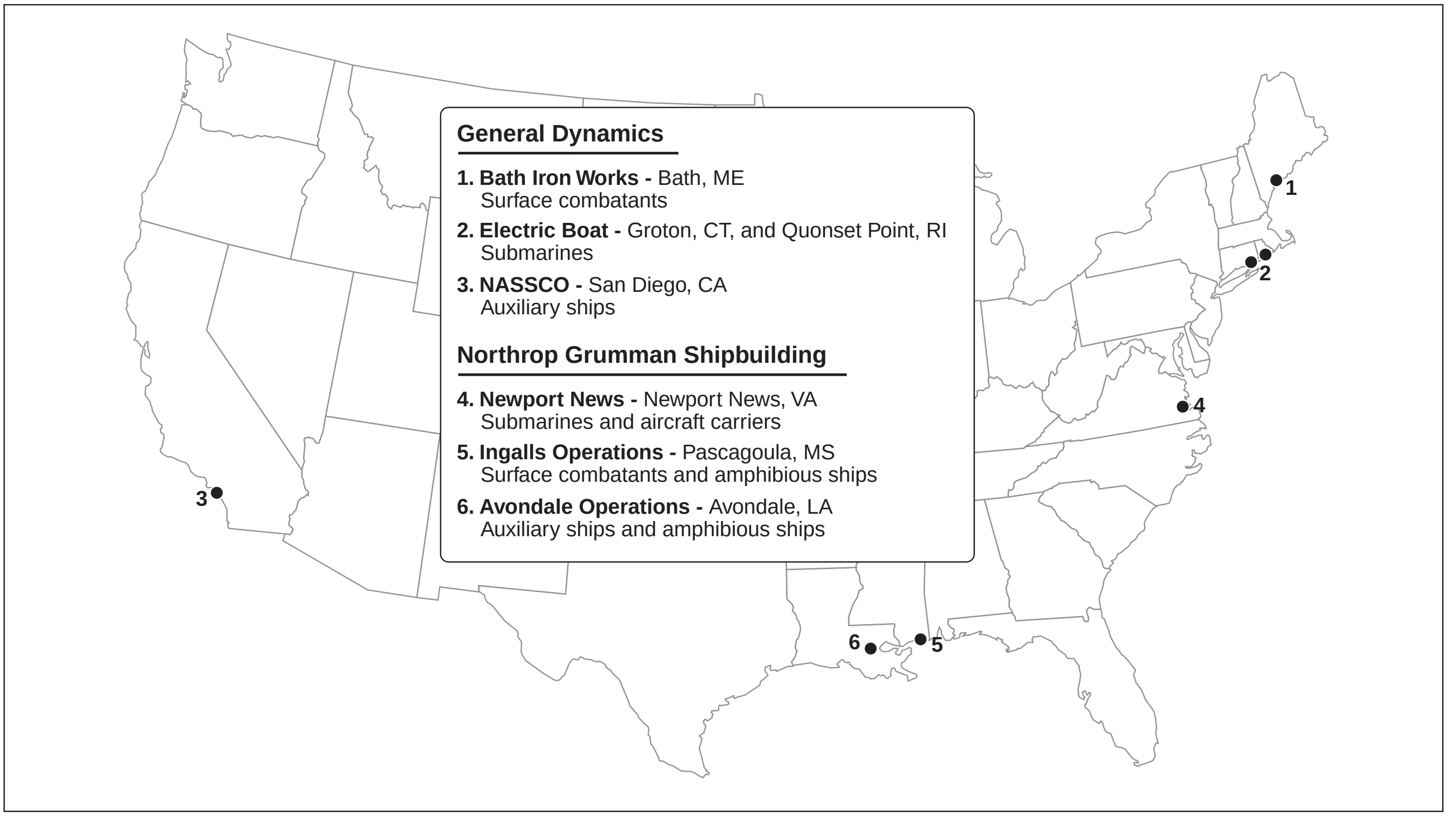
Cruise ships are typically built in European shipyards. Major builders include Aker Yards (now STX Europe) in Finland and France, Meyer Werft in Germany, and Fincantieri in Italy. Together, these three yards constitute an estimated 80 percent of global cruise shipbuilding. Commercial shipbuilding primarily occurs in Asia; Korean shipyards constitute approximately 35 percent of the market, Japanese shipyards approximately 30 percent, and Chinese shipyards approximately 12 percent.

At present, the shipbuilding industry in the United States is predominantly composed of three different types of shipyards: (1) privately owned shipyards that build commercial vessels; (2) privately owned shipyards that build Naval vessels; and (3) U.S. government-owned naval shipyards that conduct maintenance, repairs, and upgrades on Navy and Coast Guard vessels.[14] In the past, major U.S. shipyards have consolidated under larger corporate entities. As a result, two major companies—General Dynamics and Northrop Grumman Shipbuilding—now own the six largest shipyards capable of building most Navy ships.[15] General Dynamics owns Bath Iron Works in Bath, Maine; Electric Boat in Groton, Connecticut, and Quonset Point, Rhode Island; and NASSCO in San Diego, California. Northrop Grumman Shipbuilding owns Ingalls in Pascagoula, Mississippi; Newport News in Newport News, Virginia; and Avondale in Avondale, Louisiana. As figure 6 outlines, Navy vessels constructed at these yards include nuclear submarines, aircraft carriers, surface combatants, and auxiliary ships. Beyond the six major yards, there are a number of midsized, commercial shipyards the Navy uses that are capable of constructing ships smaller in size like the Littoral Combat Ship (LCS) and Maritime Prepositioning Force utility boats.

[14]The Navy operates four publicly owned shipyards located in Pearl Harbor, Hawaii; Puget Sound, Washington; Seavey Island, Maine; and Portsmouth, Virginia.

[15]The U.S. Navy is statutorily prohibited, unless waived by the President in the interests of national security, from constructing a vessel, or major component of the hull or superstructure of a vessel, in a foreign shipyard. 10 U.S.C. § 7309.

Figure 6: Major Navy Shipbuilders and Associated Product Lines



Sources: GAO, MapArt.

Several of these shipyards have specialized production capabilities that constrain the types of vessels they are capable of building. For instance, of the six major shipyards, only Newport News is capable of erecting nuclear powered aircraft carriers, and only Newport News and Electric Boat have facilities to construct nuclear submarines. In addition, of the six major shipyards, only NASSCO regularly builds commercial ships alongside Navy ships. NASSCO typically builds Navy auxiliary ships, such as the T-AKE 1 class of dry cargo/ammunition vessels that share similarities with commercial ships. According to the shipbuilder, this enables NASSCO to share production processes and equipment between the two types of projects. The commercial ships built at NASSCO and other U.S. shipyards are typically ships that will operate exclusively between U.S. ports, and thus are required by the Merchant Marine Act (commonly referred to as the Jones Act) to be built in U.S. shipyards and to be U.S. owned.[16]

Commercial Shipbuilders Minimize Risk Early by Having High Levels of Knowledge at Key Junctures

Commercial shipbuilding programs are characterized by the high levels of knowledge that ship buyers and shipbuilders insist upon at key junctures throughout the acquisition process. This knowledge enables leading commercial shipbuilders to deliver innovative new ships within cost and schedule estimates. Buyers and builders are willing to take the steps necessary to minimize the risk that a ship will deliver late or exceed its budget. Most important, commercial shipbuilders and buyers retire all major risk posed by technological advances or novel design features prior to signing a contract for a ship. In order to develop a comfort level with these new technologies or features, the shipyards will work with the buyers to test, model, and run simulations on the technology—utilizing both in-house and third-party technical experts—to validate that the risk is low enough to not jeopardize the success of the program. Once most of the program risk is retired, the shipbuilders can agree with the buyer at contract signing on the ship concept, fix the ship's cost and delivery date, and guarantee that the ship will perform as specified. All basic and functional design is completed prior to starting construction, and a disciplined construction process is followed by the shipbuilder and supervised by the buyer to ensure delivery of a quality product on cost and on schedule. Table 1 further highlights key commercial practices in shipbuilding.

[16] 46 U.S.C. § 55102.

Table 1: Best Practices in Commercial Shipbuilding

Phase	Commercial practices
Pre-contract	**Commercial shipbuilders and ship buyers retire all major risk prior to signing a contract** • Shipyards will not sign a contract if there is outstanding technical risk • Shipyards and buyers leverage existing designs to minimize risk
Contract	**Commercial shipbuilders fix the cost and delivery date at contract signing** • Leading buyers and shipbuilders use only firm, fixed-price contracts • Buyer cannot change specifications/drawings without incurring financial or technical performance penalties once a contract is signed • Shipyard guarantees that the ship will perform as defined in the agreed specifications
Design	**Commercial shipbuilders complete all basic and functional design prior to starting construction** • Shipyards will not start construction until a design is complete and stable • 3D CAD is completed prior to construction
Construction	**Commercial shipbuilders have a disciplined construction process that delivers ships within cost and on schedule** • In order to maintain tight schedules across multiple ships, drydock time is rigorously monitored and controlled by the shipbuilder • Change orders are minimized to avoid delays and cost growth • Buyers perform vigorous oversight of construction in order to ensure quality and to monitor schedule

Source: GAO analysis.

Leading Commercial Shipbuilders Routinely Deliver Innovative Ships within Planned Cost and Schedule Estimates

The shipyards we visited had recent experience successfully delivering complicated lead ships that featured new design or technological features. Table 2 highlights several of these examples.

Table 2: Shipbuilder Performance on Notable Commercial Lead Ship Programs

Buyer	Lead ship, type, and displacement	Shipyard	Approximate cost and construction cycle time[a]	Notable new features	Construction outcomes
Royal Caribbean Cruises, Ltd.	*Freedom of the Seas* Cruise 154,000 tons displacement	Aker Yards	$800 million 36 months	Largest cruise ship in the world at delivery. Ship features included an improved hull form, more efficient air conditioning systems, and a new topside surfing water park feature requiring significant pump machinery and deck stabilization.	Delivered complete, at promised cost, and within 30-day grace period outlined in contract.
A.P. Moller-Maersk	*Emma Maersk* Container 170,974 tons displacement	Odense Steel Shipyard	$145 million 32 months	Largest containership ever, high-speed capabilities, novel 14-cylinder engine, new waste heat recovery technology.	Eight-ship class delivered from July 2006 through November 2007. First ship was erected in 45 days with the yard operating on three shifts.
Star Deep Water Petroleum, Ltd. (a Chevron-affiliated company)	*Agbami* FPSO 417,000 metric tons full load displacement	Daewoo Shipbuilding and Marine Engineering	$1.2 billion 22 months (hull only)	Large FPSO vessel capable of 250,000 barrels per day crude oil production, storage of 2.1 million barrels of crude oil, and accommodations for 155 people.	Seven-year planning period for a complex, costly vessel, which was delivered on time and complete, enabling its commercial operations to begin 1 month earlier than scheduled.
Carnival Corporation	*Elation*[b] Cruise 70,367 tons displacement	Kvaerner Masa Yard (now part of STX Finland)	$280 million 22 months	First cruise ship to incorporate novel Azipod propulsion technology.	Challenges were experienced in sea trials with the newly developed bridge joystick control of the Azipods. Subsequently, an improvement program was initiated with buyer assistance, and the ship was successfully delivered 4 days earlier than specified in the contract.
Qatar Petroleum and Exxon Mobil[c]	*Q-Flex and Q-Max* LNG carriers *Q-Flex*—147,000 tons displacement, *Q-Max*—179,000 tons displacement	Samsung Heavy Industries, Daewoo Shipbuilding and Marine Engineering, and Hyundai Heavy Industries	$300 million (*Q-Max*) 32-36 months	Revolutionary size for an LNG carrier; *Q-Max* carries 80 percent more LNG than existing ships; novel reliquification technology; first two-rudder and propeller LNG design.	Forty-five ships to be acquired across all of the Qatar joint ventures; second largest single ship acquisition in history after U.S. Liberty Ship program in World War II. Ships to date have delivered on time or early, at anticipated costs, and with minimal change orders.

Source: GAO analysis of industry-provided data.

[a]Defined as the period between contract award and delivery for the lead ship.

[b]Although not technically a lead ship, *Elation* incorporated a revolutionary propulsion system.

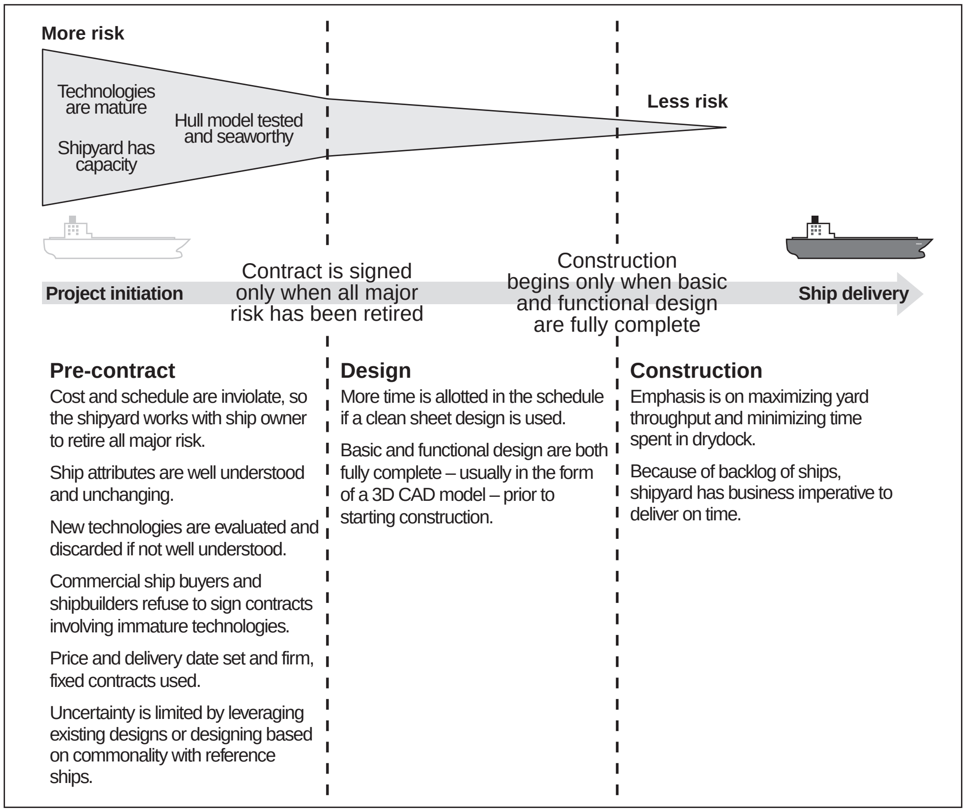
[c]Joint ventures between Qatar Petroleum and Exxon Mobil lease the *Q-Flex* and *Q-Max* LNG carriers from ship owners. In the role of lessee, these joint ventures managed the technology evaluation and design review processes for *Q-Flex* and *Q-Max* ships, and currently monitor construction activities.

Commercial Shipbuilders and Ship Buyers Retire Project Risks Prior to Signing a Contract

Leading commercial ship buyers and shipbuilders insist upon identifying and retiring all major program risks early. This analysis occurs during the pre-contract phase, which can be as long as 5 years or more depending on the complexity of the ship and the novelty of the proposed design and systems on board. Commercial shipyards may self-finance this pre-contract work to position themselves to ultimately win the contract to design and build the ship. They also do this work to gain a full understanding of potential technical risks associated with a project and to better inform the decision of whether to bid on the ship. Sometimes this process includes buyer acceptance and evaluation of several concept designs from different shipyards to determine which best meets its needs. For example, when Exxon Mobil and its partner, Qatar Petroleum, were interested in buying a number of new LNG carriers, they provided several Korean shipyards with the specifications that the Qatar project expected the ships to meet. Each shipyard was given the opportunity to develop its own concept designs for the buyer to review. Ultimately, three shipyards presented concepts that met the project's requirements. In turn, the project representatives awarded contracts to each of the three shipyards in order to maximize productivity on the project, even though the LNG ship designs differed among the three shipyards.

In the commercial model, a program will only move forward to contract signing once the ship buyer and shipbuilder reach agreement that potential showstoppers have been mitigated so as to not jeopardize the planned cost and delivery schedule for the ship. If the shipyard fails to resolve program risks or showstoppers before committing to a firm, fixed-price and a fixed-delivery schedule, it could encounter problems later in the construction process that will require the diversion of additional, unplanned resources to the project. This result could detract from the shipyard's performance on other projects in the yard and have a cascading effect, delaying multiple ships on order, which would hurt the shipyard's professional reputation and could jeopardize future business. Figure 7 illustrates the strong emphasis the commercial sector places on retiring risk early in its shipbuilding programs.

Figure 7: Commercial Practices: Risk Minimized Pre-contract



Source: GAO analysis.

In the commercial model, the pre-contract phase involves the development of the ship concept and the ship specifications based on negotiations between the ship buyer and the shipyard, which will specify the performance expected and the major equipment on the ship. Generally, the ship buyer has an idea of the type of ship it would like to buy and the performance parameters that it will require the ship to meet, which help form the basis for these negotiations. Several representatives of commercial shipbuilders and ship buyers we met with stated that during this initial phase, they will analyze one or more ship concepts to identify areas of potential risk and they will either mitigate these risks or remove the risky elements from the ship before signing a contract. Risk can be minimized in several ways before signing the contract. One option is that the buyer can opt to use a ship design that the shipyard has already built rather than requiring a new design to be created. Using an existing design minimizes the amount of design work that has to be done and provides assurances that the yard can actually build the ship for the planned cost and schedule since the shipyard has previously built the design. This approach was used in the Korean shipyards we visited. Those yards maintain standard designs for different classes of ships that buyers can select from and modify, as desired.

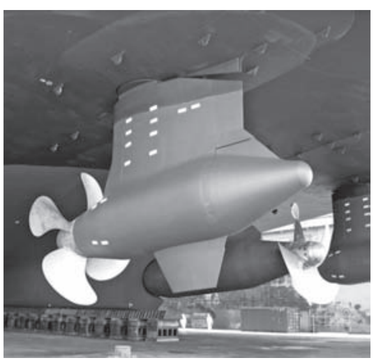
Similarly, the cruise industry relies on previous ship designs to the extent possible. Royal Caribbean's Freedom-class ship drew heavily upon design attributes from the preceding Voyager class. For example, though Freedom-class ships are 27 meters longer than Voyager-class ships, they have the same propulsion system, power lines, and other basic features as Voyager-class ships. The cruise industry also undertakes ship revitalizations—which can be quite complex in nature—during the life span of its ships. For one of its ships, *Enchantment of the Seas*, Royal Caribbean invested $90 million to perform a 60-day overhaul that included cutting the ship in half and inserting a new middle section that would provide additional cabin space and capacity. Further, these revitalization projects provide opportunities for Royal Caribbean to introduce new features or technologies to a ship—such as hydrodynamically efficient ducktails to improve fuel efficiency—that were not incorporated during initial construction. The revitalized ship could also provide a test bed for fully proving out new technologies ahead of Royal Caribbean installing them on future newbuild ships.

Alternatively, common design elements from previous ships can be incorporated to minimize the amount of new content in the design. However, should these options not meet buyer requirements, a new "clean sheet" design can be undertaken. In cases where a new hullform is necessary, the ship buyer and the shipyard will work together to model and validate design attributes, such as seakeeping abilities, speed, and fuel consumption, as desired by the buyer. This modeling exercise is completed using both water tanks and computer simulation. Performance of other items, such as new propeller designs, is also validated using these means.

According to commercial shipbuilders and buyers, new technologies are vetted through a similar process of extensive testing, modeling, and analysis. One buyer told us that among other considerations, a new technology has to earn its way onto a ship through the form of significant savings to operations and maintenance costs. However, despite the allure of innovative technologies within the competitive marketplace, if a novel technology cannot be matured to a level that provides the buyer and builder with confidence that it will not impede delivery of the ship and will perform as expected, it will be discarded to maximize the chances of program success. Additionally, one buyer's representative told us that a shipyard refused to install an air cushion hull on a ship because it thought that the project was too risky, even though the technology had been vetted through model testing and on existing ships. See figure 8 for a case study about how Royal Caribbean worked with a shipyard to vet a propulsion technology before deciding to build it into new ships.

Leading commercial shipbuilders may test new technologies aboard existing ships prior to installing them on a new ship to validate the performance of the technologies in a lower-risk environment for both the buyer—since the existing ship has redundant systems—and the shipyard—since it will not accept responsibility for installing and integrating an untested prototype under a firm, fixed-price contract. Shipbuilders and larger ship buyers maintain an in-house or contracted capability to conduct technical research to evaluate the maturity and expected performance of new technologies during the pre-contract phase.

Figure 8: Royal Caribbean Cruises, Ltd., Employment of Azipod Propulsion



In the 1990s, Royal Caribbean wanted to change the propulsion system on its cruise ships from standard fixed propellers driven by propeller shafts to a rotating, podded propulsion system called Azipod. These pods carry the propeller and motor outside of the ship and have the capability to rotate 360 degrees, allowing for the ship to be pulled through the water as well as pushed. This technology, developed by a company called ABB, offered the potential of improved fuel efficiency and greatly enhanced maneuverability—affording Royal Caribbean the ability to construct significantly larger cruise ships capable of accessing major ports. At the time Royal Caribbean wanted to move from conventional propulsion to Azipod, the technology had only been installed on smaller ships, including tug boats and icebreakers. Royal Caribbean approached ABB about the possibility of scaling Azipod up to the size required for a cruise ship and brought the shipyard it planned on using for the project on board. The three parties worked together to extensively prove the technology and built close-to-scale versions of Azipod before Royal Caribbean and the shipbuilder both became comfortable enough to move forward with the project. Further, despite its growing confidence in Azipod, Royal Caribbean decided that it was prudent to maintain some redundancy through installation of fixed pods that could provide propulsion in the event that the new Azipods failed. After overcoming some initial maintenance issues, the Azipods project proved successful for Royal Caribbean. The enhanced maneuverability offered by the Azipods enabled the company to initiate development of the new 220,000-ton *Oasis of the Seas*, which is currently under construction and planned to be the largest cruise ship ever built.

Sources: Royal Caribbean Cruises, Ltd. (photo); GAO (data).

Note: By the time Royal Caribbean built a cruise ship with Azipods, Carnival Corporation had also built ships that employed Azipods.

Before signing a contract to build its new Emma Maersk-class of containerships, ship buyer A.P. Moller-Maersk worked with its shipbuilder, Odense Steel Shipyard, to resolve several major issues that might have prevented the program from progressing. Specifically, this ship class—

consisting of eight ships—was expected to (1) be the largest containership ever designed, (2) operate at high speeds in excess of 25 knots, (3) incorporate higher fuel efficiency standards, and (4) be powered by what would be the largest diesel engine ever built. As such, this project presented many challenges to the buyer and builder, including several potential showstoppers—any one of which could threaten the viability of the program if not resolved early. Table 3 depicts how the ship buyer and shipyard worked together to mutually identify and resolve risk prior to signing a contract for the lead ship. Ultimately, the shipyard delivered eight ships that performed to specification, and *Emma Maersk* was given the Ship of the Year award, presented annually by Lloyd's List.

Table 3: Emma Maersk-Class Technology Risks and Other Concerns Resolved Prior to Contract Award

Technology risks and other concerns	Mitigation strategies
Building a ship of such a large size that would be propelled with only one propeller and one propeller shaft.	Computer modeling and simulations completed prior to signing contract to validate that propeller and shaft would work as required.
If propelling such a large ship with one propeller could be accomplished, it was unknown if any supplier could cast a propeller that large.	Contacted propeller suppliers and verified capability to produce propeller.
The ship design required a very long drive shaft (120 meters) because the engine had to be placed near midship for seakeeping (stability) purposes. It was unknown if such a long shaft would work properly with the hull and main engine so as to avoid damage to engine bearings and other components.	Computer modeling and simulations completed pre-contract to validate drive shaft concept.
A ship of the size required would need good seakeeping abilities, meaning that it would be stable at sea.	Model testing of hullforms in a model basin and computer simulations completed to validate seakeeping.
A new 14-cylinder main engine would need to be developed, and the impacts that a 14-cylinder engine would have on the crankshaft were uncertain.	Determined with the engine manufacturer that adding cylinders to existing engines would be low risk and feasible. Since a 14-cylinder engine did not already exist, the buyer had the manufacturer install and test some of the new components on existing 12-cylinder engine versions.
Higher grades of steel than previously used in this type of shipbuilding would be needed to provide the strength required for the hull and the steel plate, which had to be reinforced to carry so much cargo.	The ship classification societies American Bureau of Shipping and Lloyd's Register were brought in to assist in the technical calculations of required steel grade and thickness, and special class society approval was obtained. The Danish Technical Institute and a technical institute in St. Petersburg were also used to conduct tests on steel strength, and the shipyard performed fatigue analysis of this plate thickness to ensure that it would meet construction requirements.
The shipyard's ability to physically build/launch a ship of that size was uncertain. Physical capabilities of the yard, including the size of the drydocks and the lifting capacities of the overhead cranes, would need to be evaluated.	The shipbuilder made substantial capital investments in the shipyard, including building new production halls that could accommodate the larger ship and to enable the production of eight ships in a compressed schedule.
Overall ship cost would be controllable.	Because materials constituted 60 percent of the ship's cost, the shipyard got fixed prices for materials (with the exception of steel) and supplies in advance of signing the shipbuilding contract.

Source: Odense Steel Shipyard.

In addition, the shipyard identified other lesser, but still important, concerns to resolve prior to contract signing, including (1) the need to identify the rules under which the ship would be classified because classification rules or requirements for a ship as large as *Emma Maersk* did not exist and (2) the design's ability to meet the desired speed, maneuvering, and weight capacity requirements. Ultimately, two ship classification societies were brought into the project early to assist with the technological evaluations. Figure 9 is a photo of the completed *Emma Maersk*.

Figure 9: *Emma Maersk*

Source: Odense Steel Shipyard, Ltd; Photographer Nick Souza.

Note: *Emma Maersk* incorporated several novel design features, including the world's largest container handling ability and containership dimensions, the world's first 14-cylinder diesel engine, and the use of a waste-heat recovery technology used to maximize fuel efficiency.

Generally, a commercial shipyard will accept responsibility for the total performance of the ship, including any systems that it installs, provided that the shipyard is comfortable that the technology used on the ship is well understood and will perform as anticipated. The Azipod propulsion technology employed by Royal Caribbean and Aker Yards provides one example where this approach was employed. Owner-provided technology is rare in commercial shipbuilding; in certain cases, however, some commercial ship buyers may insist on having an unproven technology installed on a ship or on having the shipyard install a technology provided by the buyer. This may occur if a specific technology is needed to enable a new ship concept, and this practice is more common to certain industries, such as the oil and gas industry because of the specialized equipment used in this industry. In these limited instances when unproven technologies are employed, the shipyard will generally not contractually accept responsibility for the performance of the system. For example, on the Emma Maersk class, the owner wanted to include a new waste-heat recovery boiler technology with which the shipyard was not familiar. Subsequently, the yard agreed to install this technology on the ships, but would not contractually accept responsibility for the performance of this system. Further, several commercial shipbuilders we interviewed do not allow buyers to provide equipment that has to be installed deep in the ship, since a late equipment delivery could disrupt the entire construction sequence of the ship and compromise the timely delivery of other ships. Instead, owner-furnished equipment is generally restricted to that which can be mounted on the top of a ship or installed after launch or delivery.

Commercial Shipbuilders and Ship Buyers Reach Agreement on Ship Concept, Cost, Delivery Schedule, and Performance Attributes at Contract Signing

By the time a leading commercial shipyard signs a contract to build a new ship, the builder and buyer have fully defined and agreed upon the ship concept, required performance, and contract terms. A ship specification accompanies the contract as part of a larger contract package. This document originates as what is commonly called an outline specification, which may be developed by the buyer. The shipyard takes the lead in expanding this document into a ship specification, which is a highly detailed document that describes all ship performance parameters, including speed, fuel consumption rates, ship weight and draft, and required redundancies. Representatives from one shipyard told us that commercial ship specifications range from several hundred pages to thousands of pages in length, depending on the ship type and complexity. Cruise ship specifications may refer to "reference ships," which are previous ships built by the shipyard that can be used to gauge the level of quality and craftsmanship desired for the new ship. Once the contract is signed, any changes that the owner wants to make to the contract specification are considered change orders and may incur a cost to the buyer. Other contract package documents include the general arrangement drawing, the midship drawing, and the makers list. The general arrangement drawing shows the ship hull structure and the footprints of all major equipment. Alternatively, the midship drawing shows the steel hull structure of a cross section of the middle of the ship, and communicates important information on deck thicknesses, heights, and loads, which is used to estimate steel needs and subsequently inform the cost estimate. The contract package also includes the makers list, which identifies for the shipyard the owner-approved suppliers for major equipment, such as main engines and propellers. Finally, the contract itself describes the process for owner review of drawings, according to leading buyers and builders. These firms stated that generally the owner does not review and approve all drawings, but the owner identifies at the outset the key drawings it will want to review. Further, the ship buyer typically has 10 to 15 days to review and approve a drawing.

Among leading commercial shipbuilders and ship buyers, only firm, fixed-price contracts are used for design and construction activities, and the delivery date of the ship is clearly established in the contract with accompanying penalties for delays. The commercial shipbuilders we interviewed stated that they nearly always deliver new ships—be they lead ships or follow-ons—within the delivery dates specified in their contracts. Further, since the contract sets a firm, fixed price, they are required to deliver at that price. Leading shipbuilders are able to sign fixed-price contracts with confidence because they have worked beforehand with the ship buyer to close expectation gaps and minimize technical risk. Both buyers and builders stated that the shipbuilding contract generally does not include adjustment clauses for materials, which would otherwise help the shipyard manage costs if materials such as steel become more expensive after the contract is signed. The shipyards take responsibility for negotiating with their materials suppliers before signing a contract so they can accurately price their bid to the ship owner. One shipyard stated that an 80/20 rule applies to shipbuilding materials, where 20 percent of the materials and components for a ship typically constitutes 80 percent of the ship's total materials cost. In that case, the shipbuilder tries to obtain price commitments early for that key 20 percent of materials. Some shipbuilders are able to get fixed-price quotes from major equipment suppliers prior to contract signing, but this is not always the case. Leading ship buyers we interviewed stated that commercial shipbuilding contracts for containerships, LNG carriers, and other similar vessels sometimes include progress payments for milestones, including steel cutting, keel laying, and launch. Cruise ships may follow a different schedule of payments with the bulk of the payment made on delivery, causing shipyards constructing those vessels to largely self-finance construction of these projects.

According to leading commercial ship buyers we interviewed, cargo ships, including containerships, tankers, and LNG carriers, have a set delivery date and a grace period of approximately 1 month when there is no penalty for late delivery. These buyers stated that delivery after the grace period causes the commercial shipbuilder to incur financial penalties and liquidated damages. In addition, they noted that commercial shipbuilding contracts may include a cancellation clause where the buyer can cancel delivery of the ship in the event the shipyard does not deliver the ship by a certain date. Cruise ships have a different delivery model than other commercial vessels—because of the business demands, cruise lines must get new ships into operation and generating revenue as quickly as possible. Thus, delivery is expected on the exact day stipulated in the contract. During construction, cruise line owners will often book a revenue-generating cruise with passengers to embark shortly after the scheduled delivery, so late delivery of a ship can carry tremendous business consequences to a cruise line. In this sector, a late delivery qualifies as anything not delivered on the day promised.

Commercial Shipbuilders Achieve Design Stability by Completing Basic and Functional Design Prior to Construction Start

Table 4 defines the three design phases typically associated with commercial ships—basic design, functional design,[17] and production/detail design.[18]

[17]Some shipyards use different terms to denote the functional design phase. However, the tasks completed in this phase are the same regardless of terminology.

[18]The Navy uses "detail design" in a different manner than commercial industry. To minimize confusion, this report uses "production design" to refer to the final design stage for commercial shipbuilding projects.

Table 4: Design Phases Employed by Leading Commercial Firms

Design phase	Tasks involved and parties responsible
Basic design	• Fix ship steel structure and set hydrodynamics • Design safety systems and get approvals from applicable authorities • Route all major distributive systems, including electricity, water, and other utilities • Ensure that the ship will meet the performance specification • Complete (shipbuilder) and review (buyer)
Functional design	• Provide further iteration of the basic design; generally equates to 3D modeling • Provide information on exact position of piping and other outfitting in each block • Complete (shipbuilder) and review (buyer)
Design stability achieved upon completion of basic and functional design phases	
Production design/detail design	• Generate work instructions that show detailed system information, and include guidance for subcontractors and suppliers, installation drawings, schedules, materials lists, and lists of prefabricated materials and parts • Often outsourced by shipbuilder and generally not reviewed by buyer

Source: GAO analysis.

Leading commercial shipbuilders will not start ship construction until they have a stable ship design, meaning that all basic and functional design has been completed (usually in the form of a complete 3D product model). At the point of design stability, the shipbuilder has a clear understanding of both ship structure as well as every ship system, including how those systems traverse individual blocks of the ship. To achieve design stability, shipbuilders need suppliers (also called vendors) to provide complete, accurate system information prior to entering basic design. This vendor-furnished information describes the exact dimensions of a system or piece of equipment going into a ship, including space and weight requirements, and also requirements for power, water, and other utilities that will have to feed the system. Commercial shipbuilders generally know before signing a contract what vendors they will use for major equipment, and since they do not include developmental technology in ship designs, they are able to embark on their ship designs with stable, complete vendor-furnished information. This approach enables designers to lock in system requirements for power, water, and other utilities early and reduces the occurrence of design changes to previously “closed out” (completed) spaces. Reopening closed out spaces—which is a possibility when tentative or notional vendor-furnished information for a developmental system is included in a design—can create a cascading effect throughout the ship design whereby additional, unanticipated aspects of the design must be reworked to accommodate a seemingly innocuous change. By delaying construction start until a stable design is achieved—complete with final vendor-furnished information—shipbuilders minimize the risk of design changes and the subsequent costly rework and out-of-sequence work these changes can drive.

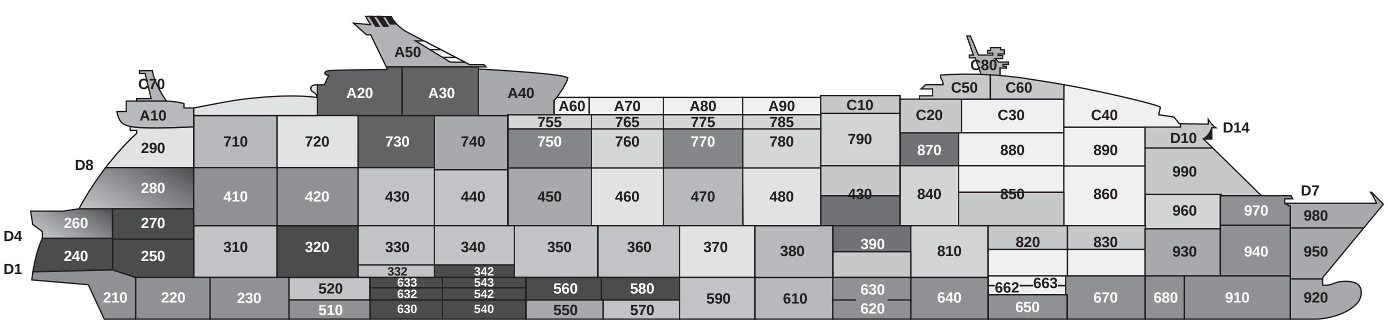
Leading commercial shipbuilders also focus intently on designing for producibility. This concept refers to efforts a shipyard employs to ensure that the ship design will ultimately be matched to the capabilities and production techniques of the shipyard and that the ship can be efficiently constructed. Activities associated with designing for producibility include (1) use of common design elements across multiple classes of ships and (2) adoption of common parts and components that support multiple classes of ships. The prevalence of 3D CAD tools in the commercial shipbuilding sector enables increased commonality among ship classes as the shipyards can readily maintain and access databases of elements or parts currently in service and reemploy them in new designs.

Commercial Shipbuilders Employ a Disciplined Construction Process with Strong Buyer Oversight to Ensure Delivery of a Quality Product within Cost and on Schedule

Among leading commercial shipbuilders, the production schedule is inviolate, and drydocks often represent the primary choke point to delivering a ship. Drydocks are thus key to efficient process flows and increased throughput in shipyards. Because shipyards generally have a backlog of ships awaiting time in the drydock, close adherence to planned construction schedules is critical. As such, commercial shipbuilders proactively work to minimize the time each ship spends in drydock to ensure on-time deliveries and to help maximize the throughput of work in their shipyards. This focus prevents the premature laying of a ship's keel as doing so would consume a valuable physical space that could be taken by another ship. In turn, shipbuilders will not advance to this stage until all the blocks for a ship have as much outfitting completed as possible. For example, STX Shipbuilding completes all outfitting, painting, cabling, and installation of insulation (if required) prior to a block being erected in the drydock. Alternatively, a shipyard may choose to launch ships like FPSO vessels or drillships that have buyer-furnished equipment or customized equipment that is mounted on the topside of the ship earlier, since this equipment can be installed at a quay after launch. In addition, leading shipyards use state-of-the-art measuring and production capabilities early on in the construction process to measure blocks and ensure that they will fit together and require little or no trimming at the erection phase. Together, these practices allow the shipbuilder to erect the ship in the shortest amount of time and move it out of the drydock. For example, Odense Steel Shipyard quality assurance inspectors employ a 3D coordinate measuring system to ensure that every block is measured in 3D detail. These measurements are then compared to the 3D design to ensure that the ship is within set tolerances and to minimize any trimming of blocks during erection in the drydock.

The block definition plan for a ship is developed months before the start of steel cutting, and the way the ship is divided into blocks determines how the ship will ultimately be constructed. Early definition of the construction strategy is important because it allows the shipyard to plan for the use of the drydock and other resources. Representatives from Aker Yards stated that any problems with blocks are resolved as soon as they are discovered to prevent later delays once the blocks are combined into grand blocks, when access to interior spaces becomes more difficult. Similarly, Meyer Werft has an intensive testing process where all systems and their subcomponents (e.g., piping, valves, etc.) are tested both in the workshop and on board before the ship is launched so that any problems can be resolved early. Commercial shipyards may build prototype blocks or sections of the ship if there are particularly challenging or dense sections to ensure that they are producible and to get their shipyard personnel familiar with the work required. Figure 10 shows a sample block definition plan for a cruise ship.

Figure 10: Block Definition Plan for a Cruise Ship



Source: GAO analysis of Aker Yards data.

Commercial ship construction is overseen by several different groups that have differing focuses. Each shipyard has quality assurance inspectors, quality control inspectors, or both responsible for monitoring the construction process and overseeing quality testing. Commercial ship buyers always have teams of inspectors in place to oversee the building of their ships to ensure quality and adherence to the contract specifications and to monitor the progress against the schedule. Buyer representatives will observe factory acceptance tests for equipment, oversee the production of blocks and prefabricated sections at subcontractor factories, and inspect each block to ensure quality and weld integrity. In addition, the classification society selected to perform a technical review of the ship will conduct similar tests—focusing primarily on safety aspects of the ship—often in combination with the buyer.

Cruise ship buyers, in particular, very aggressively monitor the progress of their ships because a delivery delay of even a few days can cost them significant revenue. The cruise ship buyers we studied often ask their shipyards to produce detailed weekly reports on construction progress data needed to track the schedule; if necessary, the buyer proactively engages the shipyard to manage variance that could affect schedule. In order to further prevent delivery delays, the shipyard will refuse to accept and execute change orders if they will cause delays to the ships in the drydock. All change orders are evaluated on the basis of their impacts on cost, weight, and labor hours to implement. Commercial buyers also restrict the type and number of change orders they submit; often change orders have to be approved by senior buyer management to minimize costs and prevent delays. For instance, at Carnival Corporation, the Corporate Chairman personally approves all change orders. Shipyards also make capital investments in equipment and procedures that reduce production time. For example, Meyer Werft has invested in a computer-aided logistics system that enables the precise bar code tracking of supplies and ship components to permit on-time and as-needed delivery of parts, limiting backlog and delays. This system also places bar codes on every part so defects can be tracked back to the specific shop and worker who made the part, enabling quality control feedback.

The cruise ship builders we interviewed stated that they were evaluating the use of modular components in their designs that can be prefabricated off-site. Currently, this practice is employed in the cruise industry through the use of prefabricated cabin compartments. For instance, both Aker Yards and Meyer Werft have all ship cabins built off-site by cabin manufacturers and bring them fully completed—including piping, wiring, furnishings, and carpeting—to the shipyard by truck and hold them in a staging area until they are needed. These prefabricated units can be slid into the ship from the outside and maneuvered into the proper location, and can have the piping and wiring connected to terminals on board. According to two shipbuilders, increased application of the prefabrication techniques could further reduce construction time and increase drydock availability at their shipyards. In addition, other commercial shipyards often use off-site suppliers to build different parts of ships. For example, the deckhouse and crew cabin blocks of ships are often built in factories external to the shipyard, and other ship blocks are outsourced as needed to maximize shipyard capacity and maintain throughput.

Navy Shipbuilding Programs Make Key Decisions with Less Knowledge Than Deemed Acceptable in Commercial Shipbuilding

Across the shipbuilding portfolio, the Navy has not been able to execute programs within cost and schedule estimates, which has, in turn, led to disruptions in its long-range construction plans. The Navy places great importance on delivering highly capable, robust ships to the fleet. This emphasis is evident in the performance requirements established in Navy shipbuilding programs, which often are not constrained by the availability of technology. As a result, the Navy initiates major technology development efforts in its shipbuilding programs prior to detail design and construction contract award. While these efforts advance individual technologies, the Navy does not allocate sufficient time in the pre-contract phase to retire technical risks, unlike the approach used in the commercial sector. Further, Navy shipbuilding programs do not devote sufficient time for engaging key stakeholders early in the program to evaluate and balance ship requirements, specifications, and costs. As a result, Navy programs often proceed to contract award with significant technical risk, unclear expectations between buyer and builder, and cost uncertainty. These conditions preclude the prudent use of fixed-price contracts and cause cost-reimbursable contracts to be the primary means of designing and constructing lead ships. Consequently, cost, schedule, and performance risk in the program resides primarily with the government. This risk often translates into cost growth and schedule delays as lingering technology immaturity destabilizes design development for the ship, and subsequent design changes produce inefficient work sequencing and rework during construction. Congress and the Navy have recently taken steps to begin addressing these challenges, but table 5 highlights key areas where Navy shipbuilding practices continue to differ significantly from best practices found in the commercial sector. These differences largely explain why the Navy does not achieve the same outcomes in its shipbuilding programs that leading commercial firms produce.

Table 5: Comparison of Navy Shipbuilding Practices and Commercial Best Practices

Phase	Navy practices	Commercial practices
Pre-contract	**Navy programs generally proceed with high levels of risk and uncertainty** • Requirements are not constrained by technology availability • Ship concepts may not leverage existing designs to minimize risk	**Commercial shipbuilders and ship buyers retire all major risk prior to signing a contract** • Shipyards will not sign a contract if there is outstanding technical risk • Shipyards and buyers leverage existing designs to minimize risk
Contract	**Navy programs cannot fix the cost and delivery date for a ship at contract signing** • Programs use cost-reimbursable contracts for lead and early follow-on ships • Navy can change specifications/drawings as critical technologies develop • Because technologies often remain in development at contract signing, eventual ship performance remains uncertain	**Commercial shipbuilders fix the cost and delivery date for a ship at contract signing** • Leading buyers and shipbuilders use only firm, fixed-price contracts • Buyer cannot change specifications/drawings without incurring financial or technical performance penalties once a contract is signed • Shipyard guarantees that the ship will perform as defined in the agreed specifications
Design	**Navy programs attain varying levels of design completion prior to starting construction** • Ship programs may prematurely start construction to support the industrial base • 3D CAD is under way, but not fully complete at construction start	**Commercial shipbuilders complete all basic and functional design prior to starting construction** • Shipyards will not start construction until a design is complete and stable • 3D CAD is completed prior to construction
Construction	**Navy programs are characterized by construction inefficiencies that impede ships from delivering within cost and on schedule** • The amount of time a ship spends under construction—or in the drydock—is not of critical importance to the shipbuilder when faced with low or uncertain future workload • Design changes during construction are common and can cause schedule delays and cost growth • Navy maintains a shipyard presence, but is often slow to respond to changes in workload distribution and complexity	**Commercial shipbuilders have a disciplined construction process that delivers ships within cost and on schedule** • In order to maintain tight schedules across multiple ships, drydock time is rigorously monitored and controlled by the shipbuilder • Change orders are minimized to avoid delays and cost growth • Buyers perform vigorous oversight of construction in order to ensure quality and to monitor schedule

Source: GAO analysis.

The Navy Consistently Underestimates the Effort Required to Successfully Execute Its New Shipbuilding Programs

Cost growth and schedule delays are persistent problems for Navy shipbuilding programs as they are for other weapon systems. These outcomes occur when project scope exceeds available resources. As tables 6 and 7 show, these challenges are amplified for lead ships in a class.

Table 6: Cost Growth in Recent Navy Lead Ships and Significant Follow-ons

Dollars in millions

Ship	Initial President's budget request[a]	Most recent President's budget request	Cost growth as a percentage of initial budget
SSN 774	$3,260	$3,752	15
SSN 775[b]	2,192	2,740	25
T-AKE 1	489	538	10
LPD 17	954	1,758	84
LHD 8	1,893	2,196	16
LCS 1	215	631	193
LCS 2[c]	257	636	147
CVN 77	4,975	5,843	17

Source: GAO analysis of Navy data.

[a]Estimated cost from the President's budget submission for year of ship authorization.

[b]SSN 775 is the second Virginia-class submarine, but is the first hull delivered by Northrop Grumman's Newport News shipyard.

[c]LCS 2 remains under construction.

Table 7: Delays in Achieving Initial Operating Capability in Recent Navy Lead Ships (Acquisition Cycle Time in Months)

Ship class	Initial schedule	Schedule slip
T-AKE 1	61	7
SSN 774	124	17
LPD 17	80	52
LCS	41	21

Source: GAO analysis of Navy data.

The Navy's six most recent lead ships[19] have experienced cumulative cost growth over $2.4 billion above their initial budgets. These cost challenges have been accompanied by delays in delivering capability totaling 97 months across these new classes. The first San Antonio-class ship (LPD 17) was delivered to the warfighter incomplete and with numerous mechanical failures—52 months late and at a cost of over $800 million

[19]While SSN 775 did not use a different ship design than SSN 774, it was constructed in a different shipyard.

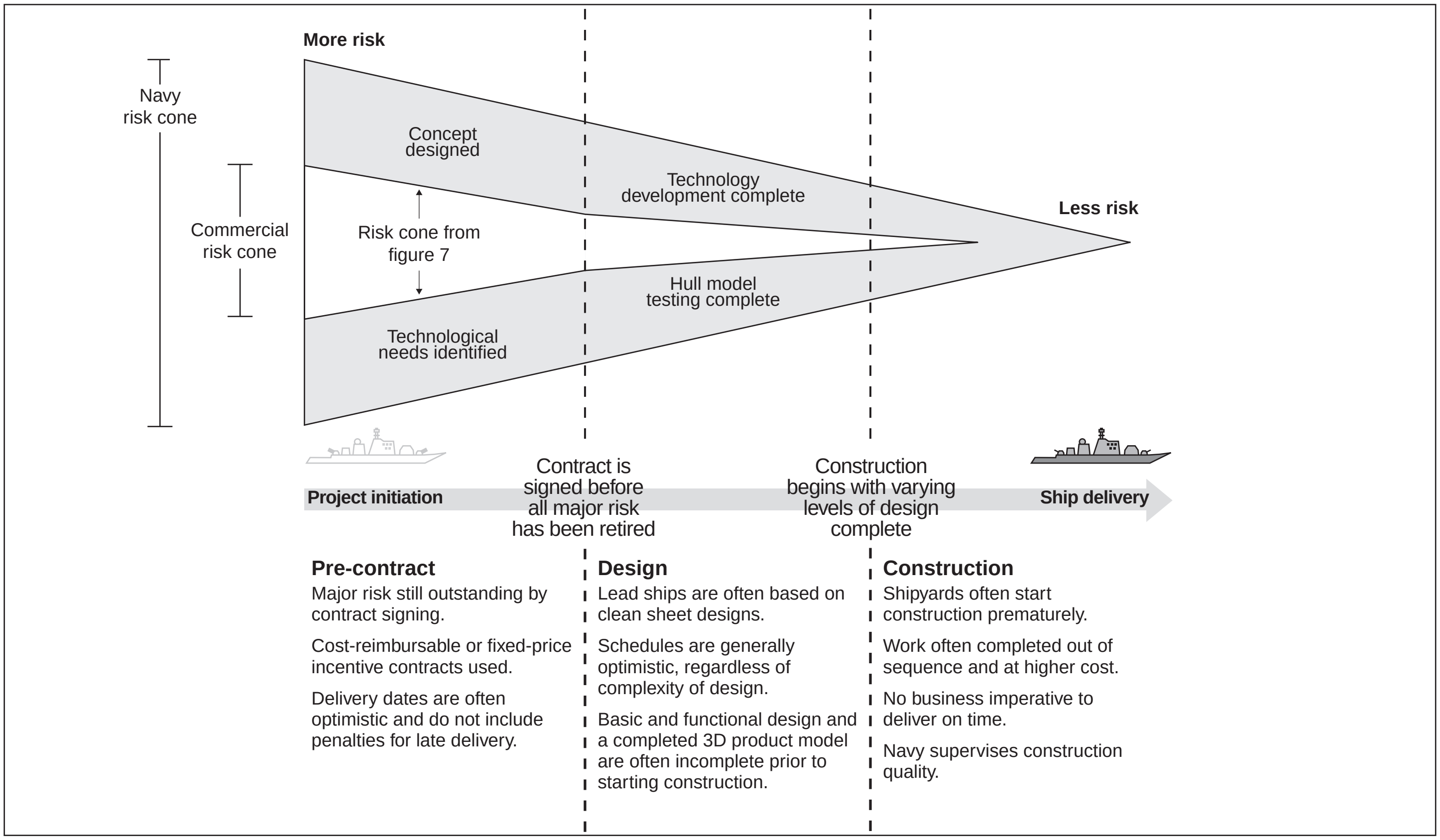
above its initial budget. For the LCS program, the Navy established a $220 million cost target and a 2-year construction cycle for each of the two lead ships. To date, combined costs for these two ships have exceeded $1 billion, and initial capability has been delayed by 21 months. Cost increases are also significant if the second ship is assembled at a different shipyard than the first ship. This was the case with SSN 775, the second Virginia-class submarine, which experienced cost growth of well over $500 million above its initial budget request of $2.192 billion.

The Navy's fiscal year 2009 long-range ship construction plan reflects many of the recent challenges that have confronted Navy shipbuilding programs. The plan provides for fewer ships at a higher unit cost—in both the near term and the long term—from what the Navy outlined in its fiscal year 2008 plan. As cost growth has mounted in current shipbuilding programs, the Navy has had to reallocate funds planned for future ships to pay for ones currently under construction. These problems have required the Navy to adjust its long-term plans and presume that significant funding increases—on the order of $22 billion from fiscal years 2014 through 2018 alone—will become available through fiscal year 2038.

Navy Shipbuilding Programs Often Afford Insufficient Time Prior to Contract Award to Retire Technology Risk and Define Realistic Requirements

The Navy seeks to deliver capabilities to the fleet that it expects will outpace and overmatch anticipated future threats. To support this goal, the Navy sets forth ambitious requirements in its shipbuilding programs that are generally not constrained by the availability of technologies. To compensate, the Navy invests considerable resources before contract award toward identifying and developing new technologies to meet its mission requirements. These efforts often increase the Navy's understanding of key technologies, but seldom does the Navy afford sufficient time to retire risk by maturing these technologies into complete, fully functional prototypes—upon which the Navy can validate its performance expectations—prior to contract signing. Absent this knowledge, the new technologies remain unproven to both the Navy (as ship buyer) and to the shipbuilder(s) it selects to design and construct the lead ship. This limitation impedes both the Navy's and the contractor's ability to clearly define the level of effort required to design and construct the lead ship, which in turn precludes the use of a fixed-price contract. Figure 11 highlights the differences in how the Navy approaches risk management in its shipbuilding programs compared with best practices used in commercial shipbuilding.

Figure 11: Navy Practices: Significant Risks Remain Unresolved at Contract Award



Source: GAO analysis.

Similar to the activities that occur in the commercial sector, the Navy uses the pre-contract phase for a lead ship to establish performance requirements, write ship specifications, and estimate design and construction costs. However, Navy shipbuilding officials reported that Navy programs often afford insufficient time to engage all stakeholders in these deliberations. Instead, decisions on requirements and specifications are frequently expedited—and cost uncertainty is downplayed—in a concerted effort to get a detail design and construction contract in place and demonstrate tangible progress to interested program observers.

The Navy's LCS program illustrates the importance of engaging stakeholders early in a program to clarify requirements and set realistic cost and schedule goals. Several Navy and industry officials reported that had the opportunity to engage in honest, open dialogue among applicable communities about program resources and requirements existed, it would have become clear that the program's $220 million lead ship cost target and 2-year construction cycle were unachievable. Figure 12 further highlights challenges the Navy has faced in the LCS program.

Figure 12: LCS

Mission: LCS is designed to perform mine countermeasures, anti-submarine warfare, and surface warfare missions in littoral (coastal) regions.

Issues: From the outset, the Navy sought to concurrently design and construct two lead ships in the LCS program in an effort to rapidly meet pressing mission needs. Implementation of the new Naval Vessel Rules (design standards) further complicated the Navy's concurrent design-build strategy for LCS. According to Navy officials, these rules required program officials to redesign major elements of each LCS design to meet enhanced survivability requirements, even after construction had begun on the first ship. While these changes improved the robustness of the LCS designs, they contributed to out-of-sequence work and rework on the lead ships. The Navy failed to fully account for these changes when establishing its $220 million cost target and 2-year construction cycle for the lead ships. When design standards were clarified with the issuance of Naval Vessel Rules and major equipment deliveries were delayed (e.g., main reduction gears), adjustments to the schedule were not made. Instead, with the first LCS, the Navy and the shipbuilder continued to focus on achieving the planned schedule, accepting the higher costs associated with out-of-sequence work and rework. This approach enabled the Navy to achieve its planned launch date for the first LCS, but required it to sacrifice its desired level of outfitting—a practice that further increased costs later in construction.

Sources: Alion Science (photo); GAO (data).

In the LCS program, the opportunity to fully engage stakeholders to identify realistic cost and schedule targets as well as potential capability trade-offs—before embarking on an unexecutable path—was lost. Alternatively, this program illustrates the consequences of proceeding into a contract absent a clear understanding among all stakeholders of the desired end product and the resources that are required to deliver it. Notably, the Navy's requirements community had an insufficient understanding of the costs associated with the capability objectives it set for these ships. Further, the program offices, contractors, and shipbuilders held unclear and sometimes conflicting interpretations of performance requirements and ship specifications. These inconsistencies were not recognized and did not preclude the Navy from entering into contract awards for the lead ships in this class.

The Navy's Ford-class aircraft carrier (CVN 21) program offers another example where more time allotted to the pre-contract phase for interaction among the Navy's acquisition program office, the requirements community, and its shipbuilder could have produced a better balance between technology scope and program resources. One of the defining technologies shaping the ship's design is the Electromagnetic Aircraft Launch System (EMALS), a catapult system that uses an electrically generated, moving magnetic field instead of steam to propel aircraft to launch speed. EMALS contributes to meeting desired sortie generation rates and manpower reductions on the ship.

EMALS finished its system integration phase over 15 months behind schedule and substantially above budget. As we reported in August 2007, delays resulted from technical challenges—largely because of failures with the prototype generator that stores the high power needed to propel the launchers—as well as difficulties meeting detailed Navy requirements.[20] Requirements challenges were amplified by limited coordination between the EMALS contractor and the CVN 21 program shipbuilder. Initially, requirements were communicated only through the Navy.[21] These issues prompted the Navy to request a $44 million increase in research, development, test, and evaluation funding for CVN 21 in fiscal year 2009. Figure 13 outlines additional challenges related to developmental efforts in the CVN 21 program.

[20]See GAO, *Defense Acquisitions: Navy Faces Challenges Constructing the Aircraft Carrier Gerald R. Ford within Budget*, GAO-07-866 (Washington, D.C.: Aug. 23, 2007).

[21]The Navy has since tasked the shipbuilder to coordinate with the EMALS contractor for production planning, and the two established a contractual relationship for that purpose in May 2008.

Figure 13: CVN 21

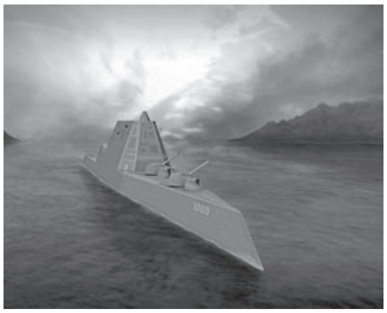
Mission: The Navy's CVN 21 program is developing a new class of nuclear-powered aircraft carriers that will replace USS *Enterprise* and the Nimitz-class as the centerpiece of the carrier strike group. The new carriers are to include advanced technologies in propulsion, weapons handling, aircraft launch and recovery, and survivability designed to improve operational efficiency and enable higher sortie rates while reducing required manpower.

Issues: CVN 21 technologies, including EMALS, the dual band radar, and the advanced arresting gear, have all experienced schedule delays that could disrupt construction of the lead ship in the Ford-class, CVN 78. EMALS was initially designed and tested in a configuration that minimized the system's weight. However, after the Navy defined the ship's survivability requirements, the system was reconfigured and its weight increased above its margin, resulting in reallocation of weight elsewhere on the ship and the redesign of a subsystem. Further, the contractor for EMALS designed one subsystem component—the power conversion system—to generic shock and vibration requirements while waiting for the Navy's final determination of shipboard requirements. At present, the subsystem may need to be reconfigured during production in order to meet final requirements—an outcome the contractor attributes to delays arising from limited coordination with the shipyard on requirements issues. Dual band radar testing has been delayed as a result of technical difficulties in developing the volume search radar. Upcoming land-based tests will be conducted at a lower voltage than needed to meet requirements and without the radar's composite shield. Full power output will not be tested on a complete system until 2012, and carrier-specific functionalities will be demonstrated shortly before shipyard delivery in 2013—an approach that leaves little time to resolve problems ahead of ship installation. In addition, the advanced arresting gear has encountered delays resulting from difficulties meeting the Navy's requirements for the system. Specifically, the Navy and the contractor disagreed on the necessary format of design drawings, drawings were delivered late, and changes in Navy requirements for shock and vibration led to a redesign of a major subsystem.

Sources: CVN 21 Program Office (photo); GAO (data).

Successful business cases for ships require balance between the concept selected to satisfy warfighter needs and the resources—technologies, design knowledge, funding, time, and management capacity—needed to transform that concept into a product. The Navy often bases its business cases for lead ships on promised capabilities associated with revolutionary, new technologies. However, when these technologies do not mature within the window of time the Navy allocates pre-contract, the ship's ability to execute its planned missions is called into question, and the business case for the program begins to erode. Compromises then have to be made, most often in the form of decisions to continue technology development after contract award—as opposed to removing the technology from the ship—despite the disruptive effect this activity can have on ship design and construction work. For example, in a program like the DDG 1000 that undertook multiple technical leaps to meet challenging requirements, yet also had to deliver in time to match shipyard availability, pressures existed to make optimistic assumptions about the pace of technology maturity. Figure 14 provides additional context on the DDG 1000 program's efforts to compress technology development activities within the confines of the design and construction schedule for the lead ships.

Figure 14: DDG 1000



Mission: DDG 1000 is a multimission surface ship designed to provide advanced land attack capability in support of forces ashore and contribute to U.S. military dominance in littoral (coastal) operations.

Issues: The Navy undertook development of 12 novel technologies to meet the DDG 1000 program's ambitious requirements. Despite significant investment to progress these technologies, the Navy has faced challenges maturing some of them as scheduled. Currently, lead ship construction is scheduled to begin before the volume search radar and integrated power system technologies are fully demonstrated. In the event that these technologies encounter any problems during later testing, resolving them could require redesign and spur out-of-sequence work or rework during lead ship construction. Earlier problems with the integrated power system led the Navy to replace the permanent magnet motor in favor of an advanced induction motor for that system. Because the Navy maintained the induction motor as a fallback technology, the integrated power system was able to meet its performance criteria. Because of a stealth requirement, DDG 1000 also includes a novel tumblehome hullform and a composite deckhouse, which were revolutionary technologies not in existence at the time requirements for the program were established. Instead of considering alternatives to the stealth requirement, the Navy proceeded under the assumption that the hull and deckhouse would be suitably mature to meet the planned design and construction schedule. As the lead ship enters construction, building the composite deckhouse now poses risks to successful cost and schedule execution. In addition, the Navy is writing and releasing six blocks of software code for the new total ship computing environment, which it initially planned to develop and demonstrate over 1 year before ship light-off (activation and testing of systems aboard ship). As a result of changes in the software development schedule, however, the Navy eliminated this margin. More recently, the Navy certified software release 4 before it met about half of its requirements, and the contractor deferred work to release 5, primarily due to issues with the ship's command and control system.

Sources: PEO Ships (PMS 500) (photo); GAO (data).

In many cases, Navy lead ships become the platforms upon which planned technologies are eventually proven. The Navy employs this approach in cases where (1) it judges further maturation of an existing, functional prototype system to be cost prohibitive—as has occurred with the DDG 1000 advanced gun system—or (2) development work for a technology is so delayed that the only viable option in order to maintain the ship construction schedule is to install the prototype system and evaluate its full functionality following delivery of the ship—as the Navy plans to do with the DDG 1000 volume search radar.

Navy Shipbuilding Contracts for Lead Ships Are Often Structured to Accommodate Uncertainty about Project Workload and Costs

Unlike the commercial model, which exclusively employs firm, fixed-price contracts for design and construction of lead ships, Navy shipbuilding relies upon contract structures that leave a higher level of risk with the buyer. Often the Navy and its shipbuilders enter into the detail design and construction contract without a full understanding of the effort needed to deliver the ship. This incomplete understanding translates into uncertainty about costs, causing contracts for the first ships of a new class to be typically negotiated as cost-reimbursable contracts. For example, cost-reimbursable contracts were used to procure the lead vessels in programs such as CVN 21, LPD 17, LCS, DDG 1000, and SSN 774. Several follow-on ships in the LPD 17 and SSN 774 classes were also bought under cost-reimbursable contracts. More mature shipbuilding programs, where there is greater certainty about costs, typically employ fixed-price contracts with an incentive fee. Fixed-price contracts are currently used, for instance, to buy Arleigh Burke-class (DDG 51) destroyers, which shipyards have been building since the 1980s.

Both cost-reimbursable and fixed-price incentive fee contracts can include a target cost, a target profit, and a formula that allows the fee to be adjusted by comparing the actual cost to the target cost. According to Navy officials, construction contracts for ships generally include provisions for controlling cost growth with incentive fees, whereby the Navy and the shipbuilder split any savings when the contract cost is less than its anticipated target. Conversely, when costs exceed the target, the excess is shared between the Navy and the shipbuilder up to a specified level. Once this level is reached, under the Navy's cost-reimbursable incentive fee contract, financial responsibility shifts to the Navy. Fixed-price incentive contracts include a ceiling price (maximum), which if reached makes the shipbuilder generally responsible for all additional costs. The nature of the risk and available knowledge used to justify the use of cost-reimbursable contracts enables shipbuilders to sign contracts without a complete understanding of the activities needed to successfully deliver the ship. If shipbuilders are unable to complete their contracts on time and within cost in this environment, it is likely that the government will be at least partially responsible for funding the associated cost increases.

The LCS program offers a vivid example of the cost risk the government can face when executing cost-reimbursable contracts for ships. The Navy awarded contracts for detail design and construction of the first two ships—LCS 1 and LCS 2—in December 2004 and October 2005 for $188.2 million and $223.2 million, respectively. The Navy later exercised options on each of these contracts in June and December 2006 for construction of the third and fourth ships (LCS 3 and LCS 4). However, changing technical requirements, evolving designs, and construction challenges drove the government's estimated prices at completion for the LCS 1 and LCS 2 seaframes to about $500 million each—cost growth that will be borne in large part by the government. This cost growth precipitated concern within the Navy that similar outcomes were possible for LCS 3 and LCS 4. In response, the Navy reassessed program costs and structure, revisited the acquisition strategy for future ships, and entered into negotiations with its shipbuilders to convert the LCS 3 and LCS 4 contracts into fixed-price contracts. The Navy was unable to reach agreement with its shipbuilders on fixed-price terms for these ships, subsequently leading the Navy to terminate the LCS 3 and LCS 4 contracts, in part, for the convenience of the government. However, it is possible that these cancellations will further increase LCS 1 and LCS 2 indirect costs (overhead) given that the LCS shipbuilders now have fewer quantities under contract against which overhead costs can be charged.

Design Processes Vary among Navy Programs but Consistently Occur Absent Key Knowledge Required in the Commercial Sector

The Navy and defense shipbuilders go through the same design steps that commercial shipbuilders follow—the ship's structure and equipment is defined along with the weight, power, cooling, and other requirements associated with each piece of equipment, and systems are subsequently routed through the ship. However, Navy design terminology varies from forms employed in the commercial model, and even internally Navy programs do not share a common language or process. The Navy uses the term detail design to encompass the three design phases commonly referred to as basic, functional, and production (detail) design in the commercial world. However, each Navy program often defines the individual stages of detail design uniquely. For example, in designing the CVN 21 aircraft carrier, the program office defined three stages—concept, arrangement, and detail—corresponding with 3D product model development. The Navy also created a three-stage process for DDG 1000, but defined its stages as functional, transition, and zone/nonzone detail. Beyond these naming differences, the design tasks completed at each stage—as well as the Navy's review processes—varied between the two programs. For DDG 1000, the Navy held its final design reviews in the third stage once design zones were 90 percent complete. Alternatively, final reviews in the CVN 21 program were held in the second stage upon inclusion of form, fit, and function of components into the 3D product model. While these divergent processes may have been appropriate at the individual program level, the lack of a common nomenclature and review process across programs makes it difficult to apply standards such as best practices. In turn, it is harder for the Department of Defense and congressional leadership to effectively assess design stability and the readiness of shipbuilding programs for construction.

In addition, design processes in Navy programs often must accommodate changing information about key aspects of systems planned for the ship that remain in development. For example, as development proceeds on a new technology, initial assumptions about size, shape, weight, and power and cooling requirements can change significantly. These changes—if not resolved during the pre-contract phase—can introduce considerable volatility to the design process for a lead ship. For instance, in the Seawolf-class attack submarine (SSN 21) program, the AN/BSY-2 combat system did not mature to fit into the space and weight reservations that the Navy had allocated for it within the submarine's design. As a result, a portion of the submarine had to be redesigned at additional cost. Figure 15 highlights additional information about the Seawolf-class's design instability. The Navy also runs the risk of changing information in the CVN 21 program that could disrupt its design processes, particularly related to EMALS, whose testing has not kept pace with the program schedule. Should EMALS not mature as anticipated, the Navy may be forced to revert to a legacy steam catapult system, which would require significant redesign across the ship.

Figure 15: SSN 21

Mission: The Navy's SSN 21 nuclear-powered submarines are designed to track and engage enemy targets with greater depth, speed, and stealth capabilities than predecessors.

Issues: The timely development of AN/BSY-2—a computer-aided detection, classification, and tracking combat system—was critical to the submarine meeting its mission requirements. Even though this technology was a modified successor to the AN/BSY-1 system found on earlier Los Angeles-class submarines, the technology did not mature as quickly as the Navy expected. Changes to the AN/BSY-2 system's design caused a portion of the submarine to be redesigned at an additional cost. The Navy originally provided Newport News with general space and weight information for the AN/BSY-2 that the shipyard used to begin designing its portion of the Seawolf. The Navy later provided the shipyard with more specific information that caused considerable redesign of the submarine and increased design costs, according to Newport News. The lead submarine ultimately experienced cost growth on the order of 45 percent above initial budget estimates.

Sources: General Dynamics Electric Boat (photo); GAO (data).

This design volatility has been a major source of cost growth in Navy programs. Construction regularly begins in Navy programs before basic and functional design activities are fully complete—that is, before the design is stable—increasing the likelihood that redesign and costly out-of-sequence work and rework will be required. This challenge is accentuated when the Navy chooses to produce a clean sheet design for a lead ship. Clean sheet designs are largely driven by the unique, challenging mission requirements that are approved for Navy programs. Accommodating new technologies intended to meet these requirements can require more space, power, cooling, and other supporting attributes than a legacy design can sometimes offer. These cases compel the use of a clean sheet design.

The Virginia-class submarine program, however, offers a more positive example of successful Navy/industry design effort. This program—although technically a clean sheet design—reused a number of components tested and used on previous submarine classes and produced a complete 3D product model before construction start. This progress contributed significantly to the relatively low number of design-related change orders—totaling 3 percent of the contract price, according to the Navy—needed for the first submarine in the class.

The Navy's plans for the DDG 1000 program call for greater design stability prior to beginning construction. More design has been completed than on other recent lead ships. As of January 2009, the Navy had completed 88 percent of the 3D product model and planned to start ship construction in February.

Construction Processes for Navy Ships Are Characterized by Inefficiencies That Impede Quality and Increase Cost and Schedule

Navy programs often enter construction with unstable designs and incomplete 3D product models, which can disrupt the planned sequence of construction. For instance, in the LPD 17 program, ship design continued to evolve even as construction proceeded. Without a stable design, outfitting work for individual ship sections was often delayed from early in the building cycle to later, when these sections were integrated on the hull. Shipbuilders stated that doing the work at this stage could cost up to five times the original cost. In total, 1.3 million labor hours were deferred from the build phase to the integration phase for LPD 17. Consequently, the ship took much longer to construct and cost more than originally estimated. Figure 16 further illustrates the challenges experienced in the program.

Figure 16: LPD 17

Mission: This amphibious ship class is designed to transport Marines and their equipment and allow them to land using helicopters, landing craft, and amphibious vehicles.

Issues: In the LPD 17 program, the Navy's reliance on an immature design tool led to problems that affected all aspects of the lead ship's design. With slightly over half of the design completed, construction of the ship began. Without a stable design, work was often delayed from early in the building cycle to later, during integration of the hull. Shipbuilders stated that doing the work at this stage could cost up to five times the original cost. The lead ship in the class, LPD 17, was delivered to the warfighter incomplete and with numerous mechanical failures, resulting in a lower-than-promised level of capability. Problems with the ship's steering system, reverse osmosis units, shipwide computing network, and electrical system—among other deficiencies—remained unresolved in a subsequent sea trials phase nearly 2 years following delivery. At that time, Navy inspectors noted that 138 of 943 ship spaces remained unfinished and identified a number of safety concerns related to personnel, equipment, ammunition, navigation, and flight activities. The Navy invested over $1.75 billion constructing LPD 17, compared with its initial budget estimate of $954 million.

Sources: LPD 17 Class Program Office (PEO Ships/PMS 317) (photo); GAO (data).

Similar to commercial buyers, the Navy maintains a visible presence in the shipyards where it has projects under way. For Navy shipbuilding contracts, this oversight function is performed by the Navy's Supervisor of Shipbuilding (SUPSHIP). SUPSHIP services include contract administration, engineering surveillance, quality assurance, logistics, and financial administration of assigned contracts. However, SUPSHIP has, at times, displayed slow response to changes in its workload distribution and the complexity of the projects it is supervising.

For example, the Navy awarded the construction contract for LCS 1 in December 2004. As we have previously reported, the LCS program was characterized by concurrent technology development, design completion, and lead ship construction—and further complicated by unclear and evolving technical requirements.[22] Despite the ambitious strategy that the Navy tasked its shipbuilder with executing, SUPSHIP Gulf Coast (the responsible organization) only assigned two people to the LCS 1 shipyard in February 2005 when construction began. As problems mounted in the program, SUPSHIP reacted by assigning nine additional personnel to the yard.

Recent Congressional and Navy Actions Encourage Technology Maturity and Design Stability at Key Points in Programs

Congress and the Navy have both taken a series of steps aimed at promoting timely attainment of technology maturity and design stability in weapons acquisition programs. However, because the acquisition process followed in Navy shipbuilding programs differs considerably from that employed in other Department of Defense programs—most notably, in the timing of key milestone reviews—the associated benefits have proven limited.

Since 2000, Department of Defense policy has called for demonstrating technologies in a relevant environment by the time a program reaches a key acquisition decision point (milestone B) marking the start of engineering and manufacturing development. Guidance defines technology prototypes as "representative" but does not require that prototypes of the

[22] See GAO, *Defense Acquisitions: Overcoming Challenges Key to Capitalizing on Mine Countermeasures Capabilities*, GAO-08-13 (Washington, D.C.: Oct. 12, 2007).

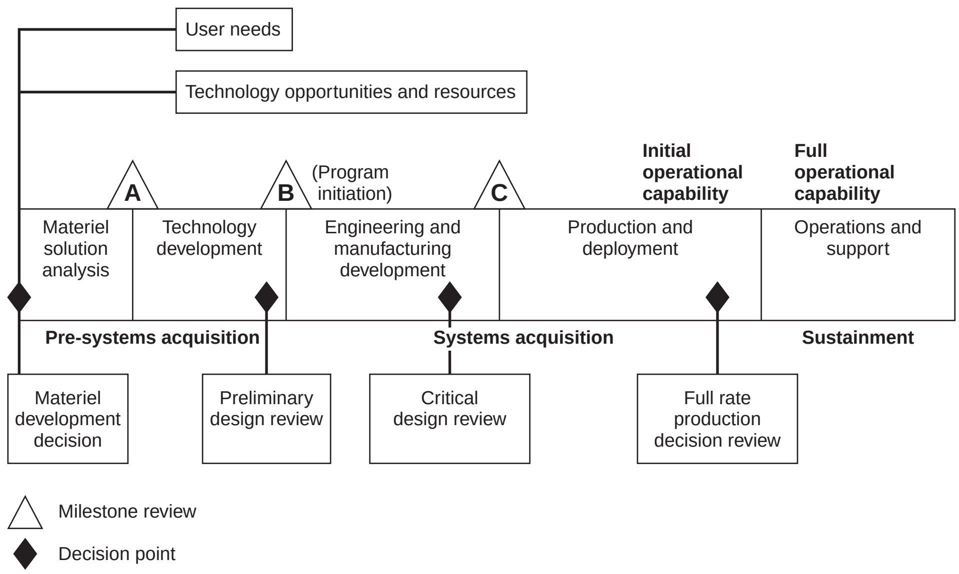
system or equipment incorporating the technology be in their final form.[23] Congress reinforced the importance of technology maturity when, as part of the National Defense Authorization Act for Fiscal Year 2006, it included a provision requiring that the approving official certify that "the technology in the program has been demonstrated in a relevant environment" before the program may receive milestone B approval.[24]

The impact of this provision on shipbuilding programs differed from other programs because of the timing of the milestone B decision for ships. As figure 17 shows, milestone B for most weapon systems acquisitions occurs at the start of engineering and manufacturing development, several years before production of the system begins.

[23]The Department of Defense uses technology readiness levels (TRL) to describe maturity of critical technologies in programs. Technologies developed into representative prototypes and successfully tested in a relevant environment meet requirements for TRL 6. Technologies developed into actual system prototypes (full form, fit, and function) and tested in an operational environment meet requirements for TRL 7.

[24]Pub. L. No. 109-163, § 801; 10 U.S.C. § 2366b.

Figure 17: Department of Defense Weapon System Acquisition Framework

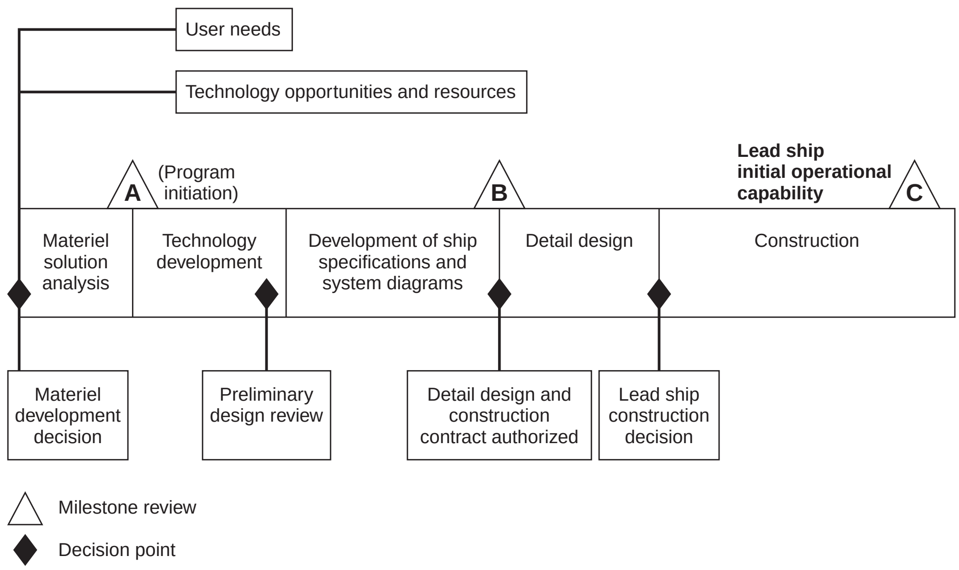


Source: GAO analysis of Department of Defense data.

Note: Figure represents a framework consistent with Department of Defense Instruction 5000.02 dated December 8, 2008. Pursuant to this policy, the technology development strategy may plan for the preliminary design review to occur before milestone B, as depicted in figure 17. If it does not occur before milestone B, the policy calls for the preliminary design review to occur as soon as feasible after milestone B.

In contrast, as figure 18 illustrates, the most common practice in ship programs is for milestone B to be aligned with the decision to authorize the start of detail design, although this is not uniformly the case. For instance, milestone B is not scheduled to be held for the LCS program until over 5 years after the first ship began detail design.

Figure 18: Typical Acquisition Framework for Navy Shipbuilding Programs



Source: GAO analysis of Department of Defense data.

Because, in practice, milestone B for ship programs occurs after development of ship specifications and system diagrams is well under way, the requirement for demonstrating representative prototypes in a relevant environment occurs later than in other weapon acquisition programs. This means that maturing the technology into its final form is occurring concurrent with detail design. Yet, completion of detail design—and subsequent achievement of design stability—requires shipbuilders to have final information on the form and fit of each system that will be installed on the ship, including the system's weight and its demand for power, cooling, and other supporting elements. To the extent that key systems are not in their final form and have not been fully demonstrated, assumptions are made about the final form, and the design proceeds based on this notional information. As development and demonstration of the system continues, changes may occur that need to be incorporated into the ship design and that potentially ripple through much of the ship design.

Congress reinforced the need for design stability in the National Defense Authorization Act for Fiscal Year 2008.[25] The act requires that at the start

[25]Pub. L. No. 110-181, § 124 (b)(1).

of ship construction, the Navy provide a report on production readiness that includes, among other things, assessments of

- the maturity of the ship's design as measured by the degree of completion of detail design and production design drawings and
- the maturity of developmental systems, including hull, mechanical, and electrical systems and warfare systems.

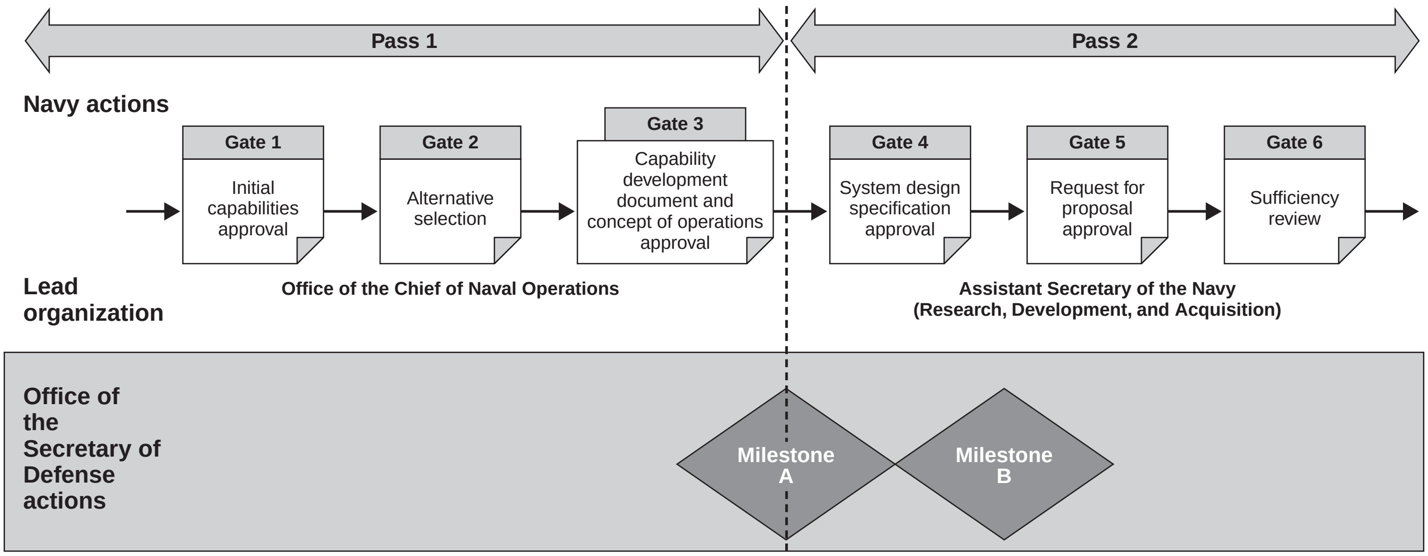
The statutory language does not specifically require that the assessment of design maturity directly address the completeness of the 3D modeling or completion of the activities that make up basic and functional design.

In addition, Navy leadership has recently expressed interest in minimizing the number of clean sheet designs employed in future programs. This interest is consistent with the findings of a 2005 analysis completed by the Office of the Secretary of Defense.[26] This analysis recommended that the Navy work to employ a common set of hulls tailored to different missions and employing modular mission systems. Further, the Navy has moved a number of recent programs into design and construction that leverage existing hull designs. These programs include the Maritime Prepositioning Force Future (MPF(F)), which will make use of several existing designs, as well as the America-class amphibious assault ship (LHA 6), which leverages approximately 45 percent of the LHD 8 hull design.

More recently, the Navy has taken initial steps to instill a more disciplined process for decision making related to requirements, specifications, and cost management in its acquisition programs through its recent implementation of a new two-pass/six-gate review process. This process aims to improve governance and insight in the development, establishment, and execution of acquisition programs in the Navy. In particular, the review process seeks to ensure alignment between service-generated capability requirements and acquisition programs, as well as to improve senior leadership decision making through better understanding of risks and costs throughout a program's entire development cycle. Figure 19 illustrates the Navy's new two-pass/six-gate review process for shipbuilding programs.

[26]Department of Defense, Office of the Secretary of Defense, *Alternative Fleet Architecture Design Report for the Congressional Defense Committee* (Washington, D.C., January 2005).

Figure 19: Navy's Two-Pass/Six-Gate Governance Process as Applied to Shipbuilding Programs



Source: GAO analysis of Navy data.

While the new two-pass/six-gate process appears to support better collaboration and communication among Navy entities and senior leadership at different stages of a program, a number of key stakeholders are excluded from or have a reduced role in the decision-making process. For example, the acquisition community does not have a leadership role in the review process until Gate 4, which for shipbuilding programs corresponds with approval of a system design specification.[27] By that point, a number of key decisions related to the ship concept and program requirements will have been defined, which the acquisition community will ultimately be charged with executing. In addition, shipbuilders are excluded in practice from the Navy's process, which limits opportunities to fully evaluate potential requirements trades and increase exchange of ideas prior to contract award.

[27]According to Navy policy, the system design specification outlines the basic functional requirements for the preferred system alternative and major programmatic actions required to deliver the system. Secretary of the Navy Instruction 5000.2D, Annex 2-C (Oct. 16, 2008).

Differences in Commercial and Navy Practices Reflect Different Environments

The differences in commercial and Navy shipbuilding practices reflect the incentives of their divergent business models. Commercial shipbuilding is structured on shared priorities between buyer and shipbuilder, a healthy industrial base, and maintaining in-house expertise. In commercial shipbuilding, both buyers and builders are incentivized by the need to sustain profitability. This incentive, in turn, drives disciplined practices. Alternatively, Navy shipbuilding is characterized by (1) a buyer that favors the introduction of new technologies on lead ships—often at the expense of other competing demands, such as fleet presence; (2) low volume and relative lack of shipyard competition; and (3) insufficient buyer and builder expertise. These factors contribute to high-risk practices in Navy programs. Table 8 further illustrates the differences.

Table 8: Comparison of Commercial and Navy Shipbuilding Environments

	Commercial shipbuilding	Navy shipbuilding
Buyer and shipbuilder priorities	• Commercial buyers and shipbuilders have shared goals and interests. Most notably, both benefit from within cost, on schedule deliveries. As such, they consider cost and schedule inviolate, resulting in an intense focus on retiring technical risks before contract signing and systematic, efficient progress through design and construction. • Buyers and shipbuilders both make acquisition decisions based on anticipated return on investment. Capability of an individual ship is balanced against the need for multiple ships to efficiently execute operations.	• The Navy often prioritizes revolutionary technological achievement over its other competing demands, such as cost and schedule performance. • Navy shipbuilders largely operate in a cost-reimbursable environment. As such, the consequences of cost and schedule growth on their programs are not as significant to their continued viability and the risk of lost business is mitigated.
Industrial base conditions	• Global demand for new ships produces high workloads that can keep shipbuilders at capacity for years into the future. • Commercial buyers have an array of yards and suppliers to choose from and generally do not need to consider the long-term health of their yards/suppliers.	• The Navy is the primary customer for the major U.S. shipbuilders. The desire to sustain workloads in each of these yards affects the Navy's ability to rely on full and open competition. • Navy shipbuilding programs are executed in an environment that often emphasizes long-term preservation of the industrial base over short-term efficiencies.
Workforce capabilities and capacities	• Commercial builders highly emphasize project management and supervision within the yard. • Commercial buyers invest in and retain experienced, talented individuals who usually have high levels of technical, design, production, and operations knowledge.	• Naval in-house technical expertise has declined because of staffing reductions, while workload requirements have increased. • Unstable workloads for Navy shipbuilders make recruitment and retention of skilled workers challenging.

Source: GAO analysis.

Commercial Shipbuilding Practices Are Driven by the Need to Sustain a Profitable Business Environment

Commercial shipbuilding is characterized by a shared priority between buyer and builder on sustaining profitability. Achieving this imperative depends on shipbuilding programs executing as planned, which compels buyers and shipbuilders to hold cost and schedule inviolate in their programs. Failure to achieve predicted cost and schedule outcomes in programs can jeopardize profitability. This is why leading commercial ship buyers and shipbuilders retire major risks prior to signing contracts; establish firm, fixed-price contracts; and progress through design and construction in systematic order to provide timely delivery of new capabilities. The buyer profits by adding the ship to its fleet, whereas the shipyard profits from moving the ship out of drydock so it can begin construction on a new ship.

Leading commercial buyers and shipbuilders make their investment decisions based on anticipated return on investment without compromising the need to deliver on schedule and on budget. Commercial buyers weigh needs and the desire for new technologies against delivery date and cost. Doing otherwise would jeopardize cost and schedule and thus profit. Risk assessments are pragmatic versus optimistic. Commercial buyers also believe that “schedule is sacred” because a ship cannot produce revenue until it has been delivered. Once a delivery date has been agreed to, buyers will not make changes to a ship that may place the delivery timeline at risk. Cruise ships, for instance, are booked and scheduled to sail with passengers as early as 1 day after delivery. Any delays to the delivery of a cruise ship can be prohibitively expensive in terms of lost revenue and damaged reputation to the buyer—at a cost far beyond what is recouped from assessing financial penalties against the shipbuilder under the terms of the contract. As such, the commercial buyer remains vigilant during the construction process and on hand to render technical assistance to the shipbuilder, as necessary.

Commercial shipbuilders are also incentivized to balance their desire for increased profits and workload against their need to deliver existing projects within promised deadlines and cost estimates. As such, leading shipbuilders will only take on projects that they are confident they can complete using the labor and facilities they are likely to have available and without jeopardizing the delivery schedules of other projects in the yard. This approach was consistent with the favorable business climate that existed in commercial shipbuilding at the time of our review. We found that leading yards were operating at full capacity with respect to their drydock(s), design and production departments, or both, which allowed them both the discipline and the flexibility to avoid projects that contained less-than-desirable levels of technical risk. This environment also instilled disciplined behaviors from buyers, who understood that pushing forward with risky, unstable projects would likely result in their not finding a willing builder.

Overall, the strong, worldwide demand for commercial shipbuilding has produced a healthy industrial base of both shipyards and suppliers. The commercial shipyards that we visited in both Europe and Korea, while differing on economies of scale, were operating at capacity for years into the future. Commercial buyers are thus able to choose from a competitive global base of available shipyards and suppliers without generally needing to consider the long-term health of any individual yard or supplier. Further, the high, global demand has contributed to years-long waiting lists across several leading yards that prevent immediate construction of new projects. For instance, representatives of one buyer we interviewed stated that their company waits almost 42 months for a new ship to deliver following contract signing, even though actual construction of the ship generally requires only 12 to 21 months. In a number of instances, we found shipbuilders willing to make capital investments aimed at expanding their capacity to take on new projects while also increasing overall efficiency. For example, Odense Steel Shipyard officials noted that their company made substantial capital investments to build new production halls to accommodate the large size and desired delivery schedule of the Emma Maersk class of containerships—all aimed at increasing the yard's prospects for future business.[28] In return, the buyer, A.P. Moller-Maersk, reportedly contracted for the construction of every vessel in the class prior to delivery of the first ship, further demonstrating its commitment to the project. Similarly, officials from both Daewoo Shipbuilding and Marine Engineering and STX Shipbuilding noted that their shipyards invested in floating drydocks, which have enabled those yards to take on additional projects and, subsequently, increase profits.

For builders, vigilant project management minimizes construction cycle time and produces cost savings for the shipyard. As such, they hire and retain experienced, talented individuals who can recognize and help eliminate technical uncertainty prior to contract award. Representatives of one major commercial ship buyer we visited noted that project management, yard supervision, and having a strong working relationship with the shipyard are more important factors than yard facilities and equipment when making a build decision.

[28]It should be noted that Odense Steel Shipyard is owned by the A.P. Moller-Maersk Group.

Commercial ship buyers also place a premium on project management and supervision within a shipyard. Leading buyers we interviewed maintain in-yard representatives to supervise construction and ensure the quality of the final product during ship construction. Buyer representatives usually have high levels of technical, design, production, and operations knowledge, and thus are capable of solving problems with the ship while it is being built. Notably, when an exceptional event occurs, buyers may supplement their existing capabilities with outside expertise to ensure that sufficient capacity is available for problem solving. One example is the assistance Royal Caribbean Cruises, Ltd., offered to Aker Yards on a cruise ship project. When faced with a potential delivery delay caused by Azipod challenges and a winter freeze of the surrounding channel, Royal Caribbean provided technical expertise and obtained the services of ice-breaking ships and tugboats to ensure that the cruise ship could be delivered as planned. Royal Caribbean could have invoked the late delivery penalties in the contract. Instead, the firm stepped in to help the builder deliver.

Leading ship buyers also take proactive steps to retain their technical expertise during periods when business declines. For instance, during the early part of this decade, Royal Caribbean recognized that in light of reduced customer demand for cruises—and the company's corresponding decline in new cruise ship construction projects—it faced the prospect of losing much of its highly skilled and trained workforce. Valuing this asset, and recognizing that the business cycle would likely rebound, Royal Caribbean initiated a number of complex revitalization projects on its existing ships to occupy its workforce in the interim. This investment enabled the company to capitalize early on a number of new ship construction projects once its business climate improved.

Navy Shipbuilding Practices Reflect an Environment of Competing Priorities and Pressures That Favor High-Risk Acquisition Approaches

The Navy often prioritizes revolutionary technological achievement at the expense of its other competing demands and has, through its decisions, favored sacrificing cost and schedule goals in programs to achieve its technology goals. Although these priorities produce capable, robust ships for the fleet, the resulting cost and schedule growth delays capability and reduces quantities. The desire to recover schedule losses while achieving technology advancement can drive practices in Navy programs such as (1) continuing technology development concurrent with design and (2) starting construction without achieving a stable design—activities that generally preclude the use of fixed-price contracts. These practices can cause shipbuilders to have to make certain assumptions about key ship equipment and systems during design. In the event the technologies do not develop and deliver according to these assumptions, shipbuilders are then faced with having to redesign aspects of the ship and complete rework or out-of-sequence work—each of which can significantly disrupt construction and carries cost consequences for the Navy.

The Navy seeks to satisfy multiple objectives across its shipbuilding programs. Most notably, the Navy works to

- build sophisticated ships to support new and existing missions,
- improve presence by increasing the numbers of ships available to execute missions,
- design ships and operating concepts that reduce manning requirements, and
- supply construction workloads that stabilize the industrial base.

Among these objectives is an inherent tension that can play out in several ways. If, for example, a class of ship is expected to perform multiple challenging missions, it will have sophisticated subsystems and costs will be high. The cost of the ship may prevent it from being built in desired numbers, subsequently reducing presence and reducing work for the industrial base. Requirements to reduce manning can actually add sophistication if mission requirements are not reduced. To some extent, this happened in the DDG 1000 program as decisions have tended to trade quantities (that affect presence and industrial base) in favor of sophistication. Several years ago, the program was expected to deliver 32 ships at an approximate unit cost of $1 billion. Over time, sophistication and cost of the ship grew as manning levels lower than current destroyer levels were maintained. Today, the lead ships are expected to cost over $3 billion each to build. Similarly, cost growth in the LCS program—a significant portion attributable to survivability improvements across the class—has precluded producing ships at the rate originally anticipated, and it is possible that the Navy will never regain the ships it traded off to save cost. Had the Navy anticipated that LCS lead ship costs would more than double, it may have altered its commitment to the program. On the other hand, competition for funds among different Department of Defense programs creates incentives to be optimistic regarding technology, design, construction, and cost risks.

The Navy's focus on maximizing the capability of its individual ships has come at the expense of decreased fleet presence in terms of the number of operationally available ships—both in the near term and long term. For instance, the Navy's decision to introduce 16 new technologies on the lead

Ford-class aircraft carrier—rather than incrementally improve capability—required the Navy to plan a lengthy design and construction schedule for the ship. The Navy currently expects the lead carrier, CVN 78, to deliver in September 2015. This strategy, however, contributes to a gap in meeting the minimum aircraft carrier force-level requirement, given that USS *Enterprise* (CVN 65) is scheduled to decommission in November 2012. The Navy's long-term force structure plans also suffer because of the cost growth and schedule delays typically associated with shipbuilding programs that seek to introduce a number of revolutionary advancements. For example, the Navy's fiscal year 2009 long-range shipbuilding plan reflects a delay to when the fleet goal of 313 ships will be met. The fiscal year 2008 plan envisioned reaching the 313 goal by 2016, while the previous fiscal year 2007 plan outlined the Navy's intention to reach 313 ships by 2012. The current fiscal year 2009 plan states that goal will now be met in 2019. In addition, while the fiscal year 2009 plan meets the goal of 313 ships by 2019, it fails to achieve specific fleet component requirements, resulting in shortfalls in the number of desired attack submarines, ballistic missile submarines, amphibious transport docks, and logistics ships.

These outcomes are consistent with the incentives at play in the Navy's environment. While commercial shipbuilders and buyers are incentivized to turn a profit and achieve maximum return on their investments, the Navy and defense shipbuilders are incentivized differently. In Navy shipbuilding, a symbiotic relationship exists where the buyer has a strong interest in sustaining its shipbuilders despite shortfalls in performance. Cost-reimbursable contracts—commonly used for lead and early ships in a class—enable this environment to exist. These contracts offer the Navy the chance to acquire highly capable ships offering the latest technologies, and they provide shipbuilders—serving a single buyer, largely—sufficient business to sustain operations. For the Navy, cost-reimbursable contracts allow it to enter into shipbuilding agreements with incomplete knowledge about what it wants built. For defense shipbuilders, cost-reimbursable contracts provide a buffer against the consequences of risks, delays, and cost growth, and also offer a means for allocating overhead costs. These shipbuilders determine overhead rates on the basis of their anticipated future work. In the event that a Navy program does not materialize as expected, overhead costs can be paid (at least in part) by other Navy projects. Under cost-reimbursable contracts, the government alone is responsible for absorbing any cost growth resulting from these increases.

In addition, Navy shipbuilding is characterized by low volume and limited sources, which limits the Navy's ability to competitively award projects.

Only two companies own the six major shipyards that build Navy vessels. These yards specialize in building specific types of ships, and some ships have only one qualified builder. Unlike commercial shipbuilding, the Navy and its shipbuilders largely operate in a monopsonistic relationship, meaning that the Navy is the only buyer for the ships constructed in these shipyards. As such, Navy shipbuilders can flourish or suffer based on the Navy's changing demand for new ships. Currently, the Navy has low demand for new ships relative to its total shipyard capacity, and this existing demand has proven unstable, as reflected in a number of recent changes to the Navy's long-range shipbuilding plan. This instability also produces peaks and valleys in shipyard labor requirements—making retention and recruitment of skilled workers difficult—as shipyards analyze and react to the Navy's changing demand signal. Further, as Navy and industry officials stated to us, during times when a shipbuilder may face a period of low or uncertain workload on Navy projects, that shipbuilder may be less inclined to provide timely delivery of the ships it is constructing. In this situation, extending a ship's build schedule can enable the shipyard to maintain its current workforce and technical expertise as opposed to laying off skilled workers.

Navy shipbuilding programs are also executed in an environment that includes restrictions and demands often not found in the commercial sector. The pressures created by low volumes in shipyards can push Navy shipbuilding programs to focus energy toward starting construction as early as possible, often at the expense of long-term efficiencies. Consequently, as recent Navy shipbuilding programs, including LCS and LPD 17, have demonstrated, sufficient time is generally not afforded before construction to permit the buyer and builder to collaborate and reach clear agreement on ship requirements, technologies, and design characteristics—all prerequisites to minimizing risk during construction. When these prerequisites are not met, cost-reimbursable contracts are used. With these contracts, Navy shipbuilders do not bear the financial risks that commercial shipbuilders face operating under firm, fixed-price contracts. Further, federal statutes and other considerations constrain the number and variety of shipbuilding and supplier sources available to the Navy. While these constraints may be warranted—for instance, the need to ensure a sufficient industrial base over the long term to meet the Navy's anticipated needs—they can sometimes preclude the Navy's selection of a shipbuilder or supplier best suited to meet its near-term program needs.

Further, the Navy often does not have the expertise it needs on hand to provide timely oversight and assistance when technical challenges arise during ship construction. Navy programs rely upon a wide range of warfare centers and laboratories throughout the pre-contract, design, and construction phases to supplement program office and shipyard technical capabilities. For the Navy, maintaining a high level of in-house, technical expertise is critically important to successfully introducing new technologies on ships. However, technical expertise in Naval Sea Systems Command and within the SUPSHIP office, which acts as in-yard buyer representative, has greatly diminished over the past 15 years. Over the past 15 years, both of these offices have experienced staffing reductions of 50 percent or more, while facing significant increases in workload. During this same time span, the number of major defense acquisition programs under the command's purview grew from 17 to 22, major ship designs increased from 15 to 21, and the number of ships constructed changed from 20 to 44, including 5 lead ships.

However, because cost identification and surveillance, schedule monitoring, and quality assurance in Navy programs are responsibilities shared among a number of Navy organizations, programs must satisfy a number of competing demands and interests to which commercial programs are not always subjected. One example Navy officials pointed to is the tension that can exist between shipbuilding program managers—responsible for delivering ships on time and within budgeted costs—and technical warrant holders, who are charged with ensuring design quality and safety. Because technical warrant holders are not held directly accountable for cost and schedule performance in a program, they are not—in the view of program officials—constrained by the program's availability of funds in their decision making on design attributes. Subsequently, as program officials described to us, technical warrant holders can insist upon a higher level of design quality and system safety late in the design or construction stage than is provided for in a program's cost and schedule budget. This situation, in turn, can result in additional work that the program's cost and schedule estimate does not provide for. In contrast, the technical community views its role as ensuring that design and construction products satisfy the existing program requirements. Should a program's funds be constrained such that it cannot execute to fully meet its requirements, the technical community believes that relief is most appropriately granted by the requirements sponsor—namely, the community representing the warfighter. The disagreements that can arise between technical warrant holders and program officials highlight the difficulties typically encountered when ship contracts are finalized before technical and design requirements are fully understood.

Conclusions

The Navy's ability to meet and counter future threats depends on having a sufficient number of ships to provide timely presence where needed. The Navy has identified a need for approximately 313 ships to execute its planned missions. However, current business practices in Navy shipbuilding programs lead to ships costing more than anticipated, making it difficult to buy ships in the needed quantities at a time of constrained budgets. New ships are increasingly complex and cost significantly more than their predecessors—often double. Moreover, they routinely exceed their budget estimates, forcing unplanned trade-offs in the form of reductions to the number of ships built and put into operation.

In Navy shipbuilding, tough decisions on trade-offs are often made late in programs. Early in a program, pressures often exist to make optimistic assumptions about the pace of technology maturity. At the same time, budget constraints exert pressure on cost estimates to be lower. Efforts to contain cost primarily involve reducing the quantity of ships. This outcome results in less work for shipbuilders, which impairs their ability to maintain skilled workforces and supplier bases. The consequences of delayed deliveries and cost growth, which would be egregious to a commercial firm, are assuaged for Navy programs through the use of cost-reimbursable contracts. On the other hand, the need to avoid workload gaps in a Navy shipyard can create pressure to start construction before the design is ready. In this sense, the incentive is to finish the ship in the commercial sector, while there may be a strong incentive to start ship construction in the Navy shipbuilding programs. The up-front incentives to accept significant risk, with the downstream consequences thus accommodated, have helped put Navy shipbuilding in a form of equilibrium.

The practices that leading commercial shipbuilding firms employ produce better outcomes. These firms have benefited from a strong market for new ships, which makes the shipyards more competitive and supports a robust industrial base for components, labor, and other assets that subcontractors can supply. Trade-offs in capabilities, quantities, and cost are all made early, before contract signing. This discipline provides clearer visibility for buyers and builders on eventual program outcomes—permitting the use of fixed-price contracts. Leading ship buyers and shipbuilders do not follow disciplined practices because of altruism, but rather because it helps them both make money. The Navy is different; its priority is not profit but capability. Navy shipbuilding is not in a period of growth but rather contraction. Its industrial base has much greater capacity than the demand for ships. Thus, there is a temptation to say that because the Navy is different, best commercial practices do not apply. Yet, the status quo for the Navy does not appear to be sustainable in the long run.

The better question to ask is how Navy shipbuilding programs can benefit from best commercial practices. Commercial practices, thoughtfully applied to a new Navy shipbuilding program, can help a ship deliver faster and at lower cost by reducing risk earlier. Moving to fixed-price contracting is an important element in changing the paradigm for shipbuilding programs—fixed-price contracting can only be used if risk is appropriately retired by the time a contract for construction is agreed on and a clear understanding of the effort needed to deliver the ship exists. However, the Navy needs a better approach to retiring technical and design risk before fixed-price contracting can be effectively used for lead ships. The Navy's gated review process could potentially be adapted to instill this discipline, but is impeded by inconsistent application of policy—both among shipbuilding programs and as compared to other weapons acquisition programs—for the timing of milestone reviews and the knowledge required at key points. Moreover, the recent congressional reporting requirement for production readiness could be refined to identify additional metrics related to design stability, which would preclude Navy shipbuilding programs from entering construction prematurely.

To reach this point, a better match is needed between the desired capabilities and the technologies, budget, and schedule to realize them. Best commercial practices can help the Navy—in cooperation with industry—achieve this match in deciding the capabilities and schedule requirements for an individual ship program. Factors outside the confines of an individual ship merit strong consideration in achieving this match as well. Specifically, the Navy's desire to provide a certain fleet size can rightly serve to limit the technical content and cost of any individual ship. These decisions will largely determine from the outset whether an executable program—one that retires risk early and enables fixed-price contracts—is possible.

Matter for Congressional Consideration

Congress may want to refine the required reporting on production readiness[29] to incorporate additional metrics into the assessment of design stability that address completion of basic and functional design activities and 3D product modeling (when employed).

Recommendations for Executive Action

We recommend that the Secretary of Defense take the following seven actions:

- Define a shipbuilding acquisition approach that calls for (1) demonstrating balance among program requirements, technology demands, and cost considerations by preliminary design review; (2) retiring technical risk and closing any remaining gaps in design requirements before a contract for detail design is awarded; and (3) stabilizing a ship's design before construction can start. While shipbuilding programs can differ in scope and complexity, any new shipbuilding program should embody these three principles.

- To attain the level of knowledge needed to demonstrate balance among requirements, technologies, and cost in programs, require that by the preliminary design review for a new ship, (1) critical technologies be developed into representative prototypes and successfully demonstrated in a relevant environment and (2) the Navy develop, in cooperation with industry, an analysis of cost and requirements trade-offs that can identify ways to further reduce the technical demands of the ship.

- To attain the level of knowledge needed to retire technical risk and close gaps in design requirements, require that before a contract is awarded for detail design of a new ship, (1) critical technologies be matured into actual system prototypes and successfully demonstrated in a realistic environment and (2) the Navy provide sufficient time for thorough discussion with the prospective shipbuilder(s) to fully understand the technical specifications that will guide the ship's design and to resolve key differences.

- To attain the level of knowledge needed to retire design risk and reduce construction disruptions, require that by the start of construction for a new ship, the design be stabilized through completion of basic and functional design and 3D product modeling

[29] Pub. L. No. 110-181, § 124 (b)(1).

(when employed), with the recognition that complete—versus notional—vendor information must be incorporated for the design to be truly stable.

- To promote disciplined application of knowledge-based practices in shipbuilding programs, direct the Secretary of the Navy to report to Congress on what steps and changes in the acquisition process would be needed to allow the Navy to rely primarily upon fixed-price contracts for lead ships within 3 years.

- To maximize the Navy's role as an intelligent buyer, direct the Secretary of the Navy to evaluate the Navy's in-house capability and capacity to provide strong, consistent buyer oversight and to make changes where necessary.

- To promote efficient investments in fleet capabilities, assess whether the Navy's desire to provide a certain fleet size sufficiently constrains decisions on the technical content and cost of each new ship class, and recommend changes where necessary.

Agency Comments and Our Evaluation

In commenting on a draft of this report, the Department of Defense concurred with five of the seven recommendations and partially concurred with two. The department partially concurred with our recommendation to report to Congress on steps and changes in the acquisition process needed to allow the Navy to rely primarily on fixed-price contracts for lead ships within 3 years. While the department committed to identifying an initial set of changes necessary within 1 year, it cited concern that the changes identified might not eliminate the significant risk to the shipbuilder that in practice, is reflected as higher bids for fixed-price contracts for lead ships. Our analysis of practices followed by leading commercial ship buyers and shipbuilders convinces us that early retirement of technical and design risk—a prerequisite for fixed-priced contracts—is essential for a paradigm change and will facilitate realistic pricing of contracts. This paradigm change would afford clear visibility on cost, schedule, and technical requirements for new ships and instill discipline in shipbuilder and ship buyer processes both before and during construction. The alternative—cost-reimbursable contracting—is a key enabler of the patterns we now see in Navy shipbuilding. Whenever a cost-reimbursable contract is employed in a shipbuilding program, the government assumes primary responsibility for cost, schedule, and performance risk. In this environment, contractors can be expected to agree to build whatever their customer wants—no matter how poorly defined the desired end product may be.

In addition, the Department of Defense partially concurred with our recommendation to provide sufficient time for thorough discussion with prospective shipbuilder(s) before detail design contract award for a new ship so that the technical specifications that will guide the ship's design can be fully understood and key differences resolved. The department expressed its intent to implement this recommendation in sole source environments, but identified a more limited application to competitive procurements. For competitive procurements, the department stated that it will encourage discussions with prospective shipbuilders to ensure that the technical specification is well understood.

The Department of Defense concurred with our remaining recommendations. However, in its responses to several of these recommendations, the department offered reasons why it could not be expected to fully change the way it does business. For example, while the department concurred with our recommendation to retire technical risk and close remaining gaps in design requirements before a contract for detail design is awarded, it also stated that some technology risk reduction appropriately occurs during detail design to reduce the overall time required from the start of design to ship delivery. Moreover, the department offered the view that the relatively long construction span for ships requires flexibility in technology development and ship design processes to deal with factors such as obsolescence and ship construction and delivery schedule requirements. As our work has shown, however, these practices have been tried before in Navy shipbuilding programs and have consistently contributed to ship deliveries that are over cost and behind schedule—LCS representing the most recent example. In fact, commercial best practices show that in order to progress rapidly through design and construction, programs must allot the necessary time up front to retire technical and design risks, respectively. This approach—in essence, going slower at first to enable going faster later—can position the Navy to improve cost outcomes in programs and deliver capabilities to the warfighter on schedule.

The Department of Defense's written comments are reprinted in appendix II. The department also provided technical comments, which were incorporated into the report as appropriate.

We are sending copies of this report to interested congressional committees, the Secretary of Defense, and the Secretary of the Navy. The report also is available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or francisp@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

Paul L. Francis
Managing Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To assess key practices used by commercial ship buyers and shipbuilders, we interviewed and met with leading ship buyers from the cruise, oil and gas, and commercial shipping industries, including Royal Caribbean Cruises, Ltd., and Carnival Corporation; Exxon Mobil, Transocean—the world's leading offshore drilling contractor—and Chevron Shipping; and A.P. Moller-Maersk, respectively. We elected to study the cruise ship industry because the complexity and cost of cruise ships are higher than for other types of commercial ships: cruise ships are densely packed and require a lot of outfitting, making these ships somewhat similar to military ships. Additionally, cruise ship buyers often include innovations or design changes in their ships and start new classes of ships regularly in order to maximize passenger satisfaction; this allowed us to examine recent lead ship programs and the outcomes of specific commercial practices. We met with buyers from the oil and gas industry because offshore oil platforms are often built in shipyards and are complex, dense structures. Similarly, Exxon Mobil and its partners recently undertook a large acquisition program for two new classes of liquefied natural gas (LNG) carriers (comprising five designs). We met with A.P. Moller-Maersk because it is one of the largest shipping companies in the world and acquires many ships: in 2007 the company took delivery of 114 new ships.

We also met with officials from high-performing commercial shipyards responsible for building a variety of complex ships: Meyer Werft (Germany) and Aker Yards (Finland), which both build cruise ships; Odense Steel Shipyard (Denmark), Samsung Heavy Industries, Hyundai Heavy Industries, Daewoo Shipbuilding and Marine Engineering, and STX Shipyard (South Korea), which all build commercial ships, including containerships, LNG carriers, floating production storage and offloading ships, and oil tankers. These shipyards were recommended to us by the ship buyers we met with as being leading shipyards that deliver quality ships on time and on cost. At some of the shipyards, we also met with buyers' representatives who were responsible for overseeing the construction of the ships and monitoring the construction schedule. We also met with a naval architecture firm that has experience advising ship owners throughout the ship acquisition process and offers a full menu of services to prospective ship owners, including concept design, preliminary design, development of contract specifications, negotiations with shipyards, and participation as owners' representatives during the construction phase.

To assess the extent to which Navy shipbuilding programs employ best practices, we drew from our prior work on programs, including the San Antonio-class amphibious transport dock ship, Littoral Combat Ship, Zumwalt-class destroyer, Ford-class aircraft carrier, Virginia-class submarine, and Lewis and Clark-class dry cargo and ammunition ship. To supplement this analysis, we held discussions with a number of Navy officials responsible for shipbuilding programs, including the Assistant Secretary of the Navy for Research, Development, and Acquisition; the Deputy Assistant Secretary of the Navy for Ship Programs; and the Program Executive Officer for Ships. To understand the gated process developed to help structure the ship acquisition process, we met with the Office of the Deputy Assistant Secretary of the Navy for Acquisition and Logistics Management. We also met with representatives from General Dynamics and Northrop Grumman Shipbuilding and visited the National Steel and Shipbuilding Company and Electric Boat shipyards. Additionally, we held a teleconference with First Marine International (FMI), an independent shipbuilding consultancy firm in England that was commissioned by the Department of Defense to study the cost-effectiveness of U.S. Navy shipbuilding programs. FMI produced a report entitled *First Marine International Findings for the Global Shipbuilding Industrial Base Benchmarking Study*, which we also reviewed as part of our work.

To evaluate how effectively the business environments that exist in commercial and Navy shipbuilding incentivize the use of best practices, we convened a panel of shipbuilding experts representing both the Navy and industry to discuss factors that compel behaviors in different shipbuilding programs. We also met with officials from the Department of Transportation's Maritime Administration, which in part seeks to ensure that the United States maintains adequate shipbuilding and repair services. Further, we met with officials from the National Shipbuilding Research Program (NSRP), an organization that is part of the Advanced Technology Institute. NSRP is a nonprofit research consortium that manages and focuses national shipbuilding and ship repair research and development funding on technologies that will reduce the cost of ships to the U.S. Navy. We also met with a senior official from the American Bureau of Shipping, one of the ship classification societies that inspect and approve ships during and following construction.

We conducted this performance audit from January 2008 to May 2009 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION TECHNOLOGY AND LOGISTICS

MAY - 4 2009

Mr. Paul L. Francis
Managing Director, Acquisition and Sourcing Management
U.S. Government Accountability Office
441 G Street, N.W.
Washington, DC 20548

Dear Mr. Francis:

This is the Department of Defense (DoD) response to the GAO draft report, GAO-09-322, "BEST PRACTICES: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding" dated March 3, 2009, (GAO Code 120703). The Department's comments on the 11 specific recommendations are enclosed.

The Department concurs with recommendations 1 through 6, 8, 10, and 11. The Department partially concurs with recommendations 7 and 9. The partial concur on recommendation 7 relates to Department concerns about the level of discussions that could be conducted under a competitive acquisition environment as compared to a sole-source environment. The partial concur on recommendation 9 relates to Department concerns about process changes targeted at eliminating shipbuilder risks that would otherwise raise shipbuilder bids under a fixed-price contracting strategy, and whether those process changes would have any real effect in practice.

The Department appreciates the opportunity to comment on the draft report. Technical comments were provided separately. For further questions concerning this report, please contact Ms. Darlene Costello, Deputy Director, Naval Warfare, 703-697-2205.

Sincerely,

David G. Ahern
Director
Portfolio Systems Acquisition

Enclosure:
As stated

GAO DRAFT REPORT DATED MARCH 3, 2009
GAO-09-322 (GAO CODE 120703)

"BEST PRACTICES: HIGH LEVELS OF KNOWLEDGE AT KEY POINTS DIFFERENTIATE COMMERCIAL SHIPBUILDING FROM NAVY SHIPBUILDING"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommends that the Secretary of Defense define a shipbuilding acquisition approach that calls for demonstrating balance among program requirements, technology demands, and cost considerations by preliminary design review. (p. 55/GAO Draft Report)

DOD RESPONSE: Concur. The Department agrees that operational requirements, critical technologies, and other cost drivers in the design need to be fully understood and balanced at the time of the shipbuilding program preliminary design review. The acquisition strategy for each shipbuilding program is the appropriate document to reflect the implementation of these provisions. The Department is preparing appropriate guidance prescribing that these items are to be reviewed at the preliminary design review (PDR) for shipbuilding programs. This element, identified as Element GAO-09-322-01, will be considered for implementation on programs that plan to conduct the preliminary design review in fiscal year 2010 and later.

RECOMMENDATION 2: The GAO recommends that the Secretary of Defense define a shipbuilding acquisition approach that calls for retiring technical risk and closing any remaining gaps in design requirements before a contract for detail design is awarded. (p. 55/GAO Draft Report)

DOD RESPONSE: Concur. The Department agrees that technical risks should be retired and gaps in design requirements should be closed before a contract for detail design is awarded. The acquisition strategy for each shipbuilding program is the appropriate document to reflect the implementation of these provisions. The Department recognizes that not every technology risk can be afforded the opportunity to be fully retired in every program prior to awarding the detail design contract. Some technology risk reduction appropriately occurs during detail design to reduce the overall time required from the start of design to ship delivery. This must be balanced within each shipbuilding program to deliver capabilities to the warfighter when needed. The relatively long construction span for ships also requires flexibility in the design process to deal with factors such as

Enclosure
Page 1 of 6

obsolescence and ship construction and delivery schedule requirements. The risks entailed by risk reduction during detail design must be assessed on an individual program basis and clearly identified early in the program. The Department is preparing appropriate guidance outlining that these items are to be reviewed prior to awarding the contract for detail design. This element, identified as Element GAO-09-322-02, will be considered for implementation on programs that plan to award detail design contracts for a lead ship in fiscal year 2011 and later.

RECOMMENDATION 3: The GAO recommends that the Secretary of Defense define a shipbuilding acquisition approach that calls for stabilizing a ship's design before construction can start. (p. 55/GAO Draft Report)

DOD RESPONSE: Concur. The Department agrees that the ship's design should be stable before starting construction. The acquisition strategy for each shipbuilding program is the appropriate document to reflect the implementation of this provision. The Department is preparing appropriate guidance outlining the design stability parameters to be reviewed prior to starting construction of shipbuilding programs, such as the levels of maturity of the ship product model and other key design artifacts, including vendor information, which will ensure that the design is stable. The guidance will also recognize that the relatively long construction span for ships requires flexibility in the design process to deal with factors such as obsolescence and ship construction and delivery schedule requirements. This element, identified as Element GAO-09-322-03, was implemented on the DDG 1000 and the CVN 21 shipbuilding programs. It will be considered for continuation on shipbuilding programs that plan to start construction of a lead ship in fiscal year 2010 or later.

RECOMMENDATION 4: The GAO recommends that the Secretary of Defense require that, by the preliminary design review for a new ship, critical technologies be developed into representative prototypes and successfully demonstrated in a relevant environment. (p. 56/GAO Draft Report)

DOD RESPONSE: Concur. The Department agrees that by the preliminary design review for a new ship, critical technologies should be developed into representative prototypes and successfully demonstrated in a relevant environment, or evaluated through modeling and simulation. The technology development strategy for each shipbuilding program is the appropriate document to reflect the implementation of this provision. The Department is preparing appropriate guidance outlining that this item is to be reviewed during the preliminary design review of shipbuilding programs. The DoD 5000.02 requires early technology readiness assessments that will identify the critical technologies. The guidance will require that the technology readiness panel follow up with validation of the proposed demonstrations or simulations for each critical technology. The guidance will also recognize that the relatively long construction span for ships requires flexibility

Enclosure
Page 2 of 6

in technology development and ship design processes to deal with factors such as obsolescence and ship construction and delivery schedule requirements. This element, identified as Element GAO-09-322-04, will be considered for implementation on shipbuilding programs that plan to enter the Technology Development phase in fiscal year 2010 or later.

RECOMMENDATION 5: The GAO recommends that the Secretary of Defense require that, by the preliminary design review for a new ship, the Navy develop, in cooperation with industry, an analysis of cost and requirements trade-offs that can identify ways to further reduce the technical demands of the ship. (p. 56/GAO Draft Report)

DOD RESPONSE: Concur. The Department agrees that an open dialogue between prospective shipbuilders, other key industrial entities, and the Government, including an analysis of cost and requirements trade-offs, might identify ways to further reduce the technical demands of the ship as the shipbuilding program requirements evolve. The Department will ensure that the acquisition strategy for each shipbuilding program reflects the implementation of this provision when properly placed within the restrictions in the Federal Acquisition Regulations (FAR) that restrict communications in a competitive environment. The Navy has and will continue to host industry days for feedback on proposed acquisition strategies. This element, identified as Element GAO-09-322-05, will be implemented in accordance with FAR guidelines and considered for programs that plan to enter the Technology Development phase in fiscal year 2010 or later.

RECOMMENDATION 6: The GAO recommends that the Secretary of Defense require that before a contract is awarded for detail design of a new ship, critical technologies be matured into actual system prototypes and successfully demonstrated in a realistic environment. (p. 56/GAO Draft Report)

DOD RESPONSE: Concur. The Department agrees that before a contract is awarded for detail design of a new ship, critical technologies should be matured into actual system prototypes and successfully demonstrated in a realistic environment, or evaluated through modeling and simulation. The technology development strategy and the acquisition strategy for each shipbuilding program are the appropriate documents to reflect the implementation of this provision. The Department is preparing appropriate guidance outlining that this item is to be reviewed during the preliminary design review of shipbuilding programs. The DoD 5000.02 requires early technology readiness assessments that will identify the critical technologies. The guidance will require that the technology readiness panel follow up with validation of the proposed demonstrations or simulations for each critical technology. However, testing all systems in a relevant shipboard environment is impractical for some systems before award of the detail design and construction contract, and, therefore, land based testing could be used where

Enclosure
Page 3 of 6

appropriate to drive out component risks in support of detail design and construction needs. The technology development strategies and acquisition strategies will need to identify that in these cases the component delivery schedule to the shipbuilder includes adequate time allowance for testing to ensure the ship detail design and construction schedules are not degraded. This element, identified as Element GAO-09-322-06, will be considered for implementation on shipbuilding programs that plan to enter the Engineering and Manufacturing Development phase in fiscal year 2011 or later.

RECOMMENDATION 7: The GAO recommends that the Secretary of Defense require that before a contract is awarded for detail design of a new ship, the Navy provide sufficient time for thorough discussion with the prospective shipbuilder(s) to fully understand the technical specifications that will guide the ship's design and to resolve key differences. (p. 56/GAO Draft Report)

DOD RESPONSE: Partially concur. For sole source environments, the Department will ensure that the acquisition strategies for shipbuilding programs require the Government and the prospective shipbuilder(s) to dedicate adequate resources and time to ensure that technical specifications that will guide the detail design of the ship are disclosed in adequate time to support the detail design contract for the lead ship of the shipbuilding program. The acquisition strategy will also identify the process for ensuring that technical differences, design concurrency, design reservations, and preplanned product improvements that emerge after the start of detail design are resolved to the Government's satisfaction while also taking into consideration program cost and schedule impacts. For competitive procurements, the Department will encourage discussions with prospective shipbuilders to ensure the technical specification is well understood. This element, identified as Element GAO-09-322-07, will be considered for implementation on programs that plan to award contracts for detail design of a lead ship in fiscal year 2011 or later.

RECOMMENDATION 8: The GAO recommends that the Secretary of Defense require that, by the start of construction of a new ship, the design be stabilized through completion of basic and functional design and 3D product modeling (when employed), with the recognition that complete - versus notional - vendor information must be incorporated for the design to be truly stable. (p. 56/GAO Draft Report)

DOD RESPONSE: Concur. The Department agrees that the ship's design should be stable before starting construction, including completion of basic and functional design and 3D product modeling (when employed), and recognizing that complete - versus notional - vendor information must be incorporated. The acquisition strategy for each shipbuilding program is the appropriate document to reflect the implementation of this provision. The Department is preparing appropriate guidance outlining that this item is to be reviewed prior to starting construction of shipbuilding programs. The Department will

Enclosure
Page 4 of 6

ensure that the acquisition strategy for each shipbuilding program will require that the ship's design is sufficiently mature before start of construction of the shipbuilding program. The guidance will define the levels of maturity of the ship product model and other key design artifacts, including vendor information, which will ensure that the design is stable. The guidance will also recognize that there is benefit to sequencing the design process to level load the design workforce as much as possible, ensuring sufficient time is allowed to prove out any new process in construction prior to widespread implementation, and to address any obsolescence issues that might occur during the design process. This element, identified as Element GAO-09-322-08, will be considered for implementation on shipbuilding programs that plan to start construction of a lead ship in fiscal year 2012 or later.

RECOMMENDATION 9: The GAO recommends that the Secretary of Defense direct the Secretary of the Navy to report to Congress on what steps and changes in the acquisition process would be needed to allow the Navy to rely primarily upon fixed-price contracts for lead ships within 3 years. (p. 56/GAO Draft Report)

DOD RESPONSE: Partially concur. The Department of the Navy, in conjunction with the Office of the Secretary of Defense, will review the shipbuilding acquisition process and the US shipbuilding environment to identify necessary steps and changes to processes that would enable the Government to use fixed-price type contracts for lead ships, where appropriate. The Department will identify an initial set of changes necessary within one year. The Department is concerned, however, that the changes identified might not eliminate the significant risk to the shipbuilder that is reflected as higher bids for fixed-price contracts for lead ships, in practice. This task is identified as Element GAO-09-322-09.

RECOMMENDATION 10: The GAO recommends that the Secretary of Defense direct the Secretary of the Navy to evaluate the Navy's in-house capability and capacity to provide strong, consistent buyer oversight, and to make changes where necessary. (p. 56/GAO Draft Report)

DOD RESPONSE: Concur. The Department of the Navy is reviewing its in-house capability and capacity to provide strong, consistent buyer oversight for shipbuilding programs over the long term. The Navy will provide a report to the Under Secretary of Defense (Acquisition, Technology and Logistics) within one year. The report will identify the specific shortfalls and provide a plan of action, with timetable and resources identified, to correct the shortfalls. This task is identified as Element GAO-09-322-10.

Enclosure
Page 5 of 6

<u>RECOMMENDATION 11:</u> The GAO recommends that the Secretary of Defense assess whether the Navy's desire to provide a certain fleet size sufficiently constrains decisions on the technical content and cost of each new ship class, and recommend changes where necessary. (p. 56/GAO Draft Report)

<u>DOD RESPONSE</u>: Concur. The Department agrees that there is a relationship between the Navy's long term shipbuilding plan and the technical content and cost of the new ship classes it entails. The Department regularly assesses this relationship when reviewing budgets, Analysis of Alternatives results, individual programs, and in conjunction with force structure decisions. However, the Department will consider if additional changes are warranted and recommend accordingly. This task is identified as Element GAO-09-322-11.

Enclosure
Page 6 of 6

Appendix III: GAO Contact and Staff Acknowledgments

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