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Great Power Competition in the Indo-Pacific Region presents unique challenges to logistics, particularly in the maritime domain. Current maritime logistics platforms' lack of capability and capacity represent a U.S. critical vulnerability to sustain the joint force. However, emerging technologies can help close these gaps. AI can assist humans in routing, load planning, provide vessel control, and enable rapid data aggregation and decision-making at a competitive battlefield pace. By automating the force allocation and supply distribution dynamically across logistics nodes, AI will enable critical materiel to arrive in the right place and time. Augmented command and decision speed is critical to achieving and sustaining a competitive tempo. Automated cargo delivery at sea and the land/sea interface achieves both risk reduction and increased effectiveness. Replacing human operators with automated systems manages risk to force. Automated cranes and vehicles can load and discharge cargo with tireless efficiency. Fielding resilient systems with redundancy in critical systems means the warfighter can count on their sustainment. The commonality of parts, automated maintenance actions, and commercial-off-the-shelf solutions avoid bottlenecks in the delivery stream and enable favorable tooth-to-tail ratios. Affordable production of logistics platforms means more systems can be in place at the start of a campaign and more capacity added should the need arise. Finally, a large enough pool of vessels that are cost-effective, easily serviceable, repairable, and relatively easy to replace contribute to system resiliency. Current advanced technology can fill gaps in maritime logistics while more holistic solutions address institutional gaps. Employing artificial intelligence, automated equipment, and resilient systems can effectively enable the Joint Force commander to control logistics.

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**NATIONAL DEFENSE UNIVERSITY**

**JOINT FORCES STAFF COLLEGE**

**JOINT ADVANCED WARFIGHTING SCHOOL**

# Advantages of Advanced Technology For Contested Maritime Logistics

by


Matthew D. Hoekstra

Commander, United States Navy


28 May 2021

**Advantages of Advanced Technology**
**For**
**Contested Maritime Logistics**

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A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense.

This paper is entirely my own work except as documented in footnotes.

Signature:
23 April 2021

Thesis Advisor:

Signature:
Bryon Greenwald, Ph.D.
Colonel (Ret), U.S. Army

Approved By:

Signature:
Dr. Phillip Saunders, Ph.D.
Committee Member

Signature:
Jody M. Owens, Colonel, U.S. Air Force
Committee Member

Signature:
Miguel L. Peko, Captain, U.S. Navy
Director, Joint Advanced Warfighting School

## Abstract

Great Power Competition in the Indo-Pacific Region is not a new experience for the United States. The western Pacific presents unique challenges to logistics, particularly in the maritime domain. Current maritime logistics platforms are legacy equipment even by today's standards; their lack of capability and capacity represents a U.S. critical vulnerability to sustain the joint force in a contested maritime environment. However, emerging technologies can help close these gaps in the near-term.

Artificial intelligence can assist humans in routing, load planning, provide vessel control, and enable rapid data aggregation and decision-making at a competitive battlefield pace. By automating the force allocation and supply distribution dynamically across logistics nodes, artificial intelligence will enable critical materiel to arrive in the right place and time. The geographic distances in the INDOPACOM region have not changed since our last Great Power Competition; augmented command and decision speed is critical to achieving and sustaining a competitive tempo.

Automated cargo delivery at sea and the land/sea interface achieves both risk reduction and increased effectiveness. By replacing human operators with automated systems to conduct routine, highly physical operations, the commander can manage risk to force. Unmanned vessels can operate for weeks at sea with no outside support. Automated cranes and vehicles can load and discharge cargo with tireless efficiency.

Fielding resilient systems means the warfighter can count on their sustainment. Redundancy in critical systems such as propulsion and cargo handling equipment ensures that long voyages are not made in vain. The commonality of parts, automated maintenance actions, and commercial-off-the-shelf solutions avoid bottlenecks in the delivery stream and enable favorable tooth-to-tail ratios. Affordable production of logistics platforms means more systems can be in place at the start of a campaign and more capacity added should the need arise. Finally, a large enough pool of vessels that are cost-effective, easily serviceable, repairable, and relatively easy to replace contribute to system resiliency.

Current technology can fill gaps in maritime logistics while more holistic solutions address institutional gaps. Employing artificial intelligence, automated equipment, and resilient systems can effectively enable the Joint Force commander to control logistics within the operational area.[1]


[1] Joint Chiefs of Staff, *JP 4-0: Joint Logistics,* Daniel J. O'Donohue. (Washington, D.C.: Joint Chiefs of Staff, 2019), page xiv.

## Dedication

This project is dedicated to the soldiers, sailors, airmen, Marines, Vanguards, and Coast Guardsmen who stand the watch daily to defend our nation and our way of life. It is my sincerest hope that whatever insight is offered in these pages contributes in some slight ay to your capability, resiliency, and safety as you move out in defense of our collective national interests.

## Acknowledgments

My sincerest thanks to Dr. Bryon Greenwald for his guidance, mentorship, and patience. Your personal example of academic rigor and approachability is an inspiration to your students, particularly this one.

Thank you also to Dr. Phillip Saunders for providing a critical eye and wealth of knowledge. Your candid feedback made this project a more focused product – it will be more useful to the affected commanders because of you.

I also must acknowledge the outstanding leaders who have afforded me unique opportunities to gain expertise and strategic insight on joint maritime warfighting in the littorals: Commandant of the Marine Corps, GEN David Berger, USMC; RADM Alvin Holsey, USN; RDML Cedric Pringle, USN; RDML John Gumbleton, USN; RADM Michael White, USN (Ret); RADM Peter Gumataotao, USN (ret), MajGen David Coffman, USMC (ret); and RDML Cathal O'Connor, USN (ret). I hope to repay the time each of you invested in me by service to our country and our comrades in arms.

Finally, I owe a lifelong debt of gratitude and love to my wife. Without her support and dedication, our exhilarating and precarious path through life would have no meaning.

**Table of Contents**

## Chapter 1: Introduction

A famous quote by General Dwight Eisenhower goes: "You will not find it difficult to prove that battles, campaigns, and even wars have been won or lost primarily because of logistics." American victories in North Africa, Normandy, the Pacific Island and Philippine campaigns, Korea, and Iraq relied heavily on joint maritime sustainment. Whether in the USINDOPACOM AOR or elsewhere, the next major conflict will also rely heavily on joint sustainment.

Joint Publication 4-0 *Joint Logistics* is the capstone doctrine document for joint logistics. It charges the Combatant Commanders (CCDRs) and Joint Force Commanders to provide adequate command and control measures to manage and direct sustainment operations. This publication provides "fundamental principles and guidance for logistics planning, execution, and assessment in support of joint operations."[1] The Joint Concept for Logistics published in September 2015 highlights that while the U.S. Armed Forces' demand for logistics is growing increasingly complex, the joint logistics enterprise (JLent) is directly susceptible to adversary A2/AD and cyber capabilities.[2] "The globally integrated operations concept envisions forces integrating across Service lines at dramatically lower echelons of command to create cross-domain synergy." Thus, maritime logistics is truly joint logistics.

At the forefront of U.S. military focus are the challenges posed by the People's Republic of China. The outgoing Director for National Intelligence (DNI) called the PRC "the greatest threat to America today, and the greatest threat to democracy and freedom

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[1] Joint Chiefs of Staff, *Joint Logistics*, JP 4-0 (Washington, DC: Joint Chiefs of Staff, May 8, 2019), i.
[2] Joint Chiefs of Staff, *Joint Concept of Logistics, Version 2.0*, (Washington D.C., Joint Chiefs of Staff, September 25, 2015), 5.

worldwide since World War II."[3] The *2017 National Security Strategy*, *2018 National Defense Strategy*, and *2018 National Military Strategy* all describe the PRC as a coercive power opposed to the global order and U.S. interests. Secretary of Defense Lloyd Austin called China "the top priority" during his Senate confirmation hearing.[4] Secretary of State Antony Blinken similarly stated that "[China] poses the most significant challenge of any nation-state to the United States" during his testimony to the Senate Foreign Relations Committee.[5]

The Department of Defense's Joint Security Campaign Plan (JSCP) designates USINDOPACOM as the coordinating authority for the Global Campaign Plan (GCP) for China. A Global Campaign plan "address[es] the most pressing transregional and multi-functional strategic challenges across all domains."[6] Unlike the authorities given to a combatant commander, Unified Command Plan (UCP) coordinating authority does not include the "power to compel agreement or direct resource allocation" across the DoD enterprise.[7] However, under USINDOPACOM's combatant command authority, the commander is charged by Title 10 USC § 146 to "giving authoritative direction to subordinate commands and forces necessary to carry out missions assigned to the

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[3] John Ratcliffe, "China Is National Security Threat No. 1," *The Wall Street Journal,* December 3, 2020, https://www.wsj.com/articles/china-is-national-security-threat-no-1-11607019599.
[4] Lloyd J. Austin, "Senate Armed Services Committee Advance Policy Questions for Lloyd J. Austin Nominee for Appointment to be Secretary of Defense," U.S. Senate Armed Services Committee, Jan 19, 2021. https://www.armed-services.senate.gov/imo/media/doc/Austin_APQs_01-19-21.pdf
[5] Michele Kelemen, "Secretary Of State Nominee Blinken Promises A Reengaged America Abroad," *National Public Radio*, January 19, 2021, https://www.npr.org/sections/biden-transition-updates/2021/01/19/958289975/secretary-of-state-nominee-antony-blinken-promises-humility-and-confidence.
[6] Chairman of the Joint Chiefs of Staff, *Joint Strategic Planning System,* CJCSI 3100.01D (Washington, DC: Joint Chiefs of Staff, July 20, 2018), C-2.
[7] Chairman of the Joint Chiefs of Staff, *Joint Strategic Planning System,* C-2.

command, including authoritative direction over all aspects of military operations, joint training, and logistics."[8]

In response to direction in the 2020 National Defense Authorization Act, USINDOPACOM submitted a report directly to Congress on "resourcing United States defense requirements for the Indo-Pacific region and study on competitive strategies."[9] In this document, titled "Regaining the Advantage," ADM Davidson calls for an "enhanced force posture that provides for dispersal, the ability to preserve regional stability, and if needed, sustain combat operations."[10] Two of the focus areas in that document, force posture and logistics, relate directly to joint force sustainment challenges. Although Great Power Competition is not unique to the INDOPACOM AOR, the area itself does present significant hurdles to achieving the desired endstate of our strategic leadership.

To answer this question required a problem definition in terms of adversary capability, geographic environment, and friendly capability. Next, a survey of best practices for advanced technology integration in commercial shipping publications identified potential solutions which are feasible in the near-term. Finally, an analysis of which technologies and practices are most applicable to address the joint logistics challenges in the INDOPACOM AOR revealed three distinct technologies: artificial intelligence, automation/robotics, and resilient shipboard systems.

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[8] *Commanders of combatant commands: assignment; powers and duties, U. S. Code* 10 (1986), § 164.
[9] CDRUSINDOPACOM, *National Defense Authorization Act (NDAA) 2020 Section 1253 Assessment: Regain the Advantage*, https://www.scribd.com/document/454815069/National-Defense-Authorization-Act-Section-1253-Executive-Summary#download&from_embed.
[10] CDRUSINDOPACOM, *National Defense Authorization Act (NDAA) 2020 Section 1253 Assessment: Regain the Advantage*.

The Challenge: Tyranny of Distance, Global Complexity, and Malign Actors

The globalized complexity of diplomatic and economic powerhouses in Asia, sheer size, and weather of the western Pacific make a challenging area for sustainment. Coupled with a robust U.S. forward presence, these factors require significant sustainment support from the joint force commander. Under current doctrine, the U.S. Indo-Pacific Command (USINDOPACOM) is the combatant command and, therefore, the joint force command initially responsible for that sustainment.[11]

USINDOPACOM's area of responsibility (AOR) is the largest of any geographic combatant command. The AOR encompasses more than half of the globe; over half of the world's population resides in this expanse of more than 100 million square miles. The thirty-six countries in the AOR include the four most populous nations (China, India, the United States, and Indonesia), largest democracy (India), and the largest majority-Muslim country (Indonesia). The USINDOPACOM AOR also includes the smallest country in Asia (Republic of Maldives). Numerous island chains characterize the area with more than 225,000 kilometers of non-U.S. coastline. The AOR includes four of the five nations recognized under the United Nations Convention on the Law of the Sea (UNCLOS) as archipelagic nations. The Hawaiian Island chain is the longest and most geographically isolated island chain in the world, and Indonesia has more inhabited islands than any other nation.

[11] Joint Chiefs of Staff, *Joint Logistics*, Joint Publication 4-0 (Washington, DC: Joint Chiefs of Staff, May 8, 2019), III-2.

In economic terms, the four top economies by Gross Domestic Product (Purchasing Power Parity) reside here–China, the United States, India, and Japan.[12] The Strait of Malacca is the busiest waterway in the world, with nearly 100,000 ships transiting annually.[13] This shipping traffic accounts for approximately 80% of China's energy supply, more than 65% of China's trade and 69% of its maritime trade.[14] Almost 25% of the world's economy transits these straits. Key U.S. partners, Japan and South Korea, also rely heavily on the Strait of Malacca for more than 90% of their energy imports.[15] The USINDOPACOM AOR also includes eight of the world's ten busiest container ports.[16]

Distances from North American ports of call to western Pacific ports are vast; the transit from the Los Angeles-Long Beach port complex to the Port of Singapore is 7,670 nautical miles; a typical container takes 30-45 days to make the transit. Naval vessels transiting at 16 knots would take almost 20 days to make the same transit. Even from Hawaii, the transit is 5,881 nm and would take more than 15 days via the shortest route. The western Pacific is expansive.

Airfreight accounts for only 10% of the volume of trade goods shipped globally. Maritime transit is far more cost-effective; it typically costs one-fifth of air freight. The trans-Pacific distances further exacerbate air transport; direct flights from the continental

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[12] International Monetary Fund World Economic Database, retrieved 1/31/2021

[13] Krishnadev Calamur, "High Traffic, High Risk in the Strait of Malacca," *The Atlantic*, (August 21, 2017), https://www.theatlantic.com/international/archive/2017/08/strait-of-malacca-uss-john-mccain/537471/

[14] U.S. Energy Information Administration, *Today in Energy: Maritime Chokepoints are Critical to Global Energy Security*, Lejla Villar and Mason Hamilton, (Washington, D.C. U.S. Energy Information Administration, August 1, 2017), https://www.eia.gov/todayinenergy/detail.php?id=32292

[15] "Strait of Malacca Key Chokepoint for Oil Trade," *The Maritime Executive*, (Fort Lauderdale, FL), August 27, 2018, https://www.maritime-executive.com/article/strait-of-malacca-key-chokepoint-for-oil-trade

[16] "Strait of Malacca Key Chokepoint for Oil Trade," *The Maritime Executive*

United States to logistics nodes in Singapore and Japan with military aircraft are not generally possible without in-flight refueling; Guam and Hawaii are even further afield.

Distance is not the only challenge in moving large quantities of military materiel to the western Pacific. Weather can be severe during the annual typhoon season from June through November and significantly influence military operations. In December 1944, Typhoon Cobra struck Admiral Halsey's Third Fleet in December 1944, sinking three destroyers and killing 790 sailors. Recent weather forecasting technology and satellite imagery does not produce immunity to severe weather, either. Between December 2020 and January 2021, four commercial ships lost a combined 3,000 containers in severe weather, nearly double the annual average.[17]

Global competition also represents a risk to forces operating in the western Pacific. The United States' *2017 National Security Strategy* (NSS) states China "seeks to displace the United States in the Indo-Pacific region."[18] The Department of Defense's 2020 Annual Report to Congress on China's military capabilities highlights China's anti-access/area denial (A2/AD) operational approach.[19] In addition to global nuclear deterrence, Chinese doctrine emphasizes hybrid and irregular warfare in terms of the "three warfares," or psychological warfare, public opinion warfare, and legal warfare.[20]

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[17] Costas Paris, "Maersk Ship Loses 750 Containers Overboard in Pacific Ocean," *The Wall Street Journal*, January 21, 2021, https://www.wsj.com/articles/maersk-ship-loses-750-containers-overboard-in-pacific-ocean-11611255703

[18] U.S. President, National Security Strategy of the United States of America (Washington, D.C.: Government Printing Office, December 2017), 25. https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf

[19] U.S. Department of Defense, *Military and Security Developments Involving the People's Republic of China 2020 Report to Congress,* (Washington D.C., September 2020), ix. https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF

[20] Elsa Kania, "The PLA's Latest Strategic Thinking on the Three Warfares," *China Brief* Volume: 16 Issue: 13, (Washington D.C., August 22, 2016), https://jamestown.org/program/the-plas-latest-strategic-thinking-on-the-three-warfares/

consistent with the Chinese policy of "active defense," the People's Liberation Army (PLA) has built robust layered capabilities to interdict U.S. tactical and sustainment formations in the region.[21] China's "Active Strategic Counterattacks on Exterior Lines" operational guidance specifically targets our vulnerable supply lines.

Generally, operational planners describe Chinese interdiction capabilities in terms of operational reach. Because of the distances involved, it is useful to describe them in terms of island chains.[22] Not only do these islands form a physical barrier with permeable chokepoints, but culturally the People's Republic of China sees these island chains as part of an "infrastructure of containment" built by America to keep China a second-rate power.[23]

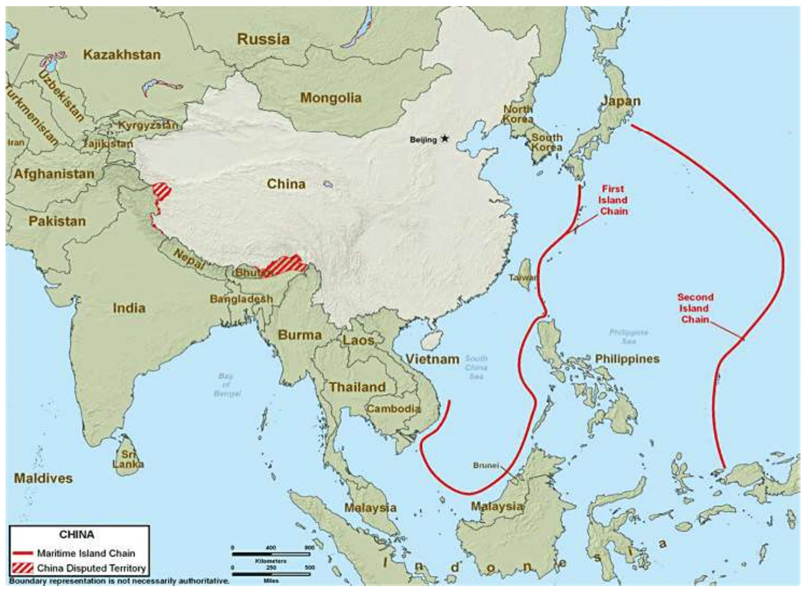

*Figure 1- First and Second Islands Chain[24]*

Within the First Island Chain, the PLA maintains a capability to enforce air and maritime superiority. The People's Liberation Army Rocket Forces (PLARF) maintain

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[21] Department of Defense, *Military and Security Developments Involving the People's Republic of China 2020 Report to Congress.* p. .
[22] Andrew Erickson and Joel Wuthnow, "Barriers, Springboards and Benchmarks: China Conceptualizes the Pacific 'Island Chains,'" *The China Quarterly* 225, (2016): 7. https://www.cambridge.org/core/journals/china-quarterly/article/barriers-springboards-and-benchmarks-china-conceptualizes-the-pacific-island-chains/B46A212145EB9D920616650669C697F0
[23] Zachary Brown, "Reviewing Red Star Over the Pacific," *The Strategy Bridge,*(Washington, D.C., May 18, 2019), https://thestrategybridge.org/the-bridge/2019/5/8/reviewing-red-star-over-the-pacific
[24] Toshi Yoshihara, "China's Vision of Its Seascape: The First Island Chain and Chinese Seapower," *Asian Politics & Policy,* Special Issue: How China's Rise Is Changing Asia's Landscape and Seascape, Volume 4 Issue 3, (July 2012): 293-314

more than 750 short- and intermediate-range rockets that can strike targets, including ships at sea, in this area. The PLA designed its DF-21D (also called the CSS-5 Mod 5) to neutralize U.S. aircraft carriers with a maneuverable reentry vehicle and potentially multiple warheads.[25] The PLARF also maintains ground launch cruise missiles, designated CJ-10, that can range ports and land targets 1,100 miles from the launcher.[26]

Ships equipped with YJ-12 and YJ-18 anti-ship cruise missiles (ASCMs) can attack targets in the South China Sea. The new Renhai-class (Type 055) cruiser may be capable of launching anti-ship ballistic missiles as well.[27] Both the People's Liberation Army Navy Air Force (PLANAF) and People's Liberation Air Force (PLAAF) can saturate the South China Sea with anti-ship cruise missiles from their H-6 bomber fleet.

Other naval assets employed inside the First Island Chain include nuclear and diesel-powered submarines with torpedoes and ASCMs. The Chinese Coast Guard (CCG) is the world's largest, fielding over 130 large patrol vessels with helicopter facilities, water cannons, and guns ranging up to 76mm. In 2018, the CCG shifted under the Central Military Commission for operational command.[28] The People's Armed Forces Maritime Militia (PAFMM) consists of thousands of vessels with crews trained by the Chinese military to enforce territorial claims, force standoffs with U.S. Navy vessels. High-profile examples include delivery of

*Figure 2- PAFMM Steaming in Formation*

[25] Department of Defense, *Military and Security Developments Involving the People's Republic of China 2020 Report to Congress,* p. 81
[26] Ibid., p. 81
[27] Ibid., p. 71
[28] Ibid., p. 94

500 troops to the Vietnam-claimed Western Paracels in 1974 and the harassment of USNS IMPECCABLE in 2009.[29] PAFMM vessels also provide intelligence, surveillance, and reconnaissance (ISR) against U.S. forces operating in the area.

In recent years, China's power projection expanded westward to the Second Island Chain. The 2020 DoD Annual Report highlights China's newly-fielded operational reach out.[30] In 2019, the Chinese carrier *Liaoning* sailed east near Guam before returning to the South China Sea for a major maritime exercise.[31] PLAARF forces can target maritime vessels inside the Second Island Chain using the ASBM-variant of the DF-26 intermediate-range ballistic missile. This same rocket can deliver conventional or nuclear warheads against ground targets. The PLA demonstrated their DF-17 missile fitted with a hypersonic glide terminal delivery vehicle (designated DF-ZF) in 2018. Development of the Xingdong-2 hypersonic missile is underway, with anticipated ranges reaching the United States' western coast.[32]

China leverages its space-based sensor system to feed targeting data to the precision fires forces.[33] Satellites in various orbits use electronic intelligence (ELINT) to listen for radio and radar emissions from vessels at sea. Meanwhile, synthetic aperture

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[29] Andrew Erickson and Conor Kennedy, "Trailblazers In Warfighting: The Maritime Militia of Danzhou," Center for International Maritime Security, February 1, 2016, https://cimsec.org/trailblazers-warfighting-maritime-militia-danzhou/21475

[30] Department of Defense, *Military and Security Developments Involving the People's Republic of China 2020 Report to Congress,* (Washington D.C., September 2020), https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF

[31] Kevin Kerrigan, "China's aircraft carrier passes near Guam," *The Guam Daily Post*, (Tamuning, Guam) June 27, 2019. https://www.postguam.com/news/local/china-s-aircraft-carrier-passes-near-guam/article_2cf9a436-97f4-11e9-a62f-7bc0bb14594c.html

[32] GlobalSecurity.org, "Xingkong-2 / Starry Sky 2," accessed January 31, 2021, https://www.globalsecurity.org/wmd/world/china/xingkong-2.htm#:~:text=Japanese%20experts%20believe%20that%20the,times%20the%20speed%20of%20sound.

[33] Mark Stokes, Gabriel Alvarado, Emily Weinstein, and Ian Easton, "China's Space and Counterspace Capabilities and Activities," U.S.-China Economic and Security Review Commission, March 30, 2020, p. 9.

radar (SAR) satellites scan hundreds of square miles at a time for radar signatures. Finally, electro-optical (E.O.) satellites can identify ship types and classes for more precise target classification.[34]

## SUMMARY OF THREAT AND SIGNIFICANCE

### What We Have, and Why It is Not Sufficient

The United States enjoys a robust military presence in the region thanks to six collective defense arrangements with Australia, New Zealand, Thailand, Japan, Philippines, and South Korea.[35] Major forward-deployed units include U.S. Seventh Fleet in Yokosuka, Japan; U.S. Eighth Army in Pyeongtaek, South Korea; the Fifth Air Force headquartered at Yokota, Japan; the Seventh Air Force at Osan Air Base, South Korea; and III Marine Expeditionary Force in Okinawa, Japan. USINDOPACOM has more than 375,000 military and civilian personnel assigned, with additional Army, Navy, Air Force, and Marine Corps formations stationed generally along the west coast. As a unified combatant command, USINDOPACOM can draw globally from forces retained by each service and assigned to other combatant commands.

Military logistics nodes in the western Pacific theater are relatively mature, but few and far between. Important ports of embarkation on the United States west coast include Tacoma in Washington, and the Ports of Oakland, Los Angeles, Long Beach and San Diego in California. Several smaller ports of embarkation also support military movement by sea. Joint Base Pearl Harbor-Hickam is more than 2,000 nm from the

[34] Defense Intelligence Agency, "China Military Power," 2019, (Washington DC: Defense Intelligence Agency, January 03, 2019), 36.
[35] "U.S. Collective Defense Arrangements," U.S. Department of State, accessed January 31, 2021, https://2009-2017.state.gov/s/l/treaty/collectivedefense//index.htm#:~:text=A%20Treaty%20signed%20September%201,accordance%20with%20its%20constitutional%20processes.

nearest port of embarkation at Oakland, CA. It serves as a waypoint for military forces moving west across the Pacific, both via sea and air. From this mid-Pacific waypoint, ships can transit another 3,300 nm to the next major complex of military installations in the Northern Marianas Islands, including Guam and Saipan. From there, a vessel may transit more than 1,200nm to Okinawa or transit 1,300nm to either Yokohama/Yokosuka or the former naval base at Subic Bay. The central naval logistics hub in Singapore is more than 2,500 nm from Guam.


*Figure 3- Logistics Hubs in the Pacific*

Outside the western Pacific, logistics hubs at Diego Garcia and Darwin, Australia have limited capacity. Diego Garcia lies 1,950 nm to the southwest of Singapore; Darwin is 1,800 nautical miles east-southeast. U.S. forces deploying from the East Coast of the United States to the western Pacific must make an even longer journey; ships departing from the Chesapeake Bay must transit more than 10,000 nm to reach Singapore via the Suez Canal and Strait of Bab-al-Mandeb near Yemen.

The Defense Logistics Agency serves a supporting role in sustainment to each of the combatant commanders.[36] In INDOPACOM's AOR, the Army's 8th Theater Sustainment Command (8th TSC) is the operational lead for joint theater sustainment. Maritime theater logistics support to the 8th TSC comes from several other commands.

[36] U.S. Department of Defense, DoD Directive 3000.06: Combat Support Agencies. Washington DC: Department of Defense, 10 July 2007.

The Navy contributes Expeditionary Strike Group Three (ESG-3) as the one-star Commander for Joint Logistics Over the Shore (JLOTS) and Naval Beach Group One (NBG-1) based in Coronado, CA as their transportation unit. The Army provides port opening and cross-beach sustainment capability from the 7th Transportation Brigade (Expeditionary), or 7th TB(X). Both Army and Navy commands have numerous subordinate units or elements assigned as needed for boats, landing craft, engineering, cargo handling, and transportation.

Other maritime assets available to provide sustainment in the western Pacific include 34 active-duty amphibious warships designed to deliver USMC combat capability. Military Sealift Command provides approximately 125 vessels of various types, functions, and states of readiness. These government-owned, contractor-operated vessels include 17 prepositioning ships and 24 strategic sealift ships for the Army, Air Force, and Marine Corps.[37] The Department of Transportation's Maritime Administration (MARAD) husbands more than 100 militarily useful vessels, including tankers and specialized cargo handling vessels. Forty-one of these vessels assigned to the Ready Reserve Force (RRF) support the U.S. Transportation Command (USTRANSCOM) for strategic sealift.[38]

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[37] Ships of the Military Sealift Command," Ship Inventory, Military Sealift Command, accessed January 31, 2021. https://www.msc.usff.navy.mil/Portals/43/Posters/MSC_USNavyShips.pdf?ver=2020-08-13-152916-247

[38] "The Ready Reserve Force (RRF)," U.S. Department of Transportation Maritime Administration, accessed January 31, 2021. https://www.maritime.dot.gov/national-defense-reserve-fleet/ndrf/maritime-administration%E2%80%99s-ready-reserve-force

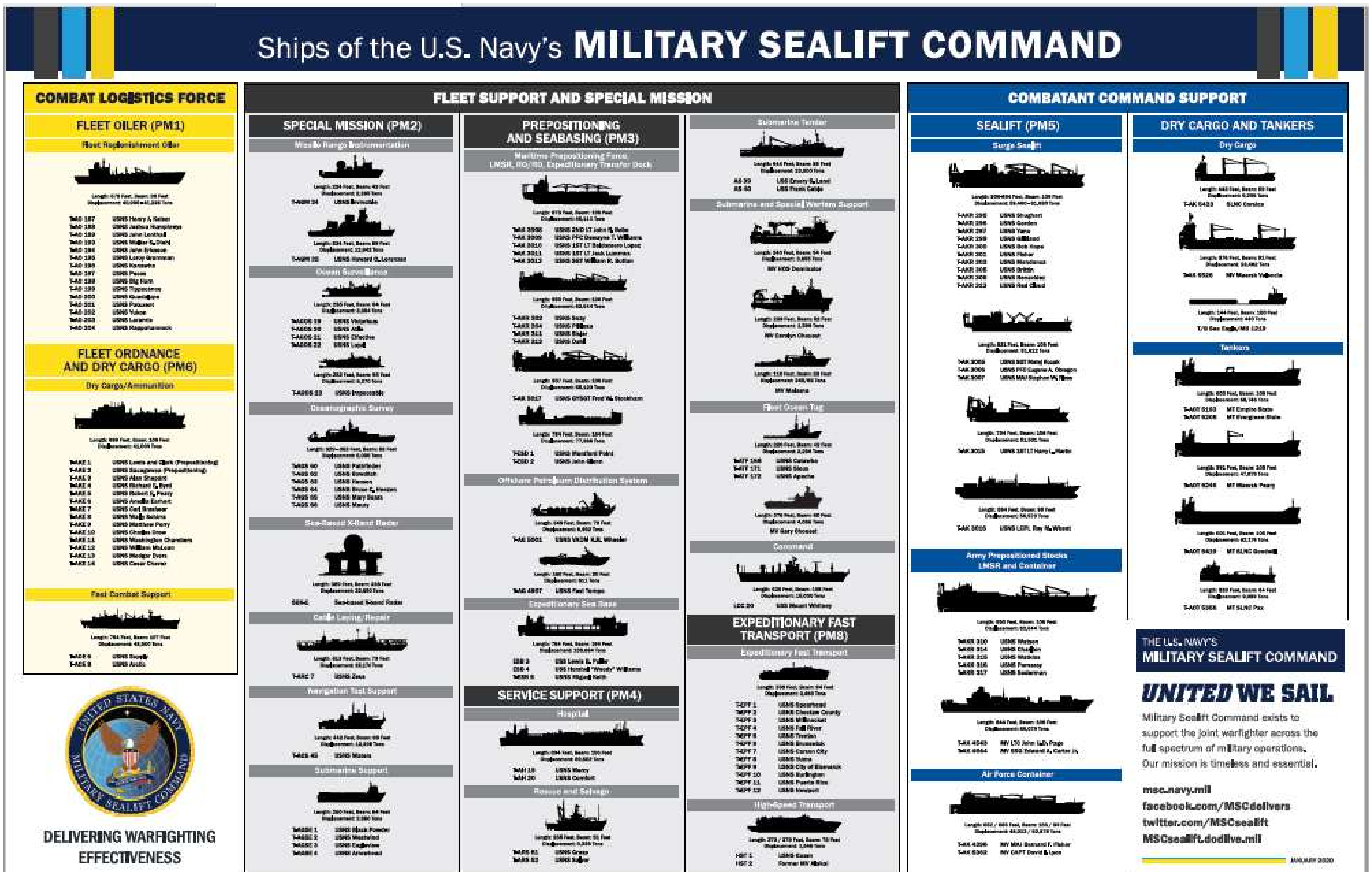


*Figure 4- Ships of the Military Sealift Command*

classes across four general modes of transport.[39] While logistics planners account for all classes of supply, DLA is the executive agent for food, medical supplies, and construction equipment.[40] Thus, operational planners focus on three classes in particular: Class III, or Petroleum, Oil and Lubricants (POL); Class V, Ammunition (all types); and Class VII, major end items (vehicles and weapon systems).

These classes of sustainment are moved into theater and initially distributed in four modes: International Organization for Standardization (ISO) cargo containers, breakbulk or palletized cargo, rolling stock, and bulk liquids. The standardization of cargo containers dramatically reduces complexity and saves time, labor, and expense.

International Organization for Standardization (ISO) Cargo Characteristics

Standard-size ISO containers are eight feet wide by eight feet six inches tall and either 20 feet or 40 feet long. Pairs of twenty-foot containers nest securely with forty-foot containers. A standard measure for cargo capacity of a vessel or port is Twenty-Foot Equivalents Units (TEUs). A forty-foot container would therefore take two TEU of space. The maximum gross weight of a twenty-foot container is 53,000 pounds; for a forty-foot container, the maximum gross weight is 67,200 pounds. However, because these containers are intermodal, i.e., they can be transported on ships, trucks, and trains alike, individual countries' restrictions may limit cargo to less than this maximum limit.

Additionally, "high cube" containers (nine feet six inches tall) are becoming more commonplace; however, their maximum gross weight remains the same. These "high

[39] Joint Chiefs of Staff, *Joint Logistics*, JP 4-0 (Washington, DC: Joint Chiefs of Staff, May 8, 2019), II-5-II-6.
[40] U.S. Department of Defense, DoD Directive 3000.06: Combat Support Agencies. Washington DC: Department of Defense, 10 July 2007.

cube" containers are therefore useful for lighter, bulkier goods. These larger containers now represent more than 50% of containers in commercial use.[41]

The Joint force logistics units often use smaller containers because TEUs remain unwieldy during military operations. The DLA provides both QuadCons (4 containers make up a TEU) and TriCons (3 containers make up a TEU).[42] BiCons are still used by some military units as well. Flatracks are essentially the floor of an ISO container with no roof or sides; they may have pillars or A-framing at the corners and edges for increased rigidity. Outsized cargo such as AM-2 aviation matting use flatracks for transport while still using standard cargo handling equipment (CHE).

Army, Navy, and Marine Corps cargo handling units typically use the Kalmar RT-240 Rough Terrain Container Handler (RTCH) for cargo container movement inside the container yard. The RTCH can also load containers onto other transport vehicles, such as light, medium, and heavy trucks. The Army's M1075 Heavy Expanded Mobility Tactical Truck (HEMTT) and Marine Corps' Logistic Vehicle System Replacement (LVSR) have self-loading capabilities for single TEUs. Some larger

*Figure 5- Rough Terrain Cargo Handler (RTCH) lifting a standard ISO container*

[41] Drewry Shipping Consultants, "40ft High Cubes set to Dominate the Container Equipment Market," accessed February 12, 2021. https://web.archive.org/web/20140829070535/http://www.drewry.co.uk/news.php?id=277
[42] Defense Logistics Agency, *Troop Support Construction and Equipment Container Program Customer Handbook*, Philadelphia, PA, December 2018, p 5-8.

forklifts can move TEUs but are often limited in lift height and cannot stack TEU containers.

Break Bulk / Palletized Characteristics

Forklifts move palletized cargo or breakbulk cargo. This mode of transport is less standardized and efficient than cargo containers but provides useable quantities to customer units. Forklifts come in a variety of sizes, weights, and lift capacities. Some are specialized for rough terrain; others require smooth surfaces. Services often optimize shipboard forklifts and aircraft material handling forklifts for confined spaces.

Notably, the U.S. Air Force uses 463L pallets for air transport of cargo, which have no commonality with intermodal containers. Transshipment typically requires the logistic support personnel to unpack the intermodal container and reload the materiel on the 463L pallet.

*Figure 6 - USAF 463L Pallet with cargo*

Rolling Stock: Vehicles

Rolling stock such as tanks, trucks, and light vehicles are self-mobile. For more extended ground movements of tracked vehicles, transportation units utilize HEMTTs to save wear on the tactical vehicles. Rail movement is also an option when available. For ship-to-shore movement, most vehicles are driven from the discharge ship to the lighter or pier. The receiving unit may provide the vehicle driver, which drives the vehicle to the marshaling yard for further preparation once discharged.

Bulk Liquids: Petroleum and Water

Bulk liquids most commonly refer to fuel or water but may include other petroleum products. Ship-to-shore movement of small amounts of liquids via bladder transport can sustain initial assault forces, but typically hose systems are required for longer-duration or more extensive operations. Once established, the terminal unit at the beach or port can receive bulk liquid by pumps for transfer into bladder farms or to tactical distribution systems for immediate use. Air-delivered fuel systems, such as the U.S. Air Force's Aerial Bulk Fuel Delivery or Marine Corp's Tactical Air-Ground Refueling System (TAGRS), are limited to tactical distribution only.

*Figure 7- USMC Fuel Distribution Site*

The current doctrine for the distribution system of cargo and liquids works very efficiently under traditional service structures. However, the future Joint Concepts for Logistics calls for "increasingly lower echelons to detach from their parent headquarters and combine effectively with similar elements from other Services or organizations to form flexible tactical groupings."[43] An example might be a composite unit of less than 120 personnel and 30 vehicles comprised of a USMC aviation support squadron detachment, an Army transport and security forces detachment, and a Navy cargo handler detachment. This small unit would be task-organized to provide expeditionary refueling capability to various joint aircraft at austere airfield locations.

[43] Joint Chiefs of Staff, "Joint Concept of Logistics," Version 2.0 (Washington DC: Joint Chiefs of Staff, September 25 2015), 12.

The current sequence of joint maritime logistics requires achieving air and maritime superiority first to allow uninterrupted flow of supplies.[44] Given the PRC's capabilities, achieving air and maritime superiority may be challenging, or intermittent at best! Deployment of prepositioned sustainment forces can take weeks; just the lighterage[45] assembly typically takes two or three days before in-stream offload commences. These extended timelines dramatically increase the risk to force and mission when conducted under the peer adversary's A2/AD threat and limited warning times. Legacy sustainment and distribution systems that require whole units and large hub-and-spoke topography cannot be agile enough to avoid detection and targeting by an adversary like China. Surviving in austere and contested environments will require rapid receiving, staging, and onward movement of forces and materiel.[46] Moreover, because what can be sensed can be targeted, signature management in all domains is essential for survival and effective operations.

Establishing and maintaining maneuver in an increasingly complex environment requires new capabilities. INDOPACOM's "Regain the Advantage" specifies joint logistics as a key enabler for their theater focus areas.[47] Key points of emphasis in the Joint Logistics Concept include a rapid and flexible transportation system able to move forces and supplies quickly between and within theaters, highly modularized and

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[44] Joint Chiefs of Staff, *Joint Logistics*, Joint Publication 4-0 (Washington, DC: Joint Chiefs of Staff, May 8, 2019), F-1.
[45] Lighterage includes smaller vessels that transport equipment and stores from large ships at anchor to port facilities or beach landing zones. Examples include the Improved Navy Lighterage System (INLS), Causeway Ferries (CF), LCUs, and Lighter, Amphibious, Resupply, Cargo (LARC), among others.
[46] Joint Chiefs of Staff, "Joint Concept of Logistics," 13.
[47] USINDOPACOM. "National Defense Authorization Act (NDAA) 2020 Section 1253 Assessment Executive Summary: Regain the Advantage, U.S. Indo-Pacific Command' s (USINDOPACOM) Investment Plan for Implementing the National Defense Strategy Fiscal Years 2022-2026," June 1 2019, accessed November 10, 2020, https://media.defense.gov/2019/Jul/01/2002152311/-1/-1/1/DEPARTMENT-OFDEFENSE-INDO-PACIFIC-STRATEGY-REPORT-2019.PDF.

interoperable logistics capabilities, and an agile global logistics resource allocation and adjudication capability.[48]

Unfortunately, multi-service platforms and organizations lack the capacity and capability to conduct sufficient inter-theater lift via the sea. Future maritime logistics platforms must leverage AI-enabled networked logistics management, vessel automation, and incorporate self-sufficient resiliency to deliver sustainment in a contested environment. Maritime logistics platforms with these characteristics are required to adequately sustain combat forces at operational tempo in a contested environment.

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[48] Joint Chiefs of Staff, "Joint Concept of Logistics," Version 2.0 (Washington DC: Joint Chiefs of Staff, September 25 2015), 13.

## Chapter 2: Gaining Advantage Using Artificial Intelligence

Artificial intelligence (A.I.) and machine learning (ML) have already arrived in commercial logistics. McKinsey & Company estimates that 20% of businesses implemented some measure of A.I. and that further implementation of artificial intelligence and deep analytics could generate more than $4.8T in value if fully implemented in the supply chain management and manufacturing sector.[1] Artificial intelligence and machine learning can similarly generate value for Department of Defense logistics.

The term "artificial intelligence" can be challenging to define. On the surface, A.I. is simply intelligence exhibited by machines or software. One can understand approaches to artificial intelligence (more correctly, computational intelligence) along two axes: first, whether the hardware/software process accurately replicates the *process* versus the *behavior* of decision making; and second, whether the hardware/software process produces results like a *rational actor* versus a *human* decision-maker.[2] Modern artificial intelligence researchers prefer the rational actor model.[3]

The rational actor model classifies A.I. into four types.[4] The first is a *reactive machine*; this type of artificial intelligence receives an input, applies a set of instructions to that input, and rapidly generates an output. An everyday example is an Excel spreadsheet; it receives the values the user (or another piece of software) provides as

[1] Michael Chui, Nicolaus Henke, and Mehdi Miremadi. "Most of AI's business uses will be in two areas," *Harvard Business Review*, (July 20, 2018).
[2] Stuart J. Russell and Peter Norvig, "Artificial Intelligence: A Modern Approach," Prentice Hall, Englewood Cliffs, New Jersey 1995, 4.
[3] Stuart J. Russell and Peter Norvig, "Artificial Intelligence: A Modern Approach," 7.
[4] Arend Hintze, "Understanding the Four Types of Artificial Intelligence," *Government Technology*, November 14 2016.l

input, performs manipulations in binary code, and returns the output. Interactive personal assistants are more complex but have similar fixed routines that receive input and provide an output. This type of artificial intelligence has been around since the 1940s and famously powered Deep Blue's victory over chess champion Gary Kasparov in 1997. Even Google's AlphaGo defeat of Lee See-dol in March 2016 is an example of reactive machine intelligence, albeit with a twist. AlphaGo used deep learning–recognition of unstructured input (in this case, Lee's moves during the game)–to run Monte Carlo tree models and determine the greatest likelihood of victory from all possible moves.[5]

The second type of artificial intelligence is called *limited memory*. These artificial intelligence machines can string occurrences together and learn from them, albeit only over a short duration. Like Pavlov's dog, the computer will observe behavior–a car moving, a clock chiming–and be able to predict (with varying accuracy) what will happen next. Limited memory artificial intelligence is still in development but can be seen in practice monitoring financial markets or predicting when mechanical failure will happen in complex systems.

The third type of artificial intelligence is "*theory of mind*:" the A.I. understands that other actors cause varying input in the environment and can then interact with them to influence the outcome. This level of A.I. has been achieved in a limited fashion only recently.[6] This type of A.I. can account for others' decisions, predict their behaviors, and then make advantageous decisions based on that anticipated environment.

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[5] David Silver et al., "Mastering the game of Go with deep neural networks and tree search". *Nature*, 529 (28 January 2016), 486.
[6] Matthew Hutson, "Artificial intelligence has learned to probe the minds of other computers," *Science*, (Jul. 27, 2018).

The final type of artificial intelligence is *self-awareness*. No such systems exist today, but they would recognize the internal identity of actions taken, such as "I want that" in type III intelligence versus "I know I want that" in self-aware intelligence.

Practical applications for artificial intelligence in maritime logistics connectors include prioritization of routing tasking while in-transit and optimizing staging locations and transit routes for distribution. Software models of transportation networks already exist in the commercial sector. By collecting cost, revenue, and time data, various computational methods can use deep learning to optimize ship placement based on a complex set of factors, such as the requirement for routine service at a particular port even when it is economically suboptimal.[7]

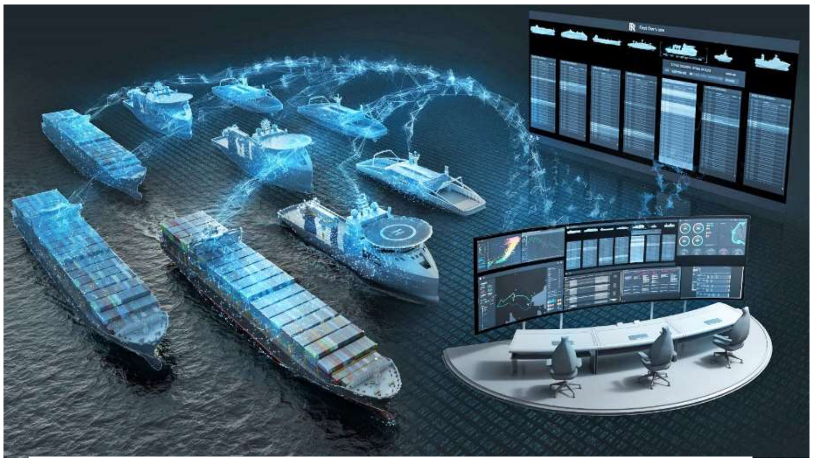

*Figure 8 -Visualization of AI-Enabled In-Transit Visibility*

Humans can provide weights to the machine's route planning algorithm to optimize different factors, such as the most timely deliveries or the most economical delivery schedule.[8] This sort of functionality can be useful when making trade-off decisions between the efficient distribution of commodities to the force versus timely delivery of critical munitions to the hardest-pressed formations.

[7] Kevin Tierney et al., "Automated Planning for Liner Shipping Fleet Repositioning," 2012, Association for the Advancement of Artificial Intelligence.
[8] Markus Fruth and Frank Teuteberg,"Digitization in maritime logistics—What is there and what is missing?," *Cogent Business & Management*, 4:1, 1411066, (2017), 4.

Optimized commodities streams require internal cargo data from the ship. Using Internet of Things (IoT) technologies, real-time monitoring of cargo can inform the distribution systems A.I. of the cargo status.[9] Real-time human understanding of this data, when associated with decision criteria, can aid in rapid decision-making.

For example, if enemy action damaged a ship sailing into contested waters, the A.I. system would receive cargo loss inputs and nearly instantly determine sustainment shortfalls. The A.I. would send notifications to units whose cargo was affected at computer speed, and the optimization routines could present alternative routing options for human or automated decisions. This in-transit visibility would also contribute to the stated goal of the Globally Integrated Logistics network called for in the current Joint Logistics Concept.[10] OPNAV and DLA have begun initiatives to address this shortcoming, but these initiatives have not been fully implemented to date.

Limited memory A.I. systems can use deep data analytics to predict point-of-need sustainment requirements.[11] This data can be collected from real-world operations, exercises, and simulated wargames to build a robust dataset. Predictive data capability enables push logistics, where intake from the source of goods flow occurs before demand. Particularly given the long transit times in the western Pacific, just-in-time delivery cannot rely on forward troops' demand signal to generate movement through the supply chain. The predictive system would ideally provide warfighters with just the right resupply at just the right time by using simulations and real-world usage data to push

[9] Markus Fruth and Frank Teuteberg,"Digitization in maritime logistics—What is there and what is missing?," *Cogent Business & Management*, 4:1, 1411066, (2017), 3.
[10] Joint Chiefs of Staff, "Joint Concept of Logistics," Version 2.0 (Washington DC: Joint Chiefs of Staff, September 25 2015), 15.
[11] Ben Gesing, Steve J. Peterson, and Dirk Michelsen, "Artificial Intelligence in Logistics: A Collaborative Report by DHL and IBM on implications and use cases for the logistics industry," 2018, 25.

sustainment forward. Because of the flexible nature of machine learning, the sustainment community could artificially inflate the flow of goods to the front line to ensure availability until the algorithm learns the proper amount and flow for that particular operation. This capability is precisely what the 2018 Department of Defense Artificial Intelligence Strategy prescribes.[12]

Artificial intelligence can also provide more accurate arrival times by considering complex variables of shipping traffic along the route, weather impacts, and in-situ specific fuel consumption.[13] The exact arrival time can also be determined earlier, giving commanders decision space to adjust plans as these variables unfold. Exacting linkup locations and times also mean less exposure to observation and less time for precision fires systems to target either the vessel or supported unit. Integrated command and control systems could provide vessel routing software with real-time avoidance areas of enemy action. The entire network of ships could be re-routed to lessen their risk from enemy action. A.I. routing could also be used in peacetime to provide a false pattern of behavior to fool adversary A.I. analytical tools by skewing the data set. This false data in turn would corrupt the machine learning processes in the adversary system.

Another application of artificial intelligence already in the water is automated voyage management systems. These A.I. systems fuse sensor data from radar, Automatic Identification System (AIS) locating data, the ship's maneuvering characteristics, and nautical chart hydrography to maintain safe navigation. The U.S. Navy's Sea Hunter

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[12] U.S. Department of Defense, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity*, (Washington DC: Department of Defense), 7.

[13] Markus Fruth and Frank Teuteberg,"Digitization in maritime logistics—What is there and what is missing?," *Cogent Business & Management*, 4:1, 1411066, (2017), 3.

medium displacement unmanned surface vessel (MDUSV) employs this type of A.I. for trans-Pacific transits.[14] Like the self-driving cars, the A.I. pilot can maneuver the ship in relation to real-world inputs from various sensors. Norway's Kongsberg Maritime teamed with Rolls Royce to implement enhanced visual sensor inputs to the A.I. pilot. The *Falco* ferry avoided other vessels and docked autonomously using this system interfaced with the ship's control systems.[15] Fuel efficiency improvements could instead be used to increase the quantities delivered to the fighting forces and reduce topline petroleum requirements.

Finally, artificial intelligence could help keep the vessels running as well. Predictive maintenance systems can provide operationally relevant data beyond Mean Time Between Failure (MBTF) and availability (Ao). Statistics such as Remaining Useful Time (RUL) indicate whether maintainers should complete an engine overhaul before sending the vessel out for its next mission. The U.S. Air Force teamed with the Defense Innovation Unit and C3.ai to implement predictive maintenance for the E-3 Sentry, C-5 Galaxy, and F-16 Fighting Falcon in 2016. Five years into the project, the Air Force sees a 3-6% increase in aircraft availability, a 40% reduction in unscheduled maintenance actions, and a 35% reduction in aircraft down time due to part non-availability.[16] This increased availability means more units providing sustainment to the joint force and possibly smaller numbers of platforms required to fulfill mission requirements.

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[14] Joseph Trevithick, "Navy's Sea Hunter Drone Ship Has Sailed Autonomously to Hawaii and Back Amid Talk of New Roles," *TheWarZone,* February 4 2019.
[15] Jessica Baron, "Rolls Royce's Autonomous Ship Gives Us A Peek Into the Future of Sea Transport," *Forbes*, January 7 2019, https://www.forbes.com/sites/jessicabaron/2019/01/07/rolls-royces-autonomous-ship-gives-us-a-peek-into-the-future-of-sea-transport/?sh=3d1adcc1659f
[16] U.S. Department of Defense, *Defense Innovation Unit Annual Report 2019*, (Washington DC: Department of Defense), 19.

Leveraging current A.I. capabilities allow maritime logistics connectors to participate directly in Global Integrated Logistics and meet the sustainment requirements in the AOR. Delivery and distribution are more efficient, more agile, and more reliable. Adaptation of commercial technologies already fielded for the maritime environment can help keep costs in check, and entities like the Defense Innovation Unit and the Joint Artificial Intelligence Center can help expedite acquisition. Integrating A.I. into maritime logistics platforms reduces and manages risk for the USINDOPACOM commander.

# Chapter 3: Gaining Advantage from Robotics

Robotics is an interdisciplinary field that focuses on the design, construction, and operation of machines capable of automatically carrying out complex actions. The most common applications include industrial robots that weld or handle material, but increasingly robots are used for industrial assembly.[1]

There are four types of robots common in industrial manufacturing; each type ties to how the manipulator functions.[2] Articulated robots have folding arms that can extend, retract, and rotate in multiple axes. Six-axis manipulators are most common, and 7-axis robots allow for the full range of manipulation like a human arm. These robots are more expensive and relatively slow but also more adaptable to various tasks.[3] For high-speed, single plane (x-y) movements such as inserting pins during assembly, Selective Compliance Articulated Robot Arm (SCARA) robots are well-suited.[4] Delta-type robots use control arms to position the wrist with only base-mounted motors. These robots are very lightweight and can move light loads very quickly, common in packing and precision assembly applications.[5] The last type of robot is a cartesian robot, commonly used for simple computer numerical control (CNC) router automation.

The DARPA/Boston Dynamics AlphaDog uses articulators for locomotion. Boston Dynamics' newest robot, Spot, is smaller and has added a manipulator arm with ten-axis movement. The base model is used for autonomous inspections and data collection and can

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[1] Matt Minner, "4 Types of Robots Every Manufacturer Should Know," *Industry Week*, June 05 2019.
[2] Matt Minner, "4 Types of Robots Every Manufacturer Should Know," *Industry Week*, June 05 2019.
[3] Mark Crawford, "How Many Axes Does Your Robot Need?," The American Society of Mechanical Engineers, Oct 11, 2017. https://www.asme.org/topics-resources/content/many-axes-does-robot-need
[4] Richard Vaughn, "The Difference between Cartesian, Six-Axis, and SCARA Robots," *Machine Design*, December 02 2013.
[5] Evan Ackerman, "Harvard's milliDelta Robot Is Tiny and Scary Fast," *IEEE Spectrum*, Jan 17 2018.

incorporate electro-optical, thermal, and LIDAR sensors.[6] Vessels could incorporate automated robots for cargo monitoring and propulsion systems monitoring and manipulation.

Simple robotic manipulation of vessel control systems is already commonplace. Commercial vessels have had autopilot systems for years; maritime safety will increase as more intelligent systems are incorporated.[7] The electro-hydraulic actuators used for the movement of control surfaces such as rudders and propulsion pods already rely on electronic inputs for movement control; an autopilot system sends signals to these actuators via controllers to manipulate propulsion and steering systems. Ship automation aids significantly in achieving greater efficiency to meet increasing emissions regulations; international shipping accounts for 12-13% of worldwide carbon emissions.[8] DoD can leverage these technologies to achieve increased resiliency and mission accomplishment.

Modern U.S. warships have already incorporated auto-start and -stop features for main propulsion and auxiliary systems. Remote actuators align fuel delivery and purification systems; critical oil supply systems have redundant controllers and additional equipment to ensure delivery of lubrication to expensive machineries like reduction gears and turbines. Pressure sensors linked to control valves maintain operating parameters, and control systems can automatically shut down at-risk equipment when operating criteria are out of assigned parameters. The Nippon Kaiji Kyokai (ClassNK) Foundation published Smart Ship standards and certified the MV Sakura Leader as the first Digital Smart Ship in 2019. That vessel incorporated energy efficiency, machinery monitoring, and onboard data processing and data transmission to land in their DSS designation.

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[6] "Boston Dynamics Shop," Boston Dynamics, accessed February 4, 2021, https://shop.bostondynamics.com/spot?cclcl=en_US&pid=aDl6g000000XdpaCAC

[7] Krzysztof Wróbel, Jakub Montewka, and Pentti Kujala, "Towards the assessment of potential impact of unmanned vessels on maritime transportation safety," *Reliability Engineering & System Safety*, Volume 165 2017, 168.

[8] Junkeon Ahn et al., "Changes in container shipping industry: Autonomous ship, environmental regulation, and reshoring," *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, 3:3-4, 2019, 21-27.

Automated systems moor offshore support vessels to rigs and derricks. Increasingly these systems moor vessels in port facilities.[9] Automatic tensioning systems assist people in the mooring procedure, reducing the time involved in mooring vessels at the pier and increasing personnel safety. These automated systems also reduce the vessel's movement at berth, avoiding works stoppages due to its excess motion.[10]

Separate from ship controls, robotics can also contribute to maritime logistics vessel missions in cargo handling operations. The Vard Brattvåg shipyard delivered MV Yara Birkeland, the first fully automated container vessel, in November 2020.[11] The ship features automated container handling equipment for 120 TEUs, an automated self-docking and mooring system, and automated voyage management and pilot systems.

Port facilities use robotics to enhance their effectiveness. More than 1,100 driverless cranes operate in container ports worldwide.[12] The Port of Rotterdam utilizes robotic cargo Electrical Automated Guided Vehicles (AGVs) to move containers from the pier to storage facilities.[13] Once there, robots automatically load containers onto outgoing trucks. Sensors across the terminal include electro-optical, RFID, and LIDAR nodes integrated with the terminal operations A.I.

*Figure 9 - AGV and Automated Crane in Yangshan, CH*

[9] Andrés Ortega Piris et al., "Reduction of CO2 emissions with automatic mooring systems. The case of the port of Santander," *Atmospheric Pollution Research*, Volume 9, Issue 1, (2018) 77.
[10] Yang, K.U., Hur, J.G., Choi, M.S. *et al.* Study on ship automatic berthing system with mooring lines. *China Ocean Eng* 31 (2017), 23.
[11] "World's First Autonomous & Zero-Emission Container Ship 'Yara Birkeland' Delivered," Marine Insight, last updated November 30, 2020. https://www.marineinsight.com/shipping-news/worlds-first-autonomous-zero-emission-container-ship-yara-birkeland-delivered/
[12] Kari Rintanen and Allen Thomas, "Container Terminal Automation: A PEMA Information Paper," Port Equipment Manufacturers Association, June 2016, 13.
[13] Loes Witschge, "Rotterdam is building the most automated port in the world," *Wired.com.uk*, October 7 2019. https://www.wired.co.uk/article/rotterdam-port-ships-automation

The port management A.I. receives container identification, location, and content information prior to a ship's arrival. The A.I. assigns pier and truck matches, and then orders are electronically transmitted to automated cranes to optimize offload order. The AGVs move containers away from the pier footprint to transshipment facilities. The A.I. management matches RFID tags on the containers and truck trailers to ensure proper distribution and highlight potential issues.

Robotic cranes facilitate the offload of containers and other cargo at ports across the world. Qingdao New Qianwan Container Terminal (QQCTN) in China was the first port to completely automate a container terminal, with 38 automated stacking cranes (ASCs) and 38 automated container transport vehicles.[14] In May 2017, these cranes used laser scanners and visual positioning systems to offload more than 13,000 TEU from a single vessel. These automated cranes can locate each container's four corners to clamp and accurately move them onto the driverless trucks. By increasing automation, QQCTN can operate in complete darkness and reduces labor costs by 70% while boosting efficiency by 30%.[15]

USINDOPACOM's Section 1253 report to Congress highlighted the need for infrastructure investment.[16] Wartime operations will require military use of smaller port facilities, but many of these facilities cannot economically justify complex automated systems for commercial purposes. Funding investment in these locations is crucial to building infrastructure ahead of need. Island nations in the Second Island Chain could gain economic benefit from U.S. military investment in infrastructure, and USINDOPACOM could gain favorable political consideration from partners' port authorities and operators for increased access during contingency operations.

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[14] "Asia Enters Fully Automated Terminal Era," Port Technology, accessed February 11, 2021. https://www.porttechnology.org/news/asia_enters_fully_automated_terminal_era/

[15] Port Technology, "Asia Enters Fully Automated Terminal Era."

[16] CDRUSINDOPACOM, *National Defense Authorization Act (NDAA) 2020 Section 1253 Assessment: Regain the Advantage*, https://www.scribd.com/document/454815069/National-Defense-Authorization-Act-Section-1253-Executive-Summary#download&from_embed.

While maritime logistics vessels may use existing infrastructure with capabilities like this, the new operating concepts' expeditionary and distributed nature require self-deployable technology. One goal could be to automate the RTCH to conduct robotic offloads in port facilities and bare beaches. An all-weather, extended duration and rough terrain offload capability that incorporates in-transit visibility and precision delivery would enable joint force sustainment. This technology would directly link the global integrated logistics network to tactical level distribution. As sustainment is consumed, the degradation would prompt the A.I. to queue additional items on the next planned resupply mission to that area.

The U.S. Army has already testing automated driving kits for their logistics support vehicles.[17] Utilizing this same technology could automate rolling stock offload. Potential benefits include more efficient throughput due to precise vehicle movement, around-the-clock loading and unloading, and decreased need for personnel and their associated support requirements.

Another application for robotic drone technology is surveying hose routes from ship to shore. Small underwater vehicles could provide survey bottom conditions covertly and routing and rendezvous point recommendations. A.I. and deep learning with the survey data can predict future locations for material transfer to make the sustainment force less predictable yet maintain effectiveness.

Similarly, drones could provide signature management awareness to tactical unit commanders during sustainment operations. Quadcopters feeding video and audio to small portable A.I. systems could identify and recommend cessation of specific activities that breach user-defined detectability thresholds. Robot cargo handling equipment could automatically go into hiding as satellites pass overhead, resuming their work after the autonomous "all-clear" signal. Robot equipment could even execute limited military deception operations, simulating an alternate transshipment site that does not require additional servicemembers to be present.

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[17] Connie Lee, "Autonomous Convoy Tech Moves Toward Official Program," National Defense Magazine, 22 Feb 2019.

One significant shortfall of automated systems and robotics is the culture of mistrust among decision-makers. The Joint Artificial Intelligence Center's 2018 strategy document identifies human trust in A.I. and automation as a barrier to implementation.[18] The National Security Commission on Artificial Intelligence identifies in numerous places that trust in the automated systems is a prerequisite to successful implementation.[19] The Center for Security and Emerging Technology identified a critical method to build that trust: demonstrate reliability, robustness, and responsiveness to the human part of the team.[20] As automated capabilities become more prevalent, this bias will diminish. Introducing this advanced technology and explaining what happens "under the hood" builds confidence in the human partners using the system.

[18] U.S. Department of Defense, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity*, (Washington DC: Department of Defense), 14.
[19] National Security Commission on Artificial Intelligence, "Final Report: National Security Commission on Artificial Intelligence," March 1, 2021, 36.
[20] Margarita Konaev, Tina Huang, Husanjot Chahal, "Trusted Partners: Human-Machine Teaming and the Future of Military AI," Center for Security and Emerging Technology issue paper, Washington D.C., February 2021, 29.

## Chapter 4: Gaining Advantage Through Resiliency

Automated systems exhibiting reliability and robustness are necessary to build the required trust within human-machine teaming.[1] Systems must have fault tolerance designed into them to operate beyond the assistance of human intervention. These traits also improve mission accomplishment through higher availability. By fielding resilient vessels able to conduct maritime logistics in a contested environment, the joint force is meeting service and joint guidance for force design.[2]

Resilience is the "ability to recover from or adjust easily to adversity or change."[3] Since the strategic guidance documents already discussed detail the requirement for a resilient sustainment system, a system approach would be appropriate. The International Council on Systems Engineering defines resilience as "the ability to provide required capability in the face of adversity," and goes on to say, "the means of achieving resilience include avoiding, withstanding, recovering from, and evolving and adapting to adversity."[4] In naval systems design terms, resilience consists of susceptibility, vulnerability, and recoverability.[5]

Naval ship design uses the term susceptibility to describe avoiding adversity; it begins with detection avoidance using signature management. Vessels generate

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[1] Margarita Konaev, Tina Huang, Husanjot Chahal, "Trusted Partners: Human-Machine Teaming and the Future of Military AI," Center for Security and Emerging Technology issue paper, Washington D.C., February 2021, 29.
[2] U.S. Department of the Navy, *Advantage at Sea: Prevailing with Integrated All-Domain Naval Power*, (Washington DC: U.S. Department of the Navy), December 16, 2020, p. 23.
[3] "Resilience," Merriam-Webster Dictionary, accessed January 23, 2021.
[4] "Resilient Systems Working Group," International Council on Systems Engineering, https://www.incose.org/incose-member-resources/working-groups/analytic/resilient-systems
[5] John Brettet al. "Integrated Survivability Analysis of Naval Platforms in High Threat Environment," Defence Science & Technology Group presentation at Pacific International Maritime Conference 3 - 5 October 2017, Sydney, Australia, 3.

signatures in various spectrums, including electromagnetic, acoustic, visual, thermal, and cognitive spectrums. Emissions control (EMCON) procedures balance the benefit of using sensors to understand the environment with securing emitters to avoid counter detection and targeting. Noise-dampening designs such as rubber mounts for vibrating machinery limit acoustic signature. External systems such as the Prairie and Masker systems of surface combatant ships also limit vulnerability to enemy submarines' acoustic sensors. Low RCS designs and materials such as those employed on guided missile destroyers (DDGs) and amphibious transport dock ship (LPDs) manage radar signature. Boundary Layer Infrared Suppression System (BLISS) caps systems on ship exhaust stacks to reduce the thermal signature.

As detailed earlier, multi-domain threat of detection exists in the contested environment of the western Pacific. Therefore, vessel design must incorporate signature management systems. This trade-off between cost and risk reduction typically increases a logistics vessel's susceptibility to interdiction. While the DDG has numerous air defense systems to jam and shoot down incoming missiles, the sustainment vessel has no such organic protection. Similarly, the DDG's high speed makes it more likely to avoid a torpedo detonation near its hull.

Unlike combatant warships, logistics vessels do not need combat systems to accomplish their mission, which generally reduces cost and complexity. An Arleigh-Burke-class DDG costs $1.843 billion and displaces 9,600 tons, whereas the Lewis and Clark-Class logistics ships cost less than $400 million, displaces more than 41,000 tons, and carries more than 10,000 tons of cargo and bulk liquids. Similarly, logistics vessels do not chase down enemy ships to accomplish their mission and therefore have no requirement for very high speeds; speed requirement is exponentially correlated with propulsion power, and therefore related to increased platform cost.

Additionally, the operational routing and speed of a logistics vessel look very similar to those of a commercial vessel. A wide-area threat detection system can overlook or discount a logistics vessel's signature if it appears like many other signatures as the satellite scans the ocean for signatures of warships. Although automated intelligence systems using high-fidelity sensors and deep data methods to effectively detect minor nuances between military logistics vessels' signature and commercial ship, wide-area surveillance systems often compromise fidelity to speed and volume covered. Without cueing for the wide-area systems, a detailed analysis may be unavailable to adversary decision-makers, resulting in lower susceptibility to tracking and targeting systems.

Vulnerability during a successful attack is managed nearly entirely by ship layout; adding this capability later is nearly impossible.[6] A traditional approach to limiting vessel vulnerability includes compartmentalizing spaces below the waterline to maintain buoyancy and righting arm.[7] Installing blast-resistant bulkheads to reduce damage in adjacent spaces is another common approach that remains valid.[8] However, with the increased reliance of modern vessels on propulsion, power, and cooling systems to maintain functions, the distribution of critical equipment across the hull becomes vitally important for reducing vulnerability.[9]

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[6] A. C. Habben Jansen et al., "Assessing complex failure scenarios of on-board distributed systems using a Markov chain," *Journal of Marine Engineering & Technology*, 19, September 30 2019, 1.

[7] Boulougouris E, Papanikolaou A. 2013. Risk-based design of naval combatants. *Ocean Engineering* 65, 49–61.

[8] D. Brefort et al., "An architectural framework for distributed naval ship systems," *Ocean Engineering* 147, 381.

[9] A. C. Habben Jansen et al., "Assessing complex failure scenarios of on-board distributed systems using a Markov chain," 46.

Integrated power systems (IPS) that use consolidated electricity generation capacity to power both propulsion and mission systems are more likely than traditional, split-system designs to retain some functionality after an enemy attack.[10] Sizing the redundant systems such that any individual source could provide minimum operational functions further reduces mission risk. Maritime logistics vessels designed to operate at maximum capability in undegraded states and able to operate on reduced yet sufficient states to continue their mission on a single generator further reduce risk.

The unique benefits of unmanned vessels also allow for improved efficiencies. By removing support spaces required by a crew, ship designs can achieve 5% weight savings and consume up to 15% less fuel.[11] Removing the cooking, sanitation, and berthing areas also frees up additional space for cargo and reduces system complexity. Finally, because risk acceptance for unmanned systems is higher than for manned systems, vulnerability impingements caused by lack of defensive systems will not impact the vessel's mission as drastically.

The final factor in ship resilience is recoverability. Recoverability's importance is reduced for unmanned vessels since there is no moral imperative to recover servicemembers in a catastrophic event. The importance of recoverability also decreases as the purchase price and time to build decreases. The Commandant of the Marine Corps recently described a price point at which the equipment is not worth recovering. At this theoretical price, building another item is both more cost-effective and has less impact on

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[10] A. C. Habben Jansen et al., "Assessing complex failure scenarios of on-board distributed systems using a Markov chain," *Journal of Marine Engineering & Technology*, 19, September 30 2019, 59.
[11] Evan Ackerman, "Unmanned Cargo Ships Face Industry Resistance, Are a Good Idea Anyway," *IEEE Spectrum*, February 27 2014.

operations.[12] Achieving this low price point will result in a significant reduction in each platform's capability. Generating adequate effects would then require many more vessels, but easy replacements would be cost-effective. Given the preponderance of A2/AD capability in the USINDOPACOM AOR and the Navy's Distributed Maritime Operations concept requirement to distribute geographically, this approach makes sense. Operationally, increasing the number of platforms that deliver capability has the most significant effect on mission accomplishment.[13]

Resiliency, quantity, and affordability are beneficial qualities under the new joint and service operating concept. Integrating design elements to enhance resiliency early helps keep costs down and reduces budgetary pressure to limit production runs. The lower cost of production also enables additional procurement in extremis. Unmanned vessels, optimized for logistics support, with distributed critical systems enable critical joint force sustainment.

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[12] Aaron Mehta and Jeff Martin, "Heavy equipment out, unmanned logistics in for the US Marine commandant's wish list," *DefenseNews* December 9, 2019.
[13] Christopher H. Popa et al., "Distributed Maritime Operations and Unmanned Systems Tactical Employment," (MS diss., Naval Postgraduate School, Monterey CA, June 2018), i, https://calhoun.nps.edu/handle/10945/59587

## Chapter 5: Conclusion

Resiliency to persist in a contested environment is the beginning of the solution. The *2018 National Defense Strategy* tasks the joint force with modernizing to achieve "resilient and agile…non-commercially dependent distributed logistics and maintenance to ensure logistics sustainment while under persistent multi-domain attack."[1] Sustainment enables fire and maneuver–the cornerstones of distributed all-domain operations. The CJCS Joint Operational Access Concept is not executable without maritime logistics.

Current logistics platforms and concepts are inadequate to provide the tempo of sustainment required even under favorable conditions. Time and distance work against our sustainment efforts. Mobilization of our sustainment assets in the reserve and National Guard will takes weeks and months. The current sustainment infrastructure supports efficient delivery of peacetime commodities, not wartime pace and volume. Contemporary vessels cannot provide fast-paced sustainment at sea and over the shore.

Anti-access/area denial exacerbates this challenge further. It is impossible to maintain long durations of maritime and air superiority early in a potential conflict. China's "Active Strategic Counterattacks on Exterior Lines" operational guidance specifically targets our vulnerable supply lines. Logistics ships cannot operate forward without substantial protection, and surface combatants cannot provide force protection and power projection simultaneously. Limited shipyard capacity in the United States' hampers production of replacement ships during a conflict.

[1] U.S. Department of Defense, *Summary of the 2018 National Defense Strategy Sharpening the American Military's Competitive Edge*, (Washington, DC: U.S. Department of Defense, 2018), 7.

Despite these challenges, incorporating emergent technology into the theater distribution system to make maritime logistics vessels more resilient and effective. Today's technology, rapidly adapted from commercial sector applications, can enable efficient, effective, and resilient joint force sustainment. Updated concepts of operations and logistics adequately guide this infusion of technology. Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy (DOTMILPF-P) analysis has already led the Marine Corps and Navy to recognize the need for new logistics platforms.[2]

Smaller craft such as Landing Craft Air Cushion (LCAC) hovercraft and the Amphibious Combat Vehicle (ACV) lack the lift capacity and range to conduct joint sustainment and distribution effectively. LCACs require significant maintenance facilities and are therefore best suited to their current employment as ship-to-shore connectors for amphibious assault.

Consideration for other in-service platforms may provide a stop-gap capability, but none meet the joint force's operational requirements. The Landing Craft (Utility), or LCU, could immediately fill some limited maritime sustainment of USMC and U.S Army forces. Two platforms share the LCU designation: the smaller Navy LCU-1600 and larger U.S. Army LCU 2000. Both vessels are too small to meet joint sustainment requirements but could augment the very near-term and support complimentary littoral sustainment to larger vessels.

The Navy LCU 1600 is compatible with welldecks on amphibious ships. It is 135 feet long and can carry up to 140 tons of cargo. The crew numbers only eleven, and the

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[2] Congressional Research Service, *Navy Light Amphibious Warship (LAW) Program: Background and Issues for Congress*, (Washington DC: Congressional Research Service, April 1, 2021), 3.

vessel can theoretically deploy approximately 1200 nm at 10 knots. It will soon be replaced by the LCU 1700, which has a similar function and mission, but is ten feet wider and can carry up to 30 tons more cargo (total 170 tons).[3] Cost is approximately $1.4 million, although production halted in the 1970s. The LCU 1700 will also feature enhanced reliability over the 50-year-old LCU 1600s.

The heftier U.S. Army LCU 2000 measures 174 feet in length, 42-foot beam, and 8-foot draft; it cannot fit in the welldeck of an amphibious warship. They are typically deployed on prepositioning ships or self-deploy with a crew of 13 up to 4,500 nm at 10 knots. The LCU 2000 can carry 350 tons of cargo and is typically used to transport rolling stock to bare beaches. Unit cost is approximately $5 million.

The research and testing of artificial intelligence, robotics, and resilient systems should utilize these vessels while the design and production of future platform proceeds. One legacy platform and two promising programs that have reached major milestones could serve as starting points for future maritime logistics platforms.

These Gen. Frank Besson-class vessels (and two Kuroda-subclass vessels) displace 4,200 tons and are 243 feet long.[4] The maximum draft is 12 feet, but these ships can beach themselves in less than four feet of water and discharge up to 900 tons of cargo. Cargo can include up to 24 M1 tanks or 50 TEUs, and each LSV can make and discharge freshwater to the beach using her pumps. A crew of 31, led by a Chief Warrant Officer, can deploy the vessel 6,500 nm at 12 knots. The per-unit cost was approximately

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[3] https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2171588/landing-craft-mechanized-and-utility-lcmlcu/

[4] https://www.naval-technology.com/projects/lsv/

$32 million between 1987 and 2006.[5] Two helicopter-capable variants LSVs are currently serving in the Philippine Navy.

The LSV platform with A.I. and automation augments could provide a solid starting point for developing future maritime logistics connectors. Already able to handle all four commodity types (ISO containers, break-bulk, bulk liquids, and rolling stock) and reasonable procurement cost make them ideal candidates to assume the research,

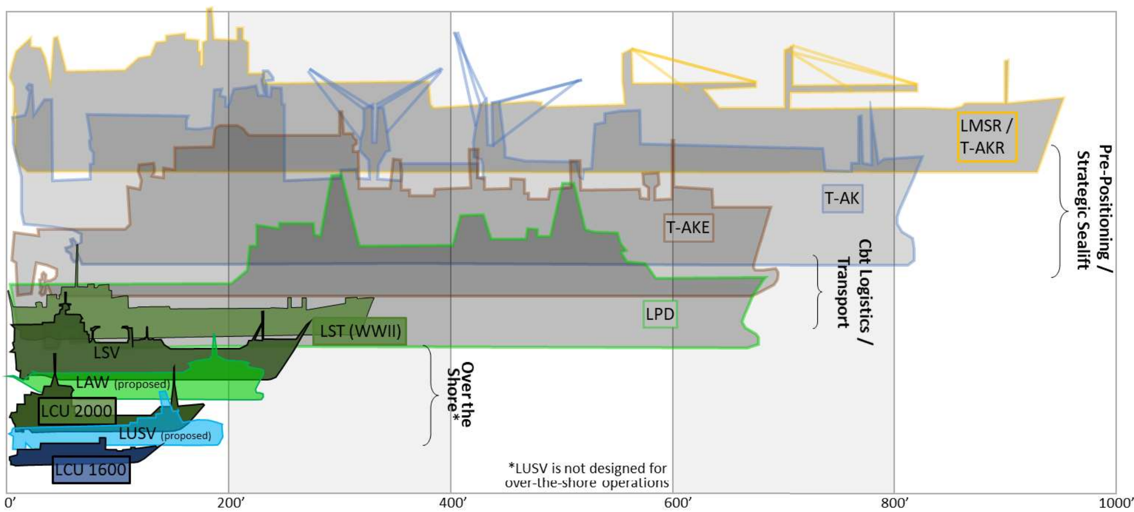


*Figure 10 - Relative Size of Maritime Logistics Platforms*

development, testing, and evaluation (RDT&E) for integration of vessel controls that can transit in open ocean, beach and unbeach themselves, and implement integrated power systems development.

The Army's Combat Capabilities Development Command Ground Vehicle Systems Center has already begun developing automated ground vehicles to deliver troops to the fight. Automated RTCH vehicles should be incorporated into the U.S. Army's automated vehicle initiative and tested alongside other vehicle platforms.

[5] U.S. Army Tactical Manual 55-500, Watercraft Equipment Characteristics and Data.

A Congressional Research Service report already proposes an updated variant of the LSV to fill the role of the United States Marine Corps and United States Navy's Light Amphibious Warship (LAWS).[6] Strong consideration should be given to the LAW as a future automated connector. Several industry designs are already under consideration by Naval Sea Systems Command.[7] Current program requirements shared with industry partners include procurement of 28 to 30 new ships; an overall length of 200 to 400 feet; a maximum draft of 12 feet; displacement of up to 4,000 tons; and a crew of no more than Navy 40 sailors.[8] Funding requested for initial studies and concept design amounts to $30 million. Procurement would begin in FY2023 and complete by 2026 with a per-unit cost between $100-130 million.[9]

As OPNAV N4 looks for future replenishment capability via Offshore Support Vessels (OSVs) to augment the large fleet oilers in today's fleet, an extended hull version of the LAW could be a strong contender. LSTs of World War II were lengthened for service in the Pacific to accommodate additional stores and fuel; an extended version of LAW could also serve this role.[10] Adding automated underway replenishment equipment could also provide the fleet with robotic counterparts from which to receive fuel, stores, and ammunition in limited, but meaningful, quantities.

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[6] Congressional Research Service, *Navy Light Amphibious Warship (LAW) Program: Background and Issues for Congress*, (Washington DC: Congressional Research Service, April 1, 2021), 15.
[7] Megan Eckstein, "Navy Officials Reveal Details of New $100M Light Amphibious Warship Concept," *USNI News*, November 19, 2020. https://news.usni.org/2020/11/19/navy-officials-reveal-details-of-new-100m-light-amphibious-warship-concept
[8] Congressional Research Service, *Navy Light Amphibious Warship (LAW) Program: Background and Issues for Congress*, 6.
[9] Eckstein, "Navy Officials Reveal Details of New $100M Light Amphibious Warship Concept."
[10] Office of Naval Intelligence, *Allied Landing Craft and Ships*, ONI-266 (Washington DC: U.S. Government Printing Office, April 7, 1944), 63.

Finally, the Large Unmanned Surface Vessel (LUSV) authorized in the FY2021 National Defense Authorization Act[11] could serve as another source of synthesis for unmanned maritime logistics connectors. Although LUSV is currently envisioned as a fire and sensor platform, the A.I. and vessel control systems developed under this program could be modified for applicable logistics vessels as well.[12] A common connected network architecture could further reduce resiliency in the fielded systems, and common mechanical systems could provide economy of scale and decrease the lifecycle costs of the platforms. A common hull could also drastically reduce the per-unit cost of the vessels and allow the procurement of a greater number of vessels necessary for sufficient system capacity.

Shortcomings in the current maritime logistics connectors can be addressed stepwise and cost-effectively by cross-pollenating various program technological aspects among LSV, LUSV, and LAW programs. A consolidated approach would reduce both technological and fiscal risk. The synergy, fusion, and eventual profusion of those technology-infused platforms can provide the capability the joint force needs to fight and win in a contested GPC environment. The Department of Defense must increase the maritime logistics vessels' capabilities and capacity to address real-world shortcomings in joint force sustainment. Artificial intelligence to leverage networked logistics management, robotics autonomy, and resilient vessel design are the key features of future

[11] National Defense Authorization Act for Fiscal Year 2021, HR. 6395, 116th Cong., 2nd sess., *Congressional Record*, H:227.
[12] Congressional Research Service, *Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress*, (Washington DC: Congressional Research Service, March 17, 2021), 8.

advanced technology in maritime logistics connectors to sustain the joint forces’ future success.

## Bibliography


*Commanders of combatant commands: assignment; powers and duties, U. S. Code* 10 (1986), § 164.

Ackerman, Evan. "Harvard's milliDelta Robot Is Tiny and Scary Fast." *IEEE Spectrum*, Jan 17 2018. Accessed February 11, 2021. https://spectrum.ieee.org/automaton/robotics/industrial-robots/harvard-millidelta-robot-is-tiny-and-scary-fast.

Ackerman, Evan. "Unmanned Cargo Ships Face Industry Resistance, Are a Good Idea Anyway." *IEEE Spectrum* February 27 2014. https://spectrum.ieee.org/automaton/robotics/industrial-robots/unmanned-cargo-ships-face-industry-resistance-are-a-good-idea-anyway.

Ahn, Junkeon; Joung, Tae-Hwan; Kang, Seong-Gil; and Lee, Jongkap. "Changes in container shipping industry: Autonomous ship, environmental regulation, and reshoring," Journal of International Maritime Safety, Environmental Affairs, and Shipping, 3:3-4. (2019) DOI: 10.1080/25725084.2019.1678564

Austin, Lloyd J. "Senate Armed Services Committee Advance Policy Questions for Lloyd J. Austin Nominee for Appointment to be Secretary of Defense," U.S. Senate Armed Services Committee, (Washington D.C.) Jan 19, 2021, https://www.armed-services.senate.gov/imo/media/doc/Austin_APQs_01-19-21.pdf.

Baron, Jessica. "Rolls Royce's Autonomous Ship Gives Us A Peek Into the Future of Sea Transport." *Forbes*, January 7 2019. https://www.forbes.com/sites/jessicabaron/2019/01/07/rolls-royces-autonomous-ship-gives-us-a-peek-into-the-future-of-sea-transport/?sh=3d1adcc1659f

Brefort, D.; Shields, C.; Habben Jansen, A.; Duchateau, E.; Pawling, R.; Droste, K.; Jaspers, T.;, Sypniewski, M.; Goodrum, C.; Parsons, M. "An architectural framework for distributed naval ship systems." *Ocean Engineering* 147:375–385.

Boston Dynamics. "Boston Dynamics Shop." Accessed February 4, 2021. https://shop.bostondynamics.com/spot?cclcl=en_US&pid=aDl6g000000XdpaCAC

Boulougouris E, Papanikolaou A.. Risk-based design of naval combatants. *Ocean Engineering* 65: 49–61.

Brett, John; Gamble, Grant; Reid, Warren; Smith, Sue; Woolley, Anthony; and Yiannakopoulos, George. "Integrated Survivability Analysis of Naval Platforms in High Threat Environment." Defence Science & Technology Group presentation at Pacific International Maritime Conference 3 - 5 October 2017. https://www.researchgate.net/publication/327392062_Integrated_Survivability_Analysis_of_Naval_Platforms_in_High_Threat_Environments

Brown, Zachary. “Reviewing Red Star Over the Pacific,” *The Strategy Bridge,* (Washington, D.C.), 2019. https://thestrategybridge.org/the-bridge/2019/5/8/reviewing-red-star-over-the-pacific.

Calamur, Krishnadev. “High Traffic, High Risk in the Strait of Malacca,” *The Atlantic*, (August 21, 2017), https://www.theatlantic.com/international/archive/2017/08/strait-of-malacca-uss-john-mccain/537471/

Chairman of the Joint Chiefs of Staff. “Joint Publication 4-0: Joint Logistics,” Washington D.C., 2019.

Chairman of the Joint Chiefs of Staff. “Joint Concept for Logistics Version 2.0,” Washington D.C., 2015.

Chairman of the Joint Chiefs of Staff. “Chairman of the Joint Chiefs of Staff Instruction 3100.01D: Joint Strategic Planning System,” Washington, D.C., 2018

Crawford, Mark. “How Many Axes Does Your Robot Need?.” The American Society of Mechanical Engineers, Oct 11, 2017. Accessed Feb 13, 2021. https://www.asme.org/topics-resources/content/many-axes-does-robot-need

Chui, Michael; Henke, Nicolaus; and Miremadi, Mehdi. “Most of AI’s business uses will be in two areas.” *Harvard Business Review*, (July 20, 2018). https://hbr.org/2018/07/most-of-ais-business-uses-will-be-in-two-areas#:~:text=Supply%20chain%20and%20sales%20and%20marketing%20are%20the%20first%20big%20opportunities.

Congressional Research Service. Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress. Washington DC: Congressional Research Service, March 17, 2021.

Congressional Research Service. Navy Light Amphibious Warship (LAW) Program: Background and Issues for Congress. Washington DC: Congressional Research Service, April 1, 2021.

Defense Logistics Agency. “Troop Support Construction and Equipment Container Program Customer Handbook.” Philadelphia, PA. 2018. https://www.dla.mil/Portals/104/Documents/TroopSupport/ConstructionandEquipment/Container_Booklet%20December%202018.pub.pdf?ver=2019-02-12-102751-910.

Drewry Shipping Consultants. “40ft High Cubes set to Dominate the Container Equipment Market.” Accessed February 12, 2021. https://web.archive.org/web/20140829070535/http://www.drewry.co.uk/news.php?id=277

Eckstein, Megan. “Navy Officials Reveal Details of New $100M Light Amphibious Warship Concept,” *USNI News*, November 19, 2020. https://news.usni.org/2020/11/19/navy-officials-reveal-details-of-new-100m-light-amphibious-warship-concept

Erickson, Andrew and Kennedy, Conor. “Trailblazers In Warfighting: The Maritime Militia of Danzhou,” Center for International Maritime Security, February 1, 2016, https://cimsec.org/trailblazers-warfighting-maritime-militia-danzhou/21475

Erickson, Andrew and Wuthnow, Joel. “Barriers, Springboards and Benchmarks: China Conceptualizes the Pacific ‘Island Chains,’” *The China Quarterly* 225, (2016), https://www.cambridge.org/core/journals/china-quarterly/article/barriers-springboards-and-benchmarks-china-conceptualizes-the-pacific-island-chains/B46A212145EB9D920616650669C697F0.

Fruth, Markus and Teuteberg, Frank. “Digitization in maritime logistics—What is there and what is missing?,” *Cogent Business & Management*, 4:1, 1411066. (2017).

Gesing, Ben; Peterson, Steve J.; and Michelsen, Dirk. “Artificial Intelligence in Logistics: A Collaborative Report by DHL and IBM on implications and use cases for the logistics industry,” 2018 Accessed February 12, 2021. http://dhl.lookbookhq.com/ao_thought-leadership_digital-analytics-2/research-report_artificial-intelligence-in-logistics

GlobalSecurity.org. “Xingkong-2 / Starry Sky 2,” accessed January 31, 2021, https://www.globalsecurity.org/wmd/world/china/xingkong-2.htm#:~:text=Japanese%20experts%20believe%20that%20the,times%20the%20speed%20of%20sound.

Habben Jansen, A. C.; Duchateau, E. A. E.; Kana, A. A. ; and Hopman, J. J.. “Assessing complex failure scenarios of on-board distributed systems using a Markov chain.” Journal of Marine Engineering & Technology, 19, September 30, 2019.

Hintze, Arend. “Understanding the Four Types of Artificial Intelligence.” *Government Technology* (November 14 2016). https://www.govtech.com/computing/Understanding-the-Four-Types-of-Artificial-Intelligence.html

Hutson, Matthew. “Artificial intelligence has learned to probe the minds of other computers,” *Science*, (Jul. 27, 2018). https://www.sciencemag.org/news/2018/07/computer-programs-can-learn-what-other-programs-are-thinking

International Council on Systems Engineering. “Resilient Systems Working Group.” Accessed January 23, 2021. https://www.incose.org/incose-member-resources/working-groups/analytic/resilient-systems

International Monetary Fund. “World Economic Outlook Database,” October 2020, accessed January 31, 2021. https://www.imf.org/en/Publications/WEO/weo-database/2020/October/select-countries?grp=2001&sg=All%20countries

Kania, Elsa. “The PLA’s Latest Strategic Thinking on the Three Warfares,” *China Brief* Volume: 16 Issue: 13, Washington D.C., 2016. https://jamestown.org/program/the-plas-latest-strategic-thinking-on-the-three-warfares/

Kelemen, Michele. “Secretary Of State Nominee Blinken Promises A Reengaged America Abroad,” *National Public Radio*, January 19, 2021, https://www.npr.org/sections/biden-transition-updates/2021/01/19/958289975/secretary-of-state-nominee-antony-blinken-promises-humility-and-confidence.

Konaev, Margarita; Huang, Tina; Chahal, Husanjot. “Trusted Partners: Human-Machine Teaming and the Future of Military AI.” Center for Security and Emerging Technology issue paper, Washington DC, February 2021. https://cset.georgetown.edu/wp-content/uploads/CSET-Trusted-Partners.pdf

Lee, Connie. “Autonomous Convoy Tech Moves Toward Official Program,” *National Defense Magazine*, 22 Feb 2019. https://www.nationaldefensemagazine.org/articles/2019/2/22/autonomous-convoy-tech-moves-toward-official-program

Marine Insight. “World’s First Autonomous & Zero-Emission Container Ship ‘Yara Birkeland’ Delivered,” last updated November 30, 2020. https://www.marineinsight.com/shipping-news/worlds-first-autonomous-zero-emission-container-ship-yara-birkeland-delivered/

Mehta, Aaron and Martin, Jeff. “Heavy equipment out, unmanned logistics in for the US Marine commandant’s wish list.” *DefenseNews* December 9, 2019. https://www.defensenews.com/smr/reagan-defense-forum/2019/12/09/heavy-equipment-out-unmanned-logistics-in-for-the-marine-commandants-wishlist/

Merriam-Webster Dictionary. “Resilience.” Accessed January 23, 2021. https://www.merriam-webster.com/dictionary/resilience

Minner, Matt. “4 Types of Robots Every Manufacturer Should Know.” *Industry Week*, June 05 2019. Accessed February 12, 2021. https://www.industryweek.com/sponsored/article/22027700/4-types-of-robots-every-manufacturer-should-know.

National Security Commission on Artificial Intelligence. “Final Report: National Security Commission on Artificial Intelligence,” March 1, 2021. https://www.nscai.gov/wp-content/uploads/2021/03/Full-Report-Digital-1.pdf.

Office of Naval Intelligence. Allied Landing Craft and Ships, ONI-266. Washington DC: U.S. Government Printing Office, April 7, 1944.

Paris, Costas. "Maersk Ship Loses 750 Containers Overboard in Pacific Ocean." *The Wall Street Journal*, January 21, 2021, https://www.wsj.com/articles/maersk-ship-loses-750-containers-overboard-in-pacific-ocean-11611255703

Popa, Christopher H.; Stone, Sydney P.; Aw, Ee Hong; Teo, Choon Pei Jeremy; Cai, Licun Edwin; Chong, Wai Hoe ; Cline, Rachel; Hong, Jiesheng Jackson ; Koh, Chong Khai Roger; Lee, Wee Leong; Lim, Jun Jie; Lin, Xinhong; Liraz, Shay Paz; Mok, Kai Boon Eugene; Ryan, Alex W.; Teow, Boon Hong Aaron ; Whitmer, Andrew R. ; Winstead, Peter J.; and Chia, Yong Jie. "Distributed Maritime Operations and Unmanned Systems Tactical Employment." MS diss., Naval Postgraduate School, Monterey CA, June 2018. https://calhoun.nps.edu/handle/10945/59587
Port Technology. "Asia Enters Fully Automated Terminal Era." Accessed February 11 2021.
https://www.porttechnology.org/news/asia_enters_fully_automated_terminal_era/

Piris, Andrés Ortega; Díaz-Ruiz-Navamuel, Emma; Pérez-Labajos, Carlos A. ; Chaveli, Jesús Oria."Reduction of CO2 emissions with automatic mooring systems. The case of the port of Santander." *Atmospheric Pollution Research*, Volume 9, Issue 1 (2018).

Ratcliffe, John. "China Is National Security Threat No. 1," *The Wall Street Journal,* (New York), December 3, 2020, https://www.wsj.com/articles/china-is-national-security-threat-no-1-11607019599.

Rintanen, Kari and Thomas, Allen. "Container Terminal Automation: A PEMA Information Paper." Port Equipment Manufacturers Association (Brussels, Belgium) June 2016. https://www.pema.org/wp-content/uploads/downloads/2016/06/PEMA-IP12-Container-Terminal-Automation.pdf

Russell, Stuart J., and Norvig, Peter. *Artificial Intelligence: A Modern Approach*, Englewood Cliffs : Prentice Hall 1995.

Silver, David; Huang, Aja; Maddison, Chris J.; Guez, Arthur; Sifre, Laurent; Driessche, George van den; Schrittwieser, Julian; Antonoglou, Ioannis; Panneershelvam, Veda; Lanctot, Marc; Dieleman, Sander; Grewe, Dominik; Nham, John; Kalchbrenner, Nal; Sutskever, Ilya; Lillicrap, Timothy; Leach, Madeleine; Kavukcuoglu, Koray; Graepel, Thore; Hassabis, Demis (28 January 2016). "Mastering the game of Go with deep neural networks and tree search". *Nature*. 529 (7587): 484–489.
https://www.nature.com/articles/nature16961

Stokes, Mark; Alvarado, Gabriel; Weinstein, Emily; and Easton, Ian. "China's Space and Counterspace Capabilities and Activities," U.S.-China Economic and Security Review Commission, (Washington D.C.), March 30, 2020.

https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf
Defense Intelligence Agency. "China Military Power," Washington DC, 2019. https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/China_Military_Power_FINAL_5MB_20190103.pdf.

The Maritime Executive. "Strait of Malacca Key Chokepoint for Oil Trade." Accessed April 15, 2021., https://www.maritime-executive.com/article/strait-of-malacca-key-chokepoint-for-oil-trade.

Tierney, Kevin; Colesz, Amanda; Colesz, Andrew; Kroery, Christian; Britty, Adam M.; and Jensen, Rune Møller. "Automated Planning for Liner Shipping Fleet Repositioning," Association for the Advancement of Artificial Intelligence. (2012).

Trevithick, Joseph. "Navy's Sea Hunter Drone Ship Has Sailed Autonomously to Hawaii and Back Amid Talk of New Roles." *TheWarZone,* February 4 2019. https://www.thedrive.com/the-war-zone/26319/usns-sea-hunter-drone-ship-has-sailed-autonomously-to-hawaii-and-back-amid-talk-of-new-roles.

U.S. Congress. House. William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021. 116th Cong., 2nd sess., 2021.

U.S. Department of Defense. Defense Innovation Unit Annual Report 2019. Washington DC: Department of Defense, 2019.

U.S. Department of Defense. DoD Directive 3000.06: Combat Support Agencies. Washington DC: Department of Defense, 10 July 2007.

U.S. Department of Defense. Military and Security Developments Involving the People's Republic of China 2020 Report to Congress. Washington D.C., September 2020. https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF

U.S. Department of Defense. Summary of the 2018 National Defense Strategy Sharpening the American Military's Competitive Edge. Washington, DC: U.S. Department of Defense, 2018.

U.S. Department of Defense. Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity. Washington DC: Department of Defense, 2018.

U.S. Department of State. "U.S. Collective Defense Arrangements,", accessed January 31, 2021. https://2009-2017.state.gov/s/l/treaty/collectivedefense//index.htm#:~:text=A%20Treaty%20signed%20September%201,accordance%20with%20its%20constitutional%20processes.

U.S. Department of the Navy, "*Advantage at Sea: Prevailing with Integrated All-Domain Naval Power*." Washington DC: U.S. Department of the Navy, December 16, 2020.

U.S. Department of Transportation Maritime Administration. "The Ready Reserve Force (RRF)." Accessed January 31, 2021. https://www.maritime.dot.gov/national-defense-reserve-fleet/ndrf/maritime-administration%E2%80%99s-ready-reserve-force

U.S. Energy Information Administration. Today in Energy: Maritime Chokepoints are Critical to Global Energy Security. by Lejla Villar and Mason Hamilton. Washington, D.C.: U.S. Energy Information Administration, 2017. https://www.eia.gov/todayinenergy/detail.php?id=32292

U.S. Indo-Pacific Command. "National Defense Authorization Act (NDAA) 2020 Section 1253 Assessment: Regain the Advantage," Camp H.M. Smith, HI, 2021. https://media.defense.gov/2019/Jul/01/2002152311/-1/-1/1/DEPARTMENT-OFDEFENSE-INDO-PACIFIC-STRATEGY-REPORT-2019.PDF.

U.S. President. National Security Strategy of the United States of America, Washington, D.C.: Government Printing Office, December 2017. https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.

Vaughn, Richard. "The Difference between Cartesian, Six-Axis, and SCARA Robots," *Machine Design*, December 02 2013. Accessed February 11, 2021. https://www.machinedesign.com/mechanical-motion-systems/article/21831692/the-difference-between-cartesian-sixaxis-and-scara-robots.

Witschge, Loes. "Rotterdam is building the most automated port in the world," *Wired.com.uk*, October 7 2019. https://www.wired.co.uk/article/rotterdam-port-ships-automation

Wróbel, Krzysztof; Montewka, Jakub; and Kujala, Pentti. "Towards the assessment of potential impact of unmanned vessels on maritime transportation safety." Reliability Engineering & System Safety, Volume 165 (2017).

Yang, K. U. ; Hur, J. G.; Choi, M. S.; Yeo, D. J. ; and Byun, J. H.. "Study on ship automatic berthing system with mooring lines." *China Ocean Eng* 31, 19–29 (2017).

Yoshihara, Toshi. "China's Vision of Its Seascape: The First Island Chain and Chinese Seapower," *Asian Politics & Policy,* Special Issue: How China's Rise Is Changing Asia's Landscape and Seascape, Volume 4 Issue 3, (Washington, D.C.), 2012.