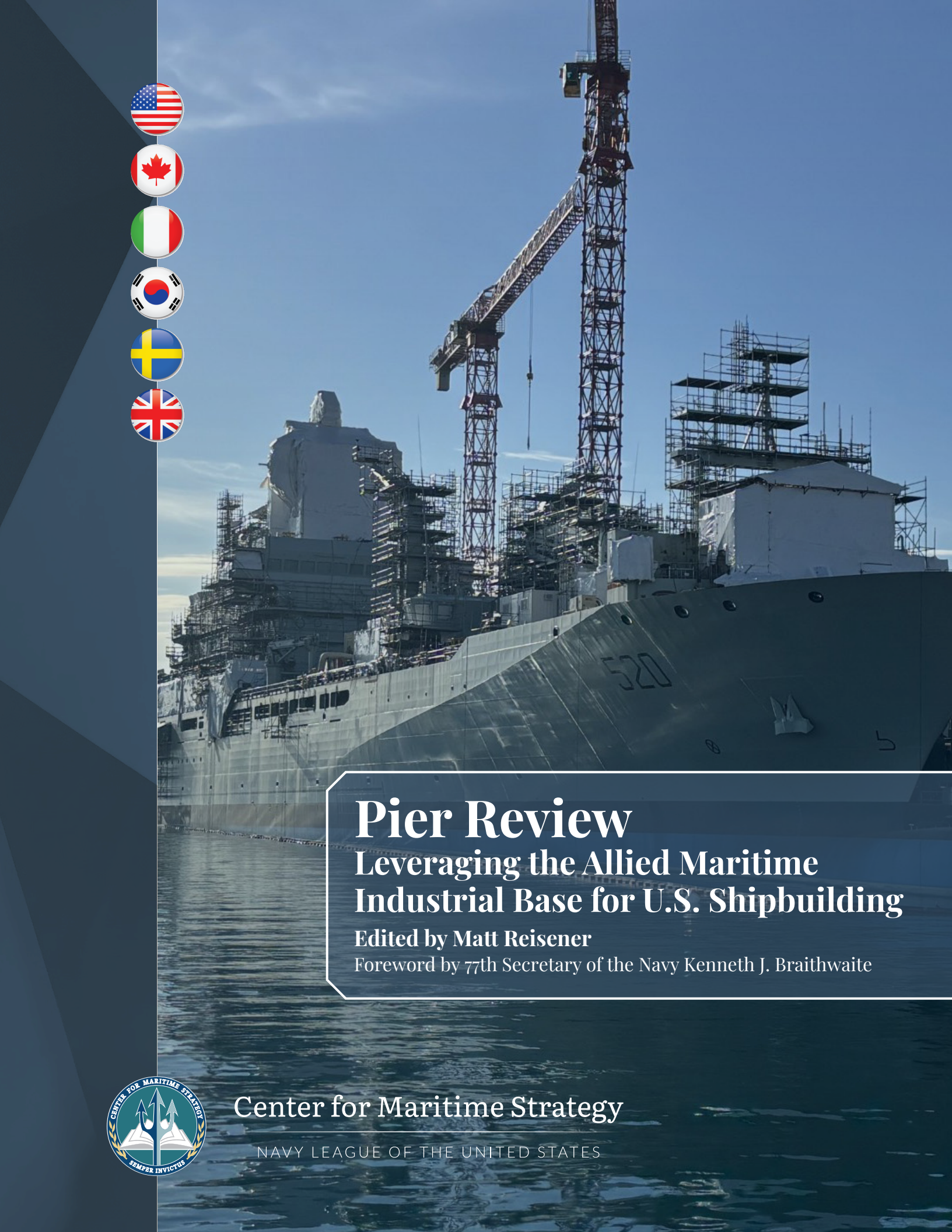

Pier Review

Leveraging the Allied Maritime Industrial Base for U.S. Shipbuilding

Edited by Matt Reisener

Foreword by 77th Secretary of the Navy Kenneth J. Braithwaite

Center for Maritime Strategy

NAVY LEAGUE OF THE UNITED STATES

"This report provides a detailed, insightful and relevant portrait of global shipbuilding now, highlighting positive aspects and underscoring hurdles. I have yet to see such a well-landscaped study in a single volume..."

Michael Fabey, author of *Heavy Metal: The Hard Days and Nights of the Shipyard Workers Who Build America's Supercarriers* and *Crashback: The Power Clash Between the U. S. and China in the Pacific*

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About the Editor

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About the Center for Maritime Strategy

The Center for Maritime Strategy (CMS) is a non-profit, non-partisan think tank and research institution dedicated to studying maritime issues and their context within wider American national security policy. Through its research and analysis, external outreach, publications, and high-level events, CMS engages key stakeholders across government, academia, and industry.

Our mission is to strengthen American national security through its sea services, conducting policy-driven research, advocacy, and education on the relationship between maritime power and national security policy.

Founded in January 2022, the Center supports all of the Nation's sea services, including the Navy, Marine Corps, Coast Guard, and Merchant Marine, through conducting scholarly research and analysis to drive prudent national security policies. Its inception came in response to several key national security challenges that demand revitalized maritime power:

1. The re-emergence of strategic competition with China and Russia.
2. The decline of the American maritime industrial base.
3. The expense and complexity of maritime platforms and systems which necessitates judicious foresight and long-term force planning.
4. Ever-increasing globalization driven by maritime highways and expanding sea-based infrastructure.
5. The difficulty of achieving political consensus on Capitol Hill in an era of heightened partisan polarization.

The Navy League of the United States sponsors the Center for Maritime Strategy, furnishing operational support and leveraging its 120-year history of supporting the American sea services with nearly 200 local chapters throughout the globe.

Foreword

By Kenneth J. Braithwaite, 77th Secretary of the United States Navy

Our founding father, General George Washington, once said, "Without a decisive naval force we can do nothing definitive, and with it, everything honorable and glorious." At the time he was not referring to a nascent Continental Navy but eyeing the support of a key ally, calling on the assistance of the French navy to stand with America in its battle for independence. In that tradition, as the 77th Secretary of the Navy, I was delighted to accept the invitation to write the foreword for the Center for Maritime Strategy's (CMS) latest report entitled *Pier Review: Leveraging the Allied Maritime Industrial Base for U.S. Shipbuilding.*

This important piece of work brought back vivid memories of my time as Secretary of the Navy from 2020-2021. Knowing that we had fallen behind on both acquisition of new platforms and maintenance and repair of our existing fleet, one of my initial actions was to convene a "Night Court" with the Chief of Naval Operations and senior flag officers and program executive officers to determine how we could jumpstart production, maintenance, modernization and repair. Despite our team's best efforts and those of my successors, we have not reached our goal of a 355-ship Navy. One of the primary reasons for this shortfall is the atrophy of our maritime industrial base, which has failed to keep pace with America's urgent need to grow our Navy in response to emerging global threats posed by China, Russia, Iran, and others.

While America's maritime industrial base has diminished, the United States still has one asset its adversaries do not—its trusted and reliable allies. For the Navy to meet the challenges it faces in the coming decades, the United States must take advantage of its strong partnerships with naval allies to support a collective revitalization of the allied maritime industrial base.

Therein lies the importance of this outstanding and invaluable report. Over a year in the making, this timely work by CMS provides a comprehensive assessment of shipbuilding infrastructure, technological capacity, and strategic positioning across key partner nations—namely the Republic of Korea, Italy, Canada, Sweden, and the United Kingdom. The report identifies opportunities and industry best practices to enhance interoperability and collective maritime readiness, and its recommendations are poised to play an important role in informing policy decisions and promoting greater international collaboration. CMS has clearly established strong and trusting relationships with foreign shipbuilders, and many of the report's most notable insights came from the remarkable access these companies and allied governments granted its researchers.

This report provides a rich examination of the maritime industrial bases of each of the five case study countries, all of which boast unique strengths in shipbuilding and have embraced varying degrees of modernization and specialization. South Korea stands out for its advanced commercial and military naval manufacturing, supported by large, highly automated yards capable of producing complex warships efficiently. Italy and the United Kingdom possess legacy naval industrial complexes with recent investments aimed at modernizing frigate and submarine construction while advancing modular construction approaches to increase flexibility and reduce build times. Italy is especially on the cutting edge of robotic and autonomous systems, as detailed in the report's examination of the luxury cruise liners being produced at the Monfalcone shipyard where their intent is to apply best practices to naval construction. Canada's shipyards are focused on patrol vessels and ice-capable ships, vital and an imperative for preserving Arctic sovereignty amidst the opening of new sea lanes in the region. Sweden's naval industry emphasizes innovative defense solutions despite operating on a low-rate production model, continuing to build submarines despite its relatively limited industrial capacity. With its analysis of the strengths, weaknesses, opportunities, and threats associated with each ally's maritime industrial base, the report provides a compelling look at what the United States can learn from each country's experience sustaining domestic shipbuilding amid a turbulent geopolitical environment, as

well as how America can best collaborate with its partners to further their mutual maritime goals.

CMS's *Pier Review* study points out several common trends across the allied maritime industrial base which are worthy of consideration for both the Navy and the American shipbuilding industry. Recruitment and retention of a qualified labor force is a common problem across all cases, thereby necessitating investment in robotic and autonomous systems. As the report outlines, countries such as South Korea and Italy have used their investments in automation to mitigate their structural labor challenges, many of which mirror those faced by America's shipbuilding industry. The adoption of a digital twin approach to managing day-to-day operations in their shipyards has also proven to be a gamechanger which could improve the efficiency of American shipyards if more widely adopted. Additive manufacturing also stands out as a viable solution to the fragility of America's shipbuilding supply chains, especially regarding critical components manufactured in casting and forging facilities. Finally, as the study reveals, many of America's allies rely on cross-national supply chain collaboration, standardization, and joint procurement efforts to sustain their shipbuilding production, which could serve as a model for the United States in how it can address its supply chain challenges. These recommendations, among others detailed in the study, warrant serious consideration by American policymakers and industry leaders as they debate how best to restore American shipbuilding to its former glory.

I commend the Center for Maritime Strategy for this body of work which will undoubtedly contribute to improvements in the way America and her allies conduct business in the maritime domain. The study does not just articulate a list of problems facing the Navy and the maritime industrial base; rather, it recommends concrete solutions that can make both the U.S. government and the shipbuilding industry more efficient and cost-effective in building the Navy the nation needs. This study is essential reading for anyone interested in the future of American seapower and serves as a model for future inquiry in other industrial base sectors in the United States and overseas.

Sea control, as provided by U.S. Navy ships, remains at the heart of American security. I have come to learn in my lifetime of maritime service that, while the purpose of an Army is to win wars, the purpose of a Navy is to prevent them! President John F. Kennedy, a former naval officer himself, said on June 6, 1963, onboard the carrier USS *Kitty Hawk*, "control of the sea means security. Control of the seas can mean peace. Control of the seas can mean victory. The United States must control the seas if it is to protect your security."

Now more than ever, America must work in concert with its allies to build a maritime industrial base capable of empowering the U.S. Navy to provide security both at home and abroad. CMS's *Pier Review* report provides important insights about how to achieve this goal, making it a worthy contribution to America's essential national discussion about the Navy's future.

With Respect,

Kenneth J. Braithwaite

77th Secretary of the United States Navy

Executive Summary

America's maritime industrial base (MIB) faces arguably its most significant crisis since World War II. Decades of deindustrialization, inconsistent policy support, labor attrition, and increasingly globalized supply chains have left the United States struggling to produce ships on time and on budget, all while strategic competition at sea intensifies. The decline of the U.S. MIB carries significant risks, as American maritime industrial capacity is inseparable from its national power. At present, the U.S. MIB is unable to support the needs of its Navy, compete with rising naval and shipbuilding powers such as China, or reliably contribute to the protection of America's most vital national interests in the decades to come. While American policymakers have increasingly recognized the importance of revitalizing the U.S. MIB, policymakers, naval officials, and industry experts remain divided on how best to achieve this goal.

America is not alone in facing these challenges. Many of the United States' maritime allies are experiencing similar threats to their domestic shipbuilding industries, including labor shortages, outdated shipbuilding technology and infrastructure, inefficient processes for designing and building ships, disjointed government-commercial relations, and supply chains that are becoming increasingly vulnerable to disruption. America's allies have developed their own unique approaches to dealing with these challenges, which carry important lessons for the United States as it attempts to chart a course to a more robust MIB. Given the scale of the task America faces in revitalizing its maritime power, the United States must utilize the experience, knowledge, and resources of its allies to cultivate the best strategy for confronting this challenge.

Accordingly, this study conducted by the Center for Maritime Strategy (CMS) examines the allied maritime industrial base (AMIB) to identify best practices, cautionary tales, and actionable pathways for revitalizing American shipbuilding capacity. The study examines how select allies and partners build both commercial and military ships and highlights valuable lessons that may be applicable to the United States and its maritime industrial base.

To accomplish this, CMS conducted case studies on a diverse group of five of America's maritime allies—South Korea, Italy, Canada, Sweden, and the United Kingdom—to evaluate their domestic shipbuilding industries and MIBs. Each case study examines how the country in question approaches six issues directly related to maritime industrial power—labor and workforce, technology integration, design and manufacturing, purchasing and government relations, infrastructure, and supply chains—and evaluates the strengths, weaknesses, opportunities, and threats (SWOTs) present in each MIB. Although South Korea and Italy have successfully maintained strong commercial and naval shipbuilding sectors, Canada and the United Kingdom have largely allowed their commercial sectors to atrophy while primarily focusing on warship construction, while Sweden has seen both sectors significantly diminish and maintains only marginal naval shipbuilding capabilities. The report analyzes these countries' varying approaches to addressing contemporary shipbuilding challenges and their applicability to the United States, and provides recommendations for how America can apply the insights from its allies to support its MIB while embracing greater multilateral cooperation in the maritime domain, summarized in the following table.

Recommendations

Reforming the Design and Build Processes

- **Design, then bend:** Only begin vessel construction once the design is 100 percent complete to avoid disruptions.
- **Make VCMs the norm:** Use vessel construction managers (VCMs) to oversee all government shipbuilding projects to streamline production and design processes.
- **Embrace modularity:** Creating common designs to be used across multiple types of ships could reduce delays in the design process and increase interoperability.

Embracing New and Emergent Technologies

- **Digitize, automate, and get "smart":** Integrate automation, digitization, and AI in shipyards to empower—not replace—the existing workforce.
- **Build ships to sail, engineer them to last:** Increase operability by incorporating condition-based maintenance (CBM) in ship design to reduce the unpredictability of maintenance and repairs
- **Cross the digital divide:** Embrace digitization by allocating Shipyard Infrastructure Optimization Program budgets to digitization, consulting mariners to address their needs, building worker trust in digital systems, and avoiding disrupting essential shipbuilding processes.

Increasing Allied Cooperation

- **Leverage maritime alliances:** Expand opportunities to collaborate with allies on shipbuilding, modeling existing frameworks like AUKUS, MASGA, and OCCAR.
- **Build a "bridge" over troubled waters:** When American yards are at capacity, construct the initial ships in a multi-vessel purchase in allied ports while simultaneously investing in U.S. shipyards to eventually onshore construction.
- **Use allied ports in a storm:** Engage U.S. maritime allies to provide drydock and port access to the U.S. Navy, especially those with maritime infrastructure in the Pacific.
- **"All hands on deck" for skilled labor:** Supplement the domestic shipbuilding labor pool with high-skilled migrants from allied countries.

Ensuring On-Time Delivery

- **Incentivize success:** Offer financial incentives (but not punitive fees) for on-time and on-budget delivery of ships.
- **Small blocks stack just as well as large ones:** Order ships in smaller blocks to allow greater flexibility in design and capabilities and avoid cascading delays across larger block buys.

Training Current and Future Shipbuilders

- **Educate, empower, lead:** Expand shipbuilding apprenticeship opportunities and increase support to trainees.
- **Engineer the future of naval architecture:** Expand existing and create new naval architecture and marine engineering programs to address labor shortages.

Strengthening U.S. Supply Chains

- **If you need it, print it:** Increase additive manufacturing capabilities and training opportunities to mitigate supply chain gaps and reduce overreliance on sole-source manufacturers.
- **Build supply chain contingencies:** Reduce supply chain vulnerabilities in a conflict by developing contingencies which identify alternate sources and lean on dependable allies.

Revitalizing Commercial Shipbuilding

- **Chart a collaborative course:** Facilitate collaboration across government and industry to strengthen America as a competitor in the commercial shipbuilding sector.
- **Shared insight, collective impact:** Share best practices to encourage cooperation among U.S. and AMIB companies to strengthen the shipbuilding industry.

Background

The U.S. maritime industrial base (MIB) is composed of a complex web of industrial and labor forces working in concert to design, build, repair, and maintain maritime vessels. It includes the shipyards, workers, and supply networks dedicated to supporting American seapower. Private shipyards and government-owned and -operated repair facilities are essential components of this industrial base. By the end of World War II, America's MIB was the envy of the industrialized world. 80 years later, this vital industrial base is a shell of its former glory and struggles to meet the demands of a global superpower which nevertheless remains, at its core, a maritime nation.

The decline of the U.S. MIB has arguably accelerated since the end of the Cold War, which ostensibly eliminated the need for the United States to maintain a Navy robust enough to wage a conventional war against a global superpower. Civilian shipbuilding has experienced an even steeper downturn since the elimination of government subsidies to shipbuilders in the early 1980s. These strategic and economic changes, coupled with over 40 years of deindustrialization in the United States, have left the nation's MIB in poor material and financial condition and dependent on U.S. government business in a monopsony relationship for its livelihood. Unfortunately, the decline of the MIB coincides with a rapid return to great power competition with the rise of the People's Republic of China (PRC) and the revanchist return of Russia—two revisionist powers intent on destabilizing and changing the post–Cold War balance of economic and military power. Additionally, in early 2026, the United States embarked on a large-scale conflict with the Islamic Republic of Iran which has primarily been waged in the naval domain.[1] The United States has struggled to rebuild its naval and maritime power, facing rapid technological change coinciding with its efforts to rebuild its larger industrial base. The nation that served as the arsenal of democracy before and during World War II and the Cold War now struggles to build and maintain sufficient naval and maritime capabilities for its own self-defense, let alone the defense of allies and partners. The United States possessed 55 shipyards capable of building ships of all sizes at the end of World War II, but that dwindled to 19 by 1980. While there are 154 active shipyards in the United States, as of 2025, only seven remain capable of building complex naval vessels.[2]

The decline of America's MIB also coincides with the continuing global war on terrorism that commenced in earnest following the attacks on the U.S. homeland on September 11, 2001. The U.S. military and defense industry's increased focus on counterinsurgency operations, in addition to wars in Afghanistan and Iraq, further shifted resources away from the maritime domain and hampered the ability of the United States to rejuvenate its aging MIB. A whole generation of new warships, the Surface Combatant for the 21st Century (SC-21), failed to fully develop in the early 2000s, forcing the U.S. Navy to rely on aging, Cold War–era ship designs. While the Navy has since developed and procured new classes, the MIB's production rate is slow and inefficient, forcing America's maritime service to field a fleet that is well short of the 355 vessels prescribed by the Navy's 2016 Force Structure Assessment, let alone the Navy's stated goal of a fleet of 381 manned ships outlined in its fiscal year (FY) 2025 30-year shipbuilding plan.[3]

While the shrinking and aging U.S. Navy has been unable to grow to its authorized size over the last decade, the People's Liberation Army Navy (PLAN) has built the world's largest fleet, with over 370 warships of all types.[4] This fleet is further supplemented by a militarized Coast Guard of 150 large offshore patrol vessels and a People's Maritime Militia comprising state-directed fishing fleets.[5] The U.S. Office of Naval Intelligence assessed that China's shipbuilding capacity is over 200 times greater than that of the United States in terms of tonnage, which would give China a significant advantage in quickly replacing naval and sealift vessels damaged during a war and maintaining a robust fleet size even if it experiences high levels of attrition.[6] China's shipbuilding industry has been bolstered by $5 billion in direct state subsidies, with government sup-

port coming in the form of cash payments to offset business costs, rebates for taxes and levies, and the issuing of credits to purchasers who buy Chinese-built ships, among other mechanisms.[7] In addition, the People's Liberation Army Rocket Force now boasts an impressive arsenal that includes hypersonic, ballistic, and cruise missiles armed with nuclear and conventional warheads. The range of these weapons and the reconnaissance strike complex of sensors that support them have been assessed as capable of prohibiting the U.S. Navy from attacking Chinese targets without incurring significant risk.[8]

China is not America's only threat in the maritime domain, however. The Russian navy remains a shadow of its former Soviet counterpart, but has improved the stealth qualities of its submarines and pioneered weapon systems to attack critical seabed infrastructure.[9] Iran and North Korea remain potential disruptors of the global economic order. In addition to attempting to close the Strait of Hormuz, Iran has supported the Houthis in Yemen, who continue to threaten the free flow of commerce through the Bab al Mandeb Strait and the Red Sea, and have engaged in active combat with U.S. and European forces seeking to protect the freedom of trade through that maritime choke point.[10] North Korea has further developed its ballistic and cruise missiles and is building a new class of missile-armed surface warships.[11] Narcotics traffickers have engaged in increasing levels of violence, sometimes against U.S. citizens, and have sought advanced maritime capabilities, including semi-submersible craft, to support their illicit drug trade.[12] Clearly, the maritime world is becoming increasingly unstable as revisionist states and non-state actors seek to disrupt trade and undermine global stability, underscoring the necessity of American strength in the maritime domain.

Finally, new technology has made it possible for revisionist entities to further threaten navies and commercial ships at sea. The continued development of unmanned air, surface, and subsurface platforms in recent conflicts increases the overall threat to the U.S. Navy, especially in littoral waters, where the shorter range and lower speed of drone platforms can be mitigated through mass deployment to overwhelm defenses.

The U.S. MIB must be reconstituted quickly, utilizing the most modern equipment and procedures to meet the growing threats to the United States and its allies and partners. Within this context of America's diminishing shipbuilding capabilities and growing need for revitalization, America must increasingly look to its allies for solutions to address this issue.

Fortunately, opportunities for collaboration towards this goal are abundant. In December 2024, South Korean defense conglomerate Hanwha Group completed its acquisition of the Philadelphia Shipyard. Initially founded in 1776, the shipyard was purchased by the U.S. Navy in 1801 and later produced warships and commercial ships during World War II, including aircraft carriers, battleships, and Liberty ships.[13] This acquisition made Hanwha the first Korean corporation to own an American shipyard and constituted an important foundation for the bilateral "Make American Shipbuilding Great Again (MASGA)" initiative later undertaken by the Trump administration to revitalize American shipbuilding through increased collaboration with South Korea. This project not only signals a growing recognition among American policymakers of the need to improve domestic shipbuilding capabilities, but also of the largely unexploited potential for increased cooperation and knowledge sharing between America and its allies to support this goal. Now more than ever, America must look to its allies for guidance and examples of how America's MIB can be modernized to meet the defining geopolitical challenges of the coming decades.

To aid in this effort, the Center for Maritime Strategy (CMS) conducted this study of the allied maritime industrial base (AMIB) to understand how allies and partners have maintained their own maritime industrial bases. To this end, this report examines the successful industrial bases of select allies—Republic of Korea, Italy, Canada, Sweden, and the United Kingdom—to identify best practices that might be employed in reversing the decline of the U.S. MIB and promoting its rejuvenation to confront current and future threats to the global maritime space.

Research Design

This report is structured as a series of five country case studies which highlight the best practices observed, strategies employed, and challenges encountered by each country's MIB. By comparing circumstances across a diverse set of countries which are each nonetheless capitalist, liberal democracies friendly to the United States, this study seeks to provide a more holistic view of how an advanced economy can tackle the challenges associated with maintaining a robust MIB than would be possible in a deep-dive study into a single country's experience. This study utilizes comparative case studies as a method to allow for in-depth qualitative examinations of the target countries' shipbuilding practices, allowing the report to focus not just on what is being produced by the MIBs of America's allies, but also on the "how" and "why" behind this production, and to explain the contextual geopolitical realities which inform these countries' shipbuilding choices and strategies. At the conclusion of each case study, the report identifies the strengths, weaknesses, opportunities, and threats (SWOTs) associated with the subject country's MIB based on CMS's research.

Case Study Subjects

The five nations selected as the focus of this study were chosen due to their robust domestic shipbuilding industries, status as American allies, and the willingness of senior government officials and/or shipbuilding industry leaders to provide CMS with comprehensive and objective insights regarding the state of their MIBs. While resource constraints limited the number of countries this study was able to include, the select cases represent a diverse picture of how America's allies confront a wide array of shipbuilding challenges within their own distinct geopolitical contexts. Accordingly, these countries were also selected in part to provide researchers with a broad range of shipbuilding best practices and experiences upon which to base their conclusions and recommendations.

For example, South Korea is one of the few U.S. allies that possesses both a major commercial shipbuilding industry as well as first-rate naval forces. While maritime powers have historically sought to maintain the balance of robust naval production as a subset of a larger commercial maritime enterprise, the United States' MIB is overwhelmingly dedicated to supporting the needs of the U.S. Navy. Meanwhile, the chaebols (large family-owned conglomerates) that dominate South Korea's shipbuilding and repairing industries have achieved sustained success in both domains while successfully integrating cutting-edge technology into their operations and supporting a large and dynamic workforce. South Korea was selected as a case study to shed light on how the country has maintained its commercial maritime industry in the face of Chinese competition, the benefits that accrue to Korean naval shipbuilding because of that commercial industry, and ways the United States can learn from South Korea's embrace of advanced and emergent shipbuilding technologies as it deepens its partnership with Korean shipbuilding companies. Given Korea's pledged $150 billion investment in American shipbuilding, as well as Hanwha's $5 billion investment in its Philly Shipyard and its plans to potentially build nuclear submarines in the United States, CMS thought it especially important to include South Korea in its analysis.[14]

The burgeoning U.S.–South Korea shipbuilding partnership is not the only example of bilateral shipbuilding cooperation, nor is the collaborative framework established by MASGA the only mechanism by which such a partnership can function. Since 2007, Italy has worked with France to jointly produce the FREMM class of frigates for its own use as well as for export to other countries. Twenty-two FREMM vessels are currently operated by five Mediterranean navies with additional vessels planned for sale to buyers around the world. The Italian case study explores the challenges of multi-national production of major naval units as well as the economies of scale obtained by pooling resources among allied powers and producing or licensing vessels for export. With America increasingly seeking to partner with other industrialized nations to make up for production delays in U.S. shipyards, Italy represents a fascinating example of both

the benefits and potential pitfalls of such undertakings. Additionally, Italy's status as one of the global leaders in cruise ship construction makes it a relevant test case for how America's commercial shipbuilding companies can more effectively integrate modern technologies and processes to streamline commercial production. While perhaps not intuitive, the technology and processes employed by Fincantieri in its production of cruise ships are directly relevant to warship construction. Finally, the Italian case study allows for an examination of the failure of the *Constellation*-class frigate, a vessel the U.S. government contracted Italian shipbuilding giant Fincantieri Marinette Marine to construct before ultimately cancelling it after several significant false starts and delays.[15] Contrasting the failed development of the *Constellation* class with the ongoing successful production of the FREMM makes Italy a noteworthy case study subject and yields several important lessons which can inform future naval shipbuilding projects.

While the *Constellation* class no longer represents the future of naval surface vessels, the Canadian-built icebreakers being produced as part of the Icebreaker Collaboration Effort (ICE) Pact remain an important part of America's strategic maritime vision. An historic naval ally of the United States, geographic and geopolitical shifts have left America's northern neighbor poised to play an increasingly important role in supporting America's naval efforts. Canadian shipbuilders are among the global leaders in the production and design of icebreakers, and the trilateral ICE Pact will enable Canada to share its expertise with its American and Finnish allies.[16] With the melting of Arctic ice opening new sea lanes and enabling access to critical resources, Canada will play an invaluable role in helping America increase its maritime presence in the Arctic and bolster its icebreaker fleet from three ships to the nine the Coast Guard estimates it needs.[17] Furthermore, the prospect of great power competition with China and the need to deter naval conflict in the Asia-Pacific will invariably necessitate America shifting a greater concentration of its naval power to the West Coast, creating opportunities for Canadian shipyards, which currently have excess capacity, to play a larger role in repairing and maintaining American vessels and supplementing American infrastructure on the Pacific. These realities make Canada a timely and important addition to this case study project.

Sweden represents something of an anomaly among American allies. While Sweden only recently became a NATO member, it spent over 200 years as a neutral nation while also maintaining its own highly capable armed forces, including a small but powerful navy for operations in the Baltic Sea. This case study afforded researchers an opportunity to examine the challenges and pitfalls of optimizing a MIB to produce warships for a relatively small domestic market and how the Swedish government and navy shepherded this national strategic asset through times of scarcity. This includes examinations of how Swedish shipbuilders recruited, trained, and maintained a skilled workforce from a small labor pool, as well as its management of low-rate naval procurement over a long period so as to preserve shipyards, workforce, and other critical elements of a viable MIB. Given the vast array of global challenges the U.S. Navy faces, lessons in how best to operationalize a MIB to do more with less are particularly valuable. Furthermore, Sweden's efforts to maintain a MIB despite boasting a low rate of industrial production provide valuable lessons for the United States about the strategies and challenges associated with sustaining robust shipbuilding and maintenance and repair sectors amid broader declines in domestic manufacturing.[18]

Finally, the United Kingdom provides important contextual lessons for a maritime power seeking to maintain a global presence. Britain was once home to the world's largest and most advanced MIB, supporting a globe-spanning Royal Navy and merchant marine. However, Britain's shipbuilding, maintenance, and repair capacity has steadily eroded to the point that the Royal Navy struggles to keep up with the demand signal for warships and one of the country's historic shipbuilders, Harland & Wolff, was forced to enter bankruptcy proceedings.[19] While Brittania once ruled the waves, it now has fewer ships than the U.S. Coast Guard.[20] This case study examines the United Kingdom as a cautionary tale for the United States—a once-dominant naval power whose maritime industrial base was neglected to the point of collapse—and draws lessons for how America can reverse course. The case study also examines British naval procurement decision-making and its long-term effects on the health of specialized maritime industrial

base assets, as well as how the U.K. has reenvisioned the role its MIB plays in its national defense amid the U.K.'s recession from global power status. The British-built Type 23 *Duke*-class frigate has had an impressive lifespan since the HMS *Norfolk* was commissioned in 1989, and British shipbuilder BAE Systems hopes to build on the ship's multi-mission capability with the forthcoming release of the Type 26 frigate. Examining the capacity of the British MIB to deliver on the production of these vessels in addition to fulfilling its obligations in support of the AUKUS program provides a fascinating and relevant case study for how a country can operationalize its declining MIB to meet its core national security needs.[21]

The data for each case study was gathered using a mixed-methods approach involving:

- In-depth desk research on each country's MIB via a thorough review of the existing literature on their respective navies, military-industrial challenges, and foreign and defense policies;
- Interviews and scoping discussions with experts and key decisionmakers (past and present) responsible for naval construction and maritime industrial development, including U.S.-based experts, experts based in each of the case study countries, and tradespeople from allied shipyards, and;
- First-hand visits to shipyards in the case study countries, which included observations of the processes, technologies, and strategies employed by these countries to facilitate shipbuilding and the challenges each country faces in using its MIB to support its national interests. This also included an examination of the labor forces in allied nations that produce commercial or naval vessels at scale to determine how they recruit, train, and retain their workforce; whether there are labor shortages; and if and how robotic and autonomous systems are employed to make up for the shortage in labor.

CMS selected shipyards to visit based largely on availability and access. CMS prioritized opportunities to visit large shipyards willing to provide extensive tours of their facilities and allow CMS's researchers to interact with the yard's leadership and workforce, as well as shipyards whose operations could be reported on in full or in part without compromising the national security of their home countries. While the case studies focus on particular shipbuilding companies as microcosms of the country's larger shipbuilding industry, it is important to note that the successes, challenges, and practices of these companies may not be reflective of the industry as a whole. Rather, the examinations of these specific companies and shipyards enabled CMS to use them as reference points in discussions about their countries' broader shipbuilding efforts, as well as provide concrete examples of how larger trends in their domestic industries are being applied on the ground.

A list of shipyards visited and interviews conducted as part of these case studies can be found in Annex II. Unless otherwise cited, all conclusions and data points included in the case studies were obtained as a result of the first-hand observations CMS's expert researchers made during their visits to foreign shipyards and/or the interviews and scoping discussions conducted to support this case study.

Research Questions

To create uniformity among the interviews and site visits, CMS developed a series of questions which were posed to every expert and shipbuilding professional consulted. These questions were developed at the outset of the study through a series of interviews with a select group of subject-matter experts who advised on specific lines of questioning to glean insights across a variety of topics aimed at supporting the U.S. MIB.

By comparing and pooling the interests of the Center's subject-matter experts, a list of 60 questions was developed for comparison across the case study subjects. These questions are included in Annex I. While not all interview subjects elected to answer each of these questions, CMS encouraged every expert and shipbuilding professional interviewed as part of this study

to provide thorough responses to all questions about which they had expertise. As a result, the interviews conducted in support of this study sparked robust and fruitful discussions about the MIBs of the case study subjects and yielded a plethora of insights which enriched the findings of the case studies.

Each case study is structured as an investigation into six research categories:

- Labor and Workforce
- Technology Integration
- Design and Manufacturing Process
- Purchasing and Government-Commercial Relations
- Infrastructure
- Supply Chains

While not exhaustive of all potential areas of research, these categories cover a broad range of issues which define the characteristics and successes of a country's shipbuilding operations. By including uniform research categories across all five case studies, this report was designed to compare the shipbuilding strategies, capabilities, and practices of each of the case study countries, and to draw comparisons to the current state of shipbuilding within the United States. Accordingly, the report concludes by analyzing the collective findings from each of these case studies, as well as outlining a series of recommendations the United States should take to address the most pressing problems facing America's domestic shipbuilding efforts.

America as a Point of Comparison

In addition to its five case studies, CMS conducted a thorough review of the current state of America's MIB to provide a reliable point of comparison to each of the case study countries and better inform the recommendations made at the conclusion of this study. The analysis of America's MIB is based on:

- In-depth desk research and a thorough review of the existing literature;
- Observations from site visits to American shipyards between 2022-2025, including: Huntington Ingalls Industries' (HII) Newport News Shipbuilding facility in Newport News, Virginia; Fincantieri Marinette Marine in Marinette, Wisconsin; and Hanwha Philly Shipyard in Philadelphia, Pennsylvania (both before and after Hanwha took ownership of the yard);
- Observations from CMS's visit to the Accelerated Training in Defense Manufacturing (ATDM) site in Danville, Virginia to examine the new facility dedicated to additive manufacturing and the associated training, machining, inspection, and testing of 3D-printed materials for the submarine industrial base, and;
- The findings produced by CMS's Maritime Industrial Base (MIB) Working Group—a six-month series of private, Chatham House rule discussions conducted between 2024-2025 that brought together key members of the U.S. government, academia, industry, and select international partners. These meetings provided a forum for candid discussions on the challenges and issues facing the MIB. Meeting monthly, the working group was briefed on critical topics, including tracking MIB funding, additive manufacturing, AUKUS, Capitol Hill perspectives, the intersection with national strategy, and workforce challenges within the MIB. The working group culminated in a discussion at the Navy League's 2025 Sea Air Space conference, summarized the problems and roadblocks identified over the previous six months of webinars, and discussed proposed solutions and policy options to alleviate sector issues.

Analyzing the Current State of America's Maritime Industrial Base

After outsourcing much of its industrial capacity during the late 20th and early 21st centuries, the United States lacks the ability to produce complex warships on a timeline that matches either the current threat level or the Navy's demand. While American shipyards once produced around five percent of the world's tonnage—the equivalent of 15-25 new ships per year—that number has declined to 0.1 percent as of 2024.[22] Currently, China, Japan, and South Korea collectively account for 90 percent of the world's tonnage.[23] Additionally, while the United States purchases an average of two attack submarines per year, America is only producing these vessels domestically at a rate of 1.3 per year over the past three years.[24] While this output was intended to increase to 1.5 submarines per year by 2024 and two per year by 2028, very little progress has been made toward achieving this goal. America's commercial shipbuilding output is even less inspiring. American shipbuilders construct under one percent of global commercial ships, whereas China produces roughly half of the world's commercial fleet.[25]

In January 2024, then-Secretary of the Navy Carlos del Toro ordered a 45-day review of the state of U.S. shipbuilding to assess the "national and local causes of shipbuilding challenges."[26] The conclusions of this investigation, released to the public in April 2024, articulated several problems which have contributed to the severe decline of America's MIB. The review found significant schedule and budget issues across multiple classes of naval shipbuilding projects. Construction of the lead *Columbia*-class ballistic missile submarine was projected to be between 12-16 months behind schedule, the latest *Ford*-class aircraft carrier was delayed by 18-26 months, and both the *Virginia*-class submarines and the now-canceled *Constellation*-class frigates were as many as 36 months behind.[27]

What can explain these significant delays and cost overruns? As outlined by Admiral James Foggo, USN (ret.) in a 2023 article published by *Breaking Defense*:

> When a vessel arrives at a shipyard it has needs: manpower, parts, services, repairs, modernizations, alterations and restorations. These activities require specific and often exotic materials, implemented as part of a defined process, driven and overseen by uniquely skilled operators. This is an incredibly complex task. Every station within a shipyard tackles a different component of the project. It's a multi-step process executed by several different teams. The work planned at any given step is dependent on actions completed in previous steps, as well as the availability of required services and parts. Any misalignment across people, material and process will result in delays.[28]

One of the largest challenges facing American shipbuilding is the struggle to recruit and retain skilled workers at American shipyards, which has only been exacerbated since the COVID-19 pandemic. This challenge is not divorced from the broader diminishment of America's manufacturing workforce. An estimated 2.1 million manufacturing jobs are projected to be unfilled by 2030, due in large part to the manufacturing skills gap, and 56 percent of the workforce currently holding manufacturing jobs will hit retirement age in the next decade.[29] This challenge is acutely felt by the shipbuilding industry, which is projected to have a deficit of 140,000 workers needed to build and repair submarines within that same timeframe.[30] The American shipbuilding industry experiences extremely high employee attrition rates, which reach 20 to 30 percent in some professions such as welding and pipefitting.[31] Low wages (often around $24.00 per hour) are a significant contributor to this attrition, as wages have stagnated since the onset of the COVID-19 pandemic and failed to rise with inflation.[32] The prospect of receiving higher wages in comparable manufacturing jobs and the desire to find pay commensurate with the difficult

nature of many shipbuilding jobs have led many skilled workers to leave the industry altogether. Many shipbuilding companies are reluctant to raise wages or provide additional benefits to workers to keep production costs down while operating on fixed-price government contracts.

American shipbuilders also face significant challenges in recruiting qualified workers to replace those exiting the labor pool. Between 20,000-30,000 American machinists enter the workforce every year, but there are over 34,000 annual openings for such roles projected over the next decade.[33] Shipbuilding companies encounter similar difficulties filling welding positions, as America produces only 35,000-40,000 welders compared to over 45,000 annual job openings.[34] Foreign-born workers could potentially help fill this gap, but the difficult and time-consuming nature of sponsoring workers for visas serves as a significant deterrent to this practice, as does the security clearance requirement associated with many of these jobs. Many of these workers seek out jobs at technology or IT companies which are willing to pay significantly higher wages for their services. America's MIB also suffers from a limited pool of skilled labor. Given how much of the American shipbuilding industry is confined to specific geographic areas in the country (primarily the Gulf Coast and mid-Atlantic), companies often risk maxing out a labor force in a particular region with too much industrial competition. Shipyards frequently compete for the same labor force, and some workers move from shipyard to shipyard in search of higher wages.[35] As reported by industry officials, this often results in a tight labor market in which hiring booms by one shipbuilding company creates workforce shortages at another, transferring labor scarcity from one arm of the MIB to another without addressing the underlying problem. Similarly, efforts to recruit new technically skilled shipbuilding workers often compete with other essential defense manufacturing industries, such as aviation. As the U.S. Navy eyes an expansion of its fleet size, it remains unclear where the workforce needed to facilitate this growth will come from. As an alarming example, the development of AUKUS submarines alone will require 100,000 new workers over the next decade.[36]

America's MIB suffers from a decrease in shipyard capabilities—the number of U.S. shipyards able to build large seafaring vessels had dropped by more than 80 percent since 1950.[37] American shipyards which once produced vessels for both commercial and military use have increasingly shifted their business models and operational infrastructure to focus exclusively on designing and building one or the other. This increased specialization has left American shipyards vulnerable to market shifts and inflexible to changes in both market demand and the Navy's strategic needs. A 2020 study of America's MIB conducted by the Center for Strategic and Budgetary Assessments noted that "companies that build military ships specialized to survive, making them vulnerable to changes in Navy strategy and acquisition such as the upcoming shift from the littoral combat ship (LCS) to Small Surface Combatant (SSC). And shipyards that build or repair a mix of commercial ships or of government and commercial ships experienced uneven and decreasing orders due to U.S. government budget uncertainty."[38]

As the U.S. Navy eyes an expansion of its fleet size, it remains unclear where the workforce needed to facilitate this growth will come from.

Additionally, many American shipyards are increasingly showing their age. Some shipyards were built as far back as the 1800s, with many still relying on infrastructure created to accommodate the World War II–era shipbuilding boom. Accordingly, much of this outdated infrastructure is incompatible with the Navy's contemporary operational needs. In 2019, the Government Accountability Office (GAO) found that nearly half of the 18 drydocks located in the Navy's four public shipyards require modernization and recapitalization efforts to host the necessary array of aircraft carriers and submarines, though these deficiencies are being incrementally addressed through the Navy's Shipyard Infrastructure Optimization Program (SIOP).[39] Other needed improvements have proven even more languid. American shipyards have largely resisted the move toward digital optimization, often resulting in disjointed operations among the many moving parts required to run such a complex operation. A 2024 study of the shipbuilding industry

conducted by McKinsey highlighted a "lack of digital integration among various systems, metrics, and departments," in many shipyards, noting that "Operating-system fragmentation can lead to delays, miscommunication, and inefficiencies that ultimately affect the shipyard's overall performance."[40] While the U.S. Navy's partnership with Palantir to develop the ShipOS tool "to organize parts ordering and delivery" in support of nuclear submarines is a step in the right direction, America's Maritime Action Plan highlighted the need to further "invest in digital shipyard infrastructure."[41] As outlined in the aforementioned *Breaking Defense* article from 2023:

> Digital technologies are foundational to driving new levels of speed and efficiency across the maintenance lifecycle. Analytics, artificial intelligence and machine learning tools can be deployed to uncover critical insights, make data-driven predictions in real-time, and seamlessly share critical information across shipyard teams. These digital solutions serve as a force-multiplier, maximizing operator talent and empowering faster, smarter decisions for everything from keeping tabs on physical machinery performance to workflow efficiency.[42]

Supply chain issues pose further problems for American shipbuilding. The number of suppliers of the parts needed to build and repair ships has fallen since the end of the Cold War, a symptom of the broader decline in American manufacturing. Seventy-five percent of the funding for supplier material used to build naval submarines is awarded to sole-source suppliers, which often results in significant production and repair delays.[43] The complexity of modern naval vessels also necessitates a greater diversity of raw materials required for production, which creates more opportunities for potential disruptions in a strained global supply chain that is still recovering from the effects of the COVID-19 pandemic. Shipyard time is extended when essential parts are not immediately available; 30 percent of submarine maintenance jobs begin without having all necessary parts on hand and, of those jobs, 25 percent require stoppage at some point in the maintenance process due to parts shortages.[44] Supply chain disruptions can significantly slow the design-build process of new ships. For example, as a result of multiple extended delays resulting from parts shortages, the second and third *Ford*-class aircraft carriers are not expected to be completed until 2029—one year overdue.[45] With America's aging aircraft carriers likely to require increasingly frequent and complex maintenance and repairs in the years to come, continued delays in supply chains risk further elongating the absence of these carriers from service, depriving the U.S. Navy of essential components of its global power projection and deterrence strategies.

All of these factors have contributed to the significant increase in the cost of building new ships. Cost overruns have become commonplace, as those associated with already-approved ship programs have tripled between the 2024 and 2025 Presidential budget requests.[46] In April 2025, 46 ships in production were experiencing cost overruns, with the *Virginia*-class submarines alone experiencing a $17 billion cost overrun.[47] America's 2025 shipbuilding program called for a 46 percent cost increase compared to the current five-year average.[48] The extensive labor turnover raises costs due to the construction delays resulting from overstretched workforces, expenses associated with recruiting and training new workers (HII alone spent $450 million training new workers between 2020 and spring 2024), as well as the significant amount of rework often required on projects involving unseasoned workers and supervisors.[49] Supply chain challenges frequently result in costly delays and higher costs for the raw materials needed for manufacturing.

The decline of America's MIB can be further attributed to several decades of poor policy decisions by the U.S. government, as well as inefficiencies in essential budgeting and acquisition processes. While American shipbuilding companies compete in international markets against heavily subsidized foreign companies, the U.S. government eliminated subsidies for shipbuilding under the Reagan administration.[50] These subsidies had long helped U.S. companies reduce operating expenses and offset some of the costs of constructing high-end vessels. This decision, combined with the government's decision to begin taxing shipping companies' foreign earnings, contributed to a 30 percent reduction in the size of the U.S.-flagged international fleet between 1986 and 1991.[51] Small- and medium-sized shipbuilding vendors, largely crowded out of the

market or absorbed by larger firms as part of the post-Cold War consolidation of defense contractors, receive only nominal support from the U.S. government, with the U.S. Maritime Administration (MARAD) awarding only $8.75 million in 2024 compared to over $20 million a few years prior.[52] Additionally, there is an absence of sufficient government oversight and strong public-private partnerships which are important to help ensure that new acquisition programs remain on time and on budget.

While the Navy has sought to provide greater predictability through the development of long-range plans outlining expected projects over the coming decades, unpredictable defense budgets have complicated shipbuilders' efforts to plan with confidence. Congress' persistent struggle to pass budgets and approve defense authorizations on time, as well as its overreliance on continuing resolutions, have contributed to significant uncertainty among shipbuilders and companies that provide essential parts and services to support the construction, maintenance, and repair of naval vessels. As outlined in a 2018 interagency task force report, "when the Navy is unable to provide consistent orders for ships, niche suppliers of components such as controllers and actuators for nuclear powered ships cannot accurately project workloads, creating inconsistency and increasing risk for production capabilities."[53] This budget instability contributed to a 20 percent reduction in the number of prime vendors supporting Pentagon contracts from 2011 to 2015, reducing the number of companies capable of contributing to the production of essential vessels, weapons, and systems by 17,000.[54] Budgetary delays frequently result in delayed payments and risk slowdowns in manufacturing and repair projects. For instance, the government shutdown in late 2025 resulted in the diversion of $2.8 billion intended to support shipbuilding projects to cover the cost of military salaries.[55] Such examples demonstrate an overstretched and inefficient MIB whose struggles to meet America's shipbuilding needs are further hampered by bureaucratic inefficiencies.

Finally, current shipbuilding projects are often hampered by flaws in the design-build process which allow for numerous alterations after construction commences. Technically, the secretary of the Navy is statutorily barred from approving the construction of a new ship class until submitting to a report to Congress on the results of the ship's "production readiness review," which is the "formal examination of a program prior to the start of construction to determine if the design is ready for production, production engineering problems have been resolved, and the producer has accomplished adequate planning for the production phase."[56] MARAD has similar guidelines which require a finished ship design prior to construction.[57] While the Navy is required to certify the ship's design maturity as measured by the "stability of the ship contract specifications and the degree of completion of detail design and production design drawings," the Navy has nevertheless proven willing to make such certifications before the design process is finalized. For example, these requirements "did not prevent the Navy from proceeding with construction of its new FFG 62 (*Constellation*) class frigate when the program's design maturity data indicated that functional design was not 100 percent completed."[58]

The *Constellation*-class frigate is a perfect example of how late-stage design changes can create massive disruptions in ship production. Fincantieri submitted a design for the ship which deviated only 15 percent from existing models in an attempt to minimize costs and expedite the design-build process. However, the Navy added multiple new requirements as the ship was being built, forcing Fincantieri to go back to the drawing board and contributing to the significant delays on this project. As reported by *Politico* in 2024, the final design of the now-cancelled *Constellation* shared only 15 percent continuity with its original design—a complete inversion of the shipbuilder's initial vision for this vessel.[59]

In many ways, the failure of the *Constellation* program is emblematic of the problems facing American shipbuilding. America's three main Congressionally-supported research and oversight entities—GAO, the Congressional Budget Office (CBO), and the Congressional Research Service (CRS)—documented a growing number of challenges to completing the ship from April 2020 through November 2025. One common challenge noted by these organizations was in the

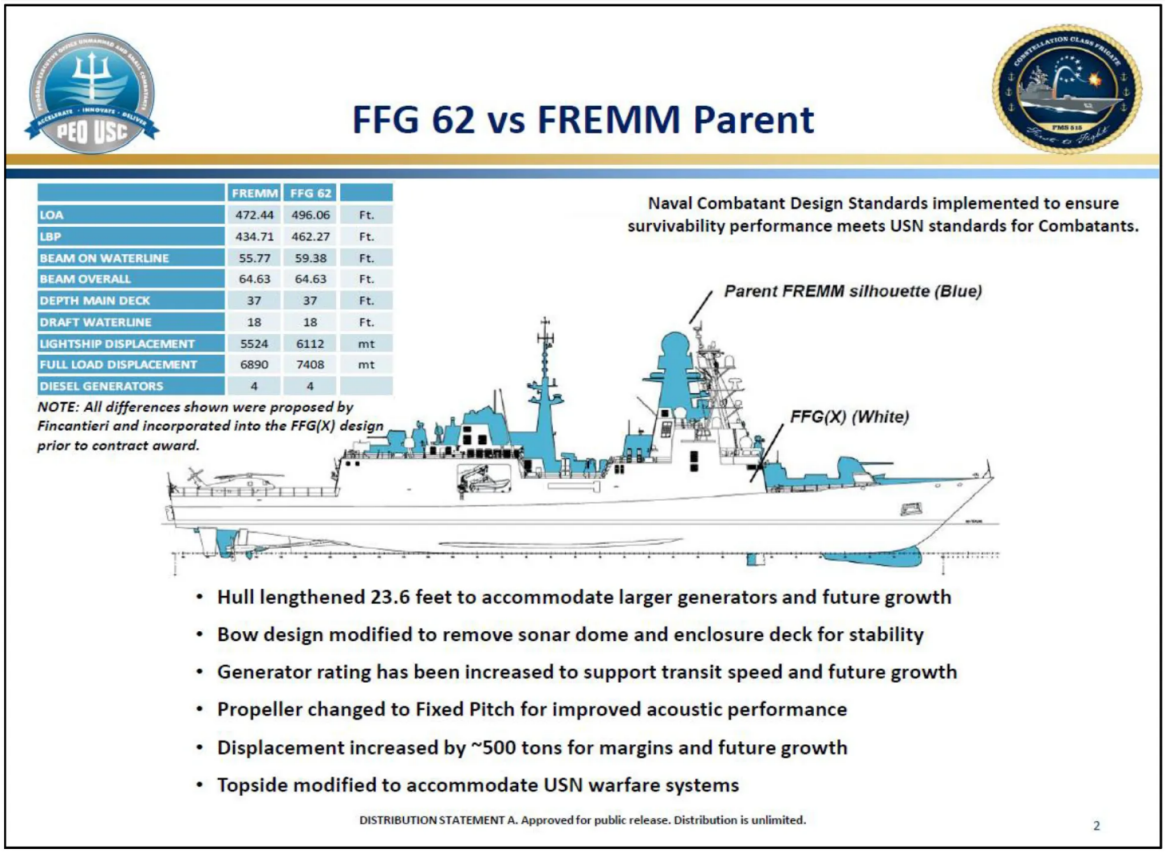

Figure 1: Comparison of original FREMM and *Constellation* designs (Source: Congressional Research Service)

modification of a foreign design to meet U.S. standards without compromising on price and timeline. When the FREMM design was accepted, both the Navy and Fincantieri believed that the use of a mature parent design would limit the design uncertainty and risk associated with problems in the LCS, where delays resulting from the use of immature equipment and designs delayed construction and raised costs. However, efforts to modify the FREMM to match U.S. standards substantially delayed production and raised the overall cost of the initial ship (see Figure 1 for a comparison). CRS also noted the many equipment changes required by various "Buy American" legislation, which required a significant portion of the equipment for these ships to be manufactured domestically.[60]

CBO noted in 2025 that these changes delayed the *Constellation* by over 36 months and made the ship 500 tons heavier than its original design.[61] GAO also reported additional major changes, such as removing the forecastle enclosure deck and the bow-mounted sonar, a key frigate characteristic, to enhance stability, and an increase in electrical generation capacity for future growth.[62] In response to these challenges, a former assistant secretary of the Navy for research, development, and acquisition stated, "[it] turns out modifying someone else's design is a lot harder than it seems," and that "sometimes, you're just better off designing a new ship."[63] All three Congressional entities monitoring this project noted that the many changes to the base design of FREMM, whether justified or not, significantly contributed to the build time and cost of the initial ship of the class. Figure 2 shows the design immaturity of the *Constellation* class as of October 2023.[64]

Ironically, the *Constellation* design which emerged from these changes was arguably less capable of meeting the Navy's needs than the original FREMM design. The *Constellation* was criticized for its perceived lack of combat capability relative to cost, particularly compared with the *Arleigh Burke*-class destroyer. Though projected to be only about 20 percent smaller—displacing nearly 8,000 tons versus the destroyer's roughly 9,800—the *Constellation* was intended to assume the

low-end surface combatant role once filled by the *Oliver Hazard Perry*–class frigate after the LCS proved less successful than hoped.[65] The *Perry*s carried a 40-round missile magazine feeding a single-arm Mk13 launcher for SM-1MR and Harpoon missiles.[66] The *Constellation* was designed to carry only 32 vertical launch missile system (VLS) cells.[67] Some experts argued the frigate had drifted too far toward a high-end combatant, with Secretary of the Navy John Phelan stating it was canceled because it cost 80 percent as much as a destroyer but delivered only 60 percent of the capability.[68] Meanwhile, GAO and CRS analyses cited concerns that the *Constellation* was not capable enough in anti-air warfare, while noting that in a fleet including much larger destroyers such as the *Zumwalt*-class destroyer, an 8,000-ton frigate would not be out of place.[69] CBO likewise questioned whether a frigate with too few VLS cells could operate independently.[70]

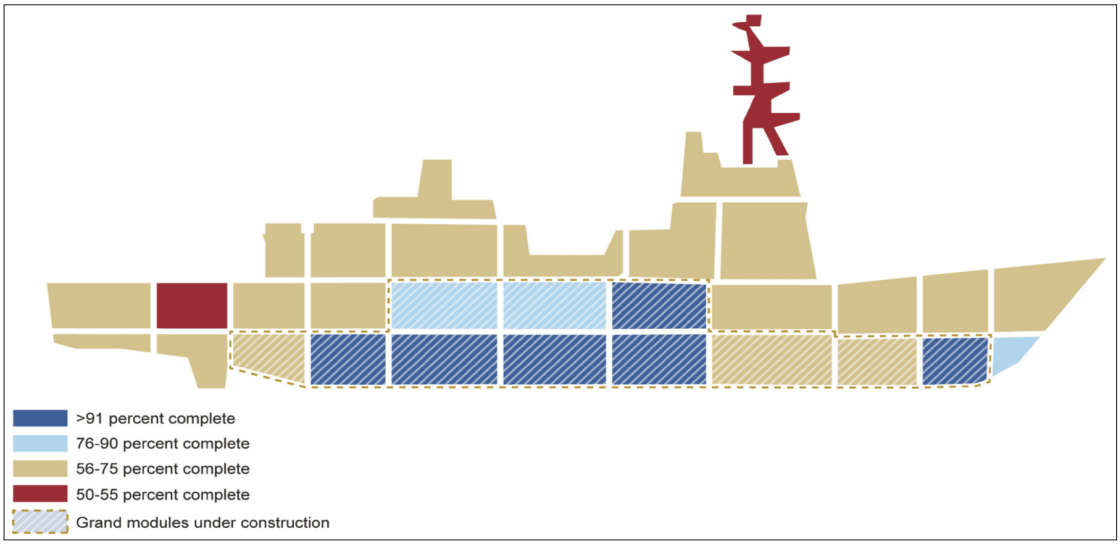

Figure 2: Design immaturity in the *Constellation* class as of October 2023 (Source: Congressional Research Service)

Not only did the late-stage design changes delay the *Constellation*, they also significantly increased its cost. CRS and CBO both suggested that the Navy's cost estimates for the frigate in 2020 were already too low. CRS concluded that the actual cost per ship was 17 to 56 percent greater than originally estimated, while CBO suggested a 40 percent greater cost in 2020.[71] In 2024, GAO stated that unplanned size growth in the *Constellation* could result in a 10 to 20 percent cost increase per vessel.[72] At last estimate, the cost for the first ship (USS *Constellation*) had risen to nearly $1.5 billion, up from the $1.2 billion estimated in 2020.[73]

Given that the final *Constellation* design possessed only 33 percent of the firepower of an *Arleigh Burke*–class destroyer, it was fair for the U.S. government to question whether these ships were worth purchasing at this elevated price point.[74] However, the root cause of the Constellation's design, cost, and capability issues lies with the U.S. government's struggles to properly manage this project. In their white paper analyzing the failure of the *Constellation*-class program, the managing consulting firm SMA concluded that:

> The challenges the program encountered were foreseeable and visible as they emerged. Design changes accumulated (many reflecting strict compliance of historical requirements rather than mission shortfalls), production assumptions were stressed, and cost and schedule pressure increased. At multiple points, the program remained recoverable through deliberate intervention.[75]

Further explanation in this document details how design changes and associated program delays and cost growth occurred, noting that, "major portions of the design remained unresolved, particularly those driven by NAVSEA [Naval Sea Systems Command] interpretations of U.S.-specific survivability standards, shock qualification, electrical-load growth, and combat-system integration requirements beyond what the parent design had been selected to satisfy."[76]

While changes to the parent design might have been managed at different points during the program,

> The responsibility to manage that tension, and to decide when accumulated change had overtaken the original acquisition logic, rested above the execution layer—specifically with the Secretary of the Navy, the Assistant Secretary of the Navy for Research, Development and Acquisition, the Chief of Naval Operations as requirements owner, and the Program Executive Officer for Ships. During this period, no senior authority assumed that role. As a result, a program that depended on actively defending its core tenet—high commonality with a proven parent design—was allowed to proceed as if that tenet still held, even as the conditions that sustained it steadily eroded. That erosion was not theoretical. Oversight reporting later showed that the cumulative effect of Navy-directed design changes during this period materially reduced commonality with the FREMM parent design and drove significant weight growth, with downstream effects on cost, schedule, and performance margins.[77]

That the failure of the *Constellation* program might have been preventable through U.S. government action speaks to the U.S. Navy's ongoing challenges with purchasing and managing commercial relations relative to many of its allies. As a result of its inability to overcome these challenges in working with an Italian shipbuilding company, the U.S. Navy was deprived of a valuable force asset, and both the Navy and Fincantieri Marine Group lost a critical learning opportunity in managing the stewardship of an existing, successful warship design. The implications of this failure will impact the Navy and U.S. national security for decades. It speaks to the need for both the U.S. government and shipbuilders to develop more collaborative processes for engagement, clearer expectations and delineation of roles during the design and manufacturing process, and more effective frameworks for communication to align both builder and buyer with a common vision of the ship being constructed.

While the *Constellation* debacle paints a dire picture of American shipbuilding, America is the most advanced naval shipbuilder in the world and remains unrivaled in its ability to build aircraft carriers and nuclear-powered submarines.[78] Despite production challenges, the *Ford*-class aircraft carriers and *Virginia*-class submarines are exceptional naval vessels designed and built in the United States within the past few decades. Older vessel designs such as the *Arleigh Burke*–class destroyer, first commissioned in 1991, remain in production today—a testament to the impeccable quality of these ships (even if it is also partly attributed to the disappointing fate of its intended successor, the *Zumwalt* class).

Recent efforts to revitalize America's MIB have also produced encouraging early results. Since FY2018, the Navy has invested more than $6 billion to recapitalize the MIB and plans to spend an additional $11 billion in support of this goal.[79] 2024 saw the domestic shipbuilding industry undertake at least 925 new builds, a 34 percent increase from the year prior.[80] That same year, the Navy established the Maritime Industrial Base Program to help repair the shipbuilding industry, and initiatives such as the aforementioned ATDM have helped bolster the MIB's workforce by quickly upskilling current and prospective workers.[81] Many American shipbuilders have also displayed an increased willingness to embrace new technologies as part of the design and manufacturing process, including investing in on-site additive manufacturing (3D printing) to reduce construction delays caused by part shortages and supply chain disruptions.[82]

Simply put, the deficiencies in the U.S. MIB are making America less safe.

The U.S. government has also shown signs of reevaluating its approach to shipbuilding and preserving the MIB at large. For example, MARAD hired TOTE Services to act as the Vessel Construction Manager (VCM) at Philadelphia Shipyard to facilitate the on-time delivery of the National Security Multi-Mission Vessel (NSMV) and manage the relationship between the shipbuilder and the future owner.[83] Similarly, the Navy announced in February 2026 that it would utilize a VCM to oversee construc-

tion of its Medium Landing Ship, marking the first time since World War II that construction on a naval vessel has been overseen by a third party.[84] Furthermore, steps taken by the White House—including issuing an executive order and releasing a Maritime Action Plan, both focused on restoring America's maritime dominance—signal an increased focus on supporting America's MIB.[85] These actions reflect the U.S. government's growing recognition that its status quo approach to shipbuilding falls short and needs reevaluation.

The U.S. MIB's diminishment has become a major constraining factor in U.S. national strategy. Faced with a shortage of shipyards capable of producing both military and commercial vessels, consistent cost overruns, and significant production delays caused by perpetual labor shortages, America is unable to dynamically respond to its ever-changing maritime security needs. The systemic delays in production for aircraft carriers, submarines, and frigates have had a significant impact on national security, particularly in the relief of the aging *Ohio*-class SSBN and SSGN with the *Columbia*-class SSBN or *Virginia*-class SSN with the Virginia Payload Module. Not only would the United States struggle to quickly replace ships lost during an armed conflict, but it would face significant time delays in developing new vessels to meet emerging threats and opportunities in a timely manner. While the United States has set benchmarks to increase its fleet size, it must also replace the roughly 213 ships it is expected to lose between 2020 and 2040, including some years in which the Navy will lose between 15 to 20 ships (mostly submarines and destroyers). Given the American maritime industry's struggles to produce new ships on time and on budget, it is hard to imagine the United States meeting its goals of a larger and more robust fleet while also replacing the outgoing vessels. Additionally, lengthy backlogs for conducting maintenance and repair on existing vessels regularly force America's already overstretched Navy to operate at a significant resource deficit. In August 2020, the GAO reported that maintenance delays on aircraft carrier and submarine repairs from 2015 to 2019 resulted in a total of 7,424 days that those vessels were unavailable for operations—the equivalent of losing half an aircraft carrier and three submarines each year.[86] Roughly a third of America's submarines are out of service due to maintenance or repair at any given time, depriving the United States of valuable assets that play significant roles in power projection, intelligence gathering, and nuclear deterrence.[87] Simply put, the deficiencies in the U.S. MIB are making America less safe.

Revitalizing America's MIB is an urgent priority that requires a creative multisectoral approach to accomplish. As America's Maritime Action Plan outlines, "Strengthening the U.S. maritime sector requires leveraging international and industry partnerships…to enhance investment in the U.S. maritime sector," and is facilitated by "[e]ngagement with U.S. allies and trading partners [which] ensures that their policies are aligned with key goals like promoting domestic shipbuilding."[88] The following case studies examine the best practices and lessons learned from America's maritime allies, while the conclusions and recommendations derived from these studies outline how the United States can implement these lessons to strengthen its MIB and support greater maritime cooperation with its seafaring allies.

Republic of Korea

South Korea's MIB pairs world-leading commercial ship construction with a capable naval production ecosystem. This case study traces Korea's rise from post-war poverty to becoming one of the world's largest shipbuilders and analyzes how this transformation was enabled through sustained state prioritization of the shipbuilding industry. The study further highlights the operating features that sustain high throughput and predictable delivery: large-scale modular construction, dense co-located supplier networks, and an industry-wide culture that treats schedule performance as a strategic requirement rather than an aspiration. South Korean shipbuilders use decades of consistent state support for the sector to invest heavily in developing and maintaining world-class shipyards with deep integration of automation, digitization, and artificial intelligence (AI), while government-funded research and development efforts continue to spur innovation in the industry. These strengths underpin Korea's ability to support allied naval readiness through maintenance and repair capacity in the Indo-Pacific and to serve as a credible partner for joint shipbuilding initiatives in the United States.

To support this case study, CMS's experts traveled to South Korea in August 2025 to observe Hanwha's Geoje shipyard, as well as the company's Seoul-based Siheung Research and Development (R&D) campus. CMS also conducted interviews with senior Hanwha executives in both the United States and South Korea, as well as shipbuilding and naval experts affiliated with the U.S. embassy in South Korea. Finally, the case study is supported by observations from CMS's visit to the Hanwha-owned Philly Shipyard in December 2025. Unless otherwise cited, all insights included in this case study are derived from these site visits and interviews.

History and Background

South Korea's rapid ascent to becoming a shipbuilding power carries many potential lessons for the United States. Despite having a population of only 51.6 million, South Korea punches well above its weight when it comes to shipbuilding, having produced 230 vessels in domestic shipyards in 2024 and accounting for nearly 21 percent of global shipbuilding output.[89] In 2025, South Korea produced roughly 22 percent of global compensated gross tonnage (CGT) with 10.03 million CGT, trailing only China that produced 26.64 million CGT in the same period.[90] South Korea's shipbuilding industry is a beacon of efficiency, owing to the country's decades-long investment in its MIB; Korean shipbuilding companies' embrace of digitization, automation, and AI as part of the design and construction processes; and an industry-wide commitment to producing ships on schedule and under budget. While American shipyards took roughly nine years to build out the *Aegis* destroyer at the approximate cost of $2.5 billion per ship, South Korea's *Sejong the Great*–class destroyer, a comparable vessel, took only five years to complete and can be produced for approximately $565 million.[91]

A South Korean *Sejong the Great*–class destroyer (Photo credit: Republic of Korea Armed Forces)

South Korea's shipbuilding prowess builds on the Korean people's impressive maritime legacy. During Korea's Three Kingdoms period (57 BCE–668 CE), the Korean kingdom of Paekche established itself as a regional maritime trading power before King Kwanggaeto of Goguryeo (a kingdom located in present-day North Korea and Manchuria) used his own naval forces to successfully conquer it in the fourth century.[92] The Goguryeo dynasty used its navy to repel Mongol invasions of its island capital on Ganghwado for nearly three decades, while legendary Kore-

CMS researchers and Hanwha officials stand in front of a Korean *Kobbukson.* (Photo credit: Center for Maritime Strategy)

an Admiral Yi Sun-sin orchestrated a stunning victory over the Japanese during the Imjin War in the 1590s.[93] The Korean Peninsula is the birthplace of several significant naval innovations, most notably the creation of the 16th-century *Kobbukson,* or turtle ships, which some historians have called "the first ironclads in history."[94] Fittingly, South Korea's navy is the longest-tenured branch of the Korean military.

Yet South Korea's continued status as a maritime power was far from certain following the Korean War. After the armistice that ended hostilities in July 1953, South Korea was one of the poorest countries in the world. Almost all the industry, mining, and electricity production that existed at the time was concentrated in what became North Korea, leaving the agrarian and impoverished South Korea with a per capita GDP of only $76.[95] However, rapid industrialization led South Korea to become a regional economic power and industrial heavyweight within a matter of decades, fueled by research and development (R&D) funding equivalent to 5 percent of its GDP. This transformation, combined with South Korea's focused efforts to cultivate a domestic shipbuilding industry during the early years of its industrialization, helped support its rise as a shipbuilding powerhouse. Economic historians have identified three key factors behind South Korea's shipbuilding ascension:

> First, South Korea managed to acquire a large share of the world shipbuilding market, expanding rapidly in a period when capacity was reduced in all major shipbuilding nations. Second, the influence of the State was substantial, with the industry placed prominently in government plans for long-term economic development. Third, South Korea managed to continuously develop and upgrade production processes, sustaining initial cost advantages through rationalization and innovation.[96]

Much of South Korea's shipbuilding growth can be attributed to the ambitious economic and industrial policies initiated by former President Park Chung-hee. After assuming power in 1961, Park Chung-hee focused much of his attention on industrialization in hopes that an economic boom would help alleviate poverty and reduce South Korea's foreign aid dependence. The regime specifically sought to support the creation of a domestic shipbuilding industry, believing South Korea could help meet the rising global demand for commercial ships.[97] The Park regime courted financing from the United States, Japan, and other lenders. The South Korean government bore the interest cost of loans to Korean companies, which in turn enabled them to invest more in their long-term growth. Additionally, the 1965 Treaty on Basic Relations facilitated a grant from Japan to South Korea in the amount of $300 million over 10 years, as well as $200 million in low-interest loans as a form of reparations for Japan's past colonial activities in Korea.[98] This massive injection of capital was equivalent to more than 20 percent of the entire South Korean GDP that year, and the Park government invested it heavily in the private sector to facilitate industrialization.[99] To distribute the money, the government relied mainly on a group of business families with extensive experience conducting business throughout the region. For instance, Pohang Iron and Steel Company took $88.68 million of loan money and $30.8 million in grants and, in exchange, was expected to meet government-set production and export targets.[100] These family-run conglomerates grew into the chaebols such as Hyundai, LG, Samsung, and Hanwha, which subsequently emerged as technological giants in the automotive, high-tech, and heavy industrial sectors, notably shipbuilding.

The South Korean government relied heavily on the private sector to manage and enjoy the fruits of its economic output.[101] As industries began to produce, the government helped private

companies finance the development of increasingly complex production; first steel, then ships and cars, and then electronics. Additionally, the government adopted an export-focused strategy to help facilitate its transformation from an agrarian to an industrial economy. The Park regime heavily incentivized Korean companies to export products, providing tax reductions, tariff exemptions, foreign currency loans, and public sector–funded export insurance to companies willing to sell their products abroad. In 1965, for example, while loans were typically given at rates of 26 percent, public loans to export companies cost a mere 6.5 percent. These "policy loans" were mainly granted by the Industrial Bank of Korea and the Korea Development Bank, two state-owned financial institutions.[102] Chaebols even received loans with negative interest, meaning they were paid by state-owned banks to borrow money.[103] These measures, combined with efforts to depress wage growth to keep production costs low and devalue the Korean won to make it cheaper for foreign countries to buy Korean products, produced a significant spike in exports which fueled massive economic growth. The Korean government also handled expropriations and built the infrastructure needed to support widescale manufacturing, including factories and roads.

While Park Chung-hee was assassinated in 1979, his death did not end the industrial momentum he had initiated. Today, South Korea is one of the richest and most technologically advanced countries in the world, manufacturing ships at scale and operating as a worldwide leader in cars, steel, and semiconductors. While more than 40 percent of the population lived in absolute poverty in the 1960s, this rate has dropped below 1 percent due to the growth fueled by Korea's "economic miracle."[104] Shipbuilding continued its rapid expansion and Korean yards like Hyundai, Daewoo, and Samsung leveraged the investments laid in the 1970s. By the late 1980s, South Korea had become a significant global shipbuilder, competing with Japan for global market share. Daewoo completed its Geoje Okpo shipyard in the early 1980s, expanding its production capacity. While South Korea ended its subsidies for shipbuilders in 1986, the industry continued to thrive on the strength of the investments made by the government in the MIB during the decades prior.[105]

The late 20th century brought about many policy changes for the South Korean shipbuilding industry. Through the 1970s and 1980s, chaebols were incredibly dependent on low labor costs and depreciated exchange rates for their operations and industrial innovation had largely begun to stall.[106] Because of their reliance on the government, shipyards were not incentivized to replace labor with capital. Increased economic openness in the 1990s and 2000s led to greater competition and the beginning of a service economy. Despite a financial crisis in 1997, South Korea had established robust economic resilience and recovered quickly. Corporate restructuring (including the dismantling of Daewoo and the selling of its assets to rival chaebols) and a more competitive labor market contributed to this success.[107] Liberalization reduced state direction but allowed greater export competitiveness for the shipbuilding industry. By 2000, South Korea had established itself as the world's largest commercial shipbuilder.[108]

After the 2008 global financial crisis, new ship orders declined worldwide, reducing the profitability of the industry from the mid-2010s into the early 2020s. Korean shipyards capitalized on their expertise in complex, high-value ships, especially liquified natural gas (LNG) carriers and eco-friendly vessels amid stricter global environmental rules.[109] During this period, China began investing heavily in shipbuilding capacity and began to gain market share, challenging Korean dominance. Korean yards took discounted orders to maintain volume targets, often at the expense of profitability, especially in the later 2010s. Mid-sized Korean shipbuilders weakened or exited segments of the business, with firms like Sungdong undergoing major restructuring and others experiencing layoffs and labor disputes.[110]

Despite these pressures and the still-precarious position of many smaller shipbuilders, the Korean shipbuilding industry remains strong. Korean shipbuilders are increasingly shifting away from producing low-cost ships (a market overwhelmingly dominated by China) to focus more on building high-value vessels such as ultra-large container ships and LNG carriers, where the industry's experience and heavy focus on R&D have allowed it to thrive.[111] In 2022, Hanwha

Group acquired a controlling stake in Daewoo Shipbuilding & Marine Engineering worth ₩2 trillion ($1.5 billion), which the government encouraged in hopes of promoting greater competition in the sector.[112] South Korea's investments in its shipbuilding industry have enabled it to emerge as a global leader in the field. Yet as the nation faces declining birthrates and an aging population, it remains to be seen whether sustained public investment and impressive innovations will be enough to keep the industry going.

In addition to helping drive economic growth, South Korea's shipbuilding industry plays an essential role in supporting the country's national defense. South Korea is one of the only U.S. allies to consistently maintain a wartime posture over the past several decades, a decision largely based on the ongoing military threat posed by North Korea. Despite the conflict being largely frozen since the signing of the 1953 armistice, the two countries remain at war and South Korea is regularly subject to threats of invasion or destruction issued by Pyongyang.[113] Accordingly, South Korea's navy plays a key role in deterring the North Korea's Korean People's Navy which boasts over 60,000 personnel, 400 patrol combatants, 260 amphibious landing craft, and what the Defense Intelligence Agency assessed to be "one of the world's largest submarine forces" with "about 70 diesel-electric attack, coastal, and midget class submarines in service divided between both coasts."[114] The threat of a naval conflict between North and South Korea remains high, as evidenced by skirmishes between the two navies in recent years. Such encounters include the 2009 Daecheong incident in which five South Korean vessels engaged a North Korean gunship after it crossed the de facto maritime boundary between the two states, as well as the 2010 sinking of Republic of Korea Navy's (ROKN) *Pohang*-class corvette *Cheonan*, which an independent investigation revealed to have been caused by a North Korean torpedo.[115] As outlined in a 2024 article in *Marine Policy,* "Between the 1960s and 1980s, North Korea engaged in a total of 61 sea-based military provocations. However, during the 1990s, this number increased to 107 times, and by the 2000s, it had risen to 180 times."[116]

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To counter the persistent maritime threat posed by North Korea, the ROKN boasts a 182-ship navy composed of 102 surface combatants, 22 submarines, 21 amphibious assault vessels, and 14 mine warfare vessels.[117] South Korea's mandatory military service requirements have allowed the country to build a robust amphibious force which includes roughly 80,000 ROKN personnel and nearly 30,000 members of the Republic of Korea Marine Corps, a service branch which also possesses amphibious landing capabilities. While the ROKN has historically served largely as a coastal defense force, it has recently taken steps toward developing blue water capabilities by developing the *Dokdo*-class amphibious assault ships, advanced diesel-electric submarines such as the *Dosan Ahn Changho*–class vessels which can fire submarine-launched ballistic missiles, and the announcement of a Task Fleet Command in February 2025 to support more ambitious multinational maritime security missions.[118]

Since 2022, South Korean naval strategy has been heavily influenced by the operational concept dubbed "Navy Sea GHOST," a vision of a lean and versatile ROKN fleet composed of both manned and unmanned vessels which communicate seamlessly with one another and which employ AI to support their operations.[119] This concept is intended to address potential manpower shortages which could result from South Korea's declining population, as well as make the ROKN less dependent on large and increasingly vulnerable surface platforms and better equipped to rapidly replace hulls in the event of a conflict. This investment in unmanned vessels, highlighted by the creation of the Maritime Unmanned Forces Command and the ROKN's plan to have unmanned vessels account for 28 percent of its assets by the mid-2030s, is possible due in large part to the Korean government's significant support for defense R&D, which has allowed its shipbuilding industry to support innovative developments in the unmanned warfare and AI spaces.[120] Seoul is also investing in the creation of a Multipurpose Manned and Unmanned Force Command Ship Program, which will reportedly replace a previous proposal to create a light

aircraft carrier capable of hosting F-35B jets with a "mothership" model that can host both manned and unmanned aerial craft, further signaling South Korea's commitment to integrating unmanned vessels into its operational plan.[121]

A South Korean *Dokdo*-class amphibious assault ship, built by Hanjin Heavy Industries. (Photo credit: Republic of Korea Armed Forces)

Korean shipbuilding companies have accordingly increased their investments in the development of unmanned systems and vessels. Hanwha is a significant proponent of "Ghost Commander II," an aircraft carrier equipped with all uncrewed systems including air, surface, and sub-surface platforms.[122] Recent years have seen the company develop systems such as the "Sea GHOST" (an unmanned surface vessel capable of supporting reconnaissance efforts and deploying drones and unmanned underwater vessels), the "M-Searcher" (an unmanned multi-mission vessel which can support both underwater and surface reconnaissance missions), and autonomous anti-mine warfare devices.[123] In January 2026, Hanwha Defense USA also announced a partnership with HavocAI to explore the prospects for jointly developing and building a 200-foot-long autonomous surface vessel, which could potentially be constructed at Hanwha Philly Shipyard.[124] With autonomous and unmanned vessels likely to play increasingly important roles in Chief of Naval Operations Admiral Daryl Caudle's vision for America's fleet, Korean shipbuilders are well positioned to play a significant role supporting the U.S. Navy's development and integration of this technology into its fleet.[125]

In recent years, the United States and South Korea have established new frameworks for increased shipbuilding cooperation. The Biden administration increased the Navy's engagement with South Korean shipbuilders, encouraging greater South Korean investment in America's MIB and the establishment of American subsidiaries and shipyards, such as Hanwha's eventual acquisition of the Philadelphia Shipyard in 2024.[126] The shipyard has begun its modernization efforts and has already signed contracts to jointly build LNG carriers with Hanwha's Geoje shipyard in Okpo, South Korea—the first such vessels being constructed in the United States in nearly half a century.[127] The Trump administration has also courted South Korean investment into the American shipbuilding industry. In July 2025, the two countries reached an agreement in which South Korea pledged $350 billion in investments from Korean companies into the United States (including $150 billion into shipbuilding cooperation and $100 billion into LNG) in exchange for a 10 percent reduction of tariffs on South Korean exports.[128] As of January 2026, this MASGA framework has resulted in the signing of 11 industrial agreements between Korean and American companies, such as the tri-party agreement between General Dynamics NASSCO, DSEC Co. Ltd., and Samsung Heavy Industries to support commercial, naval, and government shipbuilding projects.[129] Additionally, an agreement between Hyundai and HII to jointly invest in distributive shipbuilding and "pursue strategic teaming opportunities for Navy auxiliary shipbuilding programs," including jointly pursuing a contract to build the U.S. Navy's next-generation logistics ship, demonstrates the potential for further collaboration.[130]

South Korean shipbuilders have also sought to play a larger role supporting the maintenance, repair, and overhaul (MRO) of U.S. naval vessels.[131] South Korea boasts a robust maritime industrial capacity which would enable it to meaningfully contribute to MRO for American ships, and its embrace of advanced shipbuilding and naval R&D makes it an ideal collaborator for the United States in this arena.

Finally, the United States and South Korea have signaled their intent to cooperate on building nuclear submarines. Following President Donald Trump's visit to Korea in October 2025, the White House announced it had "given approval for the ROK [Republic of Korea] to build nuclear-powered attack submarines," and that America would "work closely with the ROK to advance requirements for this shipbuilding project, including avenues to source fuel."[132] These submarines will augment South Korea's existing fleet of 20 diesel-powered submarines and help Seoul keep pace with North Korea's efforts to build nuclear submarines; Pyongyang reportedly completed the hull for its first such vessel in December 2025.[133] South Korea's submarines will likely use low-enriched uranium to power over 5,000 tons of displacement, resulting in smaller, less powerful submarines than the U.S. Navy's, but with sufficient power to enable South Korea to more effectively project naval power in the Yellow Sea, East China Sea, and Sea of Japan.[134] As of the writing of this report, it remains unclear whether these submarines will be built in Philadelphia as suggested by Trump or in South Korea as suggested by ROK Prime Minister Kim Min-seok, as the Philadelphia yard is not currently certified or equipped to support the building of nuclear-powered vessels.[135] Given that it could take up to a decade for South Korea to complete its first nuclear-powered submarine, the decision of both countries to undertake this venture suggests that U.S.-Korean shipbuilding collaboration will be robust for several years to come.[136]

Labor and Workforce

Despite its status as one of the world's leading shipbuilders, South Korea faces many of the struggles other industrialized countries have encountered in maintaining a robust manufacturing workforce. The contraction of the shipbuilding industry from the mid-2010s to early 2020s resulted in labor shortages as welders, piping technicians, and electrical engineers transitioned to other industries. According to the Korean Ministry of Trade, Industry and Energy, the number of technical shipbuilding workers decreased from nearly 70,000 in 2014 to 58,042 in 2022. While the industry is slowly expanding (growing by 0.8 percent in 2023), this is in large part due to the tripling of the number of foreign workers who, in the same year, accounted for 4 percent of the industry's workforce.[137]

Korea also faces significant demographic challenges which could disrupt the shipbuilding industry. As of September 2023, workers aged 60 and older outnumbered all other age groups employed in Korea for the first time in the country's history. The number of individuals in this age group increased by 272,000 from the previous year, reaching a record 6.74 million people. Comparatively, there are only 3.71 million people within the 15-29 age range.[138] The aging workforce is particularly pronounced in the manufacturing sector. In 2023, 600,000 people aged 60 or older were employed in manufacturing, up 9.3 percent from 2022. One surveyed shipbuilding equipment subcontractor has an average employee age of 60 and reported that its youngest Korean-born welder was born in 1970, forcing the company to seek out younger temporary migrant workers to help increase production and efficiency.[139]

The Korean government has similarly looked to foreign workers to fill labor gaps within the industry (particularly drawing from countries like Vietnam, Thailand, and Indonesia) and took several actions in 2023 designed to enable the hiring of migrant workers for vacant roles. Such measures included an expansion of the Skilled Worker Points System Visa program to allocate an additional 400 visas specifically for the shipbuilding industry, a twofold reduction of visa processing times for shipbuilding workers, the waiving of the requirement for foreign welders to submit work experience certificates as part of the immigration process, and a temporary increase of the per-company cap on foreign workers from 20 percent to 30 percent of the domestic workforce for two years.[140]

Notably, while the U.S. MIB struggles to recruit and retain qualified workers to fill essential jobs building and repairing ships, South Korean companies have found creative solutions to help mitigate these challenges. To address potential labor shortages caused by the retirement of skilled workers, Hanwha Ocean implemented a "hired-back" program in which retiring welders

and other skilled employees are rehired by the company at a significantly higher salary to help train and mentor the next generation of workers, preserving institutional knowledge and keeping skilled retirees in the fold. In discussions with CMS, Hanwha indicated that it has adopted this practice at its Philly Shipyard and expressed an interest in scaling up this program to help address the yard's persistent labor shortages. Hanwha has also invested considerable resources into re-skilling and upskilling its existing labor force, providing training to help workers refine their skills and integrate new technology into their work. Hanwha has also taken advantage of government-supported programs which provide specialized technical training for workers interested in acquiring new competencies.

South Korea's shipbuilding workforce remains robust enough to support the industry despite its demographic challenges. According to Hanwha, roughly 30,000 employees and subcontractors report to its Geoje shipyard daily, and CMS observed a mass of focused human activity beyond what they had observed in U.S. shipyards, witnessing no instances of idle hands during their visit. Hanwha also boasts a large number of naval architects onsite to oversee the construction and design processes—considerably more than was observed at other shipyards visited as part of this project. CMS assessed the industriousness and level of engagement among Hanwha's Geoje employees to be a clear factor explaining the profitability and success of the Korean shipbuilding industry.

The town of Okpo developed around the Geoje shipyard and much of the town's infrastructure is designed to support the yard and its workers. Hanwha indicated that it operates the shipyard in two shifts per day, with 85 percent of the workforce on the day shift and 15 percent on the night shift. Hanwha's efforts to improve the quality of workers' lives have positively contributed to retention efforts. Approximately 80 percent of the laborers employed by Hanwha at the Geoje yard have worked there for over 10 years, allowing the yard to benefit from the invaluable institutional knowledge of long-tenured workers who can also assist in training and mentoring the next generation of shipbuilders. Workers' commutes are typically short and devoid of the parking problems endemic to many American yards. While a 2023 U.S. investigation of sailor quality of life during aircraft carrier refueling overhauls noted that several yards have inadequate parking or inadequate or inaccessible dining facilities which make life inconvenient for American sailors, CMS assessed the Geoje yard to be largely free of these issues.[141]

Efforts to improve employee quality of life likely consider past labor disruptions that have impacted South Korea's shipbuilding industry. Upon seizing power in the early 1960s, Korea's military government disbanded all labor unions and reorganized industrial unions under state supervision in addition to establishing and managing workplace job training centers.[142] These harsh labor controls created long hours and low wages for shipyard workers, sparking occasional strikes and other strife. Nationwide pro-democracy protests in 1987 emboldened many Koreans to exert power not only in government but also in their workplaces. 4,000 new unions representing some 700,000 workers were established within a year of these protests.[143] Hyundai Heavy Industries workers were often the most militant, clashing with police and often occupying shipyards and manufacturing facilities. The island of Geoje also witnessed particularly violent scenes during a large strike by Daewoo workers, where the death of a worker struck by shrapnel from a tear gas grenade sparked more violence on the island.[144] Over 3,000 labor disputes were recorded by the government between June 29 and September 15 of 1987, with an average of 44 industrial actions per day in this short period.[145] Union membership continued to steadily increase through the latter decades of the 20th century and, as a result, safety provisions, wages, benefits, and survivorship benefits improved steadily for many shipyard workers.

Even in recent history amid consolidation and relative amicability between management and labor, Korean shipbuilders have had to bend to the will of organized labor. Labor conflicts intensified during economic downturns, particularly after the Asian Financial Crisis and again following the Great Recession, when layoffs, subcontracting, and wage freezes triggered major disputes such as the 2010–2011 Hanjin Heavy Industries strike.[146] More recently, the shipbuild-

ing industry has faced a labor shortage amid an incredibly high backlog of orders. Shortages are primarily driven by demographic aging and the displacement of shipbuilding as a prized industry for up-and-coming talent, replaced by jobs in information technology, finance, and the automotive industry. Unlike the more tumultuous 1980s, labor relations in the Korean shipbuilding industry today are characterized less by violent confrontation and more by managed conflict, though the risk of future work stoppages persists.

Shipbuilding remains one of the few Korean heavy industries where unions retain meaningful leverage, even as firms increasingly seek technological and workforce strategies to insulate production from labor disruption. For U.S. defense planners and policymakers, these dynamics underscore the importance of labor relations as a factor in allied shipbuilding capacity, schedule reliability, and surge resilience, especially as South Korea's yards appear poised to play an increasingly large role in U.S. naval shipbuilding and supply chains.

Technology Integration

South Korean shipbuilders' embrace of AI and automation reflects a far more sophisticated and thorough integration of these technologies than CMS has observed in American shipyards. Hanwha has invested in AI systems that can monitor and control the LNG cargo hold environment to ensure consistency of temperature and humidity. Additionally, the company has invested in intelligent automatic welding and smart painting quality inspection technology which is designed to increase efficiency and identify potential quality issues early within these processes so they can be quickly and sufficiently addressed. Perhaps most impressively, Hanwha has invested in AI systems to monitor worker safety which can flag when workers lose their footing, when crashes occur, or when fires are at risk of breaking out to enable an immediate response to these issues, minimizing the risks to worker health and the chances of significant accidents which could delay production. Specific plans are developed by Hanwha for each yard and factory to identify the needs which can be addressed by AI integration and maximize the value of this technology.

Hanwha reports that the Geoje shipyard has an overall automation rate of 12.8 percent, meaning that a marginal share of the yard's total production processes are automated. Automation, however, is concentrated in specific stages, with as much as 67 percent of the welding process being completed by machines rather than hand-touch labor. The yard makes liberal use of robots for tasks such as block assembly, lug production, and pipe production, as well as assisting in curved plate forming. The shipyard cuts and welds approximately 1 million tons of steel annually, and roughly 90 percent of this labor is done by robots. The impact of this automation of shipyard productivity is immense. The shipyard's leadership has assessed that one robot can replace 50 workers, and that two workers who have been sufficiently trained can monitor and control 20 robots at once. Based on these calculations, two workers controlling 20 robots are capable of matching the labor output of 1,000 personnel.

CMS observed more robust use of robotics during its trip to Geoje than it has witnessed at any American shipyards visited. CMS noted the seeming ease and comfort level with which Hanwha's laborers used this technology to support their work and increase their productivity, which reflects Hanwha's considerable efforts to train its workers on its best use. The robust use of robotics and AI at Geoje illustrates the extent to which the broader employment of this technology in American shipyards would significantly reduce the manpower requirements associated with shipbuilding and would allow America's MIB to significantly increase its output even if industry-wide labor shortages persist. Hanwha's Siheung R&D campus in Seoul is investigating the development of intelligent welding technology as well as shore-based command and control systems for uncrewed maritime systems afloat.

Korean investment in next-generation technology expands beyond AI and automation. CMS was introduced not only to Hanwha's research into new paint and polymer materials and eco-friendly marine paint schemes (which can play a critical role in improving the fuel efficiency of ships

by reducing marine growth), but also to its joint development venture with the Pohang Iron and Steel Company to create high-yield manganese steel tanks for cryogenic applications. The development of high-yield manganese steel for LNG ships is significant for several reasons. Manganese is highly abundant, reducing procurement costs for steel plates by 30 percent.[147] Furthermore, manganese has better elongation properties than other metals, it is resistant to hydrogen embrittlement, it withstands extreme temperatures without degradation, and it maintains low magnetic properties despite deformation—all making it more attractive for shipbuilding and potentially submarine hull design.[148] High-yield manganese has been successfully integrated into Very Large Crude Carrier (VLCC) LNG tanks and container ships, and its properties are being examined for use in ice-breaking hulls for the same reasons. Accordingly, Hanwha's advancements in incorporating this material into the production of new ships could enable the company to capture a greater market share of global commercial and naval shipbuilding in the years to come.

Similarly, South Korea has emerged as a global leader in integrating digitization into ship design and manufacturing. Ironically, while Hanwha's digital shipbuilding infrastructure easily outstrips that of any U.S. naval shipyard, it was an American company, Carnival Cruise Lines (CCL), whose embrace of digitization inspired Hanwha's operation. CCL recently unveiled its new Fleet Operations Center (FOC) in Miami, Florida, which provides oversight of 26 CCL ships in the cruising fleet by gathering extensive amounts of data, including GPS location and routing, weather, propulsion plant performance, guest operations and logistics, and emissions and waste management. All this data is gathered in a 35,000-square-foot facility and displayed on a 74-foot-long knowledge wall composed of 57 LED screens, providing 24-hour situational awareness of every vessel in CCL's inventory. Complimentary FOCs located in Seattle, Washington and Hamburg, Germany, serve the same purpose for Carnival Corporation's (CCL's parent company) fleet of over 100 ships at sea. Furthermore, Carnival developed its own proprietary software—Argos and Neptune—for real-time monitoring of ships at sea. Argos provides information on thousands of touch points onboard ships that are input to a visual dashboard in Miami, enabling system performance assessments and indications of pending failures. Meanwhile, Neptune provides real-time information on radar, navigation, engine performance, fuel usage, and carbon footprint. The collection and integration of this data in CCL's FOC contributes to greater performance at sea and greater awareness of the material condition of every ship before scheduled overhaul periods, enabling the scheduling of maintenance well in advance to avoid the delays which have become all too common in American shipyards.[149]

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In line with the CCL model, South Korean shipbuilders are equipping ships with instrumentation to monitor key performance indicators, including speed over ground, engine performance, reduction gear performance, and system vibration. Hanwha's Siheung research team is working on introducing real-time, data-based condition monitoring to improve vessel maintenance and operational efficiency. Hanwha Ocean's smart ship solution, HS4 (Hanwha Ocean SmartShip Solution & Service), is a service developed in-house that collects and integrates vast amounts of data generated by onboard equipment and systems in real time, enabling comprehensive monitoring from a shore-based control center. This includes the vessel's GPS location and route, equipment status, fuel consumption, and carbon emissions via a web-based interface. This allows clients to monitor the status of individual vessels 24 hours a day from shore, enabling them to make operational decisions and perform trend analysis based on accumulated data. This type of Condition-Based Maintenance (CBM) is discussed in greater detail in the Italy case study.

Finally, South Korea has emerged as one of the global leaders in high-yield lithium battery technology due to the industry's significant investment in their production. While the U.S. Navy has

gradually deemphasized its efforts to develop high-yield lithium batteries for diesel submarines, in theory, they can be used as increasingly resilient sources of backup power for diesel submarines to enable extended submersible periods and are also less susceptible to leaks and fires than lead-acid batteries.[150] Hanwha's Geoje yard boasts a state-of-the-art assembly area for lithium battery production which far exceeds any comparable efforts observed by CMS in other shipyards. The assembly process is almost entirely automated and conducted by advanced robotics, with two workers overseeing the entire production of cutting-edge lithium battery technology. Korean advancements in high-yield lithium batteries could make the country's submarines increasingly competitive on the international market. Hanwha was identified as a qualified vendor for the Canadian Patrol Submarine Project to replace the *Victoria*-class submarines due in part to the ability of Hanwha's lithium battery technology to sustain extended submersions under the ice—an essential feature of sub-surface vessels intended to operate in the Arctic.[151] Greater cooperation between American and Korean shipbuilders on integrating this technology into American submarines could similarly benefit the United States as it eyes an expanded security role in the Arctic in the decades to come.

South Korea's embrace of government-funded R&D efforts for shipbuilding signals the country's broad embrace of technical innovation in this field and underscores the value of greater cooperation between the United States and South Korea on defense R&D. Collaboration in areas such as hull testing and design, cavitation and noise reduction, application and testing of new metals or materials, improved welding technology, smart ship technology, testing, deployment, and the command and control of of uncrewed systems, as well as other possibilities, could be of significant benefit to the U.S. Navy and U.S. government research labs.

Design and Manufacturing Process

Arguably the most notable feature of South Korea's shipbuilding industry is its remarkable adherence to stable delivery timelines. While persistent delays in the design and manufacturing process are overwhelming, expected, and tolerated in the American shipbuilding industry, South Korea has established a culture in which such delays are entirely unacceptable and rarely occur. Hanwha, a company established in 1978, did not experience its first delivery delay until 2014, and there are several instances in recent years of Korean companies delivering ships ahead of schedule—something virtually unheard of in the United States.[152]

The standard contract structures used in Korea's shipbuilding industry play a role in incentivizing on-time delivery. Most defense-related contracts impose financial penalties on shipbuilders for late delivery and include clauses outlining how liquidated damages are calculated based on total contract price, the length of the delay, and the agreed-upon penalty rate for these delays. Most Korean shipyards also work based on firm-fixed-price contracts which set a single, unchangeable price for the ship and force the manufacturer to bear the brunt of any cost overruns. This differs considerably from the American shipbuilding industry, where it is more common for fixed-price incentive contracts to impose shared financial burdens for cost overruns between the buyer and seller of a ship are considerably more common. For reference, a 2017 GAO study noted that over 80 percent of the Navy's shipbuilding contracts awarded during the past 10 years were fixed-price-incentive agreements.[153] Accordingly, Korean shipbuilders often face greater financial incentives to ensure the on-time and on-budget delivery of vessels than American companies that can offload a portion of the cost overruns to the buyer.

However, neither of these factors fully explain the massive efficiency gap between Korean and American shipbuilders; after all, neither firm-fixed-price contracts nor liquidated damages clauses are unheard of in American shipbuilding agreements, and delays and cost overruns still frequently occur on projects in which both are present. CMS has identified three significant factors which enable the Korean shipbuilding industry to design and construct ships with greater efficiency and at lower cost than their American counterparts: a streamlined process, design efficiency, and culture of efficiency.

Streamlined Process

The first factor is Korean shipbuilding's embrace of a relatively streamlined design process, which is particularly noticeable when examining the design and construction of military vessels. While NAVSEA is notorious for imposing significant design changes on previously approved vessels designs, including during the production phase, Hanwha's leadership reported that the overwhelming majority of the design for ships commissioned by the ROKN is completed prior to production and major design changes after production commences occur only on an emergency basis. In Korea, military ship design progresses through multiple phases which typically include a feasibility study followed by the conceptual, basic, detailed, and production design stages. Both the ROKN and Korean shipbuilding companies take great care to eliminate any design issues during the early phases of the process, prioritizing the efficient construction of the vessels over last-minute changes which could delay production. Korea's Defense Acquisition Program Administration (DAPA), the country's NAVSEA equivalent, has proven comparatively unwilling to request late-stage design changes.

Furthermore, the relatively small size of the orders of ships commissioned at a given time by the ROKN enables its leadership to commit to designs for fewer ships with the knowledge that alterations can be made to the design of the next batch being built. Rather than the large orders that typify American naval procurement, the ROKN typically orders between three to six ships of a similar design at once, which can be produced relatively quickly given the efficiency of the Korean shipbuilding industry. Any new features the ROKN might regret not including in the design of a batch of ships already in production can always be incorporated into the next, with the knowledge that those ships can also be produced on a relatively condensed timeline.

Design Efficiency

The second factor enabling Korean shipbuilders to design and produce vessels more efficiently than American companies is the extent to which the Korean industry has embraced advanced technology to improve shipyard efficiency. While many of these advancements have already been discussed, others warrant mention here.

CMS was invited to tour the Geoje yard's Smart Production Control Center, which serves as the central point for collection of data, analysis, monitoring, and formulation of corrective action to maintain the design-build process for multiple construction projects. This state-of-the-art facility acts as a digital twin for the design-build process of every hull produced in the shipyard, which represents a ship's construction or operational status in real time. Employing aggregate data and AI, the control center monitors overall construction in the yard in order to detect and alleviate any bottlenecks. Platforms ashore or alongside are monitored throughout the process, from keel-laying to delivery. The digital twin approach promotes prioritization of tasks and awareness of what is necessary to ensure on-time delivery. Shipyard personnel's compensation and bonuses are linked to key performance indicators, helping to garner buy-in to the digital twin model among Hanwha's labor force. Notably, Hanwha is not the only Korean shipbuilding company to invest in smart shipyards that use digital twins; Hyundai is partnering with Palantir to integrate digital twins into every aspect of shipbuilding from design to production and has also signed a memorandum of understanding (MOU) with HII.[154]

With multiple ships constructed simultaneously, identical hull sections are produced concurrently and monitored from the cutting of steel, through the welding and inspection process, to delivery to the appropriate drydock for modular assembly. The process is highly efficient and relies on the precise timing and sequencing of steel, personnel, welding, inspection, and crane availability. Any shortfalls can cause cascading production delays. Key supervisory personnel are equipped with smart tablet devices to assess performance and communicate any delays up or down the chain of command. CMS was impressed by the movement of steel from staging areas to hull sections, particularly with numerous hulls under construction simultaneously. Even

with roughly 30,000 workers, the shipyard employs a remarkable number of robotic welders that CMS observed firsthand. In the VLCC production line, one standard hull section is produced every three days, and timelines are significantly shortened with the integration of robots.

Shipyard safety is an important part of sustaining a robust production timeline, as a serious accident or series of systemic incidents can slow down or stop production while corrective action and follow-on training are undertaken. Each shipyard worker receives one week of intense safety training per year. Use of virtual reality (VR) enhances the quality of training by putting workers in a realistic shop-like environment where they can monitor and detect hazards or hazardous behavior and take preventive measures to avoid an accident.

To facilitate on-time delivery, drones are flown over the yard multiple times per day and feed data to the control center to provide updates on shipbuilding status. Using overhead surveillance and radio-frequency identification (RFID) tags, the shipyard can assess and manage crane operations, workforce flow, tools, materials, and module production in the shipyard. RFID also monitors supply chain logistics outside the shipyard, from vendor production and assembly facilities to the production site. The data is integrated with AI and analyzed to optimize production flows and meaningfully contributes to on-time delivery schedules. While American shipyards often struggle to identify delays in real time and become aware of them only after the underlying causes have been occurring for weeks or months, the mainstreaming of data and analytics into the operations of Korean shipyards has enabled more dynamic and proactive responses to potential slowdowns in production.

Culture of Efficiency

The third and arguably most important factor contributing to Korea's impressive efficiency in the design and production stages of shipbuilding is the industry-wide culture emphasizing efficiency and timeliness as essential and mutually shared responsibilities. Over decades, Korean shipbuilding companies have committed to instilling pride in efficiency, with workers from the C-suite level to the most junior laborers taking a personal stake in the timely delivery of vessels. Employee contracts include financial incentives for producing ships on time and on budget, while failing to do so carries similar penalties.

While delays and cost overruns are too often accepted as the norm in the American shipbuilding industry, their specters are treated as near-existential threats by Korean companies who prioritize avoiding them at all costs. Shipbuilders are proactive in setting schedules and allocating resources at the outset of the design and production processes to help avoid delays, establishing organization-wide expectations for on-time and on-budget delivery. In the rare event that vessels fall behind schedule, companies prioritize addressing the structural causes of these delays while promptly allocating the resources needed to resolve them. At Hanwha's Geoje shipyard, a projected production delay results in the deployment of a red flashing light, triggering an all-hands response from the workforce in which getting back on schedule becomes the yard's top priority. The conglomerate nature of chaebols also allows these companies to easily mobilize their diverse network of industrial resources to tackle shipbuilding delays, making them uniquely poised to effectively address labor or supply shortages in ways many global competitors cannot. While most American shipbuilders cannot replicate the scope of the chaebols' resources, the Korean shipbuilding industry's cultural emphasis on the timely and on-budget delivery of vessels is something that could greatly benefit the U.S. MIB if thoroughly embraced by both private sector and government stakeholders.

While delays and cost overruns are too often accepted as the norm in the American shipbuilding industry, their specters are treated as near-existential threats by Korean companies who prioritize avoiding them at all costs.

Purchasing and Government-Commercial Relations

While the Buy American Act requires the U.S. Navy to purchase vessels that are constructed in American shipyards and built primarily with domestic materials, South Korea has no similar requirements.[155] However, the ROKN still purchases all of its warships from Korean companies and all of these vessels are constructed domestically—the result of strong relationships between the Korean government and its domestic shipbuilding companies built over years of robust federal support for this industry, as well as the ROKN's considerable confidence in the quality of the ships being built in Korea.

While no longer federally subsidized like their Chinese competitors, South Korean shipbuilders have seen significant government support for the industry in recent years, albeit in terms of investment into sectors such as R&D rather than directly subsidizing shipbuilders' operational costs. In 2024 alone, the ROK government invested a record ₩260 billion in strengthening the industry (a 40 percent increase from 2023) as part of its effort to close the capacity gap between the Korean and Chinese shipbuilding industries.[156] This investment builds on the 2024 K-Shipbuilding Super Gap Vision 2040 initiative, a public-private partnership intended to help South Korea become the global leader in shipbuilding technology by 2040 with an initial investment of $1.4 billion into these efforts.[157]

The South Korean government also provides generous R&D funding for its defense industries. The South Korean Ministry of Defense proposed its highest budget ever of ₩66.29 trillion ($47.8 billion USD), resulting in an 8 percent increase in defense spending for 2026.[158] The South Korean Agency for Defense Development (ADD) is the primary entity providing support for defense R&D. ADD receives its funding from DAPA and focuses its efforts on advanced defense technologies. DAPA also plays a major role in defense acquisition and procurement.

South Korean investment in R&D has produced impressive new facilities with direct military applications. The Siheung R&D campus, for example, is a relatively new, state-of-the-art facility that was established by Hanwha and relies on government R&D funding the parent corporation overhead to conduct R&D. The facility includes a modern tow tank for testing new hull forms which are designed and built in the facility. There is also an acoustic water tank that can conduct experiments and analyze acoustic characteristics underwater in order to predict performance metrics such as underwater radiated noise, acoustic radiated noise, and acoustic target intensity. The site also houses what its researchers described as the world's largest commercial cavitation tunnel, used for testing new propulsors to reduce cavitation and make ships quieter.

Finally, the ROKN has demonstrated an effective working relationship with Korean shipbuilding companies in designing warships. Like all navies, the ROKN seeks to strike a balance between cost and damage control in designing warships, ensuring that vessels are safe and durable without requiring outsized production costs. In Korea, such trade-off decisions are typically made through a series of consultations between the ROKN and the shipbuilders through the system engineering process. In Hanwha's case, the company analyzes diverse threat scenarios which could endanger vessels and crewmembers (fires, flooding, impact from explosive ordinances, etc.) to identify damage cases which could result in the loss of basic mission capability. Hanwha then works with the ROKN to develop and implement mitigation measures to address these threat scenarios, ensuring that factors such as cost, vessel performance, and production timelines are thoroughly accounted for in this analysis. These consultations have allowed the ROKN to make informed decisions about how it balances its cost and damage control priorities, resulting in both smooth design and production processes and the building of trust between the ROKN and the shipbuilding companies with which it works.

Infrastructure

South Korea has made significant capital investment in shipbuilding infrastructure, resulting in modern facilities with the latest technology including robotics and AI. Unlike the United States, South Korea has no public shipyards—all naval vessels are constructed and maintained in private yards. However, robust support from the South Korean government has allowed the country's private yards to grow into entities more than capable of supporting the construction, maintenance, and repair needs of Korea's navy, as well as those of its allies. Figure 3 shows the locations of Korea's four largest shipyards, along with their annual vessel output as of August 2025.[159]

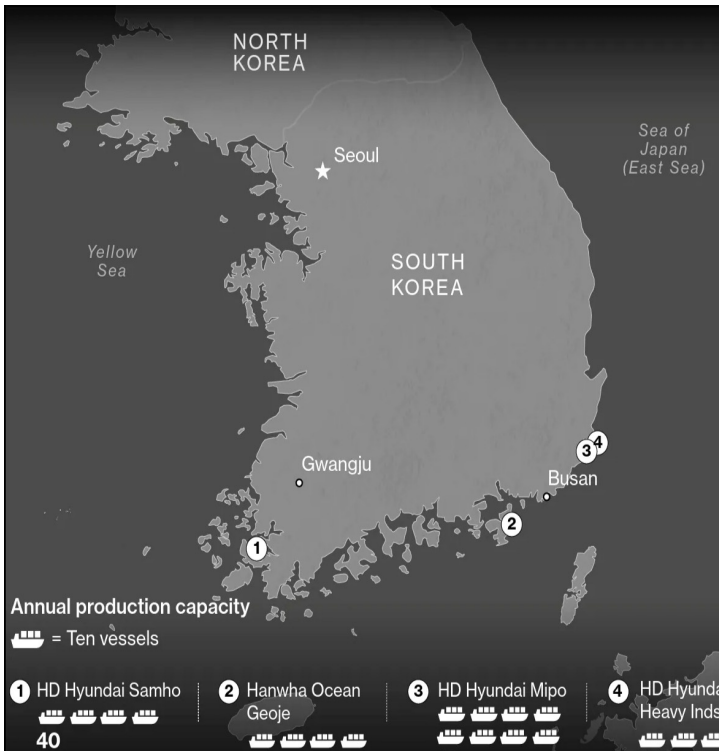


Figure 3: South Korea's four largest shipyards (Source: Bloomberg)

Founded in 1973, Hanwha's Geoje shipyard encompasses 53 million square feet of industrial space over 1,200 acres. In fact, Hanwha indicated that Geoje exceeds the combined square footage of Newport News Shipbuilding, Bath Iron Works, Electric Boat Groton, Electric Boat Quonset, and NAASCO shipyards in the United States. Geoje is also considerably more advanced than typical American yards, owing to the consistent investments made by Hanwha in upgrading its infrastructure in recent years. Since 2006, Hanwha reported having invested in the construction of a new floating dock in 2009 (with another planned for introduction in 2027), the extension of drydock number two, the installation of a new automatic welding robot, and the construction of a new assembly plant and quay wall, among other features.[160] These improvements to the yard's physical infrastructure have been complemented by the company's investments in emergent technology designed to support process improvement, such as its investment in block-scale construction to reduce loading times and the optimization of in-house logistics flows for assembly blocks.

On the commercial side, Hanwha executives told CMS the Geoje shipyard can produce up to 36 vessels per year, with 60 percent of these being VLCCs and the remainder consisting of container ships or floating production, storage, and offloading oil rigs. Drydock number one alone can support the simultaneous production of four VLCC ships. The shipyard operates four 900-ton Goliath cranes simultaneously ashore and two 3,600-ton floating cranes. Although the lift capability is adequate for current production levels, the shipyard plans to acquire a 6,500-ton offshore crane in the near future.

With its abundance of drydocks and industrial capacity, South Korea has proven capable of assisting the U.S. Navy with MRO of its older vessels operating in the Indo-Pacific. Recent examples include Hanwha availabilities on USNS *Wally Schirra*, USNS *Yukon*, and USNS *Charles Drew*.[161] The ideal outcome for the U.S. Navy would be to get the Pacific Fleet on a regular maintenance and repair schedule in Asian shipyards, rather than having to return to the continental United States for repairs. This would reduce the pressure on both public and private U.S. shipyards and increase operational availability by keeping the ships in theater, thereby reducing transit time. Options are on the table for a yard dedicated to U.S. Navy MRO near Naval Base Chinhae, South Korea, as well as other yards and docks throughout Asia. This model has worked well in

the European theater with the U.S. Navy's Sixth Fleet Command Ship, USS *Mount Whitney*, which has remained in the European area of responsibility for 20 years by conducting periodic Service Life Extension Program availabilities in European shipyards, including Genoa, Italy and Rijeka, Croatia.[162]

An aerial view of the Geoje Shipyard in Okpo, South Korea. (Photo credit: Hanwha Group)

Hanwha's acquisition of the Philadelphia Shipyard also underscores the efforts of Korean shipbuilding companies to expand production beyond their country's borders. Originally built in 1776, the Philadelphia yard has a rich history of building significant naval vessels, including *Iowa*-class battleships like the *Wisconsin* and *New Jersey* and *Essex*-class aircraft carriers such as the *Valley Forge*. At its apex, Philadelphia Shipyard employed roughly 45,000 workers and played an essential role in supporting American naval power during World War II, building 48 warships, converting 41 ships, and supporting construction and repairs on 1,250 vessels across the duration of the war.[163] In 2019, fewer than 100 workers were employed by the yard, underscoring the sensitivity of U.S. shipyards to gaps in project continuity. The yard completes an average of 1.5 ships per year, compared to Hanwha's Korean yards which make almost 40 annually.[164]

Accordingly, Hanwha's stated goal of turning the Philly Shipyard into the "American Geoje" mirrors the immense challenges associated with revitalizing American shipbuilding. The yard's leadership team has set an ambitious goal of increasing its annual output to up to 20 ships and, to achieve this, is investing in advanced robotic welding, paint and blast modernization, smart health, safety and environment management, and the installation of proven AI and digital systems utilized in Hanwha's Korean yards. These investments are designed to increase the efficiency of the yard in hopes of increasing output. Hanwha has plans to make Dock 5 (currently being used as an outfitting pier) operational for the first time in several years and to repair the yard's South Wharf in anticipation of an eventual increase in production. It is considering expanding capacity at Philly to other empty docks which are not owned by Hanwha, or building excess orders at the docks of other companies' shipyards.[165] A new fabrication shop is also being planned to support the work being done at the docks. Hanwha believes these investments will help the shipyard increase its commercial market footprint and carve out a larger role in producing LNG tankers and vessels to support American sealift operations, as well as jumpstart its production of naval vessels—a sector where the yard once held a significant market share, but where its current output is limited to the NSMVs being built to serve as training vessels for maritime academies. Hanwha envisions that the NSMV hull could also be used for a hospital ship, a submarine tender, or a command-and-control ship—each of which is a type of vessel that the U.S. Navy must urgently replace.

CMS visited the Philadelphia Shipyard twice during the writing of this study—once in 2024 before its acquisition by Hanwha to assess the current state of the U.S. MIB and again in late 2025 to observe the impact of the change of ownership. Hanwha's recapitalization efforts are still in their infancy and the yard's infrastructure appeared largely unchanged across both visits, save for the new coat of "Hanwha-orange" paint which had been applied to the yard's crane. The contrast between Philly and Geoje is stark. While the latter uses smart technology to track the location of its workers on the yard, Philly relies on a physical board where workers hang identification tags on hooks representing the sections of the ship where they are working, reflecting the legacy operational holdovers which have yet to be replaced. Many of the board's hooks held no

CMS researchers tour the Hanwha Philly Shipyard. (Photo credit: Center for Maritime Strategy)

tags at all, laying bare the extent to which the yard's latent capacity remains untapped and the breadth of the undertaking involved in its revitalization.

The South Korean shipbuilding industry is working to further expand its global footprint. Hanwha has expressed an interest in further expanding capacity in the U.S. through acquisition or development of another shipyard in anticipation of increased demand from the U.S. Navy.[166] Hanwha attempted to acquire the Australian shipbuilding company Austal in 2024, indicating its willingness to pay over AU$1 billion before ultimately settling on acquiring a nearly 20 percent stake in the company in 2025.[167] Like most Korean heavy industrial companies, Hanwha owns and operates a facility in China—specifically a shipyard in Shandong Province—that produces some non-sensitive components for commercial, non-naval ships. These components are shipped to Korea for final assembly. Whether the company will continue its presence in China has been complicated by Beijing's imposition of sanctions against five Hanwha subsidiaries in a move perceived by many experts as a response to America tariffs on Chinese imports.[168] Meanwhile, Hyundai has owned and operated the Ninh Phuoc Shipyard in Vietnam since 2011, began operating at the Subic Shipyard in the Philippines in September 2025, has signed an MOU for mutual shipbuilding cooperation with India's largest public shipyard, and has plans to begin shipbuilding operations at Saudi Arabia's King Salman Industrial Complex in 2026. Hyundai hopes these investments will enable it to build as many as 60 ships annually overseas in addition to the 130 built in South Korea, which speaks to South Korean shipbuilders' commitment to expanding into new global markets.[169] It is clear that South Korea views shipbuilding as a profitable growth industry and that its companies are investing accordingly.

Supply Chains

Korean shipbuilders face many of the same supply chain challenges as American companies, noting the difficulty in maintaining a consistent supply chain over the length of a four- to eight-year construction period and the 30+ year service-life of ships. South Korea also faces supply chain challenges given the limited number of companies capable of producing particular parts. Companies like Hanwha have actively sought to avoid purchasing from small, sole-source suppliers, instead seeking out international suppliers to diversify their options and receive parts and supplies more quickly. Hanwha reported working with approximately 1,000 partner companies that support the construction and design of ships including local shipyards, maintenance providers, and equipment suppliers. Korean shipbuilders have also sought to minimize supply chain delays by fostering a culture of accountability among suppliers. Suppliers that can consistently and quickly procure parts tend to be prioritized in purchasing decisions, whereas shipbuilding companies often seek to replace firms which they assess to be complacent.

Korean shipbuilders typically prefer sourcing supplies domestically, though they are certainly willing to look internationally as needs require. For example, Hanwha typically sources steel through domestic sources, but also occasionally from Japanese or Chinese mills when building commercial ships. While defense projects often procure steel exclusively from domestic suppliers, European vendors are used in exceptional cases where domestic supply is either insufficient or cannot meet specific delivery schedules. Meanwhile, cables are typically procured from local manufacturers such as LS Cable and TMC. When Hanwha needs to import cables, they typically purchase them from American, French, or German companies which have a manufacturing

presence in Korea to ensure fast, localized production.

Korean shipbuilders have sought to strengthen their supplier networks by developing naval MRO clusters—strategic groupings of suppliers and vendors that can pool resources, supply chains, facilities, and specialized knowledge to support vessel construction and maintenance. Hanwha signed an MOU with 15 Korean vendors, establishing an "MRO cluster council" aspiring to be the preeminent hub for supporting the U.S. Navy in the Indo-Pacific. Midsized Korean firm HJ Shipbuilding & Construction established a similar cluster and subsequently landed its first MRO contract with the U.S. Navy in December 2025.[170]

Korean firms are also proactive in attempting to anticipate supply chain crunches by forecasting potential part failures when planning ship repair schedules. During the design and construction phase, Hanwha identifies parts with potentially high failure rates by relying on military handbooks of data on the reliability of both electronic and non-electronic equipment. Warships are typically delivered to customers along with initial packages containing replacement parts intended to last two to three years, depending on the contract requirements. Part replacements for ships extending beyond the first few years of ownership are typically procured through the company's logistics system.

While many maritime nations have begun embracing additive manufacturing as a potential solution to supply chain disruptions, South Korean firms have largely shied away from doing so. The value of additive manufacturing lies in its capacity to help shipbuilders construct usable parts on-site when supply chain disruptions prevent them from purchasing or receiving them in a timely manner. However, South Korean shipbuilders have enough on-site welding and manufacturing capability to produce any missing parts themselves, reducing the additive value derived from robust investments in 3D printing operations. When parts cannot be readily produced on-site, chaebols can operationalize other arms of their manufacturing industrial base to support their production. These assets are largely unique to the Korean MIB and are likely not replicable in the United States, where most shipbuilding companies lack the capacity to quickly build assorted parts on an as-needed basis.

Key Findings

The Korean shipbuilding industry offers several valuable lessons for revitalizing the U.S. MIB, particularly in workforce strategies, technological integration, design discipline, and cultivating a culture that treats schedule performance as a central strategic priority. South Korea's status as a global shipbuilding powerhouse is the direct result of decades of ongoing nourishment and support from the Korean government, as well as the industry's willingness to embrace and integrate new and emerging technologies into Korean shipyards. Unlike the U.S. system where design changes, cost overruns, and delays are common, Korea maintains a streamlined and stable design-build process and strictly enforces on-time delivery. Shipbuilders rely heavily on robotics, integrated digital-twin production control systems, and advanced R&D infrastructure supported by national investment. This combination of disciplined design and manufacturing processes, modern infrastructure, and strong organizational culture has produced a global leader in commercial shipbuilding and a technologically sophisticated maritime defense partner. Korean shipyards are increasingly essential to allied naval readiness by providing MRO capacity for the U.S. Navy in the Indo-Pacific, while also collaborating with the United States on next-generation technologies. As the United States and South Korea deepen their collaboration on shipbuilding, this partnership creates invaluable opportunities for the American industry leaders and government officials to learn from the practices and decisions that have allowed Korea's MIB to thrive amid the American MIB's decline. Hanwha's acquisition of Philadelphia Shipyard stands as an excellent test case for the extent to which the best practices of Korean shipbuilding are applicable to the American context.

SWOT: South Korean Shipbuilding

Strengths	Weaknesses
• Proven capacity to produce both commercial and naval ships on time and within budget • Impressive integration of digitization in ship design and construction, such as Hanwha's Smart Production Control Center • Significant investments in automation which enable the production of ships at scale while also reducing the manpower requirements • Deeply rooted, industry-wide commitment to excellence and a willingness to embrace innovation and emergent technologies • Robust commitment to R&D, shared by both government and industry	• A shrinking workforce and difficulty attracting domestic laborers to support the shipbuilding industry • Struggle to compete with heavily subsidized Chinese companies
Opportunities	**Threats**
• Strong and growing ties to the American shipbuilding industry which could enable greater bilateral shipbuilding and naval cooperation • South Korea's investment in R&D could spur future innovations which could increase its global market share • South Korea's abundance of drydocks can support MRO on American naval vessels • The development of nuclear submarines could strengthen the ROKN and create a new sector for the Korean shipbuilding industry	• An aging shipbuilding workforce without sufficient successors from later generations • An outbreak of conflict with North Korea could disrupt the shipbuilding industry • Changes in U.S. or South Korean leadership could challenge opportunities for U.S.-ROK maritime cooperation, such as MASGA

Figure 4: Strengths, Weaknesses, Opportunities, and Threats (SWOT) for South Korean shipbuilding (Original graphic by the Center for Maritime Strategy).

Italy

Unlike many of America's maritime allies, Italy has successfully remained globally competitive in both its commercial and naval shipbuilding sectors. Anchored by its dominant shipbuilder Fincantieri, Italy has produced high-quality naval ships such as the FREMM through international collaboration, demonstrating how ship development efforts can create economies of scale, enforce program discipline, and sustain interoperability. In the commercial sector, cruise ships serve as the economic engine of Italy's MIB with sustained demand, creating ripple effects for naval construction by preserving skilled labor, modern infrastructure, and an advanced systems-integration culture. The Italy case demonstrates the importance of shipyard modernization and can be a model for sustaining significant naval and commercial shipbuilding output despite operating on a smaller scale than countries such as China or South Korea.

To support this case study, CMS's experts traveled to Italy in February 2026 to observe Fincantieri's Monfalcone shipyard, while also incorporating observations from previous trips to Fincantieri's U.S.-based Marinette Marine shipyard. CMS conducted interviews with both American and Italian representatives of Fincantieri, as well as Italian naval officers and shipbuilding experts. Unless otherwise cited, all insights included in this case study are derived from these site visits and interviews.

History and Background

With most of its territory bordering the sea, Italy has long been an important maritime power in the Mediterranean, dating back to the Roman Republic and the country's Renaissance-era maritime republics of Amalfi, Pisa, Genoa, and Venice. Italian ports such as Venice, Civitavecchia, Genoa, Gioia Tauro, Livorno, and Trieste have served as significant trade hubs for centuries. Italian governments have consistently invested in the country's navy, boasting a rich tradition of conventionally powered diesel-electric submarines and over 100 years of successful submarine operations.


The Roma battleship (Photo credit: Wikimedia Commons)

Despite fighting alongside Allied powers in World War I, Italy succumbed to the influence of fascism. Before World War II, the Italian Navy possessed an impressive array of large warships with significant firepower. Although engaged in numerous combat actions during the war, the Italian Navy faced overwhelming strategic limitations, poor intelligence, and inadequate air cover, preventing it from achieving decisive naval superiority in the Mediterranean.[171] The performance of the Italian submarine fleet in World War II saw significant variance depending on maritime geography. Italian submarines performed well during the Battle of the Atlantic, where 32 Italian boats operating from the submarine pens in Bordeaux, France, sank 109 Allied vessels for a total of 600,000 tons of shipping.[172] Comparatively speaking, Italian submarines on independent operations in the Atlantic were significantly more effective than their counterparts in the Mediterranean. By the end of the war, Italian submarines suffered a staggering 75 percent loss rate with 88 of 116 boats sunk.[173] By 1943, King Victor Emmanuel saw the writing on the wall as the Allies moved from North Africa into Italy, and summarily dismissed fascist leader Benito Mussolini as Prime Minister, putting him under house arrest in September 1943.[174] Once it became clear that King Victor Emmanuel was engaged in discussions with the Allies, Germany took preemptive action by attacking Italy's navy in the Mediterranean and sinking ITS *Roma*, an Italian battleship that, unfortunately, had not received notification of Italy

Amerigo Vespucci's arrival in the port of Los Angeles on July 4, 2024, during its yearlong circumnavigation of the globe including passage around Cape Horn. (Photo credit: Center for Maritime Strategy)

changing its allegiance.[175] The *Roma* is an example of the Italian state's ability to build capital ships, which it still does today thanks to the industrial capacity of Italy's Fincantieri Marine Group.

Italy's strong maritime tradition continues today. In 2024-2025, Italy deployed the *Cavour* Strike Group to the Western Pacific in solidarity with allies and partners against Chinese aggression in the South China Sea and Straits of Taiwan, successfully operating for five months in a foreign theater without a significant support base.[176] This deployment demonstrated the capabilities of the Italian Navy and its ability to extend its reach well beyond Europe. Italy's navy is composed of professional sailors, with the country having suspended conscription in January 2005.[177] The Italian Navy officer corps is professionally trained at the Italian Naval Academy in Livorno and are trained on the tall ship ITS *Amerigo Vespucci*, which was once described by the commanding officer of the aircraft carrier USS *Independence* (CVA-62) in July 1962 as "the most beautiful ship in the world."[178] Built in 1931 in the Neapolitan shipyard of Castellammare di Stabia, *Amerigo Vespucci* remains in excellent shape, embarking every summer with midshipmen of all classes performing the duties of both the crew and watch officers.

Italy's shipbuilding industry is also a significant force, responsible for 10 percent of its GDP and employing over 900,000 people across 225,000 enterprises of all sizes.[179] In particular, the Italian shipbuilding industry produced an export orientation valued at €9.1 billion in 2023. While Italian shipbuilding slowed along with the nation's economy during the COVID-19 pandemic, the industry rebounded and, by 2022, Italy was responsible for 35 percent of the European Union's compensated gross tonnage (CGT).[180] Italy's success in shipbuilding is due to a variety of factors including an abundant work force, an advanced industrial base, state of the art marine manufacturing capability, and a diversity of port facilities and shipyards scattered around

Completions of Selected Seagoing Vessels Above 100 Gross Tons by Ship Type in the World, the European Union (EU), and Italy (2012-2022)

Ship Type	World	European Union		Italy		
	CGT ('000s)	CGT ('000s)	% of World	CGT ('000s)	% of World	% of EU
Ferries	9,941	1,534	15.43%	226	2.27%	14.73%
Cruise Ships	12,976	11,918	91.85%	4,680	36.07%	39.27%
Tankers	121,123	1,641	1.35%	17	0.01%	1.04%
Bulkers	125,157	368	0.29%	-	-	-
Pure Car Carrier	6,001	129	2.15%	-	-	-
Dredgers	2,356	864	36.68%	14	0.59%	1.62%
Cargo	9,899	440	4.45%	3	0.03%	0.68%
Offshore	24,061	1,698	7.06%	70	0.29%	4.12%
Ro/Ro	3,638	539	14.81%	54	1.48%	10.02%

Figure 5: Completions of selected seagoing vessels above 100 GT by ship type in the world the European Union, and Italy, 2012-2022 (Original graphic by the Center for Maritime Strategy. Data sourced from Organisation for Economic Co-operation and Development.)

the country. While Italy is capable of producing sophisticated warships, the civilian shipbuilding sector provides a more profitable business model for the maritime industrial base. In fact, Italy provided 36 percent of the world's cruise ships in 2022 (see Figure 5).[181] While Italy is the world's highest exporter of superyachts with over 19 percent of the world share, it is also capable of producing tankers, bulk carriers, cargo ships, offshore support vessels, and deep sea roll-on/roll-off (Ro/Ro) vessels.[182]

Fincantieri Marine Group is the largest shipbuilder in Italy and was responsible for over 90 percent of Italian CGT in 2022.[183] The Organisation for Economic Co-operation and Development's (OECD) Peer Review of the Italian Shipbuilding Industry summarizes Fincantieri's diverse shipbuilding portfolio in Figure 6.[184]

Fincantieri is one of the biggest designers and shipbuilders with 230 years of history and over 7,000 ships built.

It has:

- 18 shipyards in 4 continents
- more than 20,000 employees
- 90,000 including subcontractors, and
- 100 subsidiaries.

Fincantieri's revenues amounted to EUR 7.4 billion in the fiscal year 2022, and the total backlog amounted to EUR 34.3 billion (as of 31 December 2022).

The main products of Fincantieri are cruise ships and naval vessels. Both accounts respectively for 48.7% and 22.3% of revenues in 2022 with a backlog of 19.678 billion euros. Fincantieri has a diversified product portfolio in the world combined with a wide client base.

Table: Products, Clients, Revenues and Backlog

		Main products	Revenues in 2022	Backlog	Key Clients
Shipbuilding	**Cruise ship***	▪ All cruise ships o Luxury/Niche o Upper Premium o Contemporary • Ship repairs & Conversion	EUR 4 139 mln, 51.5 % (in the total revenues of Fincantieri)	EUR 19 246 mln, 57 deliveries to 2029	▪ Carnival ▪ Norwegian Cruise Line Holdings ▪ Viking Ocean cruises ▪ MSC cruise ▪ Italian Navy and Coast Guard ▪ US Navy ▪ Qatar Emiri Naval Forces ▪ United Arab Emirates Navy ▪ Algerian Navy ▪ Royal Saudi Navy
	Marine Interiors	▪ Cabin, Bathroom and public halls	EUR 71 mln, 0.9%		
	Naval	▪ Surface vessels ▪ Auxiliary & Special vessels ▪ Submarines	EUR 2 162 mln, 26.9%		
Offshore & Specialized Vessels		▪ Offshore Wind ▪ Oil & Gas offshore ▪ Specialised vessels ▪ Fishery	EUR 751 mln, 9.3%	EUR 1 344 mln, 32 deliveries to 2026	▪ DOF Subsea ▪ Norwind Offshore ▪ Norwegian Coast Guard
Equipment, Systems & Services	**Electronics, systems & software & Mechanical components**	▪ Digital services comprehensive support ▪ Digital asset management ▪ Marine systems & components	EUR 646 mln, 8.0%	EUR 2 513 mln, of which EUR 1 996 mln infrastructure	▪ Italian Navy and Coast Guard ▪ US Navy ▪ MSC cruises ▪ edf Fenice ▪ Carnival
	Infrastructure	▪ Structural steel components ▪ Maritime works ▪ Technical buildings and facility management (i.e., hospitals)	EUR 262 mln, 3.3%		

Figure 6: Fincantieri's products, clients, revenues, and backlog (Source: Organisation for Economic Co-operation and Development).

Cruise ships serve as Fincantieri's most profitable sector. In July 2025, Fincantieri CEO Pierroberto Folgiero explained that, should the U.S. Navy cancel the *Constellation*-class frigate program, the company would fall back on its orders for luxury cruise ship production at its Monfalcone shipyard in Italy. Monfalcone boasts €9 billion in cruise ship orders through 2036, with an additional €50 billion in back orders. Fincantieri's success has attracted multiple cruise line clientele, and the Monfalcone Order Book from 2026-2030 is reflected in Figure 7.

Fincantieri also enjoys the confidence of the Italian government in warship production for the Italian Navy and may expand its production of subsurface vessels. Today, Italy operates a modern submarine force of eight hybrid diesel-electric submarines: four improved *Sauro*-class and four Type 212A *Todaro*-class vessels. Noting the emerging threats in the undersea domain, Fincantieri's CEO stated that the company is "very focused on the underwater for the future" and believes "that the Mediterranean underwater can be a kind of perfect place to validate the new approaches, new models, and new technology."[185] This is evidenced by Fincantieri's status as the sole source for the Near Future Submarine U212 replacement for the *Sauro*-class boats, on which the company began production on the fourth iteration in December 2025.[186] The protection of Italy's and Europe's critical undersea infrastructure (CUI) is extremely important to the country's national and economic security, and Fincantieri appears poised to play an essential role in ensuring the protection of this valuable asset.

Finally, Fincantieri has sought to support American shipbuilding through its acquisition of Marinette Marine Shipyard in Marinette, Wisconsin, in 2009 and repair facilities in Jacksonville,

Figure 7: Confirmed Monfalcone Order Book 2025-2036 (Source: Fincantieri)

Florida, in 2022, and $800 million investment into both. While Fincantieri eventually overcame significant delays and cost overruns to construct 16 littoral combat ships for the U.S. Navy (making up over 20 percent of the Navy's desired required number of small surface combatants), the *Constellation*-class frigate program that began with optimism came to an end with the cancellation of the program in late 2025.[187]

Labor and Workforce

Italy's MIB faces many of the same labor challenges as its American and European allies. While Italy has historically boasted an abundant maritime labor pool, the shipbuilding workforce is aging and, despite the high youth unemployment rate, young workers have not flocked to the industry.[188] Outsourcing segments of work to localities far from the assembly area or drydock has created an uneven demand signal, exacerbating the problem. Fierce competition from Asian competitors that receive significant government subsidies, particularly China, reduce the price of foreign goods and make Italian manufacturing less competitive. These realities have forced some shipbuilders into niche capability markets like the cruise ship industry, but even the requirements from the maritime entertainment industry necessitate exquisite skill sets for production that cannot be developed overnight.

For this reason, Fincantieri has created the "Masters of the Seas" (*Maestri del Mare*) program to attract, train, employ, and retain the next generation of shipbuilders. The program is divided into three phases:

1. Vocational and language training of a wide diaspora of domestic and foreign workers to better integrate with local communities in Fincantieri's shipbuilding concentration areas;
2. Focus on "smart industrialization" and the automation of repetitive tasks through robotics or autonomous systems, and;
3. Training workers to utilize AI and robotic systems as force multipliers and integrate them into their work.[189]

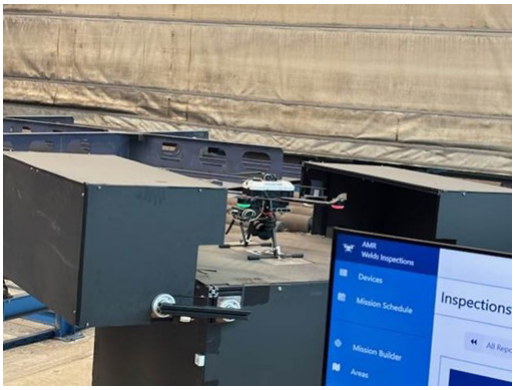
The program recruits from Italy's secondary and post-secondary school system and offers employees a monthly stipend of €1,000 while training students to use automation, robotics, AI, and digitization technologies, as well as developing the organizational and interpersonal skills to improve teamwork. Graduates receive jobs at Fincantieri's Italian shipyards along with relocation

bonuses.[190] Fincantieri executives told CMS that, within two months of opening applications in 2024, the company received 17,000 applications for 90 positions in each class, and may expand the program if it proves to be successful. Candidates are selected based on a battery of technical tests, interviews, psychological profiles, and group assessments. The first class entered training in February 2024, with Fincantieri focusing on the development of Dimensional Control Officers, Naval Equipment Operators, Crane Operators, and Ship Drivers.

These trainees will play an invaluable role in supporting Fincantieri's growing demand for new ships. Fincantieri's Monfalcone shipyard employs about 8,000 employees representing several nationalities. 1,000 of these employees are full-time and 7,000 are subcontractors. More complex vessels require a higher percentage of full-time employees given the technical specificity required to construct them. Turnover and the need to recruit a qualified sub-contractor workforce present challenges to production, since each subcontractor must adhere to the standards of safety and quality assurance maintained by the shipyard. Nevertheless, the Monfalcone shipyard achieves about 1 million man-hours per month at full-rate production, allowing the yard to build a 200,000-ton ship in just over a year. Based on the significant amount of manpower required to achieve the goals of the U.S. MIB, it would make sense to explore options for a similarly diversified workforce in North America.

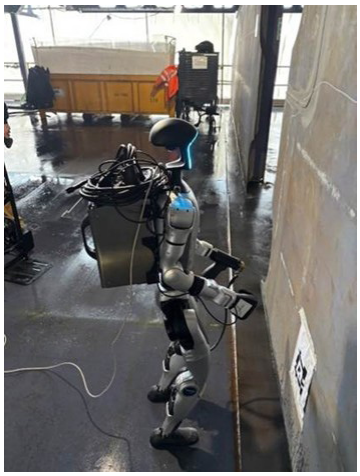
Technology Integration

Fincantieri advocates innovation through a four-part approach involving its indigenous research institution, the solicitation of startups, internal competition, and its promotion of "innovation antennas"—localized innovation hubs designed to integrate advanced, external technology into shipbuilding processes, accelerating digital and energy transitions. Through this approach, Fincantieri has sought to promote collaboration between its own engineers and third-party companies to drive shipbuilding innovations. Fincantieri is currently transforming Monfalcone into a state of the art "smart shipyard" with a five-year development plan (2026-2030) and investments totaling €1.9 billion across its facilities. These upgrades focus on what the company calls "intelligent industrialization" to support digital twins by automating highly complex and repetitive tasks. The Monfalcone yard's production line employs a variety of industrial robotic capabilities, digital twinning, real-time logistics tracking, AI and augmented reality (AR), and additive manufacturing. For example, autonomous drones are being integrated for rapid, non-invasive structural monitoring and quality control, feeding real-time data back into the digital twin for quality inspection. These same AI algorithms are used to process the video flow recorded by cameras installed along the panel line to identify welding defects and decreases in machinery performance in real time.



Electro-optical drones used for welding inspection (Photo credit: Center for Maritime Strategy)

CMS observed several robotic or cobotic (robots designed to collaboratively and safely work alongside humans) welding systems at the Monfalcone shipyard. The yard is installing state-of-the-art laser welding and profile processing lines (including PEMA-brand automated welding technology) to handle the increased precision required for mega-ships over 200,000 tons. Additionally, the yard has introduced the mobile robot for welding (MR4Weld), an independent system that uses integrated vision software to locate and weld steel joints. Mobile welding robots promote upskilling opportunities for workers and help offset the global shortage of welding professionals. This system can be used in proximity to human welders conducting other jobs, and Fincantieri notes that it has improved productivity by a factor of three. Additional cobots are used to perform pre-assembly work, where a single operator can orchestrate multiple robots to help boost the production rate. Overall, mobile robot welders offer significant time and cost



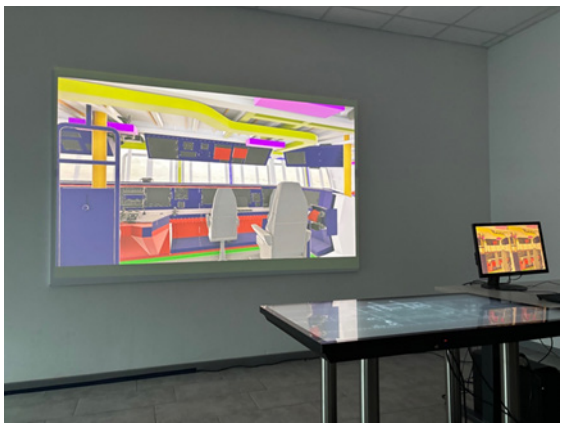
Fincantieri's Humanoid Welding Robot (Photo credit: Center for Maritime Strategy).

savings compared to manual processes.

In February 2026, Fincantieri partnered with Generative Bionics to develop AI-powered humanoid robots to support welding.[191] These robots are designed to navigate a cluttered shipyard environment and are currently in testing at Monfalcone in anticipation of being deployed by the end of 2026. One of the advantages of the humanoid robots is their intelligence and their ability to navigate and perform welding services safely and effectively in a hull after modules or components have been landed. While robots and cobots are now a significant part of the prefabrication phase, the use of humanoid robots in the hull is a potentially disruptive change which Generative Bionics believes could contribute "to the long-term sustainability of highly intensive and specialized activities."[192] Fincantieri has also launched a pilot program to develop a humanoid robot capable of welding an insulation pin or stud pin and hopes to develop robots that can perform quality inspection on the welding line by mid-2026.

Fincantieri's Monfalcone shipyard uses digital twins to create virtual, data-driven replicas of cruise ships, integrating the internet of things, 3D modeling, and AI to optimize construction from design through to production. This technology enables real-time monitoring of construction, simulation of assembly, and predictive analytics to improve efficiency, reduce risks, and ensure the ship matches the digital design. Digital twins are initiated in the design phase, creating high-fidelity 3D models that evolve into "as-built" baselines, allowing for rapid, accurate assembly. The shipyard simulates production processes, using AI and digital models to detect disruptions early and adapt, reducing throughput times and increasing efficiency. Sensors on equipment and materials feed real-time data into the digital twin, monitoring the progress of construction, material inventory (e.g., steel plates), and resource utilization. Digital twins predict potential structural issues or equipment failures during the construction phase, facilitating proactive maintenance and ensuring high-quality standards. Virtual models help plan the complex, advanced outfitting of cabins and machinery before physical installation, enhancing safety and reducing on-site work. Fincantieri uses 3D models to create virtual counterparts of ships, allowing designers and engineers to simulate operational scenarios, check design choices, and optimize the final product before physical construction begins. Through the "Fincantieri for the Digital Future" program, shipbuilders can don VR/AR helmets to assess accuracy in ship fitting a compartment while providing expertise in a safe, simulated environment.

Italy is also integrating technological innovations into its ships and has emerged as a pioneer in CBM, using a system of sensors embedded throughout the ship to provide indications of performance or pending failure. Using specially designed algorithms, ship data is analyzed through a central processor and assessed against design criteria to detect problems before they become catastrophic failures. If equipment degrades to a certain design limit, an alert is generated and maintenance is scheduled either immediately or during the next maintenance availability. This methodology reduces the need for maintenance while making it more predictable and easier to schedule in advance, thereby increasing operational availability. America's current Planned Maintenance System (PMS) is based on an average of failure rates, meaning that the prescribed maintenance periods are typically too early or too late. Additionally, PMS does not account for a ship's unique operational conditions, such as operating in a high-sea state with large slamming loads compared to operating in calm littoral waters.



Digital twinning in use at the Monfalcone shipyard's command and control center, showing the digital rendering of ships under construction or repair. (Photo credit: Center for Maritime Strategy).

One of those ships will need dry-docking and weld repairs much sooner than another, even if they are of the same class. Ship-specific sensors can address these issues by optimizing an individual ship's operational availability and reducing unnecessary maintenance while underway, such as taking critical propulsion equipment offline for inspections.

While the U.S. Navy and Department of War understand the value of CBM in warship design, they are moving ahead slowly with integration aboard current ship types. In August 2024, the Office of the Deputy Assistant Secretary of Defense for Material Readiness published the Condition-Based Maintenance Plus (CBM+) Guidebook.[193] Because the United States builds the most sophisticated and expensive weapons systems in the world, the CBM+ Guidebook calls for more widespread monitoring and better software to help reduce the cost of ownership. Figure 8 shows how CBM+ is integrated into design, acquisition, and sustainment.[194] Additionally, while current shipboard maintenance procedures such as checking oil are more reactive than predictive, the guidebook seeks to implement more predictive analysis where a built-in sensor would notify the engineering control center on the ship when the oil of an engine has gone from suitable to borderline. While ship crews currently check oil samples in off-engine instruments during their machinery rounds, a built-in sensor would allow those crews to attend to more urgent matters in a combat scenario, such as damage control, thereby saving time and prioritizing the combat mission.

If the U.S. Navy's ultimate goal is to design and instrument American warships with CBM+, Fincantieri presents a compelling model for doing so through its integration of CBM+ in the design of the FREMM, which has carryover effects on future ships based on the FREMM's design. For example, Fincantieri's Center for the Study of Naval Technology developed and deployed a system on the FREMM to monitor hull fatigue and structural integrity. Fincantieri's integration of CBM in the FREMM design is somewhat unprecedented in new warship construction, which is why the president of shipbuilding for Fincantieri Marinette Marine described it as the most instrumented ship in the world. According to one estimate, the employment of CBM principles on the FREMM-class warship has the potential to reduce maintenance time by 50 percent.[195] If this could be replicated in American warships, it could significantly strengthen the U.S. Navy's fleet by reducing the number of vessels that are out of commission at any given time and maximizing its number of readily deployable assets. Notably, in the case of the *Constellation*-class frigate, the design was intended to monitor a variety of parameters during the ship's operating life, collect-

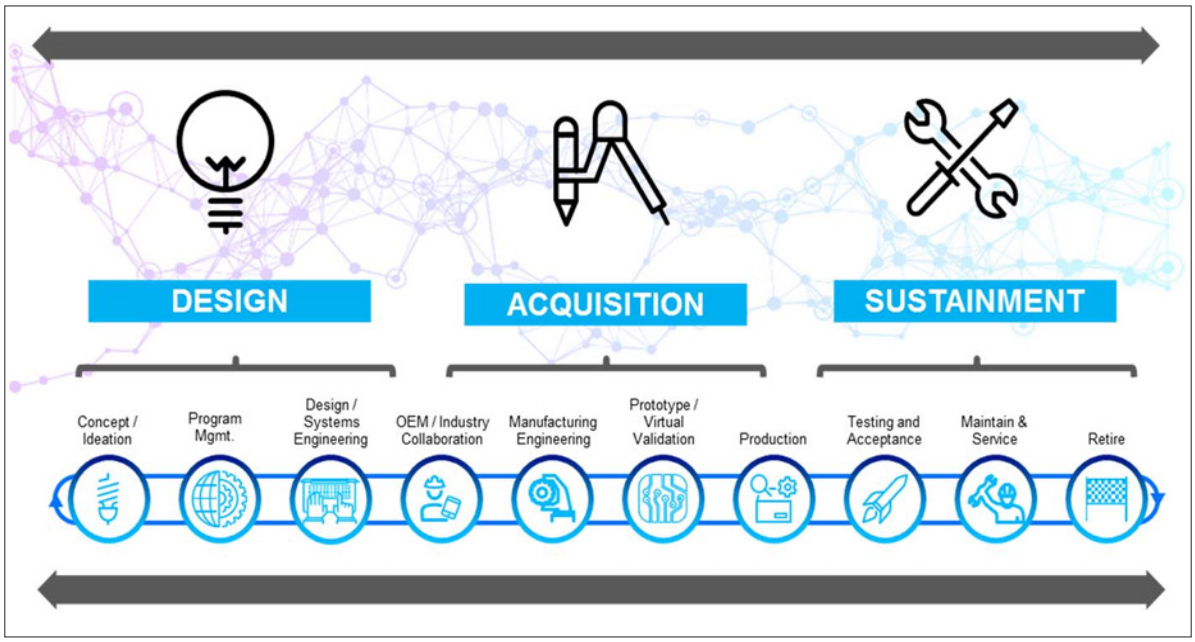


Figure 8: How CBM+ fits in the Big Picture (Source: Surface Navy Association).

ing data on everything from the remaining service life of running propulsion machinery to the fatigue stress status of non-mechanical structural members.[196]

Design and Manufacturing Process

The Monfalcone Shipyard is extremely process-oriented in its approach to shipbuilding. In this way, the shipyard has learned to build bigger and more complex ships each year. American shipbuilders refer to this phenomenon as a "shipyard learning curve," which implies learning across a common class of ships that may number 30 or more. While American shipbuilders gradually learn how to build vessels across a large common class and become more efficient over time, Fincantieri focuses on improving processes to allow for the efficient construction of one- or two-ship classes that are custom designed according to the buyer's needs. The leadership at the Monfalcone yard opined that the process of building luxury cruise ships is as much about complexity as it is system integration of individual components aboard ships that are all unique.

Embracing process improvement, Fincantieri has achieved incredible efficiency by investing in prefabrication of modules in the design-build process. Monfalcone is currently producing 15-metric-ton modules, ready for installation, in the modular production process in drydock. Not only are these modules stuffed with piping and electrical systems ready to integrate with the rest of the hull, but the shipyard also saves time and manpower by painting or powder coating these modules before integration, which is unique among all the shipyards CMS visited for this report. Fincantieri estimates that it has reduced labor production hours by a factor of five by completing most of the work on modules prior to delivering the module to the drydock for fitting, welding, and assembly.

Owing to recent infrastructure upgrades discussed elsewhere in the study, Fincantieri's Monfalcone yard successfully delivered notable ships such as *Carnival Dream* (2009) and *Carnival Magic* (2011), which were the largest passenger ships ever built by Fincantieri at the time, with each reaching 130,000 gross tons.[197] With the arrival of the *Royal*-class ship *Britannia* in 2015, Fincantieri set a record for the largest ship in Italian shipbuilding history at 141,000 gross tons.[198] As the shipyard continued to deliver bigger and better cruise ships, orders multiplied and, in 2024, Monfalcone delivered the first LNG-powered cruise ship, *Sun Princess*, for Princess Cruises at 178,000 tons, followed by a second ship of this class in 2025.[199] Fincantieri has partnered with the German company TUI Cruises on a major fleet expansion, featuring eco-friendly LNG-powered 160,000-ton InTUItion-class vessels. Following the 2025 delivery of *Mein Schiff Relax*, the next vessel, *Mein Schiff Flow*, is set for 2026, with additional ships ordered for 2031 and 2032 to strengthen the *Mein Schiff* brand. CMS was able to tour *Mein Schiff Flow* one week before sea trials scheduled for February 22, 2026, which served as an example of how Fincantieri's process-oriented approach to shipbuilding manifests in the production of state-of-the-art cruise ships and helped inform many of the observations detailed in this section.

The bridge of *Mein Schiff Flow* in Monfalcone Shipyard (Photo credit: Center for Maritime Strategy).

On the naval side, the FREMM-class frigate is the most relevant program of interest for this report and is worthy of a deep dive. The FREMM program is a joint Italian-French effort to produce advanced frigates as replacements for older platforms in both navies with Italy and France each building their own version of the ship.[200] The government of Italy authorized the pursuit of a design and construction of the FREMM in 2005 under the framework of Organization for Joint Armament Cooperation (OCCAR, *Organisation Conjointe de Coopération en matière d'Armement*), a collaborative armament program that includes Italy, Germany, Belgium, France, Spain, and the United Kingdom, which is discussed in greater detail in the "Purchasing and Government Re-

lations" section of the case study. OCCAR awarded the FREMM to Horizon Naval Systems (OSN, *Orizzonte Sistemi Navali*), a joint venture between Fincantieri and Leonardo, for six general purpose frigates and four anti-submarine warfare (ASW) frigates. The initial cost estimate for the class was €5.9 billion, roughly €600 million per ship.[201] The first of the FREMM-class frigates, ITS *Carlo Bergamini*, was completed in 2011 and delivered to the Italian Navy in 2013, while the tenth FREMM was delivered in 2025. The last two ships of the class were enhanced variants of the ASW version of the frigate. In the meantime, two Italian FREMMs were sold to Egypt for a total of €1.2 billion.[202] Due to the increased threat in the undersea domain in the Mediterranean, Italy has authorized two more enhanced variants of the ASW frigate for delivery in 2029 and 2030, bringing the total to 12 ships in the class.[203]

Mein Schiff Flow in Monfalcone Shipyard one week before sea trials (Photo credit: Center for Maritime Strategy).

In developing the FREMM, France and Italy looked for commonality in both design and equipment and settled on a common hull for all FREMM vessels. Accordingly, the Italian and French versions of the ship are extremely similar, but with important differences. Notionally, a FREMM is a 145-meter ship that displaces 6,700 tons and has a range of 6,000 nautical miles at 15 knots. The propulsion system is a combined diesel-electric and gas plant with minor variants between the French and Italian FREMMs. The biggest difference between the two ships is in the designated mission and associated armaments. Italy builds two basic variants of the FREMM—a General Purpose Frigate and an ASW Frigate. Meanwhile, France's ASW version of the FREMM is outfitted with torpedoes, a towed array sonar for detection of enemy submarines, and the Aster-15 vertical launch self-defense weapons system against cruise missiles and subsonic threats. The Italian FREMMs are also equipped with the Aster-15 defensive weapons system and the Teseo Mk2 sea-skimming anti-ship missiles.[204] Both Italian versions have bow-mounted sonars. The ASW version also carries a very low frequency towed array sonar, an ASW helicopter, and anti-submarine torpedoes.[205] Both versions of the FREMM were ergonomically designed with attention to size, weight, power, and cost (SWaP-C) to allow for efficiency and eventual upgrades and modernization. The ship has a large cargo door for loading and offloading equipment, wider passageways, and a more ergonomically designed engine room.

The FREMM's relatively smooth design process, contrasted with the uneven and ultimately ineffective design process Fincantieri experienced with the *Constellation*, highlights both the capacity of shipbuilding consortiums to produce quality vessels that can be operationalized across multiple alliance partners and the inefficiencies of America's processes for refining ship designs. Additionally, the fact that Italy and France successfully built their own versions of the FREMM which were tailored to match their navies' needs without making substantial alterations to the ship's core design underscores the value of developing common hulls or ship modules which can be shared among naval allies.

Finally, Italy is also pursuing development and modernization of its newest aircraft carrier, the Landing Helicopter Dock (LHD), ITS *Trieste*, under an OCCAR framework. Like the Italian aircraft carrier ITS *Cavour*, ITS *Trieste* is an impressive multifunctional platform capable of carrying and launching up to 20 F-35B vertical/short takeoff and landing aircraft.[206] Similarly, both Italy and France are pursuing Logistics Support Ships under an OCCAR contract with two ships under construction by Fincantieri Marine Group in Italy and an option for a third hull later on.[207]

Purchasing and Government-Commercial Relations

Since Fincantieri's founding in 1959, the Italian government has played a major role in its strategic decisionmaking with the aim of consolidating shipyards, centralizing management, boosting com-

petitiveness, and influencing Italian industrial and strategic policy. This relationship has evolved in recent years. Despite beginning as a public company without any private equity, Fincantieri had an initial public offering in 2014, marking the transition from a wholly state-owned enterprise to a publicly traded company.[208] This has given Fincantieri a greater degree of independence, although the Italian government still plays an important role in shaping the company's direction.

Italy's naval acquisition processes are largely streamlined due to the close relationship between Fincantieri and the Italian state. Fincantieri S.p.A. is majority-owned by Cassa Depositi e Prestiti S.p.A., an Italian public development bank which in turn is majority owned by the Ministry of Economy and Finance (MEF).[209] The Italian government encourages close cooperation between Fincantieri and other MEF-owned defense firms like Leonardo S.p.A. to enhance Italy's defense capabilities and industrial footprint. This ownership structure makes Italy's process of ship acquisition unique among U.S. allies. The high degree of interconnectedness between the Italian government and its largest domestic producer of warships has enabled synergy and cooperation between the two when it comes to building and buying warships. The Italian Parliament is also more involved in force design and systems decisions than the U.S. Congress, which delegates much of that work to NAVSEA.[210] Since Italian defense spending is often justified to the public based on the jobs it creates and supports, Italian lawmakers frequently insert themselves into the process to influence the geographic locations into which defense investment flows. That a significant amount of the naval acquisitions budget comes from the Ministry of Business and Made in Italy speaks to the extent to which job creation and naval acquisitions are linked in Italian politics.[211]

When it comes to naval shipbuilding, Italy's government-commercial relations are heavily shaped by OCCAR's processes. OCCAR is run similar to a U.S. public enterprise, with a board of supervisors governed by a program board for strategic decisions and a program committee for operational decisions. When a requirement is identified for multinational defense systems, OCCAR takes responsibility for the program. OCCAR is a central adjudicating authority for contracting to ensure cost savings and efficiencies across multinational borders. OCCAR's authority and resources attract competition in the marketplace to ensure that governments get the best deals possible in defense. OCCAR also ensures that standards are upheld throughout the procurement process to include a rigorous test and evaluation program, in addition to providing budget and delivery schedule oversight. As a result, OCCAR contributes to greater defense collaboration in Europe and increased interoperability across national boundaries. Finally, OCCAR's work does not stop upon delivery of a weapons system. Rather, it continues throughout the life cycle of the program to ensure sustainment and supply chain support from cradle to grave. In addition to managing the FREMM and the U212 near future submarine program, OCCAR has also been involved in the production of the Airbus A400 Atlas military transport aircraft and the Boxer multi-role armored vehicle (MRAV), among others.[212]

The Fincantieri-built ITS *Trieste* (Photo credit: Fincantieri)

While OCCAR has consistently facilitated the production of quality platforms, Fincantieri encountered a very different experience during its efforts to build the *Constellation*-class frigate. Fincantieri often struggled to work with the U.S. government, lacking the same deep working relationship it had forged with the Italian government over several decades. Poor communication between buyer and seller and the U.S. Navy's changing expectations regarding the design and capabilities of the frigate resulted in an uneven development process that ultimately doomed the project. Yet despite the *Constellation*'s failure, Fincantieri Marine Group stated it expects to receive new orders for other U.S. naval vessels including amphibious, icebreaking, and special mission vessels. The company emphasized that the agreement with the Navy guarantees continuity and workload visibility for its workforce of approximately 3,750 skilled workers across four U.S. shipyards. Whether both Fincantieri and the U.S. Navy can learn from the failures of the *Constellation* program will likely determine the success of future collaboration between the two.

Infrastructure

Italy's shipbuilding industry is distributed across five major areas in Italy.[213] Warship production occurs in four port facilities owned and operated by Fincantieri—Genoa (headquarters of the Naval Division), Muggiano, La Spezia & Riva Trigoso, and Sestri Levante. Italy has planned investments of over €3 billion to modernize port infrastructure including digitization, sustainability, infrastructure upgrades, and security.[214] Additionally, Fincantieri purchased a major port in Ancona in 2025, with plans to invest €40 million towards its modernization.[215]

Both Italy and Fincantieri offer a significant footprint for new construction warships, icebreakers, and auxiliaries, as well as the ability to conduct modernization and repair of older ships in inventory. The Monfalcone shipyard in particular serves as the nerve center of Italy's commercial shipbuilding industry. Originally founded as a small family business off the Adriatic coast, Monfalcone's proximity to transportation arteries, both road and railway, and its small population made it an ideal location, as supply chains can easily reach the shipyard. Further, its location outside of popular urban areas allow for expansion and new construction. While the yard caters to the construction of commercial vessels, Monfalcone was once a military asset due to its repair and drydock facilities and was accordingly targeted and destroyed in both World Wars. Each time the yard was destroyed, it was rebuilt bigger and better than before, eventually becoming known as "The Great Factory" and fostering economic growth in the surrounding area. After World War II, the shipyard focused solely on luxury liners and, by 1993, had broken the 100,000-ton record for a passenger liner in a contract with Carnival Cruise Lines (CCL) for the *Carnival Destiny*.[216] Since 1990, Monfalcone has produced over 40 cruise ships, establishing itself as one of the industry's largest builders of luxury cruise vessels.

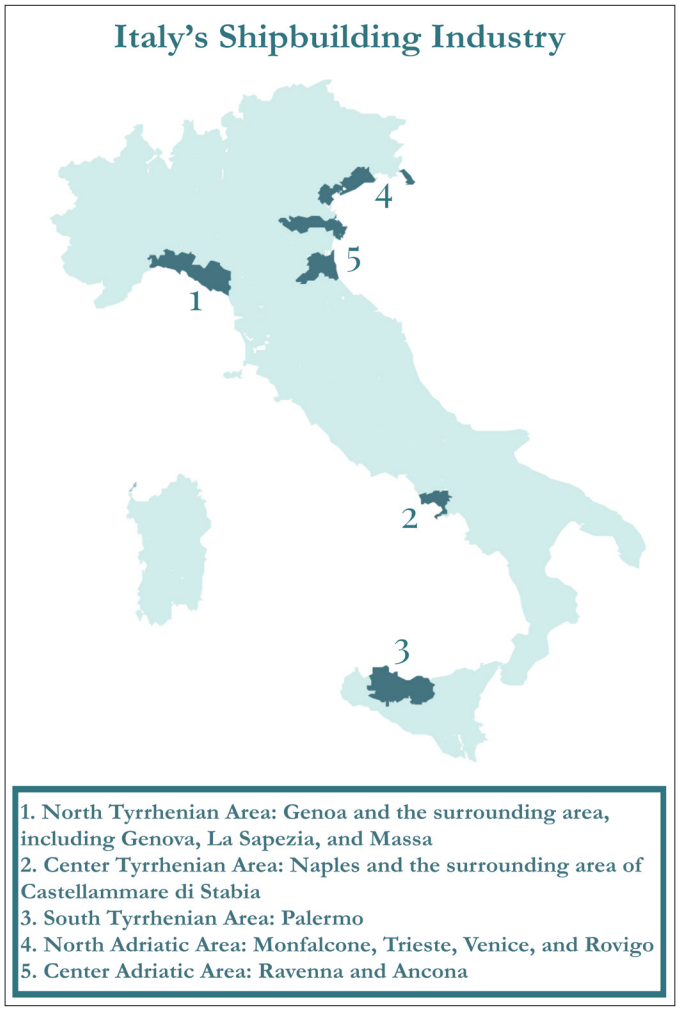


Figure 9: Map of Italy's Shipbuilding Industry (Original graphic by the Center for Maritime Strategy. Data sourced from Organisation for Economic Co-operation and Development.)

Fincantieri embarked on a capital improvement program in 2008 to double the yard's capacity for hull prefabrication with the installation of two new gantry cranes with a capacity of 1,000 tons each.[217] The Monfalcone shipyard covers a total land area of approximately 8.5 million square feet, including 252,000 square meters of covered structures which house the preponderance of prefabrication facilities. There is one main drydock (350 by 56 meters) and two outfitting quays of over 500 meters. Figure 10 shows the modern footprint.

As the size and complexity of new construction luxury liners has grown, so have the requirements for the shipyard. As it did in 2008, Monfalcone is upgrading and modernizing its facilities with a €120 million investment in two new gantry cranes that will not only double the lift capacity, but also significantly increase the height and width of existing lift capability. In doing so, the shipyard will be able to reach new dimensions in cruise ship design. At any given time in the shipyard, there is one ship in the prefabrication phase on a panel line under cover from the elements, one ship being assembled in

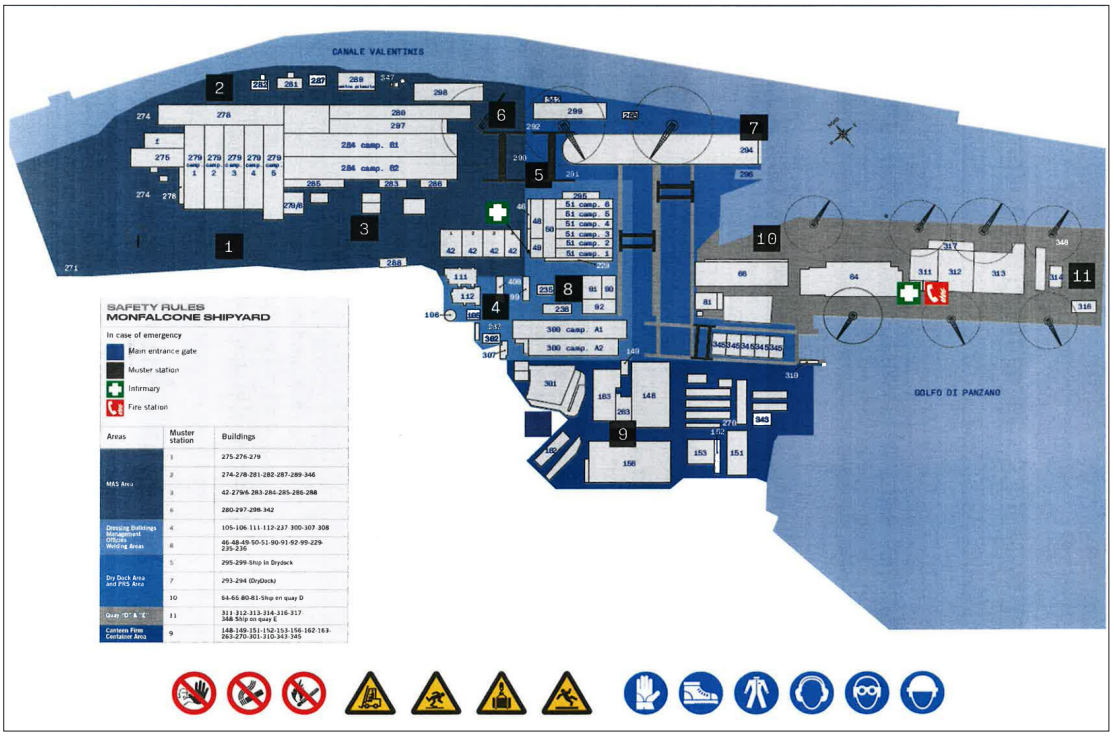


Figure 10: Map of Monfalcone Shipyard (Source: Fincantieri).

an uncovered drydock, and one ship afloat for final outfitting. This allows for the simultaneous construction of three shipbuilding projects.

Fincantieri also operates four shipyards in the United States, including three Wisconsin-based yards focusing on shipbuilding and repair (Fincantieri Marinette Marine, Fincantieri Bay Shipbuilding, and Fincantieri ACE Marine) and one repair facility based in Jacksonville, Florida (Fincantieri Marine Repair).[218] Despite Fincantieri's aforementioned $800 million investment in these facilities, the infrastructure and modernization of the Marinette yard pales in comparison to what CMS observed at Monfalcone. However, Fincantieri Marinette Marine was unable to showcase the impact of Fincantieri's planned and completed infrastructure updates (which include a new robotic panel line, a climate-controlled construction shed, ship lift, and blast and paint facility) due to the premature cancellation of the *Constellation* program.[219] Having completed only 12 percent of the program at the time of its cancellation, Fincantieri was unable to invest much of the funding it would have received from the full execution of the contract into further modernizing its American yards.[220] Absent a stronger and more stable demand signal in the U.S. market, Fincantieri understandably has not significantly increased investment in its American infrastructure given the uncertainty regarding its position there.

Fincantieri's diverse distribution of its maintenance facilities and drydocks could enable Italy to play a larger role in supporting maintenance and repair for American ships

Finally, Fincantieri has also expanded its operations beyond Italy and the United States. Fincantieri owns three Norwegian shipyards, two in Romania, one in Brazil, and another in Vietnam. These acquisitions have helped expand the reach of the Italian shipbuilding industry and support Fincantieri's penetration into diverse global markets. Furthermore, Fincantieri's diverse distribution of its maintenance facilities and drydocks could enable Italy to play a larger role in supporting maintenance and repair for American ships that might otherwise need to return to the United States, particularly those operating in the European theater.

Supply Chains

The Italian shipbuilding industry has a complex and interconnected supply chain that is supported by over 14,000 companies.[221] As of 2022, 32 percent of the value-added content in Italian naval exports comes "from Italian companies supplying materials, components, and services necessary for shipbuilding, indicating a relatively autonomous supply chain with moderate dependence on foreign suppliers."[222] Additionally, 60 percent of the economic impact from the Italian shipbuilding industry remains in Italy, which speaks to the industry's ability to successfully source a significant portion of its parts indigenously.[223] Recent years have seen Italian shipyards producing fewer parts on-site, instead outsourcing this production to external firms. As of 2024, roughly 70 to 80 percent of parts were produced outside the plants of the main shipbuilding contractors and companies, with Fincantieri describing itself as a "de facto system integrator" ensuring coordination between the company's shipbuilding operations and its extensive web of suppliers.[224]

Italian shipbuilding companies have also sought to acquire smaller manufacturers to ensure a steady flow of essential parts, with some subsectors seeing an increase in vertical integration to gain greater control over their supply chains and maintaining production capacity.[225] The De Wave Group recently acquired four Italian companies in the cruise and yachting sectors, establishing the Italian Shipbuilding Supply Chain Hub in efforts to boost production capacity.[226] However, the industry still experiences supply chain challenges. Between 2018 and 2020, the average building period for Italian cruise ships increased from 1,072 days to 1,867 days, owing in part to supply chain bottlenecks which were exacerbated by the COVID-19 pandemic.

To address these challenges, Fincantieri is incorporating additive manufacturing at its Monfalcone shipyard as part of a broader "smart manufacturing" upgrade to enhance efficiency, reduce component weight, and improve performance. The additive manufacturing hub is located within 30 minutes of the shipyard in the city of Udine which hosts several additive manufacturing facilities, ranging from industrial research hubs to specialized medical and commercial service centers. Fincantieri has also begun conducting real-time logistics tracking at the Monfalcone shipyard by integrating physical assets into a unified digital twin of the yard. This system treats logistics as a core thematic area within its broader smart manufacturing framework. The yard utilizes a network of sensors and internet-of-things devices to gather real-time data on the movement and status of materials and prefabricated product streams. Data from physical shipments and shipyard assets travel through communication networks into a centralized data lake. This allows logistics teams to access a single source of truth for tracking inventory and identifying production bottlenecks. Managed through its subsidiary Fincantieri NexTech, the shipyard uses specialized electronics and automation systems to provide end-to-end product support and monitoring. These innovative approaches to addressing supply chain issues are worthy of consideration for utilization in American shipyards.

Key Findings

During the interwar period, the owners of Monfalcone commented that

> One of the indications of the technical and organizational perfection achieved by a shipyard is its ability to win orders from abroad. It is, indeed, in the international market that the greatest battles are fought between the main shipyards of the World. Victory will only go to those who, in addition to offering a competitive price, can also guarantee vast experience and deep technical and constructional ability.[227]

The Italian shipbuilding industry has certainly taken these lessons to heart. Its success in commercial cruise ship production allows its premier builder of warships to remain commercially viable amidst a tumultuous market and survive financial hits that might sink many of its competitors, such

as the loss of the *Constellation* contract. Through its embrace of world-class automation and process-oriented approach to shipbuilding, Fincantieri has laid a blueprint for commercial dominance while developing many processes which could prove applicable to the development of naval ships. While Italy is unable to keep pace with countries like China that can produce commercial vessels at scale, Fincantieri's willingness to specialize its commercial shipbuilding on cruise ships presents a compelling pathway for the United States and other maritime nations looking to carve out a niche for themselves in the commercial market. Italy's ability to identify and play to its strengths in ship design has allowed companies like Fincantieri to focus their R&D efforts on refining shipbuilding processes and identifying innovative ways to incorporate disruptive technologies into the design and construction of its vessels.

Finally, American shipbuilders can look to Fincantieri's integration of CBM when designing future warships. For example, some CBM+ features have been incorporated into the design of the proposed replacement for the *Constellation*-class frigate (the variant of the *Legend*-class National Security Cutter currently being built for the U.S. Coast Guard by HII).[228] Like the FREMM, the cutter is instrumented with thousands of sensors that feed terabytes of data into a Coast Guard system. This is a positive step that enables the ship's Machinery Plant Control and Monitoring System to capture digital performance parameters and identify out-of-specification conditions. The system has not yet evolved to predict faults in onboard systems, but this is a goal of the Coast Guard's Reliability Centered Maintenance strategy for future operations. Ultimately, the Navy and HII have an opportunity to build the next frigate with a sophisticated CBM+ system from the keel up. While it remains to be determined what new systems will be incorporated into this parent design, Fincantieri's integration of CBM+ into the FREMM presents a compelling model for American shipbuilders to follow in designing similar warships in the future.

SWOT: Italian Shipbuilding

Strengths	Weaknesses
• Capability to produce a diversity of ships • Fincantieri set the global market standard for cruise ship production • Ability to collaborate with allies via OCCAR • Embrace of modern technologies like CBM and robotics • Fincantieri's diverse shipbuilding facilities in the United States, Europe, South America, and Asia which enable the company to compete in multiple international markets • Process-centric construction philosophy • Implementation of autonomous quality control measures (drones checking welds)	• Difficulty in recruiting, retaining, and training labor for Marinette Marine Shipyard • Sole-source supplier for Italian submarines
Opportunities	**Threats**
• Fincantieri's American presence enables it to license designs of its Italian ships to compete for American naval contracts • Growing concerns of threats to CUI could incentivize a more robust market for the ASW frigate and Italian submarines. • $800 million investment into Fincantieri Marinette Marine and Fincantieri Marine Repair • Market exists for U.S. Navy and Coast Guard new construction and repair in U.S. shipyards • Marinette Marine has excess capacity and builder expertise with LCS platform	• The continued growth of Chinese commercial shipbuilding could further erode the competitiveness of Italian commercial shipbuilding • Cancellation of USS Constellation class frigate threatens long-term viability of Fincantieri Marinette Marine Shipyard • Competition for both submarine and surface ships in the global marketplace

Figure 11: Strengths, Weaknesses, Opportunities, and Threats (SWOT) for Italian shipbuilding (Original graphic by the Center for Maritime Strategy)

Canada

While commercial shipbuilding no longer plays a significant role in Canada's MIB, America's northern neighbor has developed a maritime industrial ecosystem that reflects its unique security and economic environments. This case study traces Canada's long maritime history and shows how renewed competition in the Arctic, combined with melting sea ice and new sea lanes, has elevated the importance of icebreakers and Arctic patrol vessels while also creating new opportunities for Canadian shipbuilders. The centerpiece of Canada's efforts to revitalize its MIB is the National Shipbuilding Strategy, which has sought to end the industry's boom-and-bust cycle by providing a stable, multi-decade demand signal to its major domestic shipbuilders. This strategy has provided an impetus for the recapitalization of Canadian shipyards and their embrace of more modern shipbuilding technologies. The case study outlines how Canada has successfully specialized in its naval shipbuilding to emerge as an important player in multinational naval endeavors, as well as Canada's capacity to play a larger role in support of America's Navy.

To support this case study, CMS's experts traveled to Canada in January 2026 to observe Seaspan's Vancouver Shipyards, Vancouver Drydock, and Victoria Shipyards. CMS also conducted interviews with both American and Canadian representatives of Seaspan Shipyards, as well as officials representing Canada's Department of National Defence. Unless otherwise cited, all insights included in this case study are derived from these site visits and interviews.

History and Background

Maritime transportation in Canada predates Canada itself. The First Nations used small boats to navigate the inland waterways long before the first Europeans came to the mainland by way of oceangoing ships. Canada's initial prosperity during French and British colonization depended on its connections to Europe which could only be maintained through ocean shipping. Canada borders three oceans and has a vibrant inland shipping economy thanks to the Great Lakes, St. Lawrence Seaway, and numerous rivers throughout the country. In the 1660s, the first shipwrights came to Canada from France, bringing with them the most modern naval architecture practices of the time.[229] The first shipyard was established by Jean Talon, Quebec's Intendent, on the St. Charles River in 1663. Shipbuilding in Canada was almost entirely state-sponsored during French control of Quebec. To boost shipbuilding, the French parent government elevated shipwrights to be in a position of high respect. Shipwrights were seated equally with naval officers in the *conseils de construction*, France's society for naval professions founded in 1765.[230] While not treated the same as admirals, master shipfitters were empowered to make the same sort of decisions on vessel construction projects that a modern Supervisor of Shipbuilding or Program Manager might, such as ordering ship structural modifications. Canada's golden age of shipbuilding was in the 19th century when its vast timber resources enabled it to produce large volumes of ships domestically. During this time, Canada exported timber to the British Isles at a significant cost advantage given the lack of tariffs and duties.[231]

Canada demonstrates what is possible when a long-term fleet acquisition plan is prioritized over politics.

While Canadian shipbuilding experienced a period of decline as the industry transitioned from wooden to steel hulls, it was buoyed by the rising demand for ships with steam propulsion to help navigate North America's inland waterways. Steam shipbuilding in Canada began in 1809 in Montreal where the hull and machinery were built for the steam vessel *Accommodation*.[232] The rapid geographic expansion of the United States in the mid-1800s meant that there was significant demand for shipping. This helped keep Canadian shipbuilding steady throughout the 19th century and, for a brief time, Canada was the third largest shipping nation in the world by tonnage.[233]

The industrial revolution and the onset of steel hulls required significant investment to recapitalize Canada's shipbuilding industrial base at the turn of the 20th century. Canada's first steel shipyard, the Collingwood Shipyard and Drydock Co., produced its initial steel ship, the SS *Huronic*, in 1901.[234] As tensions rose in the leadup to World War I, Britain called upon Canada to contribute to global maritime security and establish its own independent navy.

In 1918, Canada formally established the Canadian Government Merchant Marine (CGMM) to create a fleet of government-owned merchant ships. The first order was placed in April 1918 for four vessels.[235] While Canadian shipbuilding declined in the years following World War I, it was reinvigorated by the onset of World War II and, by 1945, Canada was the fourth-largest shipbuilding nation in the world.[236] After the war, Canada established the Canadian Naval Shipbuilding Programme, which further developed the Canadian Navy and kept the shipbuilding industry vibrant.[237] In 1980, the Canadian government reduced the shipbuilding subsidy from 14 percent to only nine percent with a maximum of CAD 75 million applied for three consecutive years, which caused the industry to decline. By 1990, commercial orders only made up five percent of Canadian shipbuilding—a story similar to that of the United States.[238]

Royal Canadian Navy Combatant Vessels	
Ship	**Quantity**
Halifax-Class Frigate	12
Kingston-Class Coastal Defence Vessel	4
Harry DeWolf–Class Arctic and Offshore Patrol Vessel	4
Orca-Class Patrol Vessel	8
Victoria-Class Submarine	4

Figure 12: Royal Canadian Navy Combatant Vessels (Original graphic by the Center for Maritime Strategy. Data sourced from Globalmilitary.net)

Today, increasing Arctic sea ice melt has renewed interest in the Northwest Passage for commercial shipping. Canada seeks to enhance its Arctic operational capabilities and develop its naval and coast guard fleets to reinforce its national sovereignty. Time is of the essence as adversaries like China increase the frequency of their operations in the Arctic. To match this emergent threat, the Royal Canadian Navy (RCN) has 40 combatant ships and 32 support ships for a total fleet size of 72 ships. Figure 12 outlines the breakdown of RCN combatant vessels.[239] In addition, the Canadian Coast Guard (CCG) operates a fleet of 18 icebreakers, with more anticipated in the coming years.[240]

In 2010, Canada launched its National Shipbuilding Strategy (NSS) to modernize its RCN, CCG, and Transport Canada fleets—a landmark document that continues to impact shipbuilding policy today. Canada sought to reinvigorate its MIB which had atrophied in the 1990s and early 2000s—a decline similar to the one experienced by the United States during this period. The NSS is similar to Canada's previous Naval Shipbuilding Programme in that it aims to strengthen the Canadian MIB with a focus on sustained warship production, even though Canada is not currently in an active conflict. The NSS aims to provide a stable demand signal with projects lasting through the 2040s—a continuous-build approach which aims to incentivize public and private investment in shipbuilding and end the boom-and-bust cycle that has plagued the industry in decades past. As Canada does not have public shipyards, the NSS focuses on investment and signalling demand to private shipyards.[241] The NSS is the foundation of Canada's maritime industry and, since 2010, it has survived three different prime ministers, including a shift from the Conservative Harper government to the Liberal Trudeau government in 2015. Under the leadership of Prime Minister Mark Carney, the NSS continues to dictate Canada's orderbook for ships. In the United States, it is rare for a single class of ship to last through its fully intended class size. Canada, on the other hand, has kept an entire fleet composition policy consistent for over 15 years and through multiple changes in government leadership. Canada demonstrates what is possible when a long-term fleet acquisition plan is prioritized over politics.

The NSS is being implemented in five phases: developing the strategy, selecting the shipyards,

establishing relationships with the shipyards, designing the vessels and upgrading the shipyards' infrastructure, and constructing the vessels.[242] While the first three phases are complete, as of this writing, phases 4 and 5 are still in progress. The upgrades to shipyard infrastructure to meet the Canadian government's Target State requirements—confirmation that all of the basic skills to build ships are present to a reasonable level of competence—are being done privately by the shipyards without public investment. This includes a "design-then-build" approach, counter to the build-while-designing approach that the United States has taken in recent years.[243]

The NSS is also focused on three pillars:

1. Construction of large vessels (1,000 tonnes displacement and greater)
2. Construction of small vessels (less than 1,000 tonnes displacement)
3. Vessel repair, refit, and maintenance.[244]

Pillar 1 of the NSS calls for 55 large ships over 10 different classes. Initially, two shipyards were chosen to build Pillar 1 ships: the Canadian-owned Irving Shipbuilding in Halifax to build combatant ships, and the American-owned Seaspan's Vancouver Shipyards to build non-combatant ships. The British-owned shipbuilder Chantier Davie was added as a third NSS Pillar 1 shipyard in 2023 to supplement icebreaker production.[245] Figure 13 shows the breakdown of the NSS ships, the number in each class, and which shipyard is building them.[246] As of 2023, Pillar 1 of the NSS had contributed roughly CAD 15.5 billion to Canada's GDP.[247] Projected numbers for Pillar 1 specifically are not available.

Canadian National Shipbuilding Strategy
Pillar 1 (≥1,000 Tonnes) Orders

Class	Quantity	Builder
Joint Support Ships	2	Seaspan
Arctic and Offshore Patrol Ships, Navy Variant	6	Irving
Canadian Surface Combatants (*River*-Class)	15	Irving
Offshore Fisheries Science Vessels	3	Seaspan
Offshore Oceanographic Science Vessels	1	Seaspan
Multi-Purpose Icebreakers	Up to 16	Seaspan
Arctic and Offshore Patrol Ships, Coast Guard Variant	2	Irving
Program Icebreakers	6	Davie
Polar Icebreakers	2	Davie and Seaspan
Transport Canada Ferries	2	Davie

Figure 13: Pillar 1 (≥1,000 tonnes) order breakdown of the National Shipbuilding Strategy (Original graphic by the Center for Maritime Strategy. Data sourced from Government of Canada.)

Interestingly, each of Seaspan's three sites (Vancouver Shipyards, Victoria Shipyards, and Vancouver Drydock) are considered separate contractors by the government of Canada, even though they are all under Seaspan ownership.[248] This means Seaspan has three different contractors that can compete for a shipbuilding or ship repair contract, whereas the other two Pillar 1 yards only have one yard each.

Additionally, Seaspan Shipyards and Chantier Davie benefit from the ICE Pact trilateral agreement between the United States, Canada, and Finland. Under the ICE Pact, the U.S. Coast Guard will acquire six Arctic Security Cutters (ASCs) based off of Seaspan's Multi-Purpose Icebreaker design.[249] The first two of the Seaspan ASCs will be built at Rauma Marine in Finland, while the remaining four ASCs will be built at Bollinger Shipyards in Lockport, Louisiana, using the best practices identified during the Finnish building process. Similarly, Davie will start ASC production in Finland at its Helsinki Shipyard and then bring best practices to the Gulf Copper shipyard in Texas, which is owned by the British company Inocea. The NSS made icebreakers a clear priority for Canada, and Seaspan was eager to show the CMS team the polar icebreaker steel forming during the team's visit.

Pillar 2 of Canada's NSS includes building small vessels for the RCN and CCG, which has generated roughly CAD 389.4 million for the Canadian economy.[250] The small vessels feature large naval tugs from Ocean Industries, air cushion vehicles (hovercraft) from Griffon Hoverwork, and

Canadian National Shipbuilding Strategy Pillar 2 (<1,000 Tonnes) Orders					
Project	**Status** (as of January 30, 2026)	**Shipyard Constructing Vessels**	**Construction Region(s)**	**Quantity**	**Department Using Vessel**
Air Cushion Vehicles	Ongoing	Griffon Marine	Southampton, U.K.	4	Canadian Coast Guard
Channel Survey and Sounding Vessels	Completed	Kanter Marine	Ontario	2	Canadian Coast Guard
Coastal Patrol Boats	Solicitation phase	Undetermined	Undetermined	3	Royal Canadian Mounted Police
Coastal Research Vessels	Completed	Kanter Marine	Ontario	1	Canadian Coast Guard
Hydrographic Survey Vessels	Completed	Kanter Marine	Ontario	7	Canadian Coast Guard
Mid-shore Multi-mission Vessels	Design phase	Undetermined	Atlantic, Central, and Western Canada	Up to 6	Canadian Coast Guard
Naval Large Tugs	Ongoing	Ocean Industries	Quebec	4	Department of National Defence
Near-shore Fishery Research Vessels	Ongoing	Chantier Naval Forillon	Quebec	1	Canadian Coast Guard
Search and Rescue Lifeboats	Ongoing	Chantier Naval Forillon and Hike Metal Products	Ontario and Quebec	20 (10 per shipyard)	Canadian Coast Guard
Steel Barges	Completed	Canadian Maritime Engineering	British Columbia	4	Department of National Defence

Figure 14: Pillar 2 (<1,000 tonnes) order breakdown of the National Shipbuilding Strategy (Original graphic by the Center for Maritime Strategy. Data sourced from Government of Canada).

search and rescue lifeboats from Hike Metal Products and Chantier Naval Forillon. Numbers of vessels are subject to change, but the Canadian government states that, as of 2023, "the small vessel pillar of the NSS has successfully provided 26 ships to the CCG."[251] Figure 14 outlines the small vessel shipbuilding projects under the NSS.[252] For vessels in the solicitation and design phase, shipyards have yet to be selected.

While Pillar 3's in-service support projects cover numerous Canadian vessels, the pillar primarily supports two main projects: the *Halifax*-Class Work Period (HCWP) for vessel modernization and service life extension and the in-service support for the *Victoria*-class submarines. The HCWP is taking place at Irving, Davie, and Seaspan yards. Seaspan's Victoria Shipyards is the only private shipyard conducting *Victoria*-class in-service work. There are numerous smaller shipyards undertaking maintenance and repair work for other CCG ships and Canadian Armed Forces minor warships and auxiliary vessels.[253]

Pillar 3 also includes in-service support for the Pillar 1 Arctic and offshore patrol ships (AOPS) and joint support ships (JSS). In 2017, Thales Canada was awarded an CAD 800 million in-service support contract for these two classes for an initial service period of eight years with options to extend up to 35 years. The total cost of the contract, including the 35-year extension, would be CAD 5.2 billion.[254]

The total value of NSS contracts awarded as of 2022 exceeded CAD 21 billion.[255] Estimates for the total value of NSS contracts are closer to CAD 100 billion, with the majority of costs attributed to the *River*-class destroyer program.[256] Figure 15 shows the 10 largest contractors in the NSS by total contract value and by category of work.[257]

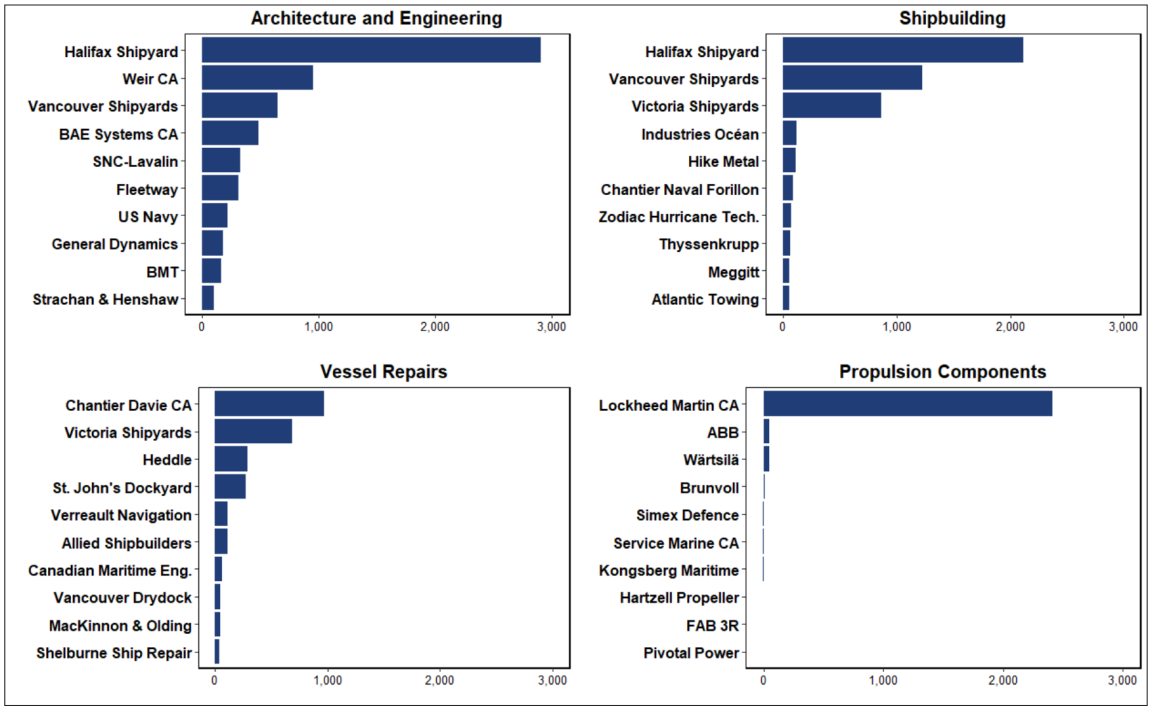


Figure 15: National Shipbuilding Strategy contractors (CAD millions) (Source: HillNotes)

Figure 16 shows how and on what each department is spending NSS money as of 2023.[258] The Department of National Defence's (DND) expenses supported the RCN while the Department of Fisheries and Oceans' expenses supported the CGG, though the CGG has subsequently been brought under the control of the DND to reflect its shift to being more of a military organization focused on maritime security and Arctic sovereignty.

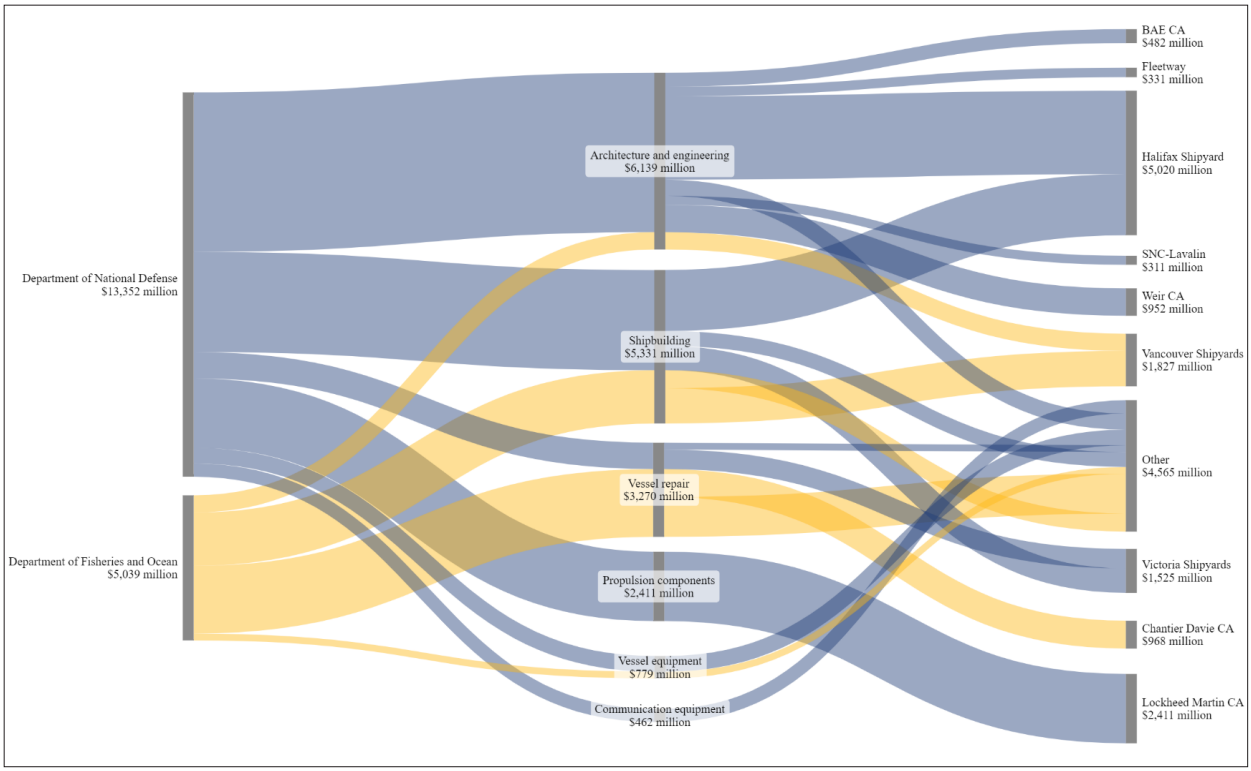


Figure 16: National Shipbuilding Strategy contractors by department, category, and contractor. This chart does not include Transport Canada. The Canadian Coast Guard is reflected as part of the Department of Fisheries and Ocean, even though it has been under the Department of National Defense since September 2025. (Source: HillNotes)

Finally, the NSS includes a Value Proposition (VP) clause that requires the large vessel yards (Irving, Davie, and Seaspan) to invest their own capital at a rate of 0.5 percent of NSS contract value into human resources development, technology development, and industrial development.[259] The VP requirement helps the major NSS shipyards address the labor, workforce, and technology integration issues addressed later in this case study.

Labor and Workforce

Canadian shipyards, like many others globally, have long struggled to manage the boom-and-bust cycle with periodic layoffs. One of the big challenges in Western Canada is the competition for skilled trades across sectors. For example, the construction of large LNG liquefaction and export terminals offers higher wages in comparison to shipyards. However, the higher-paying LNG projects are often further away from major cities and require worker relocation that shipyard employment does not. Shipyards still offer competitive wages relative to the local markets, and sometimes pay up to 35 percent more than local non-shipyard manufacturing jobs.[260]

Under the NSS, Canada's shipbuilding industry supports just under 10,000 jobs, and that number is steadily growing.[261] As in the United States, many Canadian shipyards work with union halls to source labor. The only noticeable tensions with respect to labor have to do with the fact that two ferry companies, Marine Atlantic on the East Coast and BC Ferries on the West Coast, each procured ferries from China instead of building them in Nova Scotia and British Columbia, respectively.[262] Because of a shortage of skilled tradespeople, Seaspan and Irving have started in-house apprenticeship programs to train people for work in their shipyards. Starting from trainees with zero experience, these programs culminate with apprentices sitting for the Red Seal exam in their respective trade, typically after two to five years.[263] The Red Seal exam is Canada's national standard for skilled trades, which in turn allows tradespeople to move throughout the country to different jobs without having to take a pay cut to recertify their skills when they move to a new employer. Seaspan has educational partnerships with the British Columbia Institute of Technology, University of British Columbia, Camosun College, and Simon Fraser University. Similarly, Irving Shipbuilding has an educational partnership with Nova Scotia Community College. When asked about workforce development, Seaspan responded that they aim to grow their workforce by 17 percent each year. Canadian shipbuilders increased their hiring to match the rise in demand spurred by the NSS, for which Seaspan first began cutting steel in 2015. Accordingly, Seaspan reports that the vast majority of its skilled trade workforce has less than five years of tenure with its shipyards. Canada's shipbuilding workforce is considerably younger than America's, with Irving Shipbuilding reporting an average worker age of 39 in 2023.[264]

Through competitive wages, educational partnerships, and a strong naval architecture program, Canada is growing its shipbuilding workforce to meet the demands of its NSS.

Seaspan's shipyards are impressive to see in action. The yards are exceptionally clean, the workforce appears motivated and on task for the entirety of their shift, and the general attitude of the shipbuilders reflects an immense pride in their work. When project demands require it, Seaspan uses overtime to increase throughput. Seaspan offers their workers two times the hourly wage for overtime, unlike in the United States where 1.5 times the normal hourly wage is the standard for overtime work. This difference seems small but is intended to encourage worker retention and prevent labor flight to other comparable industries in which working conditions are considered to be less strenuous.

Canada only has one accredited Naval Architecture program, located at Memorial University Newfoundland. Although the program is small (eight to 25 undergraduates and 22 to 23 graduates each year), its students rank near the best in the world, having earned three out of six undergraduate scholarships from the Society of Naval Architects and Marine Engineers (SNAME) and two of eight SNAME graduate scholarships in 2025.[265]

Through competitive wages, educational partnerships, and a strong naval architecture program, Canada is growing its shipbuilding workforce to meet the demands of its NSS. Canada has kept trades careers attractive in part by providing a broad range of options through its Red Seal national standard. A steady demand signal combined with an easily transferrable national certification creates a job market where choosing a trade does not stovepipe someone into a volatile career.

Technology Integration

About 10 percent of the shipbuilding process at Vancouver Shipyards is automated—only slightly behind the 12.8 percent automation of the Geoje shipyard in Korea. This automation includes plate burning, blasting, end prep, welding, and Computer Numerical Control (CNC) marking for stiffener placement. CMS observed Seaspan's robotic welding machines which include induction heating technology that eliminates the need for hand-placed strip heaters (a very time-intensive process) and results in no deformation after the weld processes. This technology cuts down on both the number of people needed to complete the process and the time it takes to produce a fault-free part. Additionally, Seaspan's robotic welders provide significantly improved quality control compared to the manual process, drastically reducing the amount of rework required. These robotic welders are particularly useful for the manufacturing of polar icebreakers, as they can operate in tight spaces required to produce the ice framing for these vessels. Seaspan executives reported that their workforce has embraced this technology, which has produced a higher quality of work and less intensive labor for its workforce. Because there is shortage of skilled labor, robotic technologies have thus far not displaced trades workers from job opportunities and have instead allowed shipyards to reassign workers to areas of greater need to help accelerate the production process.

In addition to smaller robots for more intricate welding requirements, Seaspan also makes use of other robotic and automated technologies including machines for steel plate cutting, marking, and welding. Notably, Seaspan uses the same PEMA machines that Fincantieri uses at its Monfalcone shipyard. Seaspan reported significant success using cobots to weld piping at its offsite sub-assembly manufacturing locations and noted that its robotic systems have improved panel assembly time between 400 and 1,000 percent, depending on the piece.

Similar to the barcode system used at American submarine yards, Seaspan puts a QR code on every piece of steel. As each piece is scanned throughout the assembly process, the QR codes allow the project managers to track every piece of steel for a ship as it goes from being cut to being installed. This digitized individual item tracking allows the engineering and leadership teams to view ship construction progress in real time from the office without having to walk into the yard. Seaspan is also considering utilizing RFID item and worker tracking to more effectively monitor shipyard operations.

The Canadian government is making significant investments in non-conventional manufacturing methods, including additive manufacturing, robotics, automation, and laser applications. The Canadian government supports a Next Generation Manufacturing supercluster that has received CAD 427 million as of 2023 from federal sources.[266] Canada also has a federal agency—Innovation, Science, and Economic Development Canada (ISED)—which supervises investments and programs for academia and industry. Irving Shipbuilding is also the largest private sector investor to the Centre for Ocean Ventures and Entrepreneurship (COVE), having invested over CAD 10 million.[267] COVE's mission is to help small businesses scale to compete with established corporations in shipbuilding. Investments such as these underscore the commitment of the Canadian MIB to embracing digitization and further innovation in shipbuilding technologies.

CMS observed the use of several digital tools at Seaspan's shipyards. One such technology is the Cadmatic software, which centralizes drawings and technical details for a ship in a common operating system that updates across all locations. Seaspan also uses Revizto, a software that creates digital twins of different work orders to provide shipyard workers a more realistic view of

the ships they are building than a black-and-white paper drawing could. Finally, Seaspan utilizes WeldEye, a program which tracks every aspect of welding. This includes the details, procedures, non-destructive testing, and status for every weld, in addition to the training, credentials, and assigned work of every welder. Seaspan's commitment to digitization and automation demonstrates motivation to advance their shipbuilding methods into the twenty-first century. The long order book and stable demand signal of the NSS have allowed Seaspan and other shipyards to invest in better integrating digital and automated technology into its shipbuilding processes, reflecting the company's confidence in the long term stability of the long-term prospects for the Canadian shipbuilding industry.

Design and Manufacturing Process

The Canadian shipbuilding industry's investments in upgrading its shipyard technology have meaningfully improved its design and manufacturing process. According to Seaspan, the most significant timesaving advancement made in recent years has been the CNC marking of plates to show where the stiffeners and joints were to be put on the plate. This eliminates the need for workers to look at plans, measure the plate, and mark the plate before welding the next piece of steel on, functionally allowing one CNC robot to perform three jobs at once. Seaspan revealed to CMS that its Vancouver Shipyards can manually weld 2,500 meters daily, in addition to 2,000 meters welded through automation for a total of 4,500 meters or 14,764 feet per day.

Telerex TXB CNC plate preparation robot (Photo credit: Center for Maritime Strategy)

One of the most important ships being produced at the Vancouver Shipyards is Canada's JSS, which is based on the German Navy's *Berlin*-class refurbishment ship. Seaspan started construction on this ship once the structural design was complete, but before the detailed outfitting design was finished. Although this is a common practice in the United States, Canadian shipyards prefer to wait until a design is finalized before starting construction. Seaspan's agreement with the CCG specifies that Seaspan would not start construction until a fully complete 3D model was finished. The timelines of design and construction were easier to control for the CCG because Seaspan was producing the design in-house. "Complete," in the eyes of Seaspan, means a 100-percent complete design. After construction begins, changes may only be made following a red line process that will impact following ships of the class. The JSS vessels being built for the RCN are constructed to military specifications, whereas the CCG ships are built to a commercial-plus standard (a commercial safety standard with some added requirements). An exception is that the Canadian frigate is built to commercial safety standards rather than making further changes to the parent design to align the ships with warfighter standards. Seaspan executives spoke to the mistakes of overly changing a parent design with the first *River*-class destroyer, a modified version of the British Type 26 frigate that started construction at Irving Shipbuilding in 2024. Dramatically changing the parent design led to construction delays and cost increases for this vessel, which the company has subsequently sought to avoid. The *River*-class is discussed in greater detail in the "Purchasing and Government-Commercial Relations" section of the case study.

Seapan experiences significant savings on the follow-on vessels when building multiple ships of a class, citing 16 months of time savings and 45 percent cost savings between JSS-1 and JSS-2. Seaspan's leadership also stated that the company benefited from building a CCG vessel in between JSS-1 and JSS-2. This gap between the first and second ships of the class afforded them enough time to document and incorporate the lessons learned from JSS-1 into the subsequent vessel, ensuring that the benefits of building multiple vessels of the same class could be realized.

Purchasing and Government-Commercial Relations

Although all Canadian government surface vessels are made domestically, there is no prohibition on buying from or building in other countries. Submarines, for example, are procured from foreign nations but are overhauled in Canada. However, Canada has an Industrial and Technological Benefits (ITB) requirement for domestic ship production that requires one dollar returned to the domestic economy for every dollar that is spent outside of Canada.[268] For defense production, Canada has a Controlled Goods Program (the equivalent of the U.S. Department of State's International Traffic in Arms Regulations) which mandates that, if Canadian shipyards want to build naval ships for export, the Canadian government must inspect them to ensure there are no technologies on board that provide Canada discrete warfighting advantages.[269]

CMS and Seaspan employees tour Seaspan's Canadian shipyards. (Photo credit: Center for Maritime Strategy)

Unlike China, Canada does not directly subsidize its shipbuilding industry. Instead, Canadian shipyards receive investment from both federal and provincial governments in the form of government contracts or support for specific recapitalization projects under the auspices of the NSS. Seaspan executives revealed to CMS that Canada's government had invested CAD 270 million into Seaspan's Vancouver Shipyard in addition to the approximately CAD 871 million the government invested into Irving's Halifax Shipyard since the start of the NSS in 2010.[270] This government support helps supplement the significant private investment made by shipyard owners into improving their operational capabilities. As of 2026, Seaspan and Irving's owners had each invested between CAD 250-300 million into their respective yards.

R&D funding comes from combined investment of government and industry. However, the Canadian government has notably provided minimal support for commercial shipbuilding, which is not covered under the NSS. Accordingly, private shipowners usually build ships in Asia rather than domestically in order to save money.

While relations between the Canadian government and shipbuilding companies are largely constructive, the controversy surrounding the contract award for the Canadian Surface Combatant (CSC) is an example of tension in these relationships. The initial plan for the CSC was to create one class of surface ship to replace the *Iroquois*-class destroyers and *Halifax*-class frigates. In the initial request for proposal (RFP), the Canadian government specified that it was only seeking existing, previously built designs for consideration and received bids for ships based on Fincantieri/Naval Group's FREMM, Navantia's F-105 frigate, and Alion's *De Zeven Provinciën*.[271] However, controversy erupted in 2016 when Lockheed Martin Canada partnered with BAE Systems in submitting the British Type 26 frigate design for consideration, despite the Type 26 still being in the concept phase of development. Canada selected Lockheed Martin/BAE as the preferred bidder in October 2018, creating the *River*-class destroyer program.[272] Alion cited technical concerns in a November 2018 appeal to the Canadian government about the Type 26, seeking to overturn the Lockheed award decision.[273] Although Alion's appeal cited vessel speed and berthing capacity as issues, other parties in Canada have alleged bid-rigging and *ex post facto* changes to the RFP to favor the Lockheed Martin bid, which was the only proposed design not yet in service (the first Type 26 ship, HMS *Glasgow*, has yet to be commissioned as of the writing of this report).[274]

Although Alion's case was eventually dismissed, controversy about the *River*-class has continued as costs have skyrocketed from the initial estimates amid government secrecy regarding the program's finances and progress.[275] This controversy illustrates the enduring distrust between the Canadian government and its shipbuilding industry. While government-commercial relations

were significantly improved as a result of the NSS, industry concerns regarding the government's lack of transparency and willingness to pick favorites remain significant points of tension which could undermine shipbuilding cooperation between the public and private sectors.

Infrastructure

Seaspan, Irving, and Davie are all owned by conglomerates—the U.S.-based Washington Companies, Canadian J.D. Irving, and British Inocea, respectively. Having a family of sibling companies allows the shipyards to leverage their corporate partners and parent company assets to best expand their operations for a "federated shipbuilding" approach of taking the work to the concentrations of labor, enabling a network of companies under common ownership to share resources in support of shipbuilding projects.

Seaspan's current infrastructure is capable of supporting even more robust production than it currently manages. Seaspan revealed to CMS that its Vancouver Shipyards has room to expand work output because its afternoon and night shifts are not yet fully filled. Victoria Shipyards usually only runs two shifts a day, but can adjust to 24/7 operations when schedules require. Additionally, Vancouver Shipyards is currently undergoing a physical expansion project to create a third building way (the final assembly location for a ship before it enters the water). Vancouver Shipyards will also build a new four-acre indoor shop for block construction. The Canadian government recently lengthened the federally-owned Esquimalt Graving Dock to fit a frigate in one section, allowing the other two sections to be flooded independently for servicing other vessels simultaneously.

In recent years, Seaspan has made efforts to improve its yard's physical infrastructure to support its laborers' daily work experience. Seaspan put permanent supervisor and support offices on the waterfront so workers did not have to walk far to see their supervisor or use the restroom or dining facilities. Additionally, Seaspan evenly distributed shop tool racks throughout the shops, which helped reduce the "hoarding" of materials from the tool crib (when workers would take more materials than they needed for a job to reduce the number of trips they would need to make to the central tool crib in a day). Similarly, Vancouver Drydock and Victoria Shipyards lower portable restrooms into the drydocks which significantly cuts down on workers' break time and improves work efficiency.

Seaspan's locations on Canada's West Coast also have a unique strategic advantage being close to both the Arctic and Pacific theaters. In an Arctic conflict, Seaspan could fit U.S. vessels up to and including the size of amphibious assault ships and *John Lewis*–class replenishment oilers for repair. Outsourcing to Seaspan yards could free up space at Puget Sound Naval Shipyard to work on nuclear submarines—functionally an Arctic equivalent to the Korean yards' advantages for keeping ships in the Indo-Pacific. The Pacific has 60 percent of U.S. Navy ships, but only 33 percent of NAVSEA certified drydocks.[276] Seaspan could be a stopgap until U.S. West Coast infrastructure becomes sufficient.

While Seaspan's Vancouver Shipyards and Vancouver Drydock own their docks, Victoria Shipyards is a tenant in the Esquimalt Graving Dock, a secure facility owned by the Canadian government that neighbors the Canadian Forces Base Esquimalt. Additionally, because Seaspan designed both the ASC and its parent vessel, the Canadian multi-purpose icebreaker, the company possesses extensive knowledge of the vessels and systems and is uniquely capable of conducting battle repairs on any ASCs deployed in the Arctic. CMS assessed that Seaspan has the bandwidth to take on such additional work—its Victoria Shipyards has capacity to add a third shift not currently being utilized full time, and the yard is already accustomed to operating at a 24/7 battle rhythm to get commercial ships in and out of the drydock in as little as one to four weeks. With the yard's capacity exceeding Canadian ship repair demand, there is an opportunity for U.S. forces to take advantage of the dock space for conventional vessel repair. Since Seaspan's parent, The Washington Companies, is an American company, the Navy may be able to get a waiver to more easily conduct maintenance at

Seaspan even though it is located in Canada. From a battle repair standpoint, several of the Seaspan executives previously worked on the U.S. Navy's *Arleigh Burke*–class destroyers at Bath Iron Works.These executives already have the technical background in *Arleigh Burke*–class ships and are, in essence, an unplanned technology transfer between the yards. Furthermore, Canada's government and Seaspan's ownership have already put over CAD 500 million into Seaspan to expand the capacities at its three locations, making it more conducive to conduct U.S. ship repair or modernization in a Canadian yard. Given that America's 2026 National Defense Strategy advocates for the United States to "increase burden-sharing with allies and partners around the world," it would not be surprising to see the Navy take greater advantage of its northern ally's robust maritime infrastructure in the years to come.[277]

Supply Chains

The ITB requirement to match spending outside of Canada with domestic spending has provided a strong incentive to focus the supply chain domestically. Accordingly, Canadian shipbuilding has become vertically integrated nationally, with very few parts having to be sourced from outside Canada. Because the CCG has component commonality across science and icebreaking vessels, one supply chain provides common parts to serve multiple classes of vessels. Seaspan works with suppliers to transition international production to Canada, with most of its procurements being handled through competitive sourcing processes. Steel mainly comes from Canada and is supplemented by supply chains in the United States, South Korea, and Finland. Copper is not procured as raw material; Seaspan purchases copper piping, fittings, and cabling from the United States and Europe. However, specialized castings and forgings are difficult to acquire, and Canada often seeks U.S. manufacturers.

Seaspan operates on a mixed lifecycle sustainment model, similar to U.S. Navy practices, meaning initial spare parts for certain systems specified in the contract are made during the initial vessel construction. Additional replacement parts are produced or sourced later in the life of the ship. Long platform service lives contribute to supply chain issues similar to those seen in the U.S. Navy and Coast Guard fleets. Significant challenges arise with aging systems whose manufacturers—often sole-source manufacturers—go out of business. This can cause a loss of original design authority and intellectual property when the drawings for parts are lost or discarded, which is why some American companies have resorted to reverse engineering parts in order to make replacements. Additionally, older vessels see highly variable work scopes that are only finalized after docking and inspection, and are often expanded beyond what the Navy and shipyard originally intended. Specialty materials for warships also have their own supply chain issues due to volume, complexity, and certification of materials and suppliers.

Seaspan runs its own warehouses and logistics network offsite that connects small assembly manufacturing facilities with waterfront shipyards, optimizing space use on the waterfront while small assemblies are kept off-site until needed. Digitization has enabled Seaspan to optimize its supply chains and logistics management to maximize the efficiency of parts flow through their shipyards. Seaspan also works with other domestic suppliers to vertically integrate their supply chains within Canada as much as possible. There are long-standing relationships on the private and government level with foreign suppliers in the United States, but the volatility of tariffs and international affairs more broadly demonstrate the importance of vertical integration domestically.[278]

Key Findings

If Korea and Italy represent the ideal end state for the U.S. MIB in terms of automation, processes, and throughput, Canada is an intermediate stepping stone that provides the U.S MIB with next steps. Canada has a defined national shipbuilding strategy that provides distributed purchase orders, constant demand signals, and federal investment across three large private shipyards and numerous small yards. Canada developed a portfolio of ships that fit its needs and

made firm decisions on the design of these ships, leaving little room for late-stage changes—a lesson learned by Canada's government and shipyards from the production of the *River*-class destroyer. Given the importance of quickly building hulls and preparing them to launch, Canada has prioritized ship procurement over ship perfection. Canada faces similar supply chain and workforce development issues to the United States. Their private yards have developed their own in-house apprenticeship programs and partnered with local community colleges to highlight shipyard trades as an attractive career path. Additionally, Canada's Red Seal national standard for the trades means workers can come into the shipyard from other industries without having to take a pay cut and re-start their certification processes. Although the use of automation in Canadian shipbuilding is not as extensive as some of its competitors, the processes that have been automated have combined as many as three tasks into one and significantly reduce the time and number of workers required to complete a task—a significant benefit when skilled labor is hard to come by. Additionally, by embracing technology, unions and trades workers have been able to increase their productivity and improve their quality of life without imperiling job security. Ultimately, Canadian shipbuilding is a good example of the success that a country can have when it makes a plan, sticks to it, funds it for its full duration, and embraces technology to improve productivity.

SWOT: Canadian Shipbuilding

Strengths	Weaknesses
• Red Seal national standard for trades certification allows for job transfer without needing to take a pay cut and recertify at a different employer • National Shipbuilding Strategy creates steady demand signal with full funding for the initial order placed • Trades workforce embraces robotic and automated systems • Partnerships with academic institutions highlight careers in shipbuilding that do not require six-figure student loan debt • Investment from federal, provincial, and private entities • Finalizes a 100-percent complete design before the start of construction to minimize late-stage design changes	• Minimal commercial shipbuilding footprint • No domestic copper/cabling production • Lack of specialty casting and forging supply chains
Opportunities	**Threats**
• Familiarity with and willingness to conduct MRO on U.S. naval vessels • Room to expand geographically and physically based on holdings of parent companies • Proximity to U.S. Pacific Fleet and Arctic theaters in event of conflict and the potential for U.S. forces to take up unused shifts in Canadian yards to keep ships closer to Arctic theater during MRO • Build greater union buy-in for embracing automation to preserve jobs, not cut them	• Some underlying tensions and distrust within the sector's government-commercial relations • Increasing Chinese presence in the Arctic constitutes an emerging security threat • Vulnerability to supply chain disruptions due to significant reliance on sole-source manufacturers for ship parts

Figure 17: Strengths, Weaknesses, Opportunities, and Threats (SWOT) for Canadian shipbuilding (Original graphic by the Center for Maritime Strategy)

Sweden

Sweden's case study highlights the challenges of sustaining a credible MIB while operating on a low-rate production model. Sweden has largely abandoned its domestic shipbuilding industry, purchasing most government and commercial surface vessels from foreign builders and focusing more on vessel construction management than the domestic building of hulls. Yet Sweden has also been strategic about preserving the remnants of its maritime sector by emphasizing domestic submarine production, an increased focus on shipyard digitization, and the training of naval architects and marine engineers while proactively protecting supply chains to prevent the disruption of its maritime economy. This case study demonstrates the importance of maintaining shipbuilding knowledge under conditions of scarcity—and the risks associated with allowing that institutional knowledge to fade away.

Unlike the other four case studies, CMS did not visit a Swedish shipyard due to the sensitivity of the country's submarine-building program. However, CMS traveled to Sweden in November 2025 to conduct interviews with officials from the Ministry of Defence (Including the Swedish Defence Materiel Administration), naval officers, shipbuilding experts from Swedish Defence University and the Swedish Defence Research Agency, and representatives of three Swedish shipbuilding companies (FKAB, Soal Marine Group, and Wallenius Lines). Unless otherwise cited, all insights included in this case study are derived from these interviews.

History and Background

The Kingdom of Sweden has a long history as a maritime nation, with a shipbuilding industry dating back to the Viking Longship of the Middle Ages, arguably the most capable warship of its day. Sweden boasted an exemplary record of shipbuilding and ship operation through the 1970s, and Swedish shipbuilders held a global share of 10 percent of the world market up to 1970.[279] The cities of Stockholm and Gothenburg were dynamic centers of both shipbuilding and the shipping industry and served as the headquarters for a number of these companies. Corporations such as Broströms, Transatlantic, and the more recent Stena Line (with its concentration on ferries, tramps and offshore activities) helped propel the rise of Swedish shipbuilding and maritime vessel operation in the mid-20th century.[280] The Swedish Navy, while relatively small even in comparison with other Scandinavian navies like Denmark or Norway, has always been composed of modern combat-capable ships. Sweden's naval capabilities were particularly robust in the years immediately following World War II, owing to the country's early emphasis on developing guided missile weapons and building quiet diesel submarines.

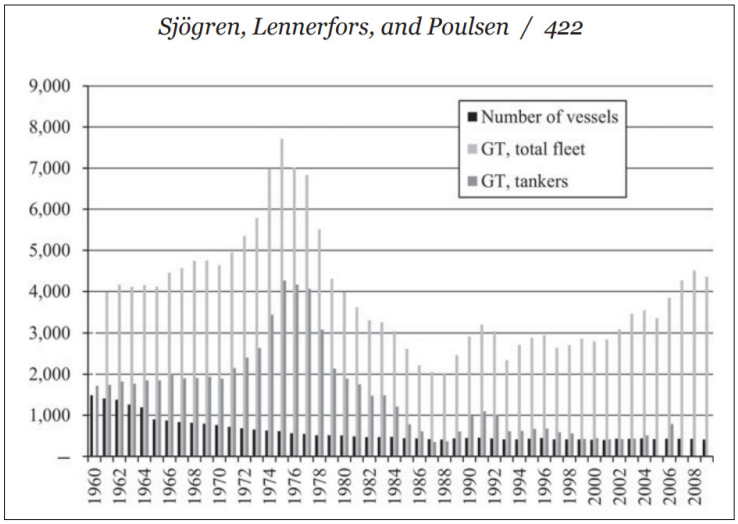


Figure 18: The Decline of the Swedish Commercial Fleet (Source: Sjögren, Lennerfors, and Poulsen).

However, the Swedish commercial shipbuilding industry experienced a massive collapse between 1973 and 1987 which had profound effects on the nation's economy and workforce distribution. Many shipbuilding industry leaders blamed the Swedish government for failing to better support

the industry with subsidies, as was the case in Norway and Denmark.[281] While all European nations saw truncation of their shipping industries during this period, the contraction of the Swedish shipping industry has arguably been more pronounced than most, as seen in Figure 18.[282]

Many challenges to European shipbuilding can be traced to the 1973 oil crisis precipitated by the Organization of Petroleum Exporting Countries' (OPEC) oil price increases, which resulted in the reduction of demand for new oil tankers. This decrease in tanker production later spread to other types of vessels in the Swedish merchant fleet. Some Swedish shipping companies sought to register their vessels under "flags of convenience," where the ship's owners select another state, often with less stringent maritime certification and operation standards and costs, under which to register their vessel rather than its origin state.[283] However, Swedish law forbade such measures, driving non-Swedish vessels away from the Swedish flag registry.[284] While Norway and Denmark created specific international shipping registers with tax incentives that helped stabilize their respective national fleets, Sweden did not adopt a similar system. The traditional Swedish shipbuilding companies in Stockholm (Saleninvest) and Gothenburg (Broströms and Transatlantic) largely failed to adapt to the wholesale changes to the commercial shipbuilding market and continued to build tankers despite the collapse of the oil shipping market. While both Broströms and Transatlantic continued to seek profit in building larger ships, both companies were significantly hurt by subsequent changes to Sweden's maritime tax system, which began assessing fees based on tonnage rather than numbers of ships. Broströms and Transatlantic both saw significant losses from 1970-1980, with Broströms in particular going from a profit margin of 44 percent to eight percent over the decade.[285] Both companies endeavored to stay afloat by diversifying and accepting primary government ownership, but these efforts came too late to save both from closure by the early 1990s.[286]

The 1980s saw a small rebound in the number of Swedish ships as newer companies such as Wallenius Lines and Stena sought new areas of business apart from oil transport and containers. Wallenius pioneered the Ro/Ro cargo vessel for the global transportation of automobiles in the mid-1950s. Wallenius became the industry leader in Ro/Ro vessels and, in 1965, was the first company approved to ship Japanese cars to a growing global market.[287] Wallenius also divested from tanker and non-container shipping before the oil crisis of the 1970s, thus insulating itself from those shocks in the global oil market. The company cultivated its image as a user of advanced technology and a pioneer in environmentally friendly marketing across the 1980s and 1990s, well ahead of competitors. Stena also sought to move past the tanker business like Wallenius. It began by operating secondhand tankers to save money, and expanded into shallow draft VLCCs in the early 2000s, even after the golden era of Swedish shipbuilding had ended.[288] The company remained committed to diversification, keeping other business in real estate, drilling, metals, and short-range ferry service. While Wallenius and Stena remain profitable companies, they no longer build ships themselves, having eventually chosen to specialize in designing and managing the construction of ships rather than undertaking the capital-heavy task of building them.

The financial crisis of 2008 effectively ended most remaining commercial shipbuilding in Sweden, but Swedish ship management companies remain active in driving innovation within the industry.

The financial crisis of 2008 effectively ended most remaining commercial shipbuilding in Sweden, but Swedish ship management companies remain active in driving innovation within the industry. The VCM concept is commonly used in Sweden and other European countries with the goal of promoting a harmonious working relationship. For example, while the Swedish company FKAB does not build large commercial ships, it is active in the business of designing such vessels and managing their construction.[289] Sweden's VCM efforts have expanded significantly into China in the 21st century. FKAB has designed and helped manage the construction of dozens of specialized commercial vessels since 2001 and has offices in both Shanghai and Dalian. Other Swedish shipping companies including Wallenius Lines and Stena AB have extensive business in

China as well, with many of their ships constructed there. According to the Swedish Ministry of Defence (MoD), Sweden's shipbuilders have embraced Chinese offsite construction to reduce costs, noting that these companies' close relationships with Chinese shipyards allow them to exercise considerable control over ship design and how the vessels are constructed despite not managing this construction directly.

Many of the challenges facing Swedish commercial shipbuilding have also impacted the naval shipbuilding sector. While Sweden once boasted several naval shipbuilders, especially in the cities of Gothenburg and Karlskrona, the 1970s shipping crisis in Sweden that damaged Saleninvest and Broströms also hurt naval shipbuilders by weakening the civilian side of their business. In 1977, the Swedish government established Svenska Varv AB (later Celsius AB) as a state-owned shipping company to help support its failing yards against foreign competition. Some long-standing warship producers including Götaverken and Eriksberg were acquired by Svenska Varv AB in 1978. Götaverken in particular had been a prolific warship builder after World War II, building most of Sweden's cruisers and destroyers through 1960. Eriksberg ended production in 1979, while Götaverken operated on a smaller scale during the 1980s. By this point, neither company had built a new warship since 1960 and both were out of the shipbuilding business by the end of the 1980s.[290]

Sweden's last larger surface warships were the *Ostergotland*-class destroyers that decommissioned in the mid 1980s (Source: Naval Encyclopedia).

As the end of the Cold War sparked a drawdown in the size of navies, the Swedish Navy had already experienced significant force reductions between 1982 and 1990, with its remaining six destroyers decommissioned without replacement throughout the decade.[291] The Defence Act of 1958 had already cut the Swedish Navy's share of the bill's funding from 19 percent to 16 percent and deprioritized the building and acquisition of larger ASW surface vessels in favor of smaller attack ships, as it was feared that larger vessels were more vulnerable to nuclear weapons.[292] The 1972 bill further prioritized anti-invasion defense at the expense of sea control in the Baltic, demanding a fleet of smaller coastal vessels that could conduct both anti-surface and anti-submarine warfare. When it came time to replace the remaining, aged larger ships in the mid-1980s, the Swedish Navy embarked on a new program of fast missile craft for operations in littoral waters against Soviet submarines and surface vessels.[293] This focus on smaller missile and ASW ships has largely continued to the present day, but is perhaps being reconsidered in light of Sweden's plans to move forward with a larger *Lulea*-class frigate, which will constitute the largest Swedish surface combatant since the *Ostergotland*-class.[294] The composition of the Royal Swedish Navy is seen in Figure 19.[295]

The only warship builder to sustain production from the 1980s on was Kockums, both at its Malmo and, eventually, its Karlskrona yards. Kockums was a pioneer submarine builder for the Swedish Navy beginning with the *Hajen*-class submarines built in 1917.[296] Kockums was known as the "Underwater Crown Jewel" of Sweden as "more than 70 submarines of various sizes and types have been built in the country, more than half of them at the Kockums shipyard in Malmö."[297] Acquired by Saab in 2014, Kockums is the owner of the sole remaining Swedish military shipyard actively producing ships and submarines for the Royal Swedish Navy. Despite the loss of general Swedish shipbuilding capacity since the 1980s, Saab Kockums managed to produce the *Visby*-class corvette, one of the most innovative ship classes to set sail under the Swedish flag, which is discussed in greater detail in the "Design and Manufacturing Process" section of the case study.

While Sweden certainly punches above its weight in terms of production from an enduring defense industrial base, its shipbuilding industry has largely disappeared, as has been the case in many Western European states. What remains is a small naval shipbuilding capacity that is

in part state-owned (such as the Kockums Shipyard parent company Saab AB,) and in a dependent, monopsony relationship with its government customers. Unlike the United States, Sweden still has a robust naval architecture education program and maritime commercial business ecosystem, although its nationally flagged ships are few in number (180 total as of 2022) and are all small ships built in foreign yards.[298] The Swedish Chief of Navy Admiral Johan Norlen has spoken bluntly about the small number of Swedish-flagged ships, stating, "If asked whether Sweden has enough Swedish-flagged ships to meet Total Defence needs during wartime or a crisis, my straightforward answer would be 'no'. We can only reliably depend on Swedish-flagged vessels to meet our critical operational requirements."[299]

Royal Swedish Navy Combatant Vessels	
Ship	**Quantity**
Visby-Class Corvette	5
Stockholm- and *Gavle*-Class Corvettes	4
Stockholm- and *Tapper*-Class Patrol Ships	13
Koster- and *Sparo*-Class Mine Countermeasure Ships	7
Gotland- and *Sodermanland*-Class Submarines	4

Figure 19: Royal Swedish Navy Combatant Vessel (Original graphic by the Center for Maritime Strategy. Data sourced from Swedish Armed Forces).

The Royal Swedish Navy is refreshingly honest about the limitations of its MIB and has sought a unique hybrid approach with elements worthy of further U.S. study. These include more extensive use of the VCM process, which executives from FKAB suggest is organic to Swedish shipbuilding and a method through which Swedish naval architects and shipbuilding engineers have remained engaged in the shipbuilding process, even when ships are constructed overseas. Sweden has also experimented with the construction of the hull and propulsion elements of a ship in an overseas yard, in the case of its new intelligence collection ship HSwMS *Artemis,* built in Poland and finished with government-furnished equipment in Sweden in 2024.[300]

Labor and Workforce

Sweden's overall shipbuilding industry is small, with only 2,018 shipbuilders across 173 businesses as of April 2024.[301] Sweden ranks tenth in Europe for number of businesses, fifteenth for number of employees, and thirteenth for annual revenue.[302] As a component of Saab, Kockums' financial footprint outstrips its size, with the company accounting for 13 percent of Saab's profits in 2024 despite employing fewer than 2,410 employees (about 10 percent of Saab's over 24,000 employees).[303] While Kockums' shipbuilding workforce is somewhat small, it has grown in recent years. In 2018, Kockums reported about 1,100 total workers, of which 500 were engineers.[304] As of 2020, some interviews suggested that the yard is increasingly reliant on immigrant labor from Poland, Estonia, and Ukraine.[305]

However, Sweden faces no such shortages of naval architects and marine engineers thanks to its impressive national naval architecture program. The nation produces 40 to 60 hirable naval architects from advanced programs at the KTH Royal Institute of Technology in Stockholm and the Chalmers University of Technology in Gothenburg. By contrast, the much larger and more populous United States produces about 100 hirable naval architects each year. While as many as 300 others are educated at the Naval, Coast Guard, and Maritime academies, they are not able to work in civilian positions for several years.[306] Such a high number of naval architects per capita in Sweden ensures that the naval engineering teams in Sweden's shipyards contain a high percentage of experts specifically trained in ship design and construction. In contrast, the vast majority of engineers in a U.S. shipyard are trained in a general STEM discipline, such as mechanical engineering or physics, before having to learn the nuances and intricacies of ship design while on the job. A civil engineer is trained to build structures that are in a predominantly static condition and not subject to corrosive agents on a regular basis. A naval architect, however, is trained to build structures that experience multiple g-forces daily, multiple axes of rotation, and

highly variable loading conditions and centers of gravity, and that are perpetually in a corrosive saltwater environment. By eliminating the learning curve for ship-specific conditions, Sweden ensures its engineers are ready to focus on ship-specific technical challenges from day one of their employment, streamlining their engineering workflows throughout their MIB. Given Sweden's increased emphasis on vessel construction management, its robust labor pool of naval architects plays an essential role in sustaining the country's MIB.

Technology Integration

The Kockums yard in Karlskrona has adopted several advanced shipbuilding techniques since its acquisition by Saab in 2014. Saab integrated these new techniques and technologies gradually, meaning they did not immediately accelerate the design and production processes. However, these changes constitute a significant investment in the modernization of Kockums' shipbuilding processes and infrastructure as the company seeks to develop its A26 submarines.

Key to these efforts is the yard's model-based system that "uses 3D models from [computer aided design] to define individual components and product assemblies."[307] All this data is shared across a common integrating hub known as ShareAspace," produced by BAE Systems. This hub "integrates the information/data from the other different engineering domains; things like common surface and mechanical design or electrical design, to prepare the information from the various sources for manufacturing, and to be used in the (Engineering Resource Proposal)," which in turn helps to manage the overall build of the submarine."[308]

While not boasting the type of shipbuilding operations center found in Korean or Italian shipyards, the Saab Kockums process functions as an impressive digital operations center tracking all aspects of the submarine building process. Kockums continues to research aspects of digital shipbuilding, especially in the field of "extreme high mix/low volume" production, such as occurs in the building of Swedish submarines. This is part of a project-based production process, defined as "highly customized and complex products in significantly low volumes, often requiring unique engineering solutions for each order."[309] This research, funded by the Swedish Defence Materiel Administration (FMV), seeks greater fusion of data on submarine parts and construction while protecting sensitive national submarine design data from industrial and foreign espionage efforts.

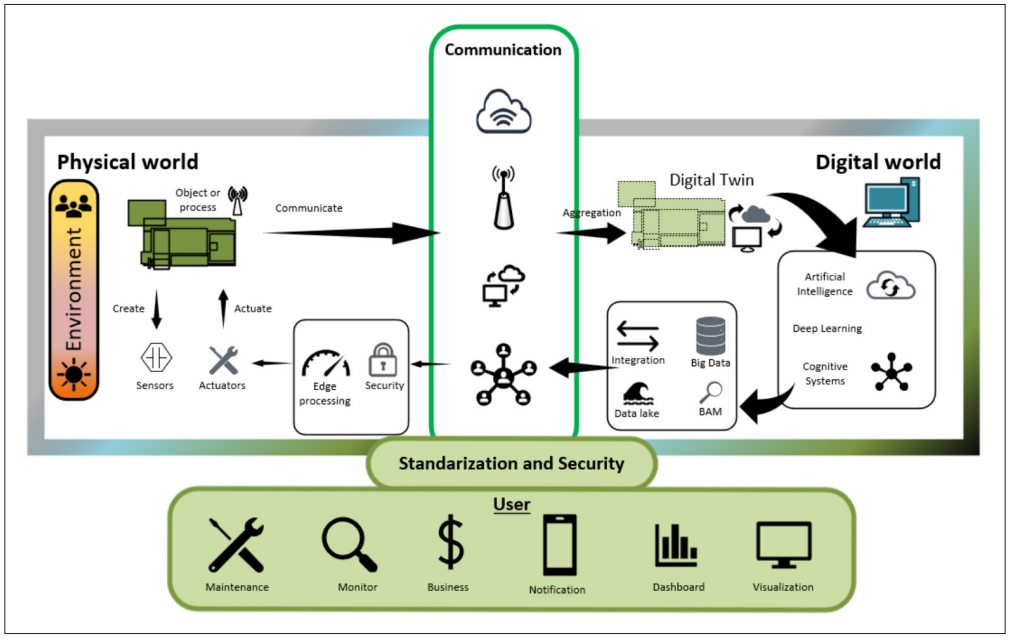


Figure 20: The Swedish Approach to Digital Twin Process (Source:Blekinge Institute of Technology)

Kockums maintains three digital twins for submarines: one for the boat when under construction, one for normal operations once the submarine is commissioned, and one for the submarine when it is in the repair yard for required maintenance and upgrades every two years. Figure 20 shows how the Swedish digital twin process works.[310] Kockums tracks all 600,000 parts used in a submarine's construction from their source to the shipyard, with appropriate scheduling to ensure they arrive on time when required for assembly. [311]

Design and Manufacturing Process

Sweden remains a maritime nation despite not building commercial ships. In general, current Swedish shipping companies are content to manage construction and operate foreign-built vessels. Perhaps the best example of the degradation of Swedish shipbuilding is the Kockums crane, a giant gantry crane built in 1973-74, with a lift capacity of 1,500 tons.[312] The loss of Swedish shipbuilding largely ended the need for such a crane and it was sold to South Korea's Hyundai Heavy Industries in 2002 after its parent shipyard went out of business. It is said that some Koreans named the structure "The Tears of Malmo," reportedly because the residents of Malmo wept when the crane was removed.[313]

The Second *Visby*-class corvette Karlstad under construction (Photo credit: defencetalk.com)

However, Swedish warship production has continued, most notably with the *Visby*-class corvette. This program was originally conceived as an attempt to combine multiple desired capabilities on one smaller hull form built to emphasize stealth and conduct anti-submarine and mine warfare operations. After building two classes of conventional missile and anti-submarine warfare corvettes in the 1980s, Sweden embarked on a research program to place the anti-submarine, mine warfare, and anti-ship missions on a stealth hull. These efforts culminated in the research vessel *Smyge* that began trials in 1991, which served as the basis for the eventual design of the *Visby*.[314]

As is often the case with naval vessels, the *Visby* experienced many design changes and production delays. Growth in the ship's missions beyond anti-submarine and mine warfare resulted in a larger ship, and the design changed from a surface effect ship to a more conventional hull constructed with composite materials as opposed to steel. Originally billed as six to 10 ships in the class, it was reduced to six, and later five ships. Development time was extended over the 2000s from the commissioning of the first ship (*Visby)* in 2002 to the second ship (*Helsingborg)*, which was not commissioned until late 2009. For a time, the only weapon system on *Visby* that functioned was its 57mm gun. There were extensive delays in getting the rest of the class into service, with speculation that combining so many systems on a small hull was challenging. There has been room for expanded capability on the *Visby*s, and the class is currently getting an anti-air missile system upgrade through 2030 in hopes of giving the ships another warfare mission area while still preserving the class's stealth design.[315]

With those upgrades in place, the Swedish Navy determined that the original *Visby* hull form cannot be further upgraded and, in 2022, sought to build a larger *Visby 2* successor ship. However, they found that the hull form that made *Visby* the largest composite hull warship in service could not be further enlarged to support the additional desired capabilities. The Swedish Navy has also said the *Visby*-class corvettes, originally planned for a 25-year service life, are aging and require replacement perhaps sooner than planned. The successor *Lulea*-class large corvette/small frigate that was intended as a Swedish-built replacement for the *Visby* has been deemed beyond the ability of the current Kockums yard in Karlskrona to produce. Swedish shipyards

Future HSwMS *Blekinge* under construction in Saab Kockums Karlskrona Shipyard (Source: Interesting Engineering)

have not built a steel-hulled warship since the late 1980s and have not constructed a frigate-sized vessel since 1958. Swedish defense officials believe the nation lacks the defense industrial base needed to produce the new combatants on a timely schedule. Sweden is now looking for a foreign design small frigate as the basis of the *Lulea*-class, most likely the British Type 31 frigate or the French *Ronarc'h*-class frigate.[316]

Unlike Sweden's surface vessels, submarine construction remains an exclusively domestic enterprise, albeit one that is relearning its art. Saab Kockums refits existing Swedish submarines at the Karlskrona yard while simultaneously building new boats. The yard completed a three-year, mid-life overhaul of the Royal Swedish Navy's third *Gotland*-class (A19) diesel-electric submarine, HSwMS *Halland*, in February 2025.[317] Saab Kockums has adopted a modular approach to submarine construction, with the A26 submarine being built in five modular sections for greater construction efficiency. Computer-aided design and manufacture are central to the construction of the A26. The company uses a fusion of data managing tools to track the production of the A26 from individual parts to complete modules that are combined into a single submarine.The use of digital twinning throughout construction is essential to the process, and to the lifecycle of the submarine. As Saab Kockums' IT leader Pål Almén said in 2024,

> A submarine project takes about seven to eight years in terms of product development. After that, they should be operational for at least 30 years. The first maintenance comes after two years, then there are more extensive maintenance efforts every eight years. That says a lot about the complexity and demands of data integrity over time.[318]

The A26 is expected to be a much-improved vessel over the previous *Gotland* class. Its propulsion system is classified, but is described as fourth-generation air-independent propulsion (AIP) and an improved Mk III variant. On board are three Stirling engine modules, each generating around 70 kW of power, which allow the submarine to maintain a constant submerged speed of about five to six knots for more than 18 days.[319] Despite a production boat not yet being available for viewing, Saab has secured a contract to build the next generation Polish submarine on the expected quality of the A26 boat.[320] As part of this deal, Sweden will provide the submarine *Södermanland* to Poland as early as 2027 in the interim until Saab Kockums can deliver A26 boats.[321]

The VCM model utilized by Swedish shipbuilders warrants serious consideration by American companies and government agencies as they consider ways to improve their design and construction processes.

Saab also retains a market for the composite materials it developed in the creation of the *Visby*-class corvettes, building composite material lightweight superstructure components for both the Finnish and Singaporean navies.[322] Such composite materials might be useful in unmanned vessel construction going forward, opening elements of unmanned ship construction to smaller yards. This practice further illustrates the industriousness of Swedish shipbuilding companies which have found creative ways to remain commercially viable despite the relative collapse of the country's naval shipbuilding market.

Finally, Sweden's adoption of the VCM model is one of its shipbuilding industry's largest contributions to the development of surface vessels. While Sweden has largely abandoned its efforts to build surface vessels domestically, its companies' deep historical knowledge of shipbuild-

ing and the country's wealth of naval architects and marine engineers have allowed Sweden to continue its tradition of shipbuilding without having to construct vessels themselves. Swedish VCMs help shipbuilders identify and mitigate risks which could result in vessels being produced late or over budget, sharing best practices with shipyards "to ensure a continuous learning curve throughout subsequent hull construction."[323] As highlighted by CMS's editorial board in a September 2024 article,

> The VCM develops the ship's logistics, standard operating procedures, and preventive maintenance plans, as well as procuring, assembling, and installing government-furnished equipment. In doing so, the VCM relieves the shipyard of the requirement to answer multiple requests for information from the purchaser…and instead allows the shipyard to do what it does best: building ships. The result is a ship built to design specifications that is delivered on time and on budget, while also streamlining the acquisition process.[324]

Sweden's expertise in vessel construction management has endured despite the country's struggles to build steel hulls to support surface vessels, which is a testament to its significant investment in the maritime knowledge economy. The VCM model utilized by Swedish shipbuilders warrants serious consideration by American companies and government agencies as they consider ways to improve their design and construction processes.

Purchasing and Government-Commercial Relations

The Swedish FMV manages joint acquisition of warships, submarines, aircraft, tanks, and other military and naval equipment. It possesses additional capabilities such as test and evaluation of systems that are often under separate leadership of U.S. military services within the Department of War. The FMV has long been a specifically Swedish-managed defense organization, reflecting the country's historic emphasis on preserving its capacity to independently build warships. The FMV's origins can be traced back to the loss of the sailing warship *Vasa* in 1628, after which King Gustavus Adolphus demanded that an independent Swedish organization exist to design arms and armaments (e.g., both warships and their cannon) rather than relying on foreigners. FMV was formally incorporated as an independent defense acquisition manager in the MoD in 1968.[325]

FMV defines "underwater" as a strategic materials area, and is historically fierce in its protections of national military technologies and systems involving submarine technology. Much of this effort revolves around a reliance on a private, monopsony relationship, with Saab AB (which is part-government-owned) operating the sole remaining military shipyard, Saab Kockums. Kockums is the essential holder of Swedish submarine building capacity and as such has been the focus of the Swedish government's efforts to control submarine building since a perceived attempt to eliminate this capability in the last decade.

In 2014, FMV raided the formerly German-controlled Kockums shipyard office in Malmo to recover submarine systems drawings it viewed as Swedish national property.[326] Kockums became the focus of a bitter industrial battle with the German defense corporation Thyssen Krupp Marine Systems (TKMS), which purchased Kockums in 2004. Tensions between the FMV and TKMS were high from the start, as the Swedes believed TKMS gave preferential treatment to its own German-produced submarines rather than those of Kockums and that TKMS was trying to transfer Swedish submarine technology to Germany without permission.[327] These challenges came to a head in 2013 when TKMS sought to take Kockums out of the fleet submarine business and perhaps force Sweden into the purchase of a TKMS German submarine. The FMV responded by terminating the A26 *Blekinge*-class AIP submarine contact with Kockums TKMS. The Swedish government, already concerned by Russian aggression and violations of Swedish airspace in April 2013, also moved quickly to transfer all Swedish submarine activity and surface ship maintenance contracts from Kockums (still owned by TKMS) to Saab. These changes, com-

bined with the FMV's forcible confiscation of defense materials it believed were being illegally transferred out of Sweden, made TKMS's ownership of Kockums untenable. This effectively forced the sale of Kockums to Saab on June 29, 2014, for 340 million Swedish kronor, despite the fact that TKMS had been demanding 1.3 billion kronor for Kockums just months earlier.[328]

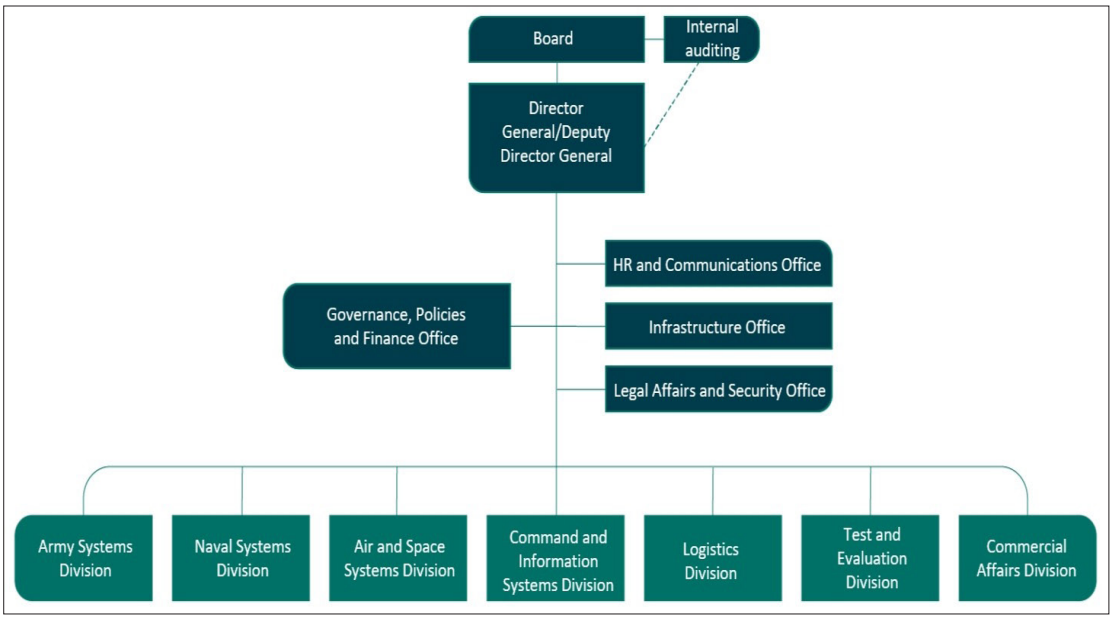


Figure 21: Organization of the Swedish Defense Material Agency (Source: Swedish Defence Materiel Administration)

Emphasizing the importance Sweden places on maintaining its capacity to build submarines domestically, former FMV Director Lena Erixon claimed credit for getting Saab to take over building submarines for Sweden, stating in a 2014 interview, "These steps–after my 'idea', as you've called it–might indeed see Saab becoming a full-service provider of submarines for Sweden–and maybe later for others countries…"[329] Figure 21 details FMV's organization.[330]

Given its hard fight to retake and retain an indigenous submarine construction capability, it seems unlikely that Sweden will accept any new submarine construction from foreign builders. Saab Kockums continues to build the A26 submarine, although recent estimates now suggest the first boat will not be complete until 2031.[331] Again, lack of experience at the Kockums yard, which has not built a submarine since the 1990s, was cited as the reason for the delay. Kockums employed less than 1,000 workers in both Malmo and Karlskrona in late 2014 when Saab took over the company.[332] Steel was first cut for the A26 in July 2015, but the keel was not laid until June 30, 2022.[333]

Infrastructure

Sweden closed four of its large state-owned shipyards in the 1980s and early 1990s, reducing its shipbuilding capacity significantly to today's smaller footprint. This has been a deliberate process in the wake of the collapse of commercial shipbuilding in Sweden in the 1970s and 1980s, and the decision of the Swedish government to downsize their Navy in favor of their Air Force in the late 1980s. Swedish MoD officials and business leaders interviewed for this report stated that a Swedish shipbuilding revival was unlikely, other than that of the submarine building yard.

While Sweden has largely divested from physical shipbuilding, the country maintains over 30 shipyards and repair facilities of all types, with most of these yards focused on the building and repair of smaller commercial and pleasure craft. The most significant active yard is the Saab Kockums facility in Karlskrona, although there are also three smaller shipyards which play important roles in supporting Sweden's MIB: Falkvarv AB, Damen Oskarhamnvarvet, and

Oresund Drydocks. Falkvarv has two floating drydocks supporting ships of 115 and 150 meters in length, but employs only 40 workers and is focused primarily on voyage repairs.[334] The Oskarhamnvarvet yard is part of Damen's worldwide network of ship repair facilities and also has primarily a repair mission for its 100-meter-long floating drydock.[335] Oresund boasts two larger drydocks that handle ships of 165 and 202 meters, as well as 800 meters of pier space with crane lift support, yet employs only 100 workers and is also focused on ship repair.

Current Swedish shipbuilding is largely focused on naval, small cargo, and recreational craft. Kockums has shipbuilding facilities in Karlskrona (its main shipyard), Malmo (its design location), and a few Swedish naval bases including Musko Island and Gothenburg. These locations have the infrastructure to facilitate building and repair of up to medium-sized vessels. However, several Swedish maritime companies have Chinese economic ties and partnerships for shipbuilding in China, supported by the Sweden China Marine Group. These partnerships enable Swedish shipbuilders to operationalize the infrastructure of their foreign partners to support the construction of ships for both domestic use and sale on the international market.

Supply Chains

Sweden, long independent of formal alliances, has operated a low-rate production defense industrial base for many decades. While the width and breadth of supply chains have been reduced due to deindustrialization over the last 30 years, they are better organized in terms of preparation for extended conflict than those of Sweden's NATO allies. Swedish defense officials revealed to CMS that the FMV has long maintained a concept called Alternative Production Plan (APP), where the agency has developed contingency plans for "different possible situations when the regular production plan is no longer fully relevant" due to wartime disruptions. Such plans have examined scenarios in which wars break out in either the near-term or long-term, as well as wars occurring in a variety of theaters which could impact supply chains in distinct ways. In particular, FMV examined what to do with very high-value Swedish Defense programs such as the A26 submarine and the Gripen E combat aircraft in 2020. FMV supposedly suggested

> Most of the resources at Saab that were then dedicated to the Gripen E and the *Blekinge* (A26) submarine should be redirected (in principle discontinued) to maximize availability, additional weapon integrations, etc. on the Gripen C/D and the existing *Gotland* and *Södermanland* type submarines. The reasons behind that proposal were simply that neither the *Blekinge* type submarine nor the Gripen E could have contributed any operational benefit whatsoever in a war that was estimated to break out a maximum of six months from now.[336]

This sort of blunt thinking regarding shipbuilding and the outbreak or imminent start of war has been practiced in the past, when in 1914 the British War Cabinet decided to suspend the construction of all capital warships that could not be finished in time to see war service in a conflict then estimated to be, at best, three years in length.[337] Similar efforts to ensure survival supply chain planning are needed in the U.S. shipbuilding industry as well.

At the individual ship level, Saab Kockums tracks individual parts across its national supply chains, using AI to assemble detailed digital twins for both those submarines under construction and those already in service. The Swedish Security and Defence Industry Association (SOFF) defines the Swedish defense industry supply process in Figure 22.[338]

This unified supply chain effort is the product of over a century of non-aligned, neutral Swedish defense preparation and—with perhaps the exception of Finland—is unique within the NATO alliance structure. Swedish defense corporations are focused on generating a profit for shareholders, but the Swedish government can take action to assert control over supply chains in a crisis, as allowed by European Union Article 346 TFEU. This article enables member nations to protect "essential security interests" related to the production of war materials and cites the underwater domain, fighter aircraft, specialized aspects of the command domain like cryptography, and the

Figure 22: SOFF Explanation of Swedish Defense Industry relationships (Source: Swedish Shipowneers' Association)

supply of ammunition and sensors as falling under its auspices.[339] Accordingly, the FMV has the authority to directly choose suppliers for products and services within these specific domains without the completion of the usual procurement procedure. This level of independent authority might be useful in near-war conditions in the United States to rapidly speed construction of ships and submarines.

Key Findings

Like many of the United States' European allies and partners, Sweden experienced deindustrialization from the mid-1980s through the present and now operates a monopsony naval shipbuilding industry that is also part-government-owned. While Swedish shipbuilding capacity and the associated workforce have substantially contracted over the last three decades, the Swedes have taken a pragmatic approach in assessing what naval platforms they can and cannot build and have configured their naval acquisition strategy to accept those limitations rather than attempting a reindustrialization effort. Swedish commercial shipbuilders have moved into the business of ship management and VCMs for foreign-built ships and still maintain a robust training program for naval architects. Sweden has prioritized submarine building as its naval shipbuilding program that must remain under national control and has acted swiftly and forcefully in the recent past to prevent that capacity from leaving Swedish-controlled shipyards.

Sweden understands it has lost the capacity to construct larger, steel-hulled surface combatants and is actively seeking a British or French design, modified with Swedish requirements, for its next class of surface warship. Sweden has experimented with the concept of building a warship in a foreign yard (the intelligence collection vessel *Artemis,* in Poland) and then outfitting the incomplete ship in a Swedish port with its own national equipment. Sweden continues to pursue advanced shipbuilding methods including the use of AI, automated robot building, and digital twinning to maximize vessel construction, as well as modernization and lifecycle management. Sweden's use of the VCM process, its receptivity to experiments such as partial building of ships in foreign yards, its expansive use of digital twinning, and its joint Defence Material Agency organization are all worthy of emulation by the U.S. Navy and the Department of War.

SWOT: Swedish Shipbuilding

Strengths	Weaknesses
• Decades of standalone, low rate ship and submarine production • Deep naval architectural knowledge and expertise in shipbuilding and commercial ship operations • Fully invested in the concept of digital twins for operational submarines, as well as those being built (A26 Blekinge-class) and those undergoing midlife overhaul • Experts in AIP submarine construction and operation • Experts in composite material warship construction, demonstrated in Visby-class corvettes • A well-organized Defence Material Agency in support of Swedish submarine building	• Little remaining commercial ship production or repair, and few plans to expand that industry • Effective inability to build steel-hulled warships • Small maritime and shipbuilding workforce, with a dependency on foreign workers • Still relearning submarine construction process after a 20-year pause in submarine production
Opportunities	**Threats**
• Willing to educate naval architects from other nations • Experts in the business of building and operating commercial ships • Poised to grow submarine building business with Polish order of two A26 submarines • Growing expertise in underwater unmanned systems • Actively seeking new models for acquiring warships such as building hulls in foreign ports and outfitting the ships in Sweden • Experts in using the VCM concept to build ships on time and on budget	• Its small maritime industrial workforce has started to depend on foreign guest workers • Lack of ability to build steel warships a threat to traditional Swedish self-reliance in building its navy

Figure 23: Strengths, Weaknesses, Opportunities, and Threats (SWOT) for Canadian shipbuilding (Original graphic by the Center for Maritime Strategy).

United Kingdom

This case study examines the 20th century decline of the British shipbuilding industry (and, by extension, British naval power), as well as the U.K.'s promising efforts to rebuild the sector. While decades of deindustrialization, episodic procurement, and the loss of commercial shipbuilding scale eroded the industry, recent revitalization efforts have yielded positive results, including the creation of a National Shipbuilding Strategy, the recapitalization of key British shipyards, the development of highly-desired frigates for export, and the U.K. assuming a leading role in multilateral maritime endeavors such as AUKUS and its efforts to develop a Global Combat Ship. The case study examines the practical trade-offs the U.K. now faces in trying to expand and preserve its maritime industrial base, and provides a compelling reminder that rebuilding domestic shipbuilding capacity is far more difficult than preserving it. The U.K. example signals that maritime decline need not be permanent if met with sustained collaborative efforts from both the public and private sectors.

To support this case study, CMS's experts traveled to the U.K. in January 2026 to observe Babcock's Rosyth shipyard and BAE Systems' twin shipyards on the River Clyde: Govan and Scotstoun. CMS also conducted interviews with representatives of the British Ministry of Defence (including the National Shipbuilding Office and Defence Equipment and Support), as well as representatives of Babcock and BAE. Unless otherwise cited, all insights included in this case study are derived from these site visits and interviews.

History and Background

While British shipbuilding has a history stretching back to the near-400-year Roman occupation of the British Isles, organized shipbuilding policy began in the 15th century. Henry V began the building of capital ships for wars with France, and Tudor successors such as Henry VII, Henry VIII, and Elizabeth I further financed the administration, dockyards, and shipbuilding needed to make England into a regional and, eventually, global naval power. The 16th through 18th centuries saw the further development of both British wooden shipbuilding and the bureaucracy of shipbuilding. British shipbuilding grew in capability and capacity alongside its overseas empire across the 17th and 18th centuries. British shipbuilding was, at times, overtaken by that of France, Spain, and later the United States in terms of quality, speed, and naval armament. Despite temporary setbacks, British shipbuilders were willing to adopt their rivals' best practices, such as French ship of the line hull design and American frigate speed—insights gleaned from captured ships.[340] In particular, British shipbuilders excelled at building both warships and merchant vessels, as well as the blending of the two in the East Indiaman, a large merchant ship capable of carrying a heavy gun battery for long voyages across pirate-infested seas.[341]

During the Industrial Revolution, British shipbuilders adopted steam power, including the innovative paddle wheel for steam propulsion, as well as iron and steel for hull construction.[342] The U.K. built some of the world's largest steamships, including 1859's *Great Eastern*, whose size and capacity to carry 4,000 passengers and crew were unmatched until the 1920s.[343] British warship building was equally innovative during this period. From HMS *Warrior* in 1860 (an iron-hulled, steam-powered armored ship that still possessed sails) to the revolutionary HMS *Dreadnought* of 1907, British warships were generally more advanced, more capable, and built faster than foreign contemporaries. *Warrior,* for example, employed an iron hull that enabled her to be larger and faster than contemporary wooden warships, and was laid down, launched, and completed as a functioning capital warship in less than two and a half years.[344] Meanwhile, the Dreadnought combined new technologies such as turbine engines, a centralized fire control and armor scheme, and an all-big-gun armament and was laid down, completed, and ready for trials in just 12 months.[345] The ability to innovate and build ships at speed and efficiency across the

19th century allowed British shipbuilders to set records in terms of size, speed, and capability of warships, commercial, and passenger vessels.

From about 1900-1920, however, British shipbuilding advances were often met or superseded by those of the United States and Germany, especially in ship construction techniques such as welding and alternating current electrical systems.[346] The post–World War I warship holiday imposed by the 1922 Washington Naval Treaty and subsequent naval arms control treaties reduced British naval shipbuilding output by 90 percent, a condition only reversed in the late 1930s by British rearmament against Germany.[347] Wartime requirements greatly augmented British shipbuilding during World War II and left the nation with a glut of both naval and commercial ships that served to drastically reduce orders from shipyards. As with many European states, postwar reconstruction diverted funds and effort away from the modernization of British shipbuilding. However, British shipbuilders continued to pioneer new concepts such as computerized plate cutting and automated engineering spaces, as seen in the vessel *Clan McGillvray*, completed in 1962.[348]

Despite these advances, British shipbuilding continued to face challenges from West German and Japanese yards, prompting a parliamentary investigation into means of improvement in 1966. The resulting Geddes Committee ultimately led to the consolidation of the British shipbuilding industry and distribution of federal financing to shipbuilders.[349] After these reforms failed to resuscitate the industry, the U.K. nationalized British shipbuilding through the 1977 Aircraft and Shipbuilding Industries Act.[350] However, nationalizing the industry did little to stop its decline, as British shipbuilding output decreased 90 percent from 1975-1985.[351] The U.K., like many European nations in the late 1960s, invested heavily in the construction of oil tankers, only to face suffering markets over the course of the 1970s oil crises. As one source recounted, "After the 1973 OPEC oil crisis, when the oil-exporting nations of the OPEC cartel increased the wholesale price of crude oil fourfold, demand for vessels to carry crude oil fell by 90 percent. Consequently, shipyards in all nations had to compete with a much-reduced demand for merchant vessels during an economic slump."[352] Despite re-privatization starting in 1983, British shipbuilding has been unable to recover its past market share. Figure 24 shows the relatively small-scale British commercial shipbuilding effort from 1963-1980, with special notice given to the global downturn in merchant (largely tanker) production due to the 1970s oil crisis.[353]

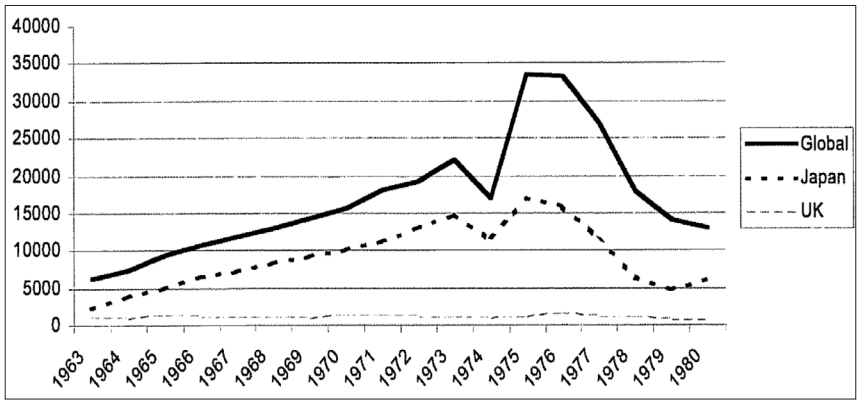


Figure 24: British and Japanese merchant vessel output in global comparison, gross tons (thousands) (Source: Conners)

While the British shipbuilding industry succeeded in building three *Invincible*-class light aircraft carriers between 1973-1981 through a collaborative effort spread across several shipyards, this project left the industry overextended and resulted in delays on the completion of subsequent projects. In the wake of the Cold War, the U.K. government reduced military spending and shrank the size of the public sector workforce, resulting in fewer resources and less manpower allocated towards shipbuilding. These events further contributed to the decline of the U.K. MIB.

The modern British shipbuilding industry remains an important economic institution, contributing £2.4 billion annually to the U.K. economy and supporting 42,000 jobs.[354] Yet this industry is a fraction of what it once was, and the U.K.'s share of the global civil maritime market is only 2 percent.[355] Commercial shipbuilding is particularly diminished, with the country's largest yards focusing primarily on military vessels. Only one to three British yards deliver commercial

ships in a given year, and the most of those vessels are relatively small in size.[356] A handful of smaller yards have found success building yachts and leisure boats for foreign markets, with this market accounting for £1.6 billion worth of exports in 2019.[357] The U.K. is also the world's second-largest exporter of floating structures (rafts, tanks, landing stages, etc.) and makes up 15 percent of the global market for these products.[358]

Britain's warship industry is dominated by three companies: BAE Systems, Babcock International Group, and Navantia, the Spanish state-owned shipbuilding company which has acquired shipyards in England, Scotland, and Northern Ireland. BAE and Babcock—both of which allowed CMS to tour their shipyards as part of this study—account for more than half of the U.K.'s shipbuilding market, and their yards at Rosyth, Barrow-in-Furness, Govan, and Scotstoun are responsible for the overwhelming majority of British warship production. Figure 25 shows the distribution of the shipbuilding industry throughout the United Kingdom.[359]

Babcock has operated continuously for 135 years after originally establishing a reputation as a premier manufacturer of boilers in the nineteenth century, while BAE was formed in 1999 fol-

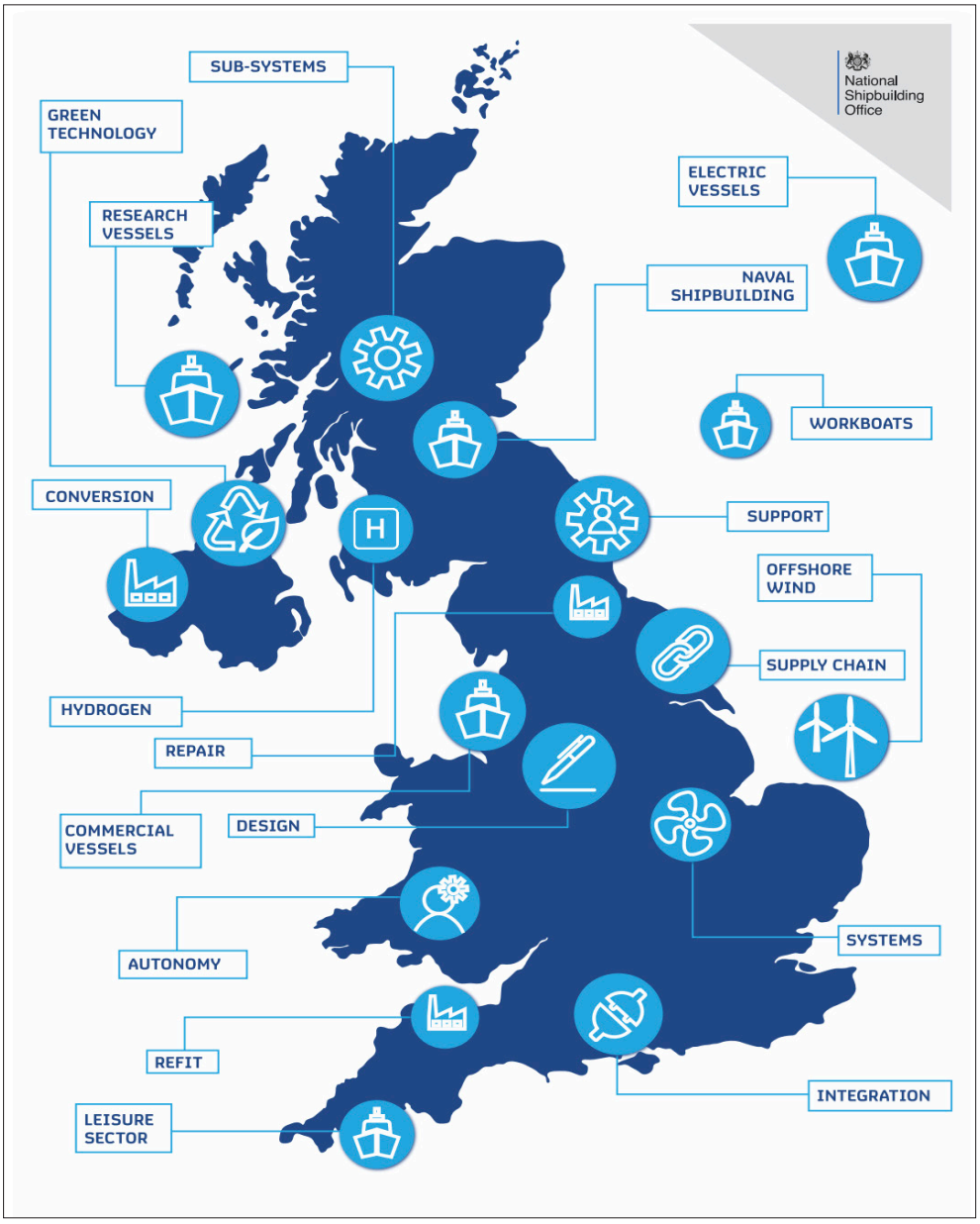


Figure 25: A geographical map of British shipbuilding (Source: U.K. Ministry of Defence)

lowing the merger of British Aerospace and Marconi Electronic Systems. Smaller companies, such as Cammell Laird, have largely abandoned the construction of naval vessels and are primarily focused on providing repair and maintenance to Royal Navy ships. For example, the Navantia-owned Harland & Wolff shipyard in Belfast, perhaps most famous for building the *Titanic*, did not complete a new vessel between 2003 and 2023 and now focuses almost exclusively on ship repair and supporting offshore energy projects.[360]

A Type 31 vessel on display at the Rosyth shipyard (Photo credit: Babcock)

While Britain cannot regain its former status as a global shipbuilding leader, its shipbuilding industry is showing signs of resurgence in recent years. The sector's economic output increased by 72 percent between 2019 and 2024 (as measured by gross value added), a period where manufacturing as a whole declined by 1.4 percent.[361] An international market has emerged for British frigates, owing to the enduring success of the older Type 23 vessel. In 2025, Norway agreed to purchase at least five Type 26 frigates from BAE Systems for £10 billion, which constitutes the largest single defense investment in Norwegian history.[362] The U.K. MoD estimates that the Type 26 program will support approximately 4,000 jobs across 400 companies in Britain, providing a substantial boost to the industry.[363] BAE has also sold the Type 26 design to Australia and Canada, with BAE constructing six ships in Australia while Canadian-owned Irving Shipbuilding builds 15 ships in its Halifax shipyard.[364] Similarly, Babcock has sold the Type 31 design to Indonesia and Poland, and both Sweden and Denmark have shown considerable interest in acquiring the ship.[365] Developing a robust export market of British-built and British-designed ships could provide a pathway toward resurgence for this industry.

British shipbuilding was also bolstered by the signing of the AUKUS security agreement between the United States, the U.K., and Australia in September 2021. Reflecting the U.K.'s growing focus on the Indo-Pacific, the agreement centers on supporting Australia's efforts to acquire and develop capabilities to support nuclear submarines. It promotes joint development and increased interoperability between the three nations on advanced technology, including AI, hypersonic missiles, and quantum technology. Australia's future nuclear-powered subs will be heavily based on the U.K.'s forthcoming next-generation submarine design, which is intended to replace the *Astute*-class. Work on these vessels is expected to start at BAE's Barrow-in-Furness shipyard in the early 2030s.[366] This project necessitated significant recapitalization efforts to upgrade the U.K.'s MIB, resulting in the government committing over $8 billion in investments to both Barrow-in-Furness and the Rolls-Royce Submarines site in Derby, which will build the submarines' nuclear reactors and propulsion units.[367] While it remains unclear how many vessels will ultimately be built under this agreement, it promises to provide a much-needed injection of capital into British shipbuilding while increasing the Royal Navy's interoperability with two of its most significant allies. It also reinforces the desirability of British submarines as potential vessels for purchase.

Submarines remain a strength of British shipbuilding, driving a domestic subsea industry valued at almost £8 billion per year.[368] The U.K.'s nuclear submarines and the military infrastructure that supports them constitute a critical part of its Defence Nuclear Enterprise (DNE), a partnership of organizations which operate, maintain, renew, and sustain the U.K.'s nuclear deterrent. The British government spent £10.9 billion supporting the DNE in fiscal years 2024 and 2025 (just under 20 percent of the MoD's entire equipment budget), and funding for the DNE is projected to increase over the coming decade.[369] The U.K. has ambitious goals for the production

of subsea vessels and hopes to "achieve a construction drumbeat to one submarine every 18 months."[370] However, submarine construction has encountered many of the same challenges facing the broader British shipbuilding industry. The development of the *Astute*-class submarines has been particularly fraught, as discussed in the "Design and Manufacturing Process" section of this case study.

In addition to the maximum of 12 submarines which will be constructed under AUKUS, British shipbuilders are set to build 27 ships for the Royal Navy: 11 nuclear submarines, 13 frigates, and three Solid Support Ships (see Figure 26).[371] The overwhelming majority of these vessels will be constructed in the U.K. BAE estimates that 90 percent of the labor supporting the building of its four *Dreadnought*-class submarines will take place domestically and that half of the program's total economic value will be delivered by Britain's supply chain.

Ongoing and Future Royal Navy Construction Projects as of September 2025

Class	Type	Displacement	First Ordered	Total Requirement	Completed	In Construction
Submarines						
Astute	Nuclear-powered attack submarine (SSN)	c. 7,500 tonnes	1997	7	5	2
Dreadnought	Nuclear-powered strategic submarine (SSBN)	c. 17,000 tonnes	2016	4	0	3
SSN-AUKUS	Nuclear-powered attack submarine (SSN)	Unknown	TBD (design and initial long-lead items ordered)	Up to 12	0	0
Surface Vessels						
Type 26 "City"	Frigate (FFG)	c. 7,000 tonnes	2017	8	0	5
Type 31 "Inspiration"	Frigate (FF)	c. 6,000 tonnes	2019	5	0	5
Auxilaries						
Solid Support Ship	Replenishment ship (FSS)	c. 40,000 tonnes	2021	3	0	0

Figure 26: Ongoing and future Royal Navy construction projects as of September 2025 (Original graphic by the Center for Maritime Strategy. Data sourced from European Security & Defence.)

Furthermore, like Canada, the U.K. has developed an NSS which was released in 2017 and refreshed in 2022. The NSS called for the formation of a National Shipbuilding Office (NSO), which was subsequently established in 2021 and tasked with coordinating national procurement and investment strategies across the shipbuilding sector. To address inconsistent demand, the strategy outlined a 30-year shipbuilding program across the naval and civilian sectors in hopes of creating steady workflow and reducing industry volatility. The strategy called for the increased use of automation and robotic technologies in shipbuilding, the integration of new naval technology such as AI and open architecture combat management systems into the principles for new ship designs, the reduction of carbon emissions, and an increased emphasis on building green-energy ships. Finally, the strategy committed to bolstering the industry through financial incentives for exports such as government loan guarantees, as well as increasing investment in training programs to address labor shortages and ensure shipyard workers are trained to the standards required for the modern industry.[372] While the strategy is ambitious, the U.K.'s commitment to fully implementing it remains to be seen. A 2019 independent review assessed that "progress on implementing the National Shipbuilding Strategy is encouraging," though industry leaders have urged the government to enact the strategy with greater urgency and transparency.[373]

The surge in shipbuilding envisioned by this strategy is designed to bolster both the British economy and the Royal Navy. No longer the world's envy, the Royal Navy nevertheless re-

mains a formidable maritime force capable of projecting power both regionally and globally. The Royal Navy and Royal Marines boast a combined fighting force of nearly 38,000 service members and account for just under one quarter of the U.K. armed forces' personnel.[374] As of November 2025, "The Royal Navy and the civilian-operated Royal Fleet Auxiliary (RFA) operate a combined total of 70 surface vessels (seven of which have been or are being decommissioned)."[375] The fleet includes two aircraft carriers, 11 nuclear submarines (including four nuclear ballistic missile submarines), 11 frigates, and two amphibious assault vessels, in addition to several patrol, anti-mine, survey, and auxiliary ships.[376] His Majesty's Naval Service has an important presence in many of Britain's 145 military installations spread across 42 countries, including key naval installations at Gibraltar, the Falklands, Oman, Bahrain, Diego Garcia, and Singapore.[377]

The U.K.'s character as an island nation makes it uniquely dependent on naval power to ensure its survival. Maritime trade constitutes Britain's most essential economic engine, accounting for roughly 95 percent of all imports and exports.[378] Accordingly, Britain has assumed an important global role in assuring the free flow of maritime commerce, including conducting counter-piracy operations and promoting freedom of navigation in critical waterways such as the Taiwan Strait. The U.K.'s energy interests are also closely linked to the maritime domain. The North Sea serves as an important source of oil and gas reserves, and the U.K. now boasts the world's second largest offshore windfarm capacity in an effort to reach net zero greenhouse gas emissions by 2050, relying on undersea cables to carry power generated by these farms to the national grid.[379]

The Royal Navy also plays a critical function in preserving national security, contributing considerable naval strength to NATO and regional efforts to monitor and track Russian submarine activity. In particular, the U.K. has assumed a significant role in countering the efforts of Russia's shadow fleet of civilian oilers and container ships which have caused tens of millions of euros in damage by clandestinely dragging their anchors over critical undersea infrastructure.[380] The Royal Navy works closely with NATO's U.K.-based Allied Maritime Command to survey and deter these attacks.[381]

Yet there are concerns regarding the Royal Navy's capacity to effectively carry out these duties. The MoD is experiencing a £28 billion gap between its financial commitments and its capacity to fund them, raising questions about whether Britain can follow through on its plans to procure and maintain essential defense equipment and infrastructure.[382] British Defence Secretary John Healey has warned that the Royal Navy lacks sufficient manpower to crew and support its current and forthcoming vessels, while government assessments project uncertainty "about the Royal Navy's ability to protect vulnerable cable regions and escort repair ships without undermining commitments to other NATO tasks."[383] Given the critical role the Royal Navy plays in supporting both national and regional security, resolving these capacity and resource gaps stand as a top priority for British policymakers.

Labor and Workforce

The British shipbuilding industry has long faced challenges in attracting and retaining workers, particularly in the wake of the COVID-19 pandemic which caused significant workforce attrition. The government and industry officials CMS spoke with noted shortages of skilled workers such as welders, electrical engineers, sheet metal workers, and pipefitters. These experts also observed that the industry struggles with retention because similar industries (plumbing, construction, etc.) can offer comparable or higher wages with greater employment flexibility or less arduous working conditions.

Similarly, the U.K. suffers from a shortage of engineers to help design ships; a 2019 study by the Institute for Engineering and Technology projected an annual shortfall of 59,000 new engineering graduates and technicians in the U.K.[384] There is a significant shortage of both skilled and unskilled workers between the ages of 34 and 45, which reflects the contraction of the

shipbuilding industry that occurred 15 to 20 years ago. At BAE, 57.3 percent of the skilled workforce has under five years of service, while a staggering 97 percent of the company's unskilled workers have been with the company for less than five years. As is the case in the United States, the British shipbuilding industry often competes for the limited labor pool. BAE's Govan and Scotstoun shipyards must not only vie for labor against other shipbuilders and manufacturing industries, but also risk losing workers to its own submarine division, which pays workers more than those who work on surface vessels. Shipbuilders must further contend with "a negative public perception of the sector" as being a dying industry, "which forms a barrier to attracting new talent, especially in the context of high demand for advanced STEM skills."[385] Shipbuilders particularly struggle to recruit women laborers, with BAE reporting that women constitute less than five percent of its roster of tradespeople.

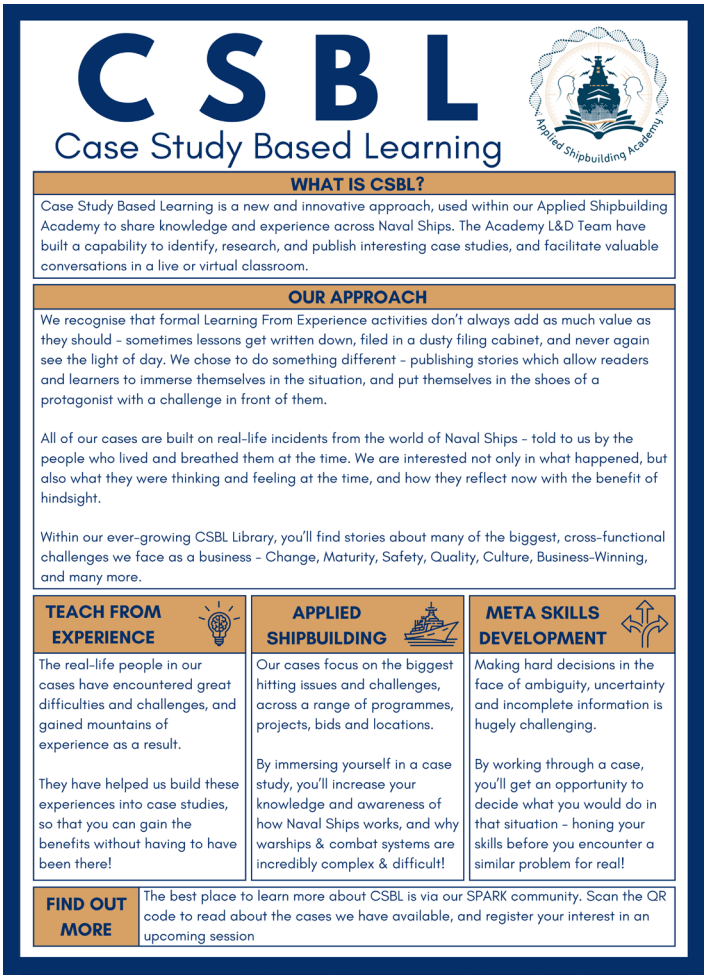


Figure 27: BAE's approach to Case Study Based Learning (Source: BAE Systems).

Like many countries, the U.K. shipbuilding industry relies on migrant laborers to support its workforce needs, as evidenced by the presence of Polish-language signage aboard HMS *Glasgow*, the first of the Type 26 ships being produced by BAE. Babcock employs 250 Filipino workers at its Rosyth yard in addition to laborers from Eastern Europe, and primarily uses foreign workers to fill mid-term gaps in its apprentice program. While Babcock conducts rigorous background checks on migrant workers during the hiring process, the company avoids tasking them with installing complex systems containing classified information, leaving that work to indigenous tradespeople. Unfortunately, access to migrant workers has been complicated by the U.K.'s departure from the European Union in 2020, which resulted in the imposition of additional, more rigorous visa requirements. The MoD has successfully negotiated exceptions with the Home Office, the U.K.'s interior ministry, for some foreign shipbuilding workers to enter the U.K. to support the Type 26 and Type 31 programs on the grounds that these ships constitute a key national security need. However, MoD officials expressed significant skepticism that these exemptions could be renewed considering the increasingly polarized political climate surrounding immigration in the U.K., which could result in additional labor shortages in the coming years.

Despite these challenges, the national shipbuilding workforce is expanding because of increased demand. While Babcock was originally short 400 to 500 workers to build the Type 31 ships, it has significantly increased its labor footprint at Rosyth and now has 1,500 workers supporting the project. BAE currently has 6,000 employees working on naval ships (with the majority of them located in its twin shipyards in Glasgow) and has reduced its attrition rate for these workers to 7.9 percent—a fraction of what it was during the COVID-19 pandemic. Employment at Barrow-in-Furness grew from 11,000 to 13,500 between 2023-2025 and is expected to increase to 16,500 by 2027, supported by a £20 million investment in housing, transportation, and social infrastructure to support the growing workforce.[386] Notably, the majority of the shipbuilding

jobs being created are in Scotland, a region which has largely underinvested in promoting the development of the industrial skills needed to support rising demand for British-built ships.

Both the British government and the shipbuilding industry appear to be taking this skills gap seriously, with the 2022 National Shipbuilding Strategy Refresh committing to "reduce skills shortfalls by 35% by 2027 and 50% by 2030" and "enable employers to report improvements in skills availability and quality increases by 25% in 2024, 50% in 2027 and 75% in 2030."[387] Shipbuilders have also invested considerable capital into training the next generation of skilled workers. BAE committed more than £30 million to the creation of an Applied Shipbuilding Academy, which allows apprentices to simulate a shipyard in a safe environment while working to master the same equipment used in the yard. BAE has creatively begun employing case study–based learning to train both blue- and white-collar workers in critical thinking in the design and manufacturing stages of shipbuilding, drawing on the company's past challenges and critical decisions to teach employees how to think through complex problems while also institutionalizing historical knowledge and industry best practices. Other companies have similarly invested in sophisticated training programs, with Babcock supporting 100 apprentices per year and Cammell Laird graduating 75 new apprentices annually.[388]

Notably, interest in entry-level shipbuilding positions far exceeds the capacity of companies to support trainees. Babcock receives up to 18 times more apprenticeship applicants annually than it can support, while BAE's early career roles (which currently constitute 20 percent of the company's blue- and white-collar shipbuilding workforce) receive 20 applications for every job they fill. The lack of capacity to train apprentices is partly attributed to a series of government-mandated hourly wage hikes for apprentices which have increased pay rates from £5.28 in 2024 to £8 in April 2026.[389] Shipbuilders also struggle to upskill those apprentices quickly enough to meet rising labor demands. To mitigate this challenge, Babcock has implemented a Production Support Operative (PSO) program in which it hires full-time, semi-skilled laborers who receive foundational pre-employment and on-the-job training to complete less technically complex tasks. Babcock estimates that there is one PSO for every three-to-four skilled tradespeople in its Rosyth yard and noted that the program has emerged as an alternative pipeline to recruit full-time workers who can advance to the apprenticeship program and qualify to become a tradesperson. The PSO program has largely been embraced by union workers, who appreciate that PSOs free up bandwidth for skilled workers to focus on their specialized trade.

Workers have accepted that mastering emergent technology can not only allow them to work faster, more efficiently, and with less physical exertion, but can also reduce the risk of their positions becoming obsolete.

Relations between organized labor and British shipbuilding companies have often been tense throughout the industry's history. Shipbuilding workers formed unions in response to the extreme volatility of the industry, which quickly grew into powerful advocates that helped shepherd much-needed reforms. However, the unions' growing strength further slowed innovation in the industry as unions pushed back against efforts to adopt new technologies and methods which threatened job security.[390] Because there were separate unions for each job on the shipyard (riveters, boilermakers, etc.), laborers were extremely reluctant to learn multiple skills, which over time led to a workforce that was extremely specialized. In some cases, workers only knew how to perform job duties which had been rendered obsolete by subsequent technical advancements. In one shipyard, job duties were so rigidly demarcated that three workers were required to change a lightbulb—a level of rigidity which significantly slowed production.[391]

Fortunately, relations between management and labor have improved dramatically in recent decades. Both skilled laborers and members of the management teams at BAE and Babcock spoke to the strong working relations between the Confederation of Shipbuilding and Engineering

Unions and industry management, noting that the most common labor disagreements are often between local union chapters and the unions' national leadership. While relations ebbed amid industry-wide layoffs in the 1990s and 2000s, they have deepened due to the establishment of clear lines of communication and management's investment in supporting the upskilling of its workers. The MoD and management at both Babcock and BAE spoke to the unions' enthusiastic embrace of modern technology such as autonomy and AI—a sentiment which CMS confirmed through conversations with skilled tradespeople. Workers have accepted that mastering emergent technology can not only allow them to work faster, more efficiently, and with less physical exertion, but can also reduce the risk of their positions becoming obsolete. One worker described this concept as "learning to use the machines so you don't get replaced by the machines." While future reductions in demand or layoffs resulting from the embrace of automation could result in renewed antagonism between labor and management, both sides appear increasingly committed to a collaborative approach and united by a shared pride in their work and desire to produce the best ships possible.

Technology Integration

When British shipbuilding was at its apex, many companies opted not to invest in more modern machinery to help increase productivity, instead retaining more labor-intensive methods. Accordingly, shipbuilders were slow to embrace welding and prefabricated construction, even though they would allow shipyards to produce boats faster in the long run, as the United States and Japan would post–World War II.[392] Based on conversations with CMS, the NSO is acutely aware of the role such decisions played in the decline of British shipbuilding and appears committed to not repeating these mistakes. Accordingly, the contracts signed by the British government to produce the Type 26 and 31 vessels were written to provide Babcock and BAE with sufficient funds to invest in developing and integrating new technology into their shipbuilding processes to help modernize their yards.

A recent OECD peer review study of U.K. shipbuilding cited the "uneven adoption" of digital transformation and technical innovations across the British shipbuilding sector, as well as "government failure in the design of policy support to innovation."[393] While broadly true across the British MIB, CMS observed several positive signs of the industry's increased focus on technology integration during its shipyard visits. For example, Babcock is increasing its use of digitization and automation, which is apparent from viewing its Rosyth shipyard. When the aircraft carriers HMS *Queen Elizabeth* and *Prince of Wales* were being built at Rosyth in the 2010s, they were constructed almost exclusively by hand by approximately 3,500 laborers. Now, 20 percent of ships at Rosyth are built in an automated environment—a number which Babcock is committed to increasing in the coming years. Rosyth's primary panel line has a six-stage process to put steel together (prep, weld, mark, stiffener mounting, T-Beam mounting, and robotic weld) which is aided by 3D models. This process, largely done manually only a few years ago, is now undertaken almost exclusively using a complex system of robotics overseen by 12 workers. The company has also gone from manually lifting shafts with cranes to digitally aligning them—a testament to how its investment in modernizing the yard has created a more efficient and streamlined building process. Babcock is integrating VR into the inspection of ship components and has introduced new modeling tools which allow for automatic output, as well as completion management systems which enable the digital handover of all documents and materials that accompany ship deliveries. The company also uses CATIA Ship Structure Detail Design 2, a specialized software solution by Dassault Systèmes for creating, managing, and defining detailed ship structural systems and connections.

Babcock lacks the ability to monitor the activity of each individual worker across the yard in real time. However, its two-year partnership with Palantir has significantly improved the company's ability to access and operationalize data. Babcock has integrated Palantir's Foundry operational data platform into Rosyth, which the company reports has helped the yard centralize the digital

design and construction process and monitor supply chains more effectively. Work that was once conducted across a large swath of manually updated spreadsheets—prone to user errors which could produce significant setbacks—is now automated and completed accurately in a fraction of the time. Babcock reported that its planning cycle time has decreased from roughly six weeks to 48 hours because of this tool.

Perhaps the most significant process improvement Babcock has made through its investment in upgraded technology is related to its production of Common Missile Compartment missile tubes. Babcock plays an essential role supporting the navies of the U.K. and its allies. In addition to serving as the original equipment manufacturer for all the U.K.'s submarine weapons handling systems, Babcock exports such systems to countries including Australia, Spain, and South Korea. Babcock also contributes to the assembly of *Virginia*-class Block VI fast-attack submarines and produces 80 percent of the missile tubes for both the *Dreadnought*- and *Columbia*-class submarines.[394] These tubes are remarkably complex, with each containing 1,200 components and seven miles worth of welding. To support their production, Babcock has invested heavily in robotics (such as heavy-duty CNC machining centers) and digitization to provide world-class welding for these highly important parts. Using a complex system of video monitors, robotics, and computers, Babcock's robotic welders can match the output of eight workers while producing welds that are functionally defect-free. Babcock boasts a 99.9 percent pass rate for welds on its missile tubes and has used this technology to produce these parts more precisely and more quickly.

BAE has similarly invested in integrating advanced and emergent technology into its shipbuilding and design processes. BAE uses digital twins at its Govan and Scotstoun shipyards, allowing for real-time monitoring of every ship in production. The Govan yard boasts six visualization suites which have been operational since 2014 and can digitally render ship designs in 3D to provide both first- and third-person views of any room of the ship from any angle to allow shipbuilders to identify potential design flaws early in the process. Roughly half of its workers now carry tablets to virtually access ship design materials using a site-wide secure Wi-Fi network. Meanwhile, BAE's embrace of automation has resulted in a 50 percent reduction of the manpower needed in the Govan yard's fabrication shed while simultaneously decreasing the amount of welding errors since beginning the production of HMS *Glasgow* in 2017. That BAE has accomplished these feats while simultaneously experiencing a fourfold increase in productivity in its fabrication shed speaks to the transformative power of this technology on its production capabilities.

Design and Manufacturing Process

In 1988, the Barrow-in-Furness shipyard accidentally welded part of a *Trafalgar*-class submarine upside down, a mistake which cost almost $2 million to fix.[395] This embarrassing incident serves as an excellent encapsulation of the challenges the British MIB faced in the designing and constructing naval vessels in the years immediately preceding and following the end of the Cold War. The A*stute*-class submarines, on which BAE began construction in 2001, were replete with difficulties which resulted in several years of delay and significant cost overruns. The challenges associated with building and designing these ships yielded several lessons, which were outlined by the RAND Corporation in a 2011 study into the submarines' tumultuous production process.[396] This report concluded that the MoD and BAE seriously underestimated the complexity of designing the vessel and the risks associated with new design tools, due in large part to a lack of institutional expertise designing and building complex submarines. The nearly two decades between the start of the *Astute* program and the design of the Brits' most recent submarine class, the *Vanguard*, resulted in a significant loss of institutional memory and lack of familiarity with new technology such as computer-aided design. This increased complexity, raised costs, and slowed progress because the design programs were not properly configured for a complex nuclear submarine program and few designers had the expertise to use them effectively. The construction of the submarine began before the design process was complete, predictably resulting in numerous false starts and mid-build design changes. The combination of weak gov-

ernment oversight, misaligned expectations about contractor capability, and the failure to plan for reteaching lost skills meant that technical challenges, cost growth, and schedule slips became entrenched in the program.

Recent years have seen the British shipbuilding industry make considerable improvements to its design and manufacturing processes, though many of the challenges observed during the early years of the *Astute*-class program remain. The *Astute* is far from the only class of ships to undergo significant design renovations or to begin production before reaching design-complete. Cammell Laird was forced to absorb £37.4 million in losses and a £15.8 million impairment charge on its £200 million contract to build the polar research ship named after Sir David Attenborough (rather than "Boaty McBoatface," the name infamously chosen for the vessel by a public poll) after attempting to build on an immature design, which nearly bankrupted the company.[397] Additionally, while construction on both the *Queen Elizabeth*–class aircraft carriers and Type 45 frigates began at around 85 to 90 percent design maturity, both projects nevertheless encountered significant design changes and were brought into service with changes still being required (between 400 to 600 changes for the Type 45 vessels and roughly 3,000 changes needed for the carriers). However, the Type 26 and 31 ships have seen a relative decrease in mid-build design changes relative to previous shipbuilding programs. While the MoD made several changes to the Type 26 early in the design process, BAE reported that the government has micromanaged less since construction began, and Babcock reported that any changes deemed necessary to the Type 31 will likely be made post-build to accommodate the needs identified by naval officers once the ship is in use.

CMS, BAE, and MoD officials on the deck of HMS *Glasgow*, the first Type 26 ship under production. (Photo credit: BAE Systems)

Unlike in the United States, individual members of parliament are largely incapable of forcing changes to ship design to support domestic constituencies. Instead, the sole authority to approve or deny proposed alterations rests with the Senior Responsible Officer (SRO), the U.K. government official responsible to parliament for the cost of the ships. The SRO often receives counsel on the merit of proposed changes from the MoD's Defence Equipment and Support (DE&S) unit. The British equivalent of NAVSEA, DE&S was formed in 2007 and has played a key role in dissuading potential design changes to the Type 31 vessel, according to Babcock. In some instances, the government vetoes design changes proposed by the shipbuilders, such as when BAE proposed adding LED lighting on the flight deck of the Type 26 ships, which would have added approximately £100 million in costs. Notably, design changes made to one ship must be made uniformly across all vessels within that class, which complicates the process of making changes to ships once construction has begun on the first vessel.

While the risk of mid-build design changes remains omnipresent, shipbuilders have taken steps to mitigate it. Computer-aided design, which once contributed to the challenges in building the *Astute*-class, is now widely used in the U.K. along with 3D modeling to catch potential design flaws early in the process. BAE is also using its builds of the Canadian and Australian Type 26 variants to experiment with "modular packs" in which they release the basic design of the ship's hull early in the process, followed by additional building specifications on a rolling basis. In theory, this strategy could allow for construction on ships to begin as soon as the hull's specifications have been decided, with additional design specifications being added in the form of subsequent "modules" in hopes of accelerating the build process while reducing the number of reworks.

The Type 26 provides a fascinating window into how BAE handles the design and manufacturing process for modern naval vessels. The original concept for the Type 26 predates BAE's

existence and dates to 1998, when it was conceived as the Future Surface Combatant.[398] BAE executives stated that the ship was designed with exports in mind, with the goal of building the most adaptable ship ever constructed in the U.K. The Type 26 has 26-knot speed, a flight deck onto which one Chinook or two Merlin helicopters can land, and a mission bay handling system crane that can lift 15 tons at full-reach and can extend out 12 meters, according to both BAE and the MoD. The ship is built to maximize survivability, building two to three levels of redundancy into its design to help it stay afloat and operational even after taking damage. It was also designed to run quietly to support ASW, and its diesel engine was quiet enough at 100 percent mechanical load for CMS's researchers to carry out a conversation while standing next to the engine bay. The hull is being built with a 35-year lifecycle in mind, but BAE acknowledged that they expect these ships may be in use for up to a decade longer.

While the MoD did not expect a high-end warship to emerge as the U.K.'s most successful warship export, the Type 26 has proven to be extremely desirable on the basis of the Type 23 frigates' strong reputation and the growing need for anti-submarine vessels to counter rising Chinese and Russian threats. In total, 34 Type 26 ships will be built for four countries with 55 percent commonality across the designs (the greatest variation lies with the combat systems, while the navigation, bridge, and float and move systems are largely uniform across the ships). While Canada and Australia have been willing to accept a longer build time in exchange for BAE designing their ships to be more like the rest of their fleets, Norway requested fewer design changes, instead prioritizing a faster build. Unsurprisingly, BAE has made significant advancements in the construction of these ships since work began on HSM *Glasgow* in 2017; while *Glasgow* left the Govan shipyard for Scotstoun in 2022 with no electrical systems installed, HMS *Belfast* (the third *City*-class frigate) will leave the yard with a fully installed switchboard.

Babcock's Type 31 frigate was similarly envisioned as a lower-cost vessel which would generate interest on the export market. Babcock did not design the ship to serve as a high-end warfighter; instead, the Type 31 was intended to be built quickly and affordably with the simplest possible mission-capable platform while maintaining warfighting adaptability. Unlike the Type 26 which underwent nearly two decades of design refinements, Babcock based the Type 31 on the Danish *Iver Huitfeldt*–class frigate, refitting the design to match modern British combat and shipbuilding standards before taking it to market. Babcock described the Type 31 as a "disruptive program" meant to quickly get the ship to market and establish Babcock as a peer competitor on more even footing with BAE. The Type 31 has a lifespan of 25 years and is being built to sustain extensive use and be replaced, which will in turn support continuous shipbuilding for the yard. The ship uses the Tacticos combat management system (which is used commonly across various NATO platforms) and is designed to be highly configurable to allow this combat system to be used for a variety of missions. The design and build margins on the Type 26 are exceptionally small to ensure generous in-service growth margins across its key technical parameters (weight, power, cooling, etc.). While adding supplemental capabilities to the Type 26 typically requires the removal of one feature, the Type 31 was designed with considerable flexibility for weight over its lifespan, allowing buyers to add to and customize the ship to meet changing needs. The Type 31 is being built in the Rosyth yard's new grand blocking hall, which has introduced more modular "super blocks" as part of a block build process. The third ship of the class (HMS *Formidable*) is being constructed using this modular build strategy, which has been greatly aided by Babcock's integration of 3D modeling into the design and build process.

Both Babcock and BAE are using some degree of distributive building processes to construct their latest frigates. While the vast majority of the Type 31 is being built at Rosyth, some components are being produced elsewhere in Europe and shipped to Rosyth for incorporation into the vessel. Similarly, BAE relies on smaller yards throughout the U.K. to support its block build of the Type 26 vessel.

As the design and construction of the Type 26 and 31 frigates suggest, the British MIB is increasingly intentional about designing vessels which play to the strengths of its builders and

CMS, Babcock, and MoD officials stand in front of a Type 31 ship in a drydock at Babcock's Rosyth shipyard (Photo credit: Babcock)

can be competitive on the open market. The government commissioned a study through the OECD on commercial shipbuilding which concluded that the U.K. needs to specialize in order to compete in that market. The study identified "ferries, leisure vessels, and offshore wind vessels—as well as emerging technology-driven sub-sectors—green maritime, digital transformation, and autonomy" as potential markets for U.K. builders.[399] Although the U.K. is only recently breaking into some of these sub-sectors, resources are being allocated to catch up to other European countries that have been proactively developing in these areas.[400] A separate study conducted by the nation's Board of Trade concluded that "the U.K. can compete globally for complex vessels, such as offshore work boats, fast and ROPAX ferries, research vessels and expedition cruise ships" and that, "alongside globally competitive vessels, U.K. capability in services, decarbonisation, marine engineering, digital and tech can make a substantial contribution to the global shipbuilding supply chain."[401] The NSO further identified British-built commercial offshore wind vessels, small research vessels, ferries, and maritime autonomy as potential markets for U.K. builders, noting that ships which are 80 meters or less in length are more likely to turn a profit on the open market than larger vessels. Whether British shipbuilders continue pursuing projects which play to their strengths could help determine whether the country's commercial shipbuilding sector can rebound the way the market for British-built naval vessels has.

Purchasing and Government-Commercial Relations

Warships have historically been the U.K. shipbuilding industry's most significant product, and the British government has long been and remains its largest client. Between 1895 and 1914, battleship construction was the British government's single largest expenditure, occupying the same social and political status currently held by healthcare and other social welfare spending.[402] Since then, public sector demand for ships has precipitously decreased, while British shipbuilders have sought a more diverse clientele by designing naval ships specifically with foreign exports in mind. Yet the British shipbuilding industry remains largely dependent on government funding, meaning future reductions in orders from the MoD could cause the industry to contract. While the NSS is designed to create a 30-year pipeline of government ship purchases, the U.K. government's inability to commit to defense spending more than three years in advance creates significant uncertainty regarding this pipeline's durability. Shipbuilding companies have adopted a "wait and see" approach regarding the proposed 30-year pipeline and expect the forthcoming Defense Investment Plan to provide greater clarity on the MoD's procurement priorities. While the British government plans for defense spending to account for 2.5 percent of its GDP by 2027, both industry and MoD officials expressed concerns regarding whether budgetary constraints will result in reduced funding for shipbuilding relative to what was envisioned by the NSS.

To meet these challenges, the NSO is developing an action plan to promote sovereign shipbuilding and greater interagency cooperation to support this industry. However, the NSO cannot unilaterally order ships and must lobby parliament and other government offices to emphasize the role shipbuilding plays in supporting job creation and national defense. Given that foreign companies can often produce ships 15 to 20 percent cheaper than British builders due to lower labor costs, the NSO has encountered difficulties explaining to Treasury, Parliament, and other

government officials the value of investing those additional expenditures into the British MIB. While warships purchased by the MoD are legally required to be built in British shipyards, other vessels such as the RFA *Tide*-class tanker ships (built by Daewoo before its acquisition by Hanwha) are not. Accordingly, internal debates often occur between government officials who want certain ships classified as "warships" to help support shipbuilding jobs in the U.K. and those who oppose the designation in order to allow them to be built faster and cheaper overseas.

Incentivizing shipbuilding has been a longstanding challenge in the U.K. It took seven years for the MoD to convince the Treasury to review and reform its tonnage tax on shipbuilding, which eventually occurred in 2023. Due to the Treasury's enduring skepticism of the return on investment related to manufacturing, the U.K. offers among the lowest levels of industrial subsidies in Europe at only 0.7 percent of its GDP, as outlined in Figure 28.[403] The shipbuilding industry is similarly undersubsidized, with the OECD concluding that "Significant subsidies by other governments create a global market that is not a level playing field" for British shipbuilding.[404] While the U.K. Shipbuilding Credit Guarantee Scheme provides underwriting support, awards are typically small and insufficient to cover the cost of ambitious shipbuilding projects. Requirements for any subsidies to be compliant with both World Trade Organization (WTO) regulations and EU-U.K. Trade and Cooperation Agreement were further cited by MoD officials as a barrier to more robust government support for shipbuilding.

However, the U.K. government has sought to increase its investments in the shipbuilding industry. Industry leaders described these efforts as "capital light, but systems heavy," meaning the government has historically been more inclined to directly invest in developing new combat systems for ships than in supporting the use of emergent technologies in shipyards, instead relying on shipbuilders to use funds from their MoD contracts to fund such innovations. One significant government investment came in the form of Project Kraken, a Royal Navy-industry partnership focused on integrating aggregate data into the Navy and allowing for faster accumulation, analysis, and sharing of data to enable real-time decisionmaking. The success of this project could ultimately make British exports such as the Type 26 considerably more attractive, as the concept of a common Global Combat Ship gains traction. This ship would be operated by four allied navies across multiple theaters in which ships can share data with one another, and becomes significantly more attractive to prospective buyers when the U.K.—one of the four allies—boasts considerable data analytics capabilities. The government has also invested significant capital into decarbonizing Britain's naval and commercial fleets, funding 55 clean maritime projects in 2022 to support its net zero goals, investments which the NSS Refresh concluded could allow the U.K. to establish a "particular competitive advantage" in alternative maritime fuel production.[405] Still, shipbuilding executives noted that most naval R&D efforts are being led by private industry. While the government formed a National Armaments Director Group in March 2025 to strengthen engagement with industry on the procurement of weapons systems, this entity is in its infancy, and both government and industry officials expressed a desire for more robust cooperation on naval R&D.

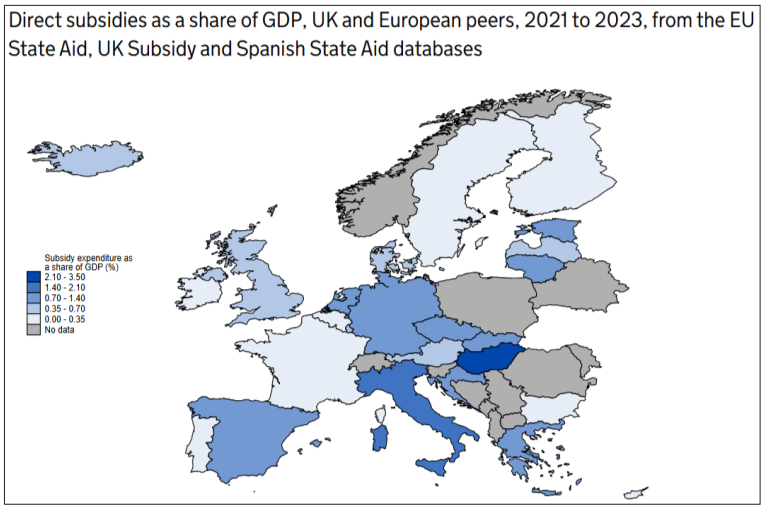


Figure 28: Direct subsidies as a share of GDP, 2021-2023 (Source: Competition and Markets Authority).

Shipbuilding contracts in the U.K. are typically a mix of either fixed-price (such as the Type 31) or cost-incentive agreements (such as the Type 26). In some cases, the use of fixed-price con-

tracts has resulted in shipbuilders facing significant cost overruns, as is the case with Babcock, which has sought relief against supply chain and inflationary costs because building the Type 31 has cost more than was originally projected. The government typically avoids penalizing builders for the late delivery of ships to avoid imposing fines which could weaken the handful of companies still capable of building warships. Accordingly, the Type 26 contract includes a Target Cost Incentive Fee structure in which potential cost overruns or cost savings are shared by the shipbuilder and the government. Increasingly, contracts are being written to include funds for training the Royal Navy on how to man and operate the ships being built. Warships have historically been delivered in unknown maintenance states due to poor communication and the lack of pre-handover live testing, and sailors typically require several weeks of training to become familiar with the ship before they can be deployed. However, the Royal Navy hopes to have a trained crew ready to operate the Type 26 and Type 31 on the day of delivery and has been closely involved in safety checks during the construction of these ships to increase institutional familiarity with the vessels prior to handover. The Navy hopes to adopt a "test once, use many times" approach, and even envisions the Norwegian Type 26 ships setting sail with a mixed British-Norwegian crew to promote greater interoperability between the two allied navies.

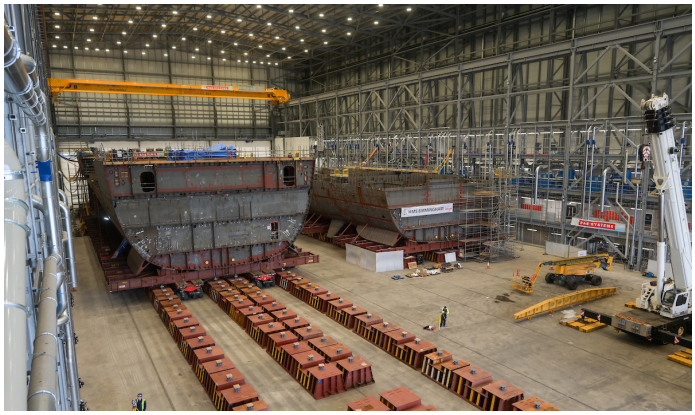
Portions of the fourth Type 26 ship (HMS *Birmingham*) in transit from the Govan shipyard (Photo credit: BAE Systems)

The British government has paradoxically sought to foster both competition and cooperation between shipbuilding companies. On one hand, the NSS was intended in part to elevate shipbuilders such as Babcock to be peer competitors of BAE in hopes of spurring greater innovation and avoiding the overextension of BAE's capabilities. However, the government has also encouraged a collaborative approach to shipbuilding in which companies divide and conquer in the interest of supporting the Royal Navy's needs, including ceding some contract opportunities to their peers rather than having every shipbuilder compete for every contract. Both Babcock and BAE spoke exceptionally highly of the other company and expressed pride in their past collaborations and willingness to share best practices with one another. British companies have previously collaborated on large shipbuilding projects such as the formation of risk-sharing "Aircraft Carrier Alliances," through which a significant number of workers from BAE and the Thales Group relocated to Rosyth to support the production of the *Queen Elizabeth*–class carriers under a common management team. This model of cooperation has influenced subsequent projects—General Dynamics Electric Boat staffers are currently stationed at Rosyth to support Babcock's missile tube program, and the British submarine delivery agency is considering a model similar to the aircraft carrier alliance for future projects.

Navantia's entry into the British shipbuilding market has notably created a stir. On one hand, Navantia's eleventh-hour acquisition of Harland & Wolff saved its historic Belfast shipyard from closure, and its presence in the market provides the Royal Navy with another proven shipbuilder to support the British MIB. On the other hand, the MoD noted concerns expressed by some indigenous British shipbuilders about their ability to compete with a sovereign-backed company that can offshore production to its Spanish yards to reduce costs. While a Navantia-led shipbuilding alliance outbid a joint BAE-Babcock proposal to build the RFA's Fleet Solid Support (FSS) ship, the inability of its Belfast yard to support the production of these ships resulted in the first FSS being built in Spain.[406] Navantia's ability to build ships overseas at a lower cost could potentially allow it to outcompete British builders for non-naval government contracts, reducing the economic value of these projects to the British MIB. Whether its entry into the British market will disrupt the current state of government-commercial relations remains to be seen.

Infrastructure

The U.K.'s four prime shipbuilders—BAE, Babcock, Navantia, and Cammell Laird—currently have 13 shipyards capable of constructing new builds, which marks a precipitous decline from the nation's shipbuilding heyday. For comparison, in 1840, there were 65 working shipyards in the town of Sunderland alone.[407] Given the lack of suitable space available for such infrastructure, the U.K. is not planning to build additional shipyards capable of producing naval vessels. In the case of the Rosyth yard, a former naval base was converted into a commercial yard when Babcock purchased it in 1997 after managing it for almost a decade. Shipbuilders have had to make creative use of their space given their inability to build outward and expand their yards. The space constraints are particularly noticeable at BAE's Scotstoun yard, which is considerably longer and narrower than typical shipyards. Because BAE's Govan yard cannot support the docking of ships, vessel construction begins at this yard before the completed hulls are placed onto a barge using a heavy-lift transporter, submerged in deep water, towed up the River Clyde, and placed in one of Scotstoun's three docks for final fitting. BAE's Osborne Shipyard in Adelaide, Australia—which has considerably more space to support a comprehensive rebuild—will likely reflect the company's ideal vision for a modern shipyard given the absence of the geographic constraints seen in Govan and Scotstoun.



Two Type 26 ships under construction in the Govan Shipyard's Janet Harvey Hall (Photo credit: BAE Systems)

Instead of creating new yards, shipbuilders have used recent contracts to recapitalize their yards and update their infrastructure. Babcock has spent £400 million on recapitalization and has plans to upgrade the panel line at its Rosyth yards to triple its capacity. This yard, which amazingly produced aircraft carriers as the first-ever vessels constructed after its privatization, resumed shipbuilding activities in earnest with the construction of the Type 31 following a lull in contracts after the conclusion of the carrier project. The yard boasts three drydocks for housing ships in addition to the largest non-tidal basin in Europe. Both Babcock and BAE have invested in creating covered sheds to enable shipbuilding projects to continue unaffected by the elements and the harsh Scottish winters. BAE invested in the construction of the Janet Harvey Hall, a massive indoor facility opened in 2025 and named after a trailblazing electrician who supported British shipbuilding efforts during World War II. The hall is large enough for two Type 26 ships to be built next to each other simultaneously and can accommodate up to 450 workers on each vessel. BAE hopes this facility can eventually support up to 600 workers on each ship at once and support 100 percent of the ships' ironwork.

Two Type 31 ships under construction in the Rosyth Shipyard's Venturer Hall (Photo Credit: Babcock)

Similarly, Babcock's Rosyth yard opened the Venturer Hall in 2021 which allows for the simultaneous construction of two Type 31 ships under cover, signaling the industry's growing acknowledgement of the need to invest in infrastructure that supports yearlong construction.

Supply Chains

British shipbuilders encounter many of the supply chain challenges experienced by other seafaring nations. The Russo-Ukrainian War has increased the cost of steel while decreasing its supply, with many shipbuilders becoming increasingly reliant on Swedish steel in response to the U.K.'s ban on Russian steel imports. While this rerouting of the supply chain has not led to significant manufacturing delays, it has increased production costs and caused the U.K. to scale back its efforts to standardize the thickness of steel used in manufacturing.

Although both Babcock and BAE rely heavily on sole-source suppliers to support their shipbuilding efforts, the two companies reported disparities in the resilience of their supply chains. While Babcock reported experiencing only minimal supply chain–related delays, both BAE and the MoD lamented the delays in the production of the Type 26 ships caused by a deficit in the supply of reduction gears. The Type 26's ASW capabilities require the ship to run as quietly as possible, and only a single British supplier can produce gearboxes that can meet the ship's needs. Years worth of delays in the delivery of these parts forced BAE to install HMS *Glasgow*'s gearbox through the side of the already-built ship to avoid halting production, which naturally proved time-intensive and disruptive to its construction. BAE has been forced to adopt a more hands-on approach to monitoring and assisting the operations of some sole-source manufacturers that support its supply chain. Both BAE and Babcock are continuously monitoring supplier resilience to determine whether their sole-source providers are at risk of collapse so they can start looking for alternatives or help keep these providers afloat.

The high volume of exports anticipated for the Type 26 and Type 31 vessels could allow BAE and Babcock to pool spare parts and supplies among the allied nations using these ships, which could potentially help alleviate supply chain issues in the future. However, both BAE and Babcock expressed frustration with the "high level of low-level obsolescence" in the parts and equipment used for the construction of the Type 26 and Type 31 ships. Sole-source manufacturers frequently make small changes to their products, preventing shipbuilders from stockpiling spare parts which may not work with future generations of replacement equipment. BAE and Babcock do very little casting and forging on-site and have made minimal investments in additive manufacturing, though the latter is increasingly being used to support Britain's submarine repair program.

Key Findings

The story of the British MIB serves as both a cautionary and aspirational tale for the United States. On one hand, decades of underinvestment in shipbuilding and a failure to embrace modern shipbuilding technology and methods enabled the collapse of British naval and maritime dominance. This story is a more extreme version of America's own shipbuilding decline and reinforces the urgency behind current attempts to revitalize this sector. On the other hand, the U.K.'s renewed commitment to the industry and willingness to adopt strategies which emphasize its strengths present a potential path forward for the United States. Rather than accepting the permanence of its shipbuilding decline, the U.K. has embraced an export-heavy model, prioritized the development of ships such as frigates and submarines with which British builders have a demonstrated track record of success, and encouraged shipbuilders to strategically corner sectors of the commercial market in which they are poised to be competitive. While the U.K. government remains the sector's largest client, the establishment of a 30-year pipeline, combined with the increased focus on exports, has brought greater stability to the industry and allowed shipbuilders to invest in modernizing their facilities. Similarly, the willingness of shipbuilding companies and their workers to enthusiastically embrace modern technology and manufacturing processes has positioned the industry to build on its growing success. These all serve as valuable lessons for the United States as it recommits to supporting its MIB.

British shipbuilding is unlikely to ever regain its former market share, but it still has an important role to play in supporting British seapower and strengthening alliances such as NATO. The

high demand for both the Type 26 and Type 31 create opportunities for greater commonality and interoperability among America's allies, while the AUKUS agreement and the U.K.'s submarine-building capabilities could strengthen America's allied deterrence in both the European and Asia-Pacific theaters. Government and private investments into the industry have positioned British shipbuilders to deliver on these promises and carve out greater success in the years and decades to come.

SWOT: U.K. Shipbuilding

Strengths

- A strong and growing export market for British-built warships
- A shipbuilding industry and workforce committed to embracing automation and digitization to improve design and construction processes
- Collaboration among indigenous shipbuilding companies and a willingness to share best practices, cede contract opportunities to their competitors, and partner on large shipbuilding projects
- A proven capacity to build high-end subsea vessels
- A National Shipbuilding Office dedicated to implementing an ambitious National Shipbuilding Strategy
- Innovative approaches to training the next generation of shipbuilders

Weaknesses

- Uncertainty within the shipbuilding industry about the government's demand for future ships in the face of coming fiscal and budgetary challenges
- Naval ships frequently face significant time and cost overruns and often encounter late-stage design changes
- A significantly diminished commercial shipbuilding industry
- The Royal Navy faces manpower gaps which could reduce its operational capacity
- Only a handful of yards can produce naval vessels
- The industry faces labor shortages and limited capacity to absorb and train new apprentices

Opportunities

- Exporting variants of a Global Combat Ship with high levels of commonality can enhance interoperability between Britain and its allies and deepen relations with customer states
- AUKUS could create new export markets for British-built submarines and deepen naval cooperation between the U.K., United States, and Australia
- Greater specialization in commercial shipbuilding could allow the U.K. to carve out a larger market for itself in the commercial sector
- High and growing demand for shipbuilding apprenticeships could help revitalize the industry's labor pool

Threats

- Unstable political support for continuous shipbuilding
- Any dips in the demand for U.K.-built frigates (including from recurring construction delays) could result in a contraction of the industry
- British shipbuilders could offshore more vessel construction, weakening the domestic shipbuilding industry
- Future budget cuts could reduce funding for the Royal Navy, jeopardizing demand for British-built warships
- The industry's struggles to quickly replace an aging workforce could result in future labor shortages, cost overruns, and production delays

Figure 29: Strengths, Weaknesses, Opportunities, and Threats (SWOT) for U.K. shipbuilding (Original graphic by the Center for Maritime Strategy)

Comparison and Analysis

CMS's examination of America's AMIB yielded several illuminating insights that can inform America's efforts to restore its maritime dominance.

The extent to which America's allies have committed to maintaining and supporting their domestic shipbuilding industries since World War II and the end of the Cold War varies dramatically. On one hand, the South Korean government made a concerted, multi-decade effort to build a robust shipbuilding industry and continued to support and prioritize this industry even after ending its subsidies in 1986. This decision carried both economic and security dimensions—South Korea correctly identified the shipbuilding industry as one which could spur domestic economic growth, but also one that was essential to its national defense considering the omnipresent military threat posed by North Korea and the specter of an ascendent China. Meanwhile, America and many of its European allies responded to the end of the Cold War, globalization, and the spread of free trade by gradually deemphasizing and defunding efforts to support shipbuilding and the preservation of their MIBs.

AMIB Commercial and Naval Shipbuilding		
Country	**State of Commercial Shipbuilding Sector**	**State of Naval Shipbuilding Sector**
Canada	Weak	Strong
Italy	Strong	Strong
South Korea	Strong	Strong
Sweden	Weak	Weak
United Kingdom	Weak	Strong
United States	Weak	Strong

Figure 30: Commercial & naval shipbuilding in America's AMIB (Original graphic by the Center for Maritime Strategy.)

Among these Western countries, there are clear disparities in the extent to which their shipbuilding industries were preserved in wake of World War II and the Cold War. Of the European nations, Italy stands out as the country which most intentionally preserved strong commercial and naval shipbuilding sectors due to the Italian government's strong and continued support for its largest domestic shipbuilder, Fincantieri's ability to emerge as a global leader in cruise ships, and Italy's commitment to continue building both surface and subsea naval vessels. Because of Italy's commitment to preserving both commercial and naval shipbuilding, the former sector has proven capable of supporting the latter, with Fincantieri's commercial shipbuilding projects inspiring innovations in ship design and manufacturing which have proven directly applicable to warship production. Meanwhile, the U.K. and Canada are similar to the United States in that their commercial shipbuilding industries have largely atrophied due to a lack of institutional support and an inability to compete with heavily subsidized foreign competitors such as China. While Italy, Canada, and the U.K. preserved enough naval shipbuilding and repair capabilities to support their most basic national defense needs, Sweden allowed its MIB to degrade the point where it is no longer capable of building steel hulls from scratch and has become heavily dependent on foreign shipbuilders to construct its surface naval vessels.

The different shipbuilding approaches adopted by America's maritime allies produced wildly different outcomes and, predictably, a diverse set of observations which can be applied to America's efforts to revitalize its shipbuilding industry. These insights are organized below into six categories, mirroring those used in each of the case studies: Labor and Workforce, Technology Integration, Design and Manufacturing Process, Purchasing and Government-Commercial Relations, Infrastructure, and Supply Chains.

Labor and Workforce

Many of the most significant labor challenges faced by American shipbuilders are also present in the countries studied in this report. Each case study country faces meaningful challenges in the recruitment and retention of skilled workers, as decades of industrial and economic policy

deemphasizing manufacturing and trades jobs created significant shortages of workers to meet the current shipbuilding demands. While some nations like South Korea and Italy have aging workforces similar to those supporting America's MIB, other countries like Canada skew considerably younger, owing to surges in domestic shipbuilding demand over the past decade because of its NSS. All the countries examined as part of this project face competition for skilled labor from other shipbuilders and defense contractors, as well as from other industries employing skilled engineers and tradespeople who can offer higher wages and, in many cases, less physically demanding working conditions. COVID-19 served as an inflection point for each country, exacerbating existing challenges with recruiting and retaining their MIBs' workforces. Meanwhile, while countries such as Canada and the U.K. mirror the United States in their underinvestment in the training and educating of naval architects and marine engineers, other nations like Sweden and South Korea have maintained a steady supply of new professionals in these industries, allowing these nations to make noteworthy innovations in areas such as vessel construction management and ship design, respectively.

Amid these labor challenges, the United States and its allies have all become reliant on migrant labor to support domestic shipbuilding. While some countries like South Korea have taken concrete steps to reduce the barriers for shipbuilders to employ migrant workers, other countries like the U.K. face political pressure to reduce their immigrant labor footprint, as well as structural hurdles to hosting migrant workers resulting from Brexit. The shortage of domestic shipbuilding workers necessitates American shipbuilders incorporating migrant workers into the vessel construction process, which warrants more careful consideration by American policymakers as to how best to account for this reality.

While labor-related challenges were consistent across the case study countries, each of these nations is also investing in training and apprenticeship programs which could help address labor gaps. British and Italian shipbuilders have developed fast-growing apprenticeship programs which struggle to keep up with the high number of annual applications, illustrating how the labor market responds to rising demand when prospective employees are provided with sufficiently enticing incentives and opportunities to enter the shipbuilding field. Creative approaches to educating and training tradespeople, such as BAE's Applied Manufacturing Shipbuilding Academy and Fincantieri's *Maestri del Mare,* underscore the importance of similar American efforts such as HII's Apprentice School and the Danville ATDM program in producing the next generation of American shipbuilders. Meanwhile, Canada's Red Seal has created a high national competency and training standard for the field while simultaneously making shipbuilding jobs more attractive by easing skilled workers' transition to shipbuilding from other industries without risking pay cuts and mandating recertification. Hanwha's efforts to recruit outgoing master shipbuilders to serve as educators and mentors for the next generation could serve as an effective model for American companies to turn its aging workforce into an asset, operationalizing the experience of its retiring tradespeople to imbue younger workers with the knowledge and best practices gained over decades in the industry. Finally, Sweden's concerted efforts to train and educate naval architects highlights the importance of producing more hirable white-collar shipbuilders in the United States, which would require a greater investment from both the government and industry to expand.

As American shipbuilders increase their reliance on AI, automation, and digitization, they must also follow the example of their allies and ensure buy-in from organized labor regarding the use of these technologies

Technology Integration

As American shipbuilders train the next generation of skilled tradespeople, they must also take care to encourage their labor forces to integrate new and emergent technologies into their work. In each of the case study countries, CMS observed a greater willingness of the labor force to embrace technologies such as AI, automation, and digitization than has been ob-

served in American shipyards—an observation which was confirmed through CMS's discussions with the executives of South Korean, Italian, Canadian, and British shipbuilding companies (CMS was unable to observe this trend in Sweden since it was not afforded the opportunity to conduct a shipyard site visit). While American shipbuilding executives spoke to CMS about the pervasiveness of their employees' concerns that these technologies could result in job loss, shipyard workers across America's allies have largely treated these technologies as additive rather than disruptive, seeking to master new tools which allow them to work more efficiently and accurately rather than resisting their integration into the design and manufacturing processes. As American shipbuilders increase their reliance on AI, automation, and digitization, they must also follow the example of their allies and ensure buy-in from organized labor regarding the use of these technologies, including by adopting a collaborative approach to ensure that these tools are used to support rather than replace the existing workforce. Additionally, more programs such Fincantieri's *Maestri del Mare* program which train workers to utilize AI and robotic systems as force multipliers could help change how American workers perceive emergent technologies.

The integration of such technology varies heavily across America's AMIB. Figure 31 provides a brief summary of the extent to which the case study countries have integrated AI, automation, and digitization into their ship design and manufacturing processes.

While every case study country has taken concrete steps to embrace the "smart shipyards" concept, South Korea and Italy have achieved a more mature integration of this vision. Both utilize analytics and real-time data collection in their operations while relying on state-of-the-art technology and intelligence systems to monitor shipyard operations in real time and anticipate and rapidly respond to challenges and potential slowdowns. Both countries have embraced AI, automation, and digitization on a much larger scale than American shipbuilders, allowing them to produce commercial and naval vessels much faster and more efficiently than their American counterparts. Their use of robotics and unmanned systems for welding, inspection, and machining has helped streamline production and reduce the labor required to produce an individual hull. Hanwha's world-class digital control center and robust digital twin architecture have proven transformative to its shipbuilding operations, while Fincantieri's use of robotics at its Monfalcone shipyard constituted the most impressive use of automation observed by CMS during its site visits.

Meanwhile, the shipbuilding operations CMS observed in Canada and the U.K. are much more similar to American yards. Shipbuilders in these countries have made significant capital investments in updating their infrastructure and improving their ship design and production processes. As a result, they have seen meaningful improvements in their productivity, underscoring the importance of further investing in modernization. While CMS was unable to conduct field visits to Swedish shipyards, the case study revealed the country's significant and impressive strides towards integrating digitization into its remaining shipyards, while its use of automation and AI remains in a more nascent state. Each case study conducted for this report supports the conclusion that

AMIB Technology Integration in Ship Design and Manufacturing

Country	Utilization of AI	Utilization of Automation	Utilization of Digitation
Canada	Medium	Medium	Medium
Italy	Strong	Strong	Strong
South Korea	Strong	Strong	Strong
Sweden	Emergent	Emergent	Strong
United Kingdom	Medium	Strong	Medium

Figure 31: AMIB technology integration in ship design and manufacturing (Original graphic by the Center for Maritime Strategy.)

greater investment in AI, automation, and digitization into U.S. shipbuilding is essential to reverse the decline of America's MIB and enable it to become more competitive with global shipbuilding powers such as China and South Korea.

Design and Manufacturing Process

Investments into technological integration can only yield so many improvements if not accompanied by reforms to ship design and manufacturing. Specifically, this study illustrates the importance of minimizing the frequency and severity of ship design changes, particularly once construction has begun. While some countries like South Korea and Canada have succeeded in minimizing the number of late-stage design changes made to ships, other allied nations such as Sweden and the U.K. have experienced many of the same delays and cost overruns often seen in the United States as a result of either lengthy design processes or structural changes imposed on the design of ships that are allegedly design-complete. Some countries have sought to create guardrails to prevent the over-instrumentalization of ships and protect against the late-stage imposition of design changes, such as the U.K.'s creation of the DE&S to run interference against potential meddling in ship design. However, with the exception of South Korea and Fincantieri's cruise ships, ballooning costs and ship delays are often the norm across the AMIB, which can largely be attributed to the over-engineering of vessels. Creative approaches to this issue—such as South Korean shipbuilders filling orders of comparatively fewer ships to enable subsequent orders to reflect any design changes—are worthy of consideration.

However, this study also revealed the significant impact of industry-wide cultural norms surrounding delays and cost overruns on the health of domestic shipbuilding. While each case study country takes great pride in producing quality ships which support national defense and the defense of their allies, only South Korea (and, to a lesser extent, Italy) have truly committed to uniformly producing vessels on time and at cost without exception. While the disparity between South Korea and the United States and its other allies is at least partly attributable to cultural norms, the fact that South Korea is both the most consistent of these countries at producing ships on time and under budget and the largest and most successful shipbuilding industry among this group highlights the need for the United States to place greater emphasis on reducing delays and cost overruns. The VCM model, which has been thoroughly embraced by Sweden and is being used to support Hanwha's construction of the NSMV at the Philly Shipyard, could serve as an important mechanism for reducing external meddling in ship design and ensuring construction remains on schedule and under budget.

The most expensive way to build ships is to stop building them and then try starting again.

Another important lesson of this study was best summarized by a representative of the U.K.'s DE&S: the most expensive way to build ships is to stop building them and then try starting again. South Korea's continued commitment to building ships at scale has allowed its shipbuilding industry to remain incredibly efficient. In contrast, Sweden and the U.K. experienced significant challenges in attempting to ramp up production on types of ships which had not been produced domestically for several years, resulting in fraught production processes such as the U.K.'s *Astute*-class submarines and the virtual abandonment of hull production by Swedish shipbuilders. This lesson underscores the importance of America's efforts to revitalize its MIB to ensure its shipbuilding capabilities do not atrophy even further, which could make it even more difficult for America to support the needs of its navy.

One common trend that has emerged among America's seafaring allies is the growing recognition of the need to specialize in the types of vessels being prioritized. While China's heavily subsidized shipbuilding industry can produce a plethora of commercial and naval vessels at scale, countries with smaller MIBs must choose between building a fewer vessels across several different types or focusing their efforts on excelling in the design and construction of particular categories of ships in which its MIB can be more competitive. For example, South Korean

shipbuilders have increasingly focused on building bulk carriers and LNG tankers, leaning on the strength of government-supported R&D efforts to develop world-class technology to construct these vessels rather than compete with China in the production of low-cost cargo ships. Similarly, Italy has heavily invested in Ro/Ro and cruise ship production, allowing it to emerge as a global leader in these fields while yielding several innovations that have supported Italy's broader shipbuilding efforts. On the naval side, the U.K. has leaned heavily into the production of frigates to both support the Royal Navy and meet global demand for the export of such vessels while also identifying sub-sectors in which British commercial shipbuilding can be globally competitive. Meanwhile, Canada's NSS elevated the production of icebreakers as an industrial priority to support the national defense of both Canada and its allies. Finally, despite largely abandoning its domestic shipbuilding industry, Sweden has steadfastly maintained its need to produce submarines in-country, and has identified the VCM market as a way its shipbuilders can remain active and profitable despite Sweden's deindustrialization over the past four decades. The U.K., Italy, and South Korea have similarly committed to preserving the domestic production of submarines, perhaps owing in part to the growing concerns regarding the safety of CUI, which was cited by multiple case study countries as a growing national priority. Of the five countries studied for this report, Canada is the only nation that purchases its submarines from foreign countries rather than building them indigenously, which reflects the Canadian shipbuilding industry's growing prioritization of surface combatants and icebreakers to match the nation's current security needs.

Purchasing and Government-Commercial Relations

The case studies also yielded fascinating insights regarding the importance of government support for domestic shipbuilding industries. During the 1980s, both South Korea and the United States eliminated federal subsidies for the shipbuilding industry. While this decision significantly accelerated the decline of American shipbuilding, South Korea's industry continued to thrive even after the loss of these subsidies. This disparity is largely attributable to the investments South Korea's government made over several decades to support the shipbuilding industry and develop its infrastructure (both before and after the elimination of subsidies), as well as its national industrial policy which prioritized shipbuilding as a key tenet of South Korea's economic future. The lesson from this example is clear: shipbuilding can thrive when properly supported by the government, even if that support does not come in the form of subsidies. However, if shipbuilding is not made into a national industrial and defense priority, domestic industries will struggle to compete against heavily subsidized foreign competition.

If shipbuilding is not made into a national industrial and defense priority, domestic industries will struggle to compete against heavily subsidized foreign competition.

America's maritime allies are clearly beginning to take these lessons to heart. Sweden, a country which has largely abandoned its domestic shipbuilding industry, nevertheless took aggressive steps to prevent the outsourcing of its submarine production and has subsequently adopted a more active approach to protecting this niche defense industry. Additionally, in the last decade, Canada and the U.K. created national shipbuilding strategies to adopt a whole-of-government approach to supporting the industry, set benchmarks and clear plans to achieve them, and provide a stable demand signal to encourage recapitalization of domestic shipyards. The United States has taken an important similar step with the release of the Maritime Action Plan in February 2026 and must build on these efforts to develop a more fully realized blueprint for implementing the tenants of this plan. Additionally, South Korea stands as a shining example of the importance of government-funded R&D efforts to support advancements in domestic shipbuilding, with these efforts yielding several significant breakthroughs which allowed South Korean companies to become more competitive in the production of both naval and commercial vessels.

The case studies also support the United States adopting more creative multilateral approaches to shipbuilding. Existing frameworks such as AUKUS, MASGA, and the ICE Pact illustrate the ability of America's maritime allies to support the U.S. MIB and produce vessels which align with the U.S. Navy's needs. Similarly, the consortium-based approach which produced the FREMM shows that close naval allies can cooperate on the design and production of new ships largely from scratch, an approach which not only shares this industrial burden across multiple nations but can also promote greater interoperability among allies. This same principle of interoperability applies to the U.K.'s approach to developing the Type 26 as a Global Combat Ship which could help foster greater tactical and strategic collaboration among the U.K.'s allies while creating new opportunities to forge stronger relations with allied navies through joint training exercises, supply chain cooperation, and foreign military sales. America may struggle to unilaterally match the size and output of China's MIB, but increased collaboration with allies to support domestic shipbuilding and a greater focus on promoting interoperability could help to considerably level the playing field.

Infrastructure

This report reveals clear connections between the commitment of America's allies to supporting their MIBs and the quality and quantity of their remaining maritime infrastructure. On one hand, countries like South Korea and Italy maintain a large number of drydocks, repair facilities, and domestic shipbuilding companies, owing to their governments' sustained support for the industry over several decades. On the other hand, countries like the U.K. and Sweden experienced the widespread closure and bankruptcy of shipyards and shipbuilding companies in the decades following World War II and the OPEC oil shocks, respectively, and now lack usable infrastructure to support their domestic industries. Given the significant contraction of American shipyards capable of producing complex naval vessels, this lesson underscores the need for greater government investment in the preservation and enhancement of the infrastructure that supports America's MIB.

The U.S. MIB also benefits from the presence of foreign shipbuilders on its shores. Fincantieri, Hanwha, and BAE currently operate shipyards in the United States, while companies such as Saab, Seaspan, and Babcock have developed strategic partnerships with American-based defense contractors. Not all foreign shipbuilders have experienced smooth sailing in the American market, as evidenced by Fincantieri's history with the now-canceled *Constellation*-class frigate. However, Hanwha's efforts to grow its footprint in the United States, combined with initiatives such as MASGA which promote foreign investment in American shipbuilding, can play an important role in revitalizing the industry in the United States while deepening America's cooperation with its allies. Similarly, opportunities exist for the U.S. Navy to take greater advantage of the maritime infrastructure of its allies. U.S. allies possess drydocks and repair facilities which are strategically located across the globe and could contribute to the Navy's MRO, enabling essential maintenance and repair work to be conducted on deployed vessels without forcing them to return to the United States. The infrastructure of Canada and South Korea could prove particularly valuable in supporting America's growing naval presence in East Asia and increased need to focus on the Pacific theater.

Supply Chains

Many of the supply chain challenges facing American shipbuilders are also experienced by its maritime allies. Foreign shipbuilders report challenges in sourcing essential parts needed for manufacturing and repair, and widespread reliance on sole-source suppliers is a significant pain point. Just as American shipbuilders must find a way to decrease their reliance on sole-source suppliers, so too must the companies within the AMIB develop solutions to alleviate this common cause of delays in vessel production.

Fortunately, the case studies offer potential solutions to these challenges. Some of these models are not applicable to the American context, such as the ability of South Korean chaebols to muster their multisectoral manufacturing might and commercial infrastructure to quickly make and deliver parts to their shipyards. However, Italy's deepening embrace of additive manufacturing could provide a solution to parts shortages by allowing shipbuilders to quickly design and create parts when they are not otherwise available. While some American shipbuilders have begun investing in additive manufacturing, a broader commitment to this practice may be warranted to avoid delays in light of American shipyards' lack of casting and forging facilities. Similarly, Sweden's development of Alternative Production Plans and a unified supply chain model represent a comprehensive and proactive response to potential disruptions which could be replicated by the U.S. government and shipbuilders to develop contingency plans to navigate parts or materials shortages. Additionally, the use of digitization and AI to optimize supply chains and manage logistics by companies such as Fincantieri and Seaspan mirrors a practice which is becoming increasingly common among American shipbuilders, but which could be more widely adopted to address potential supply chain issues.

Finally, greater commonality among the ships used by the U.S. Navy and its allies could enable a multilateral approach to combating existing supply chain challenges. Platforms shared across multiple allies such as the FREMM and the Global Combat Ship could allow for the creation of unified supply chains in which part shortages experienced by one country could be backfilled by suppliers in another. This model becomes less effective the more the ships of allied navies deviate from their parent designs, much as the *Constellation* deviated from the FREMM and the Canadian *River*-class destroyer deviated from the Type 26. However, the more common hulls and systems are shared across America's AMIB, the easier such cooperation becomes. While China's massive manufacturing footprint reduces its shipbuilding industry's vulnerability to supply chain disruptions, America's network of maritime alliances could help put the U.S. MIB on a more even footing.

Limitations and Areas for Future Study

While this report provides a robust examination of the AMIB and how the best practices and lessons learned from America's maritime allies can help revitalize the U.S. MIB, there are nonetheless limitations to this study which warrant mentioning.

Resource constraints served as the largest impediment to developing a truly comprehensive examination of America's AMIB. CMS was limited in the number of countries on which it could conduct case studies, resulting in the exclusion of several important maritime allies such as Japan, Australia, Spain, and Finland from the report's analysis. The capacity to conduct a greater number of case studies likely would have illuminated additional best practices and lessons learned from other allies, which may have in turn impacted the report's final recommendations and conclusions. Resource constraints also limited the number of individual shipyards and shipbuilding companies with whom CMS was able to engage in-depth. Accordingly, the case studies are not holistic representations of each country's MIB, as the perspectives of other shipbuilders may have impacted final assessments of these nations' MIBs and/or produced additional insights worthy of inclusion in this report.

CMS also encountered uneven and inconsistent access to shipyards and shipbuilding companies across case studies, which further limited its investigations. While CMS visited shipyards in South Korea, Italy, Canada, and the U.K., its researchers did not visit Swedish shipyards due to national security concerns. As previously mentioned, Sweden's domestic shipbuilding industry is primarily focused on the production of subsea vessels, an industry which holds significant national security importance to the Swedish government and which it has gone to great lengths to protect from foreign influence. Because CMS was unable to conduct site visits to Swedish shipyards, this case study lacks many of the first-hand observations regarding its shipbuilding industry's labor dynamics, maritime infrastructure, integration of advanced and emerging technology, as well as vessel design and manufacturing processes which are found in the other case studies. The lack of shipyard access not only prevented CMS from soliciting insights directly from Swedish shipyard workers, but also prevented independently verifying the assessments of the Swedish MIB provided by government and industry officials in fact-finding interviews.

Disparities of access also emerged in countries where CMS conducted shipyard visits. South Korea was the only country in which CMS was able to observe submarine-building activities, making the other case studies more reliant on desk research and interviews with subject-matter experts to analyze the role submarines play in each country's MIB. These access disparities potentially influenced the report's recommendations and conclusions, as CMS may have gained additional information with more robust access to allied shipyards. Similarly, the unclassified nature of this report likely means that case study countries withheld important information about their MIB or shipbuilding capabilities for national security reasons, which may have otherwise influenced the study's conclusions.

Furthermore, this study is inherently limited due to heavy reliance on stakeholder interviews and first-person observations. It is impossible to draw comprehensive conclusions related to labor relations and workforce culture from short-term in-person visits. There is additional risk that insights gleaned from such observations may fall victim to the observer effect, with workers going out of their way to appear busy, engaged, and productive because they are being observed.

Finally, CMS notes that the information provided by subject-matter experts and government and industry stakeholders in scoping discussions could potentially reflect and be influenced by the biases and motives of the interview subjects. Government officials and shipbuilding industry leaders may have answered CMS's research questions in ways which would paint a more positive image of their country's MIB or indigenous shipbuilding operations, and even the shipyard workers with whom CMS spoke may have been reluctant to speak honestly out of fear of potential reprisal

from management. While these limitations open up the possibility that the report's assessments of the case study countries are not completely accurate, CMS took care to avoid including details provided by interview subjects which were directly contradicted either by peer-reviewed sources or by CMS's own observations. Additionally, while CMS anticipated that many interview subjects might attempt to shape their answers to encourage more flattering case studies, the investigators assessed these experts to be largely forthcoming about the challenges, technical limitations, and past failures they have encountered. Accordingly, while readers should consider this inherent limitation in reflecting on the report's conclusions, they should do so with the knowledge that CMS remains confident in its final assessments of each of the case study countries.

The topic of America's AMIB is ripe for future study. This study could be replicated with a focus on additional maritime allies, or on different shipbuilding companies within the same case study subjects chosen for this report, to identify additional best practices or lessons learned which may be applicable in the U.S. context. Such studies could compare and contrast their own findings with the conclusions drawn in this report to provide a more comprehensive view of America's AMIB. Similarly, future researchers could conduct longer-term observations of allied shipyards to examine whether the observations reached in this report's case studies remain true over time, potentially even observing shipyards throughout the duration of a single ship construction project to provide more detailed assessments of how each stage of this process is handled in comparison to what is typically observed in American yards. Future scholarship could also conduct field interviews with other maritime stakeholders whose perspectives were not prominently featured in this report, but who nevertheless play important roles in preserving maritime power in America's naval allies. This could include representatives of shipbuilding labor unions, commercial shipping companies, manufacturers whose products support shipbuilding and repair efforts, and enlisted personnel within the sea services of America's allies. Finally, similar research could be conducted for classified government audiences, which could potentially enable greater access to third-country shipyards and a deeper examination of the specific ways the AMIB supports national and collective security among America's allies.

Recommendations

To address the maritime challenges facing the United States, CMS has developed the following recommendations rooted in the best practices and lessons learned collected from the examination of America's AMIB, which have been divided into seven categories: Reforming the Design and Build Processes, Embracing New and Emergent Technologies, Revitalizing Commercial Shipbuilding, Ensuring On-Time Delivery, Training Current and Future Shipbuilders, Strengthening U.S. Supply Chains, and Increasing Allied Cooperation.

Reforming the Design and Build Processes

Design, then bend. To prevent future shipbuilding projects from befalling the fate of the *Constellation*-class frigate, the Navy and the shipbuilders that support it must be aligned on their visions for future ship designs. Accordingly, the Secretary of the Navy could ensure that no construction on naval vessels can commence until the Secretary has certified 100 percent completion of an approved and unwaivable ship design. Fully abiding by existing statutes to this effect while explicitly raising the existing design-complete requirement to 100 percent could help reduce production delays and cost overruns caused by late-stage design changes. The Navy could also consider adopting the GAO's recommendation that "shipbuilding programs complete functional design for new ships before awarding detail design and construction contracts," which would force the Navy to be more proactive in finalizing designs and eliminate protracted deliberations between the client and manufacturer on design questions which so frequently contribute to scheduling delays.[408]

Make VCMs the norm. VCMs have helped streamline ship design and production processes across many of America's maritime allies, have been successfully utilized domestically in the production of the NSMV, and will be used to oversee construction of the Medium Landing Ship. Accordingly, either Congress or a combination of the Departments of War and Transportation could mandate or officially recommend the use of VCMs to oversee the production of all government shipbuilding projects in the United States. Such a measure could help reduce construction delays, minimize cost overruns, and prevent late-stage design changes.

Embrace modularity. To reduce delays in the design process and increase interoperability among different classes, American warship builders could strive to incorporate greater modularity into warship design. This could include exploring the creation of "common hulls" which could be used across multiple types of ships, as well as common propulsion systems, combat systems, bridges, berthing, and magazines. Examples include the NSMV hull, which could be used for multiple classes of ships; the VLS, which can be operationalized on both surface and subsurface vessels; and many of the components of the Global Combat Ship, which are common across multiple variants. Embracing greater modularity where appropriate could reduce the cost and time associated with naval shipbuilding projects.

Embracing New and Emergent Technologies

Digitize, automate, and get "smart." Both the public and private sectors must increase their commitment to integrating proven and emergent automation, digitization, and AI tools into their shipyards, while ensuring such tools are implemented in a way that empowers rath-

er than displaces the existing workforce. This could be achieved through more robust private sector and foreign direct investment in these technologies, the inclusion of additional funds in government shipbuilding contracts to support digital and robotic infrastructure upgrades, and embracing the Maritime Action Plan's recommendation to "Develop 'incubator' funding opportunities that incentivize shipbuilders to focus capital investments on emerging technology to prepare the MIB workforce for the future of shipbuilding."[409]

Build ships to sail, engineer them to last. The Department of War could provide grants to American shipyards to subsidize the cost of incorporating the DoW's CBM+ recommendations into the design and manufacturing of all naval ships. Robust institutional support for this practice could help normalize CBM+, which would reduce the frequency and unpredictability of maintenance and repairs on American naval vessels. The resulting increase in operational availability would enable the U.S. Navy to more effectively project power on a global scale while increasing the number of platforms and tactical options available to respond to future maritime crises.

Cross the digital divide. American shipbuilding companies could embrace digitization, as outlined by CMS's Dean Admiral James G. Foggo, USN (ret.) in the aforementioned 2023 *Breaking Defense* article.[410] These recommendations include dedicating 3 percent of SIOP budgets to digitization, consulting mariners to understand issues they face as operators, building worker trust in digital systems by demonstrating the technology on datasets with which workers are already familiar, and adopting a "do no harm" approach which avoids disrupting essential shipbuilding processes. Federal grants supporting the adoption of these best practices could further encourage their proliferation throughout the industry.

Revitalizing Commercial Shipbuilding

Chart a collaborative course. To better compete with China, the United States must invest in its own domestic commercial shipbuilding industry, particularly given that commercial shipbuilding can support the U.S. Navy. To devise a strategy for the U.S. commercial industry to thrive, MARAD could fund a study (or Congress could establish a commission composed of federal and industry experts) to identify the subcategories of commercial shipping in which the U.S. shipbuilding industry can be most competitive. Releasing these findings to American commercial shipbuilders would allow the industry to chart a path to financial sustainability through specialization and targeted investments into resources and process improvements which can help American companies fill existing or emerging market gaps.

Shared insight, collective impact. Shipbuilders must facilitate the sharing of industry best practices among all companies that support America's MIB, including the cruise ship industry, whose innovations in the ship design and construction processes are being modeled by America's allies but largely ignored by domestic shipbuilders. Leveraging existing collaborative frameworks such as the American Maritime Partnership, the U.S. shipbuilding industry could support the creation of an "American Academy of Shipbuilders" to identify and share the best practices for digitization, AI, and automation industrywide. The federal government could pursue similar frameworks to promote the sharing of best practices and lessons learned between American and allied shipbuilders.

Ensuring On-Time Delivery

Incentivize success. Rather than accept the inevitability of ships being delivered late and over budget, both the Navy and U.S. shipbuilding industry must promote on-time shipbuilding as the rule rather than the exception. To support such efforts, the Navy could reform its contracting procedures to provide significant financial incentives for shipbuilders to deliver ships on time or ahead of schedule. While enacting punitive fees for late delivery could imperil America's already vulnerable shipbuilding industry, incentives for both workers and shipbuilding companies to produce vessels on time and on budget without compromising safety or quality standards would constitute an important first step towards changing the industry's culture for the better.

Small blocks stack just as well as large ones. When the Navy places large orders of ship classes, delays in the production of the initial vessels often have cascading effects which can postpone the production of future ships. Additionally, these delays often risk the final ships scheduled for production becoming outdated by the time the manufacturer is ready to build them. To address this issue, the Navy could standardize the practice of breaking large ship orders into smaller blocks, which would allow the shipbuilder to produce the initial vessels to match the original design and make any adjustments to future ships based on the Navy's changing needs and the data gathered from the deployment of the first block of ships.

Training Current and Future Shipbuilders

Educate, empower, lead. To encourage more young Americans to enter the shipbuilding industry, both the private and public sectors could increase funding to create new or expand upon existing shipbuilding apprenticeship programs to enable a more robust recruitment effort, as well as provide additional financial resources to trainees such as expanded tuition reimbursement and free or reduced housing. All federally funded apprenticeship programs should be heavily focused on teaching shipbuilders to integrate AI, automation, and digitization into their work. Federal and private funds could also support the hiring of retired master shipbuilders to serve as mentors to junior tradespeople to help impart industry best practices to younger cohorts of workers.

Engineer the future of naval architecture. The U.S. government could invest in the expansion of federally funded naval architecture and marine engineering training programs to address labor shortages in these fields. This could include the growth of existing programs at American colleges and universities to increase the annual output of naval architects, as well as subsidizing the creation of new programs at additional schools. An increase in naval architects and marine engineers would not only create more hirable experts in these fields to fill private sector openings, but could also allow the Navy to directly hire and commission graduates to contribute to the design of new government shipbuilding projects.

Strengthening U.S. Supply Chains

If you need it, print it. To address existing supply chain gaps and decrease overreliance on sole-source manufacturers, both the federal government and shipbuilding industry could increase their investments in additive manufacturing. This could come in the form of both government-issued grants to shipbuilders to invest in additive manufacturing infrastructure, as well as increased funding for educational and training opportunities to encourage growth in this labor market. Both the public and private sector could expand financial aid to students in addi-

tive manufacturing, in addition to funding the creation of new additive manufacturing training academies modeled after the ATDM program, including among the nearly 1,300 American colleges and universities that confer two-year degrees.[411]

Build supply chain contingencies. The Department of the Navy could form a working committee composed of naval officers and shipbuilding industry leaders to develop maritime supply chain contingency plans similar to the APPs developed by the Swedish government. Such plans should identify backup sources of raw materials and ship parts and recommend alternative supply chains relying on American allies to help manufacture and deliver critical components to support naval shipbuilding and repair efforts. Developing these contingencies would reduce America's supply chain vulnerability in the event of a conflict or disruptive global event and lessen the risk such shocks pose to the U.S. MIB. Similarly, American shipyards could create "supply chain reliability managers" who proactively monitor supplier resilience and develop contingency plans in case sole-source suppliers go out of business.

Increasing Allied Collaboration

Leverage maritime alliances. To support greater shipbuilding collaboration with America's allies, the White House could instruct the Departments of State and War to compile a list of potential allied shipbuilding consortiums to encourage multilateral shipbuilding cooperation along the lines of AUKUS, MASGA, or even non-American collaborative mechanisms such as OCCAR. In addition to encouraging greater allied investment in America's MIB, the United States could assess opportunities to create ships with common designs which could be shared across allies, similar to the British Global Combat Ship concept. This could be further supported by an "Allied Naval Supply Chain Alliance" to promote multilateral maritime supply chain resilience among America and its allies, as well as multilateral maritime R&D collaboration.

Build a "bridge" over troubled waters. While many of the report's recommendations will take time to implement or reach maturity, America's Navy remains in urgent need of a more robust fleet. Accordingly, the United States could adopt a "bridge strategy" similar to the one recommended in the Maritime Action Plan which seeks to bypass potential delays in ship production caused by recapitalization by enabling the initial ships in a multi-vessel purchase to be built in allied shipyards "while concurrent direct capital investments are made in a U.S. shipyard they have purchased or partnered with to eventually onshore construction."[412] Such a strategy could particularly be pursued with foreign shipbuilders who have already made significant capital investments in American shipyards, but whose infrastructure and process upgrades are a few years away from bearing fruit. This could also involve foreign shipbuilders constructing a ship's hull as well as mechanical and electrical systems, then towing the incomplete ship to a U.S. yard for final outfitting. Paired with an increased effort by the White House and Department of State to encourage more foreign shipbuilders opening shipyards in the United States, such a strategy could enable the production of naval vessels in the short-term without compromising the long-term viability of American shipbuilding, as long as it is used to supplement rather than replace work that could be done by American yards.

Use allied ports in a storm. The U.S. Departments of State and War could engage its maritime allies—particularly those with maritime infrastructure located in the Pacific Ocean—to arrange for the U.S. Navy to utilize their existing drydocks and ports to support MRO for U.S. vessels. This would not only help compensate for America's shortage of drydocks and repair facilities, but could allow naval ships to operate for longer periods of time in the Pacific to support regional allies and confront the rising Chinese naval threat. This measure could also be

accompanied by an increase in joint naval exercises among America's maritime allies focused on maintenance and repair to prepare allied shipyards to more efficiently support MRO for the U.S. Navy in times of conflict, as well as concentrated efforts by the Navy to encourage foreign investment into American ship repair facilities and to facilitate the multilateral sharing of best practices for MRO.

"All hands on deck" for skilled labor. To address the domestic shortage of skilled shipbuilding workers, the United States must be willing to tap into the labor pools of its maritime allies when necessary. Accordingly, the Departments of Homeland Security and State could create standing visa exceptions to facilitate skilled migrant workers from allied countries entering the United States to support domestic shipbuilding efforts. An example of this could be the Partner with Korea Act (H.R. 4687), which proposes granting 15,000 visas for high-skilled workers from the ROK and includes specific safeguards to prevent these workers from being brought in to replace Americans.[413] If necessary, migrant workers could primarily be brought in to support shipbuilding tasks which minimize their exposure to classified data or systems to reduce security risks.

While not reflective of every viable solution to help revitalize America's MIB, these recommendations provide a blueprint for the U.S. Navy, Congress, the shipbuilding industry, and other actors with significant stake in American maritime power to keep the U.S. MIB afloat and sailing towards calmer waters.

Conclusion

After years of decline and neglect, revitalizing America's MIB will be a substantial undertaking requiring significant resources and years of sustained focus from both the government and the American shipbuilding industry to complete. Yet America's seafaring allies present a clear path towards a maritime revival, serving as a source of best practices and lessons learned which can inform efforts to restore American seapower. The AMIB is a potential force multiplier which can accelerate American shipbuilding efforts through multilateral collaboration and strengthen the U.S. Navy through deepened allied naval cooperation.

Fortunately, America and its allies have shown recent signs of reaching this same conclusion. While CMS was in South Korea conducting case study research in August 2025, South Korean President Lee Jae-myung visited Hanwha's newly acquired Philly Shipyard to highlight the importance of the bilateral U.S.-ROK shipbuilding partnership. While Hanwha's efforts to revitalize the Philly Shipyard are in the early stages, Hanwha's initial impact on the yard is readily apparent. Hanwha reported that the yard's employment had increased to 2,000 workers as of March 2026, with 150 new apprentices being trained and a goal to increase the size of the apprentice program to over 200 new annual students by 2027. Hanwha plans to rotate workers from Philadelphia to Korea to train with the company's experienced shipbuilders and bring their best practices back to the yard, and roughly 100 employees were on-site from Korea in late 2025 to help infuse Philly with the company's institutional knowledge. Whiteboards showing English translations of Korean phrases were observed across the yard, highlighting the workers' embrace of the new ownership and eagerness to engage and exchange knowledge with their Korean counterparts. From its leadership to its blue-collar workforce, the yard radiated an immense sense of pride in its history, as well as an understanding that embracing modern technologies and new ways of thinking is needed to return the yard to its former greatness. This type of thinking which celebrates the past greatness of American shipbuilding while also embracing the need for progress is essential to revitalizing this industry.

America's seafaring allies present a clear path towards a maritime revival, serving as a source of best practices and lessons learned which can inform efforts to restore American seapower.

At the outset of the Korean War, the Philadelphia-built USS *Valley Forge* was America's only aircraft carrier in the region and played an essential role in the defense of what became the ROK, using its repetitive strike capability to target military assets in Pyongyang and slow the Korean People's Army's southward advance to support the landing of American troops at Inchon. 75 years later, President Lee's visit to the Philly Shipyard to herald the dawning of a new Korean-American shipbuilding partnership fittingly saw him issue his remarks on the occasion in front of Dock 5—the very dock in which *Valley Forge* was constructed. The shipyard that produced the vessel which helped save the ROK now serves as the epicenter for renewed cooperation between America and South Korea in the maritime domain. Just as American naval might helped defend South Korea during its time of crisis, so too can greater collaboration with the shipbuilding industries of South Korea and other American allies help reverse the decades-long decline of America's MIB.

No single ship can defeat an entire fleet by itself, even one armed with world-class weapons systems and crewed by experienced and battle-hardened sailors. America's best chance to overcome its significant security challenges at sea rests not in fighting alone, but rather in forming an allied armada sailing together towards a common goal.

Annex I: Research Questions

The following research questions were presented to each of the allied naval and shipbuilding experts interviewed as part of this study to help inform the case studies.

Research Category 1: Labor and Workforce

1. What labor challenges are you experiencing in the shipbuilding industry?
2. How do you recruit skilled and unskilled labor in your shipyards?
3. Do you hire third-country nationals to work in commercial or military shipyards?
4. Do you embrace the concept of "federated shipbuilding," i.e., taking the work to the labor concentration areas and not taking labor to the shipbuilding industrial base?
5. What are the retention statistics for newly hired shipyard workers? What percentage of skilled workers hired remain on the job for five years, 10 years, or 20 years?
6. Are the wages of skilled or unskilled shipyard workers commensurate with the market for other skilled or unskilled positions outside of shipbuilding?
7. How do you train your shipyard workforce?
8. How do you grow and retain the supervisory work force in your shipyards?
9. What is the percentage of hand-touch labor versus automation in your shipyards?
10. How many shifts do you run in your new construction of modernization yards? (One plus backshift; three shifts at 24/7 battle rhythm, or ramp up as needed?)

Research Category 2: Technology Integration

1. Do you incorporate robotics into shipbuilding?
2. Do you incorporate artificial intelligence into shipbuilding?
3. How would you grade your shipbuilding industrial base on digitization of your shipyards? Can you give any good examples?
4. Do you employ commercial off-the-shelf technology in the combat system of your warships?
5. Is the combat system incorporated during the new construction phase, or is it added later on?
6. How much capital investment is your government making in advanced manufacturing?

Research Category 3: Design and Manufacturing Process

1. Do you outsource new construction shipbuilding work (i.e., modules) outside of your national borders and, if so, what percentage of work is outsourced?
2. What improvements has your shipbuilding industry made on the production line in the past 10, 20 or 50 years?
3. How many linear feet can you weld in your shipyards?
4. What does the design-build process look like in military shipbuilding? Is there a requirement to have a complete design before beginning ship construction?
5. Do you use computer-aided design (CAD) in your shipyards?

6. What is your definition of a complete design? 80 percent, 90 percent, or 100 percent?
7. How do you incorporate design changes during construction?
8. If you find a mistake on a drawing during new construction, how do you fix it?
9. Do you rely on nationalized or private industry for warship construction?
10. Are there penalties for late work in your military shipyards?
11. Are your warships modular-designed?
12. Do you incentivize commonality in warship design; i.e., do you have a common hull for frigates, destroyers, and escorts?
13. Do you utilize common "drop-in" modules on your ships, i.e., a common combat system, radio room, electronic bridge, etc.?
14. Do you see the positive impact of a learning curve during new construction of an entire class of ships? Can you provide any examples on how the learning curve has created efficiencies in new construction?
15. Are your warships built to a commercial or military standard?
16. Are high-pressure or low-pressure fluid systems onboard your warships welded or bolted together?
17. What is the tradeoff between cost and damage control in warship construction?
18. Do you design your warships to be interoperable with allies and partners?
19. How do you control corrosion in your warships? Do you use high solid paints in tanks and voids?
20. How do you determine the HVAC needs and heat balance required for new construction warships? Do you leave a margin of additional cooling capacity for later modifications/modernization of onboard ship systems?
21. How do you plan for low-rate production of warships, i.e., one or two ships in a class (conventional aircraft carriers)?
22. Do you embrace a "consortium" approach for shipbuilding, i.e., multiple nations involved in the construction of a common submarine (U-212 or FREMM)?
23. How do you identify high failure rate parts during the design and new construction phase?
24. What is the expected service life of a destroyer, frigate, or submarine in your navy?
25. Do you plan and budget for the sustainment of your warships over the life of the platform?

Research Category 4: Purchasing and Government-Commercial Relations

1. Is there synergy between civilian and military shipbuilding in your country?
2. Do you purchase foreign warships for your navy?
3. Are there any domestic laws that preclude the purchase of foreign warships?
4. Do commercial or military shipbuilders in your country receive any kind of subsidies?
5. Who is responsible for military R&D—the government or private industry?
6. What restrictions do you have on tech transfer to another nation?

Research Category 5: Infrastructure

1. Do you have a long-term plan for modernizing your shipyards and drydocks?
2. Do you have adequate drydocks to support both new construction and maintenance and modernization in your shipyards?
3. What is your shipyard recapitalization plan?
4. Do you have an adequate footprint of space in your shipyards to support the demand for warships in support of national security?
5. Do you have any plans to build new shipyards or shipbuilding facilities?
6. Do you employ only drydocks, or do you have a dry lift capability for maintenance and modernization of warships?
7. Do you embrace the concept of "continuous shipbuilding" to level load labor and capacity of your shipyards?
8. Do you have a shortage of casting and forging facilities that meet military specifications and requirements for your warships?

Research Category 6: Supply Chains

1. Do you manufacture replacement parts to sustain the platform during new construction or do you order and produce them later on during the life of the ship?
2. Are you satisfied with supply chains in support of warship maintenance and modernization over the life cycle of the platform?
3. How do you source your supply chains?
4. Where do you get your raw materials? Steel? Copper? Cabling?
5. Have you embraced advanced manufacturing (i.e., industrial quality 3D printing) to alleviate supply chain shortages?

Annex II: List of Shipyards Visited

To complete this study, CMS's experts visited the following shipyard, naval repair, and research and development facilities:

- Geoje Shipyard, operated by Hanwha Ocean in Okpo, Republic of Korea
- Govan Shipyard, operated by BAE Systems in Glasgow, United Kingdom
- Monfalcone Shipyard, operated by Fincantieri S.p.A in Monfalcone, Italy
- Rosyth Shipyard, operated by Babcock International in Rosyth, United Kingdom
- Scotstoun Shipyard, operated by BAE Systems in Glasgow, United Kingdom
- Siheung R&D Campus, operated by Hanwha Ocean in Seoul, Republic of Korea
- Vancouver Drydock, operated by Seaspan in North Vancouver, Canada
- Vancouver Shipyards, operated by Seaspan in North Vancouver, Canada
- Victoria Shipyards, operated by Seaspan in Victoria, Canada

Annex III: Contributors to the Study

CMS thanks the following subject-matter experts, government officials, and industry leaders for their intellectual contributions to the production of this report, including the crafting of research questions to the report or participating in scoping discussions as part of the case studies:

Hon. Richard Spencer, Chairman of Austal and 76th Secretary of the Navy

Hon. Nicholas Guertin, former Assistant Secretary of the Navy for Research, Development, and Acquisition

Admiral Sir Philip Jones, RN (ret.), former First Sea Lord and Senior Naval Advisor, BAE Systems Maritime & Land U.K.

Admiral John Richardson, USN (ret.), Member of the Board of the Boeing Company, Vice President of the Navy League of the United States, and 31st Chief of Naval Operations

Vice Admiral Robert Gaucher, USN, Submarine Direct Reporting Portfolio Manager (DPRM), U.S. Navy

Vice Admiral Sir Simon Lister, RN (ret.), Managing Director, BAE Systems Naval Ships

Vice Admiral Tom Moore, USN (ret.), Senior Vice President for Government Relations, HII and former Commander of Naval Sea Systems Command

Vice Admiral Ewa Skoog-Haslum, Royal Swedish Navy

Vice Admiral Ricky Williamson, USN (ret.), Senior Advisor, Roosevelt Group

Commodore Jonathan Carrigan, RN, Deputy Director, National Shipbuilding Office (U.K.)

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Commodore Alex Higgins, RN, Senior Naval Officer, HMS Glasgow

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Annex IV: Glossary of Key Terms

Advanced or Additive Manufacturing: A set of modern production methods that use digital tools, automation, and raw materials to make parts more quickly and precisely. Additive manufacturing usually refers specifically to building parts layer by layer, often called 3D printing.

Air-Independent Propulsion (AIP): A marine propulsion system used in non-nuclear submarines to operate without access to atmospheric oxygen, allowing them to remain submerged for longer periods compared to conventional diesel-electric propulsion submarine systems. This system offers a higher-tech and stealthier alternative compared to conventional systems. AIP variants include the Stirling engine, fuel cells, and closed-cycle diesel or gas turbine engines.

Allied Maritime Industrial Base (AMIB): The collective industrial assets and capabilities of America's allies which support the designing, building, repair, and maintenance of maritime vessels.

Anti-Submarine Warfare (ASW): An area of warfare within the maritime domain concerned with finding, fixing, tracking, and engaging submarines. In the AMIB case, it refers to this capability being present on military vessels based on their available weapons systems.

Area of Responsibility: A geographic region assigned to a military commander or command for planning and operations. In maritime discussions, it helps explain where naval forces are expected to operate.

Berth: A designated place where a ship is moored or tied up at a pier, quay, or dock. In shipyard usage, it can also refer broadly to a location where a vessel is worked on.

Block: In shipbuilding, a block is a large pre-fabricated section of a ship that is built separately and later joined with other sections during final assembly. Block construction allows multiple parts of a ship to be built at the same time.

Block-Scale Construction: A production method centered on assembling ships from large pre-fabricated structural sections rather than building everything in place. It is a form of modular construction intended to improve speed and efficiency.

Bow: The forward end of a ship. It is the front-most part of the vessel when moving ahead. The bow lies opposite the stern, which is the back or aft-most part of a ship or boat, technically defined as the area built up over the sternpost, extending upwards from the counter rail to the taffrail.

Cavitation: The formation and collapse of vapor bubbles on a spinning propeller blade, caused when water pressure drops low enough for the water to essentially boil. It reduces thrust, erodes metal surfaces, generates underwater noise, and is one of the most significant engineering challenges in marine propulsion.

Chaebol: A large family-controlled South Korean conglomerate with business interests across multiple sectors. Major Korean shipbuilders are often part of these large industrial groups.

Cobot: A collaborative robot designed to work safely alongside human workers and are often used for repetitive or physically demanding tasks such as welding.

Common Hull: A ship design approach in which different classes or variants share the same basic hull form. This simplifies design, production, maintenance, and training.

Compensated Gross Tonnage (CGT): A shipbuilding metric that estimates the labor and complexity required to build a vessel, not just its size. It is often used to compare shipbuilding output across countries or ship types.

Computer Numerical Control (CNC): A manufacturing process in which machine tools are controlled by computer-programmed instructions. It is commonly used for cutting, drilling, milling, and shaping metal parts with high precision.

Computer-Aided Design: Software used to create, modify, and manage engineering drawings and technical designs. In shipbuilding, computer-aided design helps design teams coordinate highly complex vessel layouts.

Corvette: A small warship generally designed for patrol, escort, and coastal or regional combat missions. It is usually smaller and less heavily armed than a frigate.

Deck: A deck is a horizontal structural surface or floor aboard a ship. Ships usually have multiple decks for equipment, crew, and operations.

Design-Build: A shipbuilding project delivery method in which a shipyard is responsible for both the design and construction of a vessel.

Design-Complete: The point in ship design where the design is finalized and ready for construction. Ideally, a design complete designation would correlate with a high design maturity.

Design Maturity: A measure of how complete and stable a ship design is before construction begins. Low design maturity usually means more changes during construction, increasing cost and schedule risk.

Destroyer: A large surface combatant designed for missions such as air defense, missile defense, anti-submarine warfare, and escort operations. In most navies, destroyers are generally larger and more heavily armed than frigates.

Digital Twin: A digital model of a physical object or process that is updated with real-world, and often real-time, data. In shipbuilding, a digital twin can help managers track production, bottlenecks, maintenance, or part locations in near-real time.

Displacement: The measurement of displaced water that a ship causes when afloat, which is understood to be the ship's weight.

Drydock: A dock that can be drained of water so a ship can be built, inspected, repaired, or modernized below the waterline. Drydocks are critical infrastructure for ship construction and maintenance.

Federated Shipbuilding: A production model that distributes work across multiple sites or firms rather than concentrating all work in one yard. In practical terms, it means spreading shipbuilding activity across a network of facilities and suppliers.

Floating Crane: A heavy-lift crane mounted on a floating platform or barge. It is used to move very large ship sections, equipment, or industrial loads on the water.

Frigate: A medium-sized warship usually designed for escort, air defense, anti-submarine warfare, and general-purpose missions. In most navies, frigates are smaller than destroyers but larger or more capable than corvettes.

FREMM (French: *Frégate Européenne Multi-Mission*; Italian: *Fregata Europea Multi-Missione*)**:** The FREMM is a Franco-Italian family of warships designed by Naval Group and Fincantieri. The design is often cited as the parent design for the U.S. *Constellation*-class frigate.

Gantry or Goliath Crane: A very large crane used to lift and move heavy ship sections, equipment, or modules in a shipyard. Goliath crane usually refers to an especially large gantry crane spanning a work area.

Hull: The main structural body of a ship. It is the watertight shell that gives the vessel its shape and buoyancy.

Hull Section: A large structural portion of a ship's hull built separately before final assembly. Hull sections are often joined together in a drydock or on a building way.

Icebreaker: A special-purpose vessel that is designed to navigate and break through ice-covered waters in order to create safe paths for other vessels. These ships are characterized by strengthened hulls, stronger engines, and a rounded ice-clearing shape.

Industrial and Technological Benefits (ITB): A policy mechanism, used notably by Canada, that requires defense contractors to generate domestic economic or industrial benefits as part of major procurements. These benefits can include local investment, jobs, supplier development, or technology transfer.

In-Service Support: The maintenance, repair, sustainment, and upgrade work needed after a ship enters service. It covers the activities required to keep a vessel operational over its service life.

Keel: The keel is the main longitudinal structural piece running along the bottom of a ship. It is often described as the ship's backbone because it provides foundational strength and alignment.

Keel-Laying: A traditional milestone marking the formal start of ship construction. In modern modular shipbuilding, it may occur after significant fabrication work has already begun.

Landing Helicopter Dock (LHD): A large-deck amphibious assault ship designed to embark Marines, aircraft, and landing forces for expeditionary operations. It resembles a small aircraft carrier and is built primarily for amphibious warfare.

Littoral Combat Ship (LCS): A class of small, modular U.S. Navy surface combatants designed primarily for operations in coastal waters. The program is often cited in policy debates about acquisition, survivability, and mission design.

Maintenance, Repair, and Overhaul (MRO): A common industrial term for the work required to keep ships or equipment in serviceable condition. In maritime use, it can range from routine repairs to major refits.

Maritime Industrial Base (MIB): A complex web of industrial and labor forces working in concert to design, build, repair, and maintain maritime vessels. It includes the shipyards, workers, and supply networks dedicated to supporting American seapower. Private shipyards and government-owned and -operated repair facilities are essential components of this industrial base.

Memorandum of Understanding (MOU): A formal but usually non-binding agreement outlining cooperation between parties which is often used to signal intent before a binding contract is signed.

Modular Assembly or Modular Construction: A method of building ships from preassembled modules or blocks that are later joined together. This approach can shorten schedules and make production more efficient.

Monopsony: A market condition in which there is effectively only one major buyer, usually a government. In naval shipbuilding, the government often acts as the dominant or only buyer for certain vessels.

National Security Multi-Mission Vessel (NSMV): A class of training ships being built for U.S. maritime academies. The program is often cited as a recent U.S. shipbuilding example outside traditional Navy combatant procurement.

Naval Architecture: The engineering discipline concerned with the design, structure, stability, and performance of ships and other marine vessels. It combines elements of mechanical, structural, and marine engineering.

Outfitting: The stage of ship construction in which equipment, piping, wiring, systems, and furnishings are installed after the main structure is built. A ship may be launched before outfitting is complete.

Radio Frequency Identification (RFID): A technology that uses radio waves to identify and track tagged objects automatically. In shipbuilding, RFID can help yards monitor parts, tools, and material flows.

Service Life Extension Program (SLEP): A program intended to extend the useful life of a ship or other platform through major maintenance, repair, and modernization.

Shipyard Infrastructure Optimization Program (SIOP): A U.S. Navy effort to modernize public naval shipyards and improve their layout, facilities, and workflow. It is intended to reduce maintenance delays and improve long-term capacity.

Small Surface Combatant (SSC): A general term for a smaller warship used for missions such as escort, patrol, or limited combat operations. In procurement discussions, it often serves as a category rather than a specific class name.

Sole-Source Supplier: A supplier that is the only approved or available source for a particular component. This can create a serious bottleneck if that supplier falls behind or exits the market.

Surface Combatant: A general term for a warship designed to fight on the surface of the sea, such as a destroyer, frigate, or corvette. It excludes submarines and most auxiliary ships.

Vertical Launch System (VLS): A system of vertical missile cells built into a warship to store and fire missiles. VLS is a common shorthand in discussions of naval combat capability.

Very Large Crude Carrier (VLCC): A very large tanker ship used to transport crude oil. It is a common benchmark for discussing commercial shipyard capacity and productivity.

Vessel Construction Manager (VCM): An entity hired to coordinate ship construction on the government's behalf. The goal is usually to improve schedule control and accountability. The VCM typically adjudicates any disputes that may arise between shipyards and the government's representatives.

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