NPS-AM-26-040

ACQUISITION RESEARCH PROGRAM SPONSORED REPORT SERIES

Strategic Acquisition Framework for Manned-Unmanned Teaming in Naval Aviation

June 2025

ENS David M. Giba, USN
ENS Jonathan D. Forbes, USN

Thesis Advisors: Dr. Robert F. Mortlock, Professor
Raymond D. Jones, Professor

Department of Defense Management

Naval Postgraduate School

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

The research presented in this report was supported by the Acquisition Research Program of the Department of Defense Management at the Naval Postgraduate School.

To request defense acquisition research, to become a research sponsor, or to print additional copies of reports, please contact the Acquisition Research Program (ARP) via email, arp@nps.edu or at 831-656-3793.

ABSTRACT

Unmanned aerial systems (UAS) are at the cutting edge of the United States military's development efforts. The U.S. Navy aims to integrate UAS into Carrier Air Wings (CVW), leveraging Manned-Unmanned Teaming (MUMT) to extend and increase its operational capabilities. Programs of record for past systems, such as the MQ-8, MQ-4C, and MQ-25, have faced significant challenges, including scope creep, cost overruns, and unsustainable integration. MUMT must overcome technical, operational, and logistical challenges while coordinating with existing CVW operations. To assess these challenges, a modified capabilities-based assessment (CBA) was used to determine the current capability gaps, followed by a Doctrine, Organization, Training, materiel, Leadership, Personnel, and Facilities (DOTmLPF) analysis to identify non-materiel solutions to those existing gaps. The study revealed a definitive need for UAS to be integrated into CVWs that incorporate MUMT. However, single-role, attritable UAS must be expanded to mature technology and demonstrate that MUMT can perform in contested environments. The Navy needs to pivot to a more open and capability-centric module of sustainment for these systems. Additional non-materiel solutions were found using the DOTmLPF framework, showing shortcomings in many areas where MUMT requires support. Collaboration with allies to rapidly adopt these systems will help close the capability gaps in the CVWs and propel naval aviation into the future.

THIS PAGE INTENTIONALLY LEFT BLANK

NPS-AM-26-040

ACQUISITION RESEARCH PROGRAM
SPONSORED REPORT SERIES

Strategic Acquisition Framework for Manned-Unmanned Teaming in Naval Aviation

June 2025

ENS David M. Giba, USN

ENS Jonathan D. Forbes, USN

Thesis Advisors: Dr. Robert F. Mortlock, Professor
Raymond D. Jones, Professor

Department of Defense Management

Naval Postgraduate School

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

A2/AD	Anti-Access/Area Denial
AAF	Adaptive Acquisition Framework
AI	Artificial Intelligence
AIS	Automatic Identification System
APB	Acquisition Program Baseline
ASW	Anti-Submarine Warfare
AVO	Air Vehicle Operators
AVP	Air Vehicle Pilot
AWOTF	Air Wing of the Future
BRAC	Base Realignment and Closure
C2	Command and Control
CAG	Carrier Air Wing Commander
CBA	Capability-Based Assessment
CBARS	Carrier-Based Aerial Refueling System
CCA	Collaborative Combat Aircraft
CNO	Chief of Naval Operations
CSG	Carrier Strike Group
CVN	Aircraft Carrier - Nuclear
CVW	Carrier Air Wing
DAPA	Defense Acquisition Performance Assessment
DARPA	Defense Advanced Research Projects Agency
DAS	Defense Acquisition System
DCR	DOTmLPF-P Change Recommendation
DIU	Defense Innovation Unit
DMO	Distributed Maritime Operations
DoD	Department of Defense
DON	Department of the Navy

DOTmLPF	Doctrine, Organization, Training, materiel, Leadership and Education, Personnel, Facilities
EO/IR	Electro-Optical/Infrared
EW	Electronic Warfare
FAA	Federal Aviation Administration
	Functional Area Analysis
FNA	Functional Needs Analysis
FRS	Fleet-Replacement Squadron
FSA	Functional Solutions Analysis
FY	Fiscal Year
FYDP	Future Years Defense Program
GAO	Government Accountability Office
GCS	Ground Control System
HALE	High-Altitude Long-Endurance
HFSWR	High-Frequency Surface Wave Radar
ICAO	International Civil Aviation Organization
ICD	Initial Capabilities Document
IFC	Integrated Functional Capabilities
IOC	Initial Operational Capability
ISR	Intelligence, Surveillance, and Reconnaissance
JADC2	Joint All-Domain Command and Control
JCIDS	Joint Capabilities Integration and Development System
KPP	Key Performance Parameter
LCS	Littoral Combat Ship
LOS	Line of Sight
LRIP	Low-Rate Initial Production
MCM	Mine Countermeasure Warfare
MOE	Measure of Effectiveness
MULTI-INT	Multiple Intelligence Disciplines

MUMT	Manned-Unmanned Teaming
N-UCAS	Naval Unmanned Combat Air System
NGAD	Next Generation Air Dominance
NSC	National Security Cutter
OIG	Office of Inspector General
OT&E	Operational Test and Evaluation
PME	Professional Military Education
PPBE	Planning, Programming, and Budgeting Execution
R&D	Research and Development
SIGINT	Signals Intelligence
SUW	Surface Warfare
TEMP	Test and Evaluation Master Plan
TTP	Tactics, Techniques, and Procedures
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UAWC	Unmanned Air Warfare Center
UCLASS	Unmanned Carrier-Launched Airborne Surveillance and Strike
USCG	United States Coast Guard
USDIV	U.S. Unmanned Surface Vessel Division
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
VTOL	Vertical Take-off and Landing
VUAV	Vertical-Takeoff-and-Landing Unmanned Aerial Vehicle
WEST	Western Naval Conference

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

The United States Navy continually seeks to be at the cutting edge of innovation in military capability, with its vast network of operational areas. A focal point of this innovation inevitably falls on the Navy's most expensive asset, the aircraft carrier and the respective Carrier Air Wings (CVW). To advance the Air Wing of the Future (AWOTF), Manned-Unmanned Teaming (MUMT) became a critical operational capability enabler in the Carrier Based Aerial Refueling System (CBARS) program to leverage unmanned capabilities as a cornerstone of next-generation Naval Aviation (NAVAIR, 2021). For good reason, the second "North Star," or strategic focus area, of Naval Air System Command is Unmanned Carrier Aviation/MUMT (NAVAIR, 2025).

A. PROBLEM STATEMENT

MUMT technologies offer a strategic advantage by enabling a combination of manned and unmanned aircraft to work collaboratively, which will enhance mission flexibility, resilience, and operational tempo (Phua, 2022). However, integrating MUMT into Naval operations presents a significant hurdle due to complex requirements placed on systems such as the Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) program (Phua, 2022). UCLASS was drastically shifted due to lofty goals and improper scoping for a cost-effective capability that meets operational requirements (Wickert et al., 2016). This misalignment generates challenges in providing the systems that will be instrumental for the future of Naval Aviation. An analysis of the need for carrier-based unmanned aerial systems (UAS) and the associated capability gap will inform the development of an appropriate acquisition strategy.

The challenges of integrating MUMT capabilities within the U.S. Navy stem from the need to fill capability gaps cost-efficiently to fully meet the operational demands of coordinating manned and unmanned platforms in complex maritime environments. With the vast amount of strain placed on the resources of the U.S. Navy's CVWs, there is a desperate need to fill future capability gaps without putting additional strain on sailors (NAVAIR, 2025). Programs have been proposed and developed in areas where UAS can remove operational burdens. These systems require seamless interoperability between manned and unmanned assets to achieve successful missions, as well as additional maintenance demands, training infrastructure, and life cycle sustainment (Mrusek et al., 2018). The Navy has successfully utilized complementary drone capabilities, such as the MQ-4C Triton, in support of the P-8 Poseidon, which can be leveraged for lessons learned in implementation. Still, carrier-based MUMT is in the infancy stage (Mrusek et al., 2018).

The emphasis on incorporating unmanned systems in the military is ubiquitous, and the leaps in the maturity of critical technologies have made it a reality for carrier-based operations (Mrusek et al., 2018). Without properly scoping where the systems need to be incorporated and a robust understanding of what capability gaps should be filled with these innovations, system acquisition programs may begin with unknown requirements and unstable program baseline estimates for cost, schedule, and technical maturity. For the U.S. Navy to remain at the cutting edge of innovation for unmanned systems and lead the world in operational capability, the gaps in current capabilities must be addressed in a manner that is efficient and prioritized adequately for the incorporation of unmanned systems. If the adoption of these systems is not tailored to meet the distinct requirements, the Navy risks setbacks in MUMT deployment, increased costs, and limitations in fulfilling its strategic objectives for future Naval Aviation.

B. RESEARCH QUESTIONS

The guiding questions for this research are:

1. Where are the current capability gaps in CVWs that UAS or MUMT could address? An abbreviated capabilities-based assessment (CBA) will be used to assess whether there are current capability gaps in carrier-based operations and whether MUMT would be a viable option.

2. Do past programs provide lessons learned for actionable steps to help mitigate risk in integrating solutions that fill those capability gaps? Lessons learned from past program analyses will help shape recommendations for how systems should be developed and integrated to mitigate scope creep and enable sustained implementations of the systems.

3. Can a doctrine, organization, materiel, leadership and education, personnel, and facilities (DOTmLPF) framework reveal solutions for integrating MUMT into Naval operations? This framework guides the analysis toward seeking non-materiel solutions before implementing a program of record to fill capability gaps and areas where implementing MUMT could be supported in a holistic framework in the U.S. Navy.

These research questions helped guide the methodology and frame the analysis for developing and implementing MUMT in the U.S. Navy.

C. METHODOLOGY

Department of Defense (DoD) MUMT applications have typically focused on multiple technical challenges and combined them into a single system that can deliver on many mission sets rather than providing a framework for systems suited to a realistic operational context in the Navy. The strategies adopted by other departments within the DoD and past programs of record can reveal areas where MUMT Naval Aviation could be improved. There are factors and demands placed on aviation within the maritime environment, such as deck density and sustainment requirements, that make the incorporation of UAS unique for the Navy (Shelbourne, 2022). To fill this gap, a CBA assessment will help identify specific areas where current capabilities fall short, supporting a DOTmLPF analysis to determine where non-materiel solutions could help fill these capability gaps.

This study provides the Navy with a framework for UAS and MUMT where critical capability gaps currently exist and recommendations for how they could be filled with non-materiel solutions. The insights from the CBA and the subsequent DOTmLPF assessment contribute to the Navy's MUMT initiatives and serve as a reference for broader DoD efforts in unmanned aviation integration. The adoption of MUMT is a significant challenge facing Naval Aviation. Still, by examining current acquisition challenges and making targeted recommendations, this research can help establish a path forward in acquiring capabilities that will enhance the U.S. Navy's ability to execute missions effectively.

D. SCOPE

This research focuses primarily on carrier-based UAS and MUMT systems and programs developed to support unmanned maritime aviation. The research approach involves utilizing a CBA and DOTmLPF analysis, both of which are scoped down to a feasible level that can be conducted within the time and manpower constraints of this thesis. Both forms of analysis generally require large teams and often take multiple years to complete, incorporating feedback from all major stakeholders that may pertain to the issue at hand. Considering this, the analysis conducted is limited in detail. The recommendations developed will be specific to MUMT and UAS within carrier-based operations, helping to refine and direct the study to actionable items pertinent to the Navy's needs.

Another limitation of this research is the limited availability of data. Only publicly accessible sources are utilized in this analysis, which may unintentionally limit the discussion and conclusions. Insights gathered from other branches in the DoD may also be limited in relevance as the operational environments differ vastly, potentially impacting the relevance of their insights. Additionally, the study assumes specific future technological and operational scenarios that could evolve, potentially affecting the relevance of its recommendations.

E. THESIS OUTLINE

Chapter II provides a deeper background for this thesis, examining both the history of unmanned acquisition programs and a review of current theories for the Naval integration of unmanned systems, as well as lessons learned from past acquisition programs that directly inform the recommendations for future integration. Chapter III conducts a literature review of current and past unmanned systems in the maritime environment, as well as an introduction to CBAs and DOTmLPF analysis. Chapter IV presents the CBA conducted, providing a more in-depth view of where capability gaps exist and the research analysis through the DOTmLPF assessment, as well as the results of both evaluations. Chapter V summarizes the research, revisits the research questions, and gives guidance on future research directions for this topic.

II. BACKGROUND

A. ACQUISITION REFORM

Acquiring the latest technology or services needed to enhance warfighters has always been a complex matter. Balancing quality with financial and scheduling constraints, as well as navigating bureaucratic challenges, is a constant in the acquisition world. Since the establishment of the military-industrial complex in the 1950s, its primary objective has been to equip warfighters with the best technology possible.

The Honorable Robert McNamara, Secretary of Defense from 1961 to 1968, centralized defense acquisition and funding by introducing the Planning, Programming, and Budgeting System and establishing the Office of Systems Analysis to improve cost estimation and accountability (Fox, 2011). The remainder of the 1970s, under Melvin Lairs and David Packard, saw the creation of new initiatives to focus on improved training on newly procured systems and procurement procedures, consolidating procurement laws, and strengthening congressional oversight (Fox, 2011).

During the 1980s, growing concerns over waste and mismanagement prompted Frank Carlucci to launch the acquisition improvement program aimed at streamlining processes and fostering competition. The Nunn-McCurdy Amendment of 1982 introduced congressional notification for cost overruns above 15%, while the Packard Commission (1985–1986) established the Under Secretary of Defense for Acquisition to centralize civilian control of acquisitions (Fox, 2011).

In the 1990s, the Clinton administration's "reinventing government" initiative, led by William Perry, promoted commercial practices and reduced bureaucratic hurdles with defense acquisition pilot programs testing new methods (Fox, 2011). However, a study by RAND Corporation, a global policy think tank, found that program managers lacked the resources and authority to implement reforms fully (Fox, 2011). While reforms have introduced cost controls and competition, challenges like cost growth, schedule delays, and limited program manager authority have persisted.

President George W. Bush's administration sought to address ongoing military acquisition challenges through initiatives like the Defense Acquisition Performance Assessment (DAPA) Project and Base Realignment and Closure (BRAC). Launched in 2005 by Gordon England, DAPA identified three main issues: consolidation of the industrial base, the need for flexibility after the Cold War, and excessive oversight causing delays and cost overruns (Eide, 2011). Simultaneously, the 2005 BRAC round consolidated military installations to reduce operational costs, impacting the Navy by centralizing training facilities and support services (Eide, 2011). Bush wanted to essentially reverse the oversight and competition-promoting initiatives of the Clinton era. Eventually, DAPA found that consolidation limited competition, driving up costs and stifling innovation as fewer companies dominated critical defense technologies (Eide, 2011). Simplified oversight, intended to reduce regulatory burdens, unintentionally gave large contractors more influence, raising concerns about accountability (Eide, 2011). Cultural resistance within the DoD, combined with political pressures, further limited reform effectiveness (Eide, 2011). DAPA concluded that lasting improvements required empowering program managers, reducing micromanagement, and fostering a more competitive industrial base (Eide, 2011).

With that mindset, the current procedure for acquisitions within the DoD relies on big "A" acquisition, carried out via three interdependent yet closely aligned processes: Joint Capabilities Integration and Development System (JCIDS) for requirements, Planning, Programming, Budgeting, and Execution (PPBE) for funding, and Defense Acquisition System (DAS) for materiel solutions. Specifically, within DAS, the Adaptive Acquisition Framework (AAF) allows for rapid prototyping and fielding of materiel solutions for expedited acquisition processing (Defense Systems Management College [DSMC], 2024)

JCIDS is a mechanism for identifying and prioritizing required capabilities, a "needs-driven" system. It utilizes a CBA to evaluate capability gaps in a service and then determine the best approach to resolve it. These capability gaps are first addressed through changes to DOTmLPF-P or a non-materiel solution, rather than a new program of record

(DSMC, 2024). This path is less expensive and could be less intricate than developing a new materiel solution via DAS.

Through PPBE, strategy, funding, and acquisition plans are aligned (DSMC, 2024). Its very name includes the phases involved within it, including planning to define goals and assess capabilities, programming by translating plans into resource packages, budgeting resources, submitting funding requests, and executing the plans. It is calendar-driven, linking policy to budget decisions to keep programs on time and budget (DSMC, 2024). DAS is the brother to JCIDS and PPBE, military systems through the development of materiel solutions. DAS is event-driven through various phases, including planning, development, production, and sustainment (DSMC, 2024). This is executed through the AAF, shown in Figure 1 (Department of deffense [DoD], 2020). The AAF empowers the program manager to rapidly assess risk and develop new technology, as well as the processes to manufacture and sustain it.

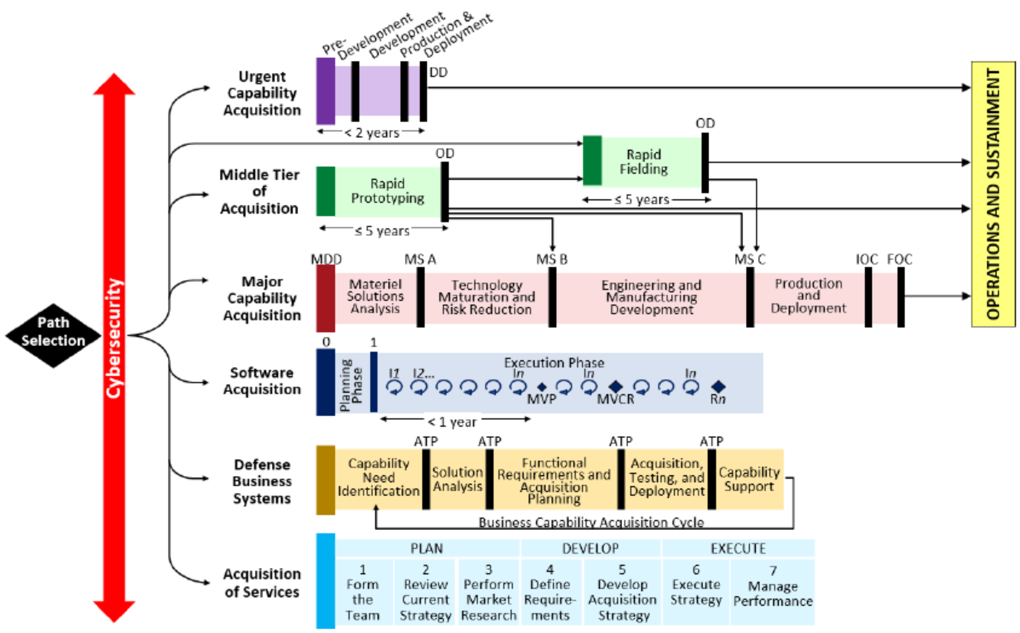

Figure 1. The AAF Diagram. Source: DoDI 5000.02 (2020).

Big "A" acquisition aims to define capability needs, secure funding, and deliver solutions. In practice, the potential for timeline derailment, budget inflation, and other difficulties still inherently exist (DSMC, 2024). This "three-body problem" requires balance, ensuring that projects stay on time, within budget, and meet performance expectations. A delicate interplay of these processes, with constant feedback, coordination, and risk management, ensures that strategic objectives are met without significant waste.

B. THE SURFACE NAVY AND MUMT

At the beginning of each year, the Navy, Coast Guard, and Marine Corps meet at the Western Naval Conference (WEST), where military personnel and innovative companies discuss current and future drives to evolve technology for maritime security (AFCEA International & U.S. Naval Institute, 2024). In 2024, this conference was supplemented by a symposium held by the Chief of Naval Operations (CNO), Admiral Franchetti, where she reiterated the U.S. Navy's strategic priorities and the role of emerging technologies in maritime dominance (Franchetti, 2024).

The CNO provided a brief overview of how Naval doctrine evolved over the decades, transitioning from a flagship-focused fleet to an integrated force above and below the water alongside the Marines (Franchetti, 2024). The shift in doctrine and the rapid evolution of technology in the Naval battlespace led to a culture that required assumptions to be questioned and innovation to be paramount. In this spirit, current developing technologies, such as hypersonic weapons, artificial intelligence (AI), directed energy weapons and countermeasures, cyber weapons, and unmanned systems, have become priorities in military innovation (Franchetti, 2024). Unmanned systems, according to the CNO, have "an enormous potential to multiply our combat power by complementing our existing fleet of ships, submarines, and aircraft, through manned-unmanned teaming, especially in areas like maritime surveillance and reconnaissance, mine countermeasures operations, seabed exploration, and carrier airwing support" (Franchetti, 2024). The emphasis on technological development is more prevalent in our adversaries, as stated in the White papers of the People's Republic of China, "There is a prevailing trend to develop long-range precision, intelligent, stealthy, or unmanned weaponry and equipment. War is evolving in form towards informationized warfare, and intelligent warfare is on the horizon" (Xinhua, 2019).

Military leaders are looking toward the potential of unmanned systems as Congress demands it. Defense News spoke with House Armed Services Committee Representative Rob Wittman, and he noted that the Navy's aging fleet needs to be phased out in favor of new inventory. He emphasized a rapid push to the use of more attritable and inexpensive alternatives when he claimed, "Unmanned systems can become a gap-filler because our exquisite platforms — aircraft carriers, our surface ships, our submarines — all great platforms, but it takes years and years and years to get them in the inventory. So even with the best of intentions, we're not going to have that capability (in time for when China might attack Taiwan)" (Eckstein, 2023b). The Littoral Combat Shio (LCS) program was expensive and yielded inadequate ships that are already being decommissioned (Thomas, 2024). The Gerald R. Ford carriers are over budget, and only the first iteration is in sea trials (Eckstein, 2021). The integration of the F-35 is currently underway; however, the program serves as a prime example of unsustainable financial management and evolving requirements (Government Accountability Office [GAO] 2023). The military seeks to accelerate and improve the development of unmanned platforms to enhance its warfighting capabilities.

Unmanned systems have become a tangible reality and represent a focal point of Naval innovation. The U.S. Navy's 4th, 5th, and 7th Fleets, which are active in the regions around South America, the Middle East, and the Indo-Pacific, respectively, have played crucial roles in developing unmanned systems. The CNO remarks they "are real-world laboratories of learning to develop tactics, techniques, and procedures and help us refine manned and unmanned command and control infrastructure" (Franchetti, 2024). The CNO emphasized the role of Task Force 59, a new unit that serves as the vanguard in both the development of unmanned systems and the advancement of MUMT capabilities (Franchetti, 2024). According to a DefenseScoop article, Task Force 59, a hybrid unit attached to the 5th Fleet, was activated in 2021 and achieved full operational capability within 15 months (Vincent, 2023). According to Vice Admiral Brad Cooper, commander of the 5th Fleet at the time, they completed "11 bilateral maritime exercises, three major international exercises, and over 30,000 hours of safely operating [unmanned surface vessels] in waters around the Arabian Peninsula" (Vincent, 2023). The goal is to enhance joint capabilities in MUMT, with the task force's primary focus being the construction of a "mesh network" of artificial intelligence (AI) supported Unmanned Surface Vessels (USVs) equipped with cameras and sensors that can communicate seamlessly (Vincent, 2023). The phrase repeatedly alluded to is for integrating a "digital ocean." The idea is to combine "thousands of images from the seabed to space, from ships, unmanned systems, subsea sensors, satellites, buoys, and other persistent technologies" (Vincent, 2023) to create a battle picture. The task force's goal is to integrate the world's first entirely USV fleet. In January of 2024, the task force created its prodigal son, Task Group 59.1 or "The Pioneers," to lead the way on MUMT in making this hybrid fleet (Naval Forces Central Command Public Affairs, 2024).

The focus of the 4th Fleet has been on securing waters with data and launching experimentations with MUMT with a framework derived from Task Force 59 (Easley, 2024a). In what is an offensive experiment, the 4th Fleet is undertaking Operation Southern Spear to test MUMT capabilities in South America to expand intelligence, surveillance, and reconnaissance (ISR) capabilities to combat illicit fishing and drug and human trafficking in the Caribbean Basin (Easley, 2024a). Announced in February 2025, Southern Spear will develop MUMT and employ robotic and autonomous systems within existing traditional structures and daily operations. The goal is to steer away from short-term experimentation by taking this technology on the offensive while figuring out its capabilities in long-duration operations to learn and enhance techniques and procedures (Katz, 2025).

One of the platforms tested through Operation Windward Stack was Saildrone's Voyager USV, as shown in Figure 2 (Easley, 2024a). By leveraging machine learning models, this system autonomously detects and classifies targets. It is a highly cost-effective and expandable platform for the Navy to integrate into a MUMT system (Katz, 2025). Ten of these drones were deployed previously for MUMT development (Katz, 2025). With Operation Southern Spear, the company plans to deploy 20 with "a newly upgraded sensor suite," according to Saildrone Chief Executive Officer Richard Jenkins (Katz, 2025).

Jenkins notes that employing these drones in a realistic environment, with real weather and real drug runners avoiding detection, “is where we really start to learn the lessons very quickly” (Katz, 2025). He wants to continue to up-scale the drones’ numbers to gain operational cadence and enhance machine learning. Saildrone is entirely responsible for these drones under a unique concept of acquisition, specifically for deploying, operating, and maintaining them (Katz, 2025). The lessons learned in machine learning and drone upkeep within this operation will be crucial to extending MUMT into the remaining Navy, especially a combat context that the CNO anticipates.

Figure 2. Voyager Drones in the Florida Keys. Source: Easley (2024a).

Thus far, the core concept of drone ISR and data-network infrastructure development has been a priority for the 5th and 4th Fleets. The 7th Fleet, or U.S. Pacific Fleet, has been guiding its MUMT maturation to support the defense of Taiwan

(Shelbourne & Lagrone, 2024). These efforts are less transparent than those of her sister's fleets, as the Chinese tend to buy or covertly acquire systems rather than waste research and development funding for their capability gaps. What is transparent is that Commander of Indo-Pacific Command Admiral Paparo, envisions a concept of sacrificial technology, to say, "Don't send a human being to do something dangerous that a machine can do better, faster, and more cheaply" (Shelbourne & Lagrone, 2024).

Paparo told the audience at the 2024 WEST conference that a second unmanned surface vessel division (USDIV) would be stood up, and contrary to 4th Fleet, these squadrons are completely Navy-owned (Shelbourne & Lagrone, 2024). This contingent would be composed of small USVs that would complement the larger USVs utilized by USDIV-1 (Shelbourne & Lagrone, 2024). Under Integrated Battle Problem 23.2 off southern California shores (battle problem referring to an extensive exercise that tests how new systems and personnel work in a combat scenario), large USVs Mariner and Ranger, and their medium-sized brothers Sea Hunter and Seahawk "sailed more than 46,000 nautical miles and tested continuous navigation in transits that took them across the vast region" (Shelbourne & Lagrone, 2024). Specifically, they were able to transit to Japan and Australia autonomously, joining those maritime forces to engage in various exercises USDIV-1 dug a foothold in solidifying the MUMT model, not just for the United States but also for its allies (Shelbourne & Lagrone, 2024).

Admiral Paparo believes that the key mindset is more towards area denial and creating a "hellscape" concept where swarms of unmanned systems can contest battlespaces "simply to deny its use to an enemy" without necessarily going one-for-one with larger assets (Shelbourne & Lagrone, 2024). The ultimate goal is to use subsurface, surface, and aerial unmanned vehicles for sea denial. The aim is to rapidly integrate these smaller USV prototypes into real-world operations and continuously expose them to fleet operations.

This highlights the importance of acknowledging the role of the Defense Innovation Unit (DIU). Given the new demands for small, lethal surface drones, DIU issued a solicitation in early 2024 to companies in the industry to fill that capability gap (Shelbourne & Lagrone, 2024). At WEST, Deputy Secretary of Defense Kath Hicks and Admiral

Christopher Grady had selected a vehicle that DIU presented, a close cousin to the small "kamikaze" style of boat drones used in Ukraine, called Replicator 1, as shown in Figure 3 (Shelbourne & Lagrone, 2024). Along with the former Secretary of the Navy Del Toro's Disruptive Capability Office, DIU is creating the software and network necessary to enable unison and autonomy for individual drones within a larger swarm (Shelbourne & Lagrone, 2024).

Figure 3. Ukrainian Explosive USV. Source: Axe (2022).

Off the shores of San Diego, Costa Mesa-based tech company Anduril took the lead on Integrated Battle Problem 24.1, another exercise the CNO had alluded to in her symposium (Anduril Industries, 2024). Among other industry partners, their goal was to bolster teaming unmanned and autonomous assets above and below the water to amplify the success of Battle Problem 23.2 (Anduril Industries, 2024). Anduril utilized their proprietary program, Lattice, an AI-enabled software that joins these assets and provides a mission management display, as shown in Figure 4. Through this, 100 different, physically separated operators could manage their vehicles and achieve targeting sequences of find, fix, track, target, engage, and assess (Anduril Industries, 2024). These operators oversaw seven different USV variants, three unmanned aerial vehicle (UAV) variants, one underwater vehicle variant (the Dive-LD), and other commercial, non-asset feeds that are integrated into low-latency mesh networks (Anduril Industries, 2024). They were able to task the Dive-LD to autonomously patrol designated waypoints as well as conduct high-speed patrols with USVs, which also deployed several tube-launched ISR USVs, Altius, of which several were recovered for reuse (Anduril Industries, 2024). The efforts of Anduril and its counterparts demonstrated the feasibility of Lattice AI beyond line of sight (LOS) control for multi-domain unmanned vehicles. Just as USDIV-1 shows the feasibility of MUMT, this battle problem proves to the Navy that the programs and strategies necessary to execute MUMT are well underway.

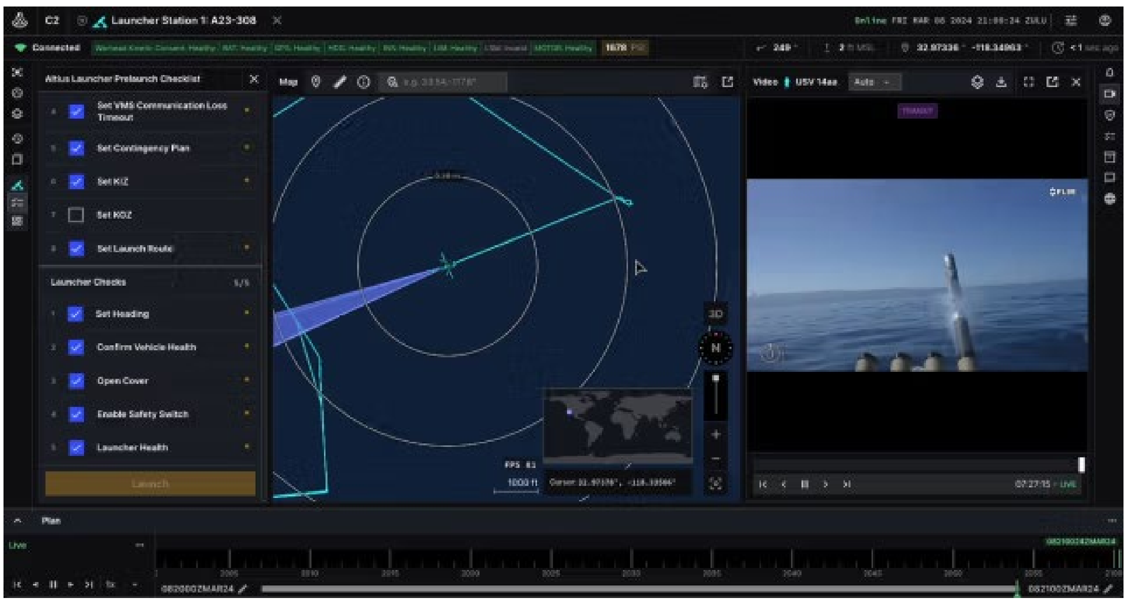

Figure 4. Altius UAV Being Monitored via Lattice Interface. Source: Anduril (2024).

With the reality of near-peer rival China increasingly extending its military control and corroborating to invade its neighbor, Taiwan, the United States is seeking to create a technological advantage. The Navy's overall strategic concept is utilizing many USVs, unmanned underwater vehicles (UUVs), and eventually UAVs to heavily disrupt and complicate an amphibious assault across the Taiwan Strait (Shelbourne & Lagrone, 2024). That is, to minimize the number of allied sailors between China and the Taiwanese shores.

Admiral Paparo senses that drones will be crucial to the big fight (Tucker, 2024). Of greater importance is their role in the Joint Fires Network, which is conceptually the Battle Management System that allied forces are developing to provide real-time threat data to every asset involved, augmented by a program known as Stormbreaker (Tucker, 2024). Stormbreaker is an AI-driven joint operational planning toolkit for planning and wargaming potential (Indo-Pacific Command, 2023).

The focus is early detection and decision-making capability based on relevant, real-time data. Following the CNO's intent, Admiral Paparo suggests that the U.S. and Chinese competition has created a paradigm shift to an "information revolution" (Tucker, 2024). This emerging field will determine who prevails over future conflicts, combining computing power, AI, cyber, data linkage, and information flow (Tucker, 2024). Unmanned system incorporation is still in its infancy stage. The obvious logistical nightmare is manufacturing and sustaining these unmanned systems. The Sail drone experiment is fruitful, but commercial entities cannot be expected to employ and maintain Naval assets in a mass conflict. The Navy needs to know how to wield these weapons. Drones can supplement many major combat roles, including ISR, electronic warfare (EW), and combat support (Tucker, 2024). With that, the capability demand is not hundreds of drones but thousands, especially as China prioritizes having many military systems and personnel.

1. Project Overmatch

The Surface Navy needs to enhance the acquisition of unmanned systems and explore their integration with manned control. As previously suggested, the primary advantage of drone technology lies in its ability to deliver real-time information, which is verified and synthesized by other interconnected assets performing similar functions, forming a network or a hive mind. This concept of network pairing between systems is shown in Figure 5. The effectiveness of drones in any combat scenario cannot be fully understood without considering the combat systems that enable their operation. The Navy's push for MUMT is embodied in Project Overmatch, an initiative designed to create seamless fleet-wide connectivity (Franchetti, 2024). At its core, Project Overmatch is about integrating distributed maritime operations (DMO) with a scalable combat system, ensuring ships, unmanned systems, and personnel operate as a unified force (Eckstein & Demarest, 2022). Adm. Franchetti describes it as "building a software-defined network solution and modern software pipelines to provide as many pathways as possible to connect and share information" (Franchetti, 2024). The goal is to achieve decision superiority at machine speed, creating real-time data transmission over any network and bridging today's fleet with the emerging hybrid fleet of manned and unmanned assets (Franchetti, 2024).

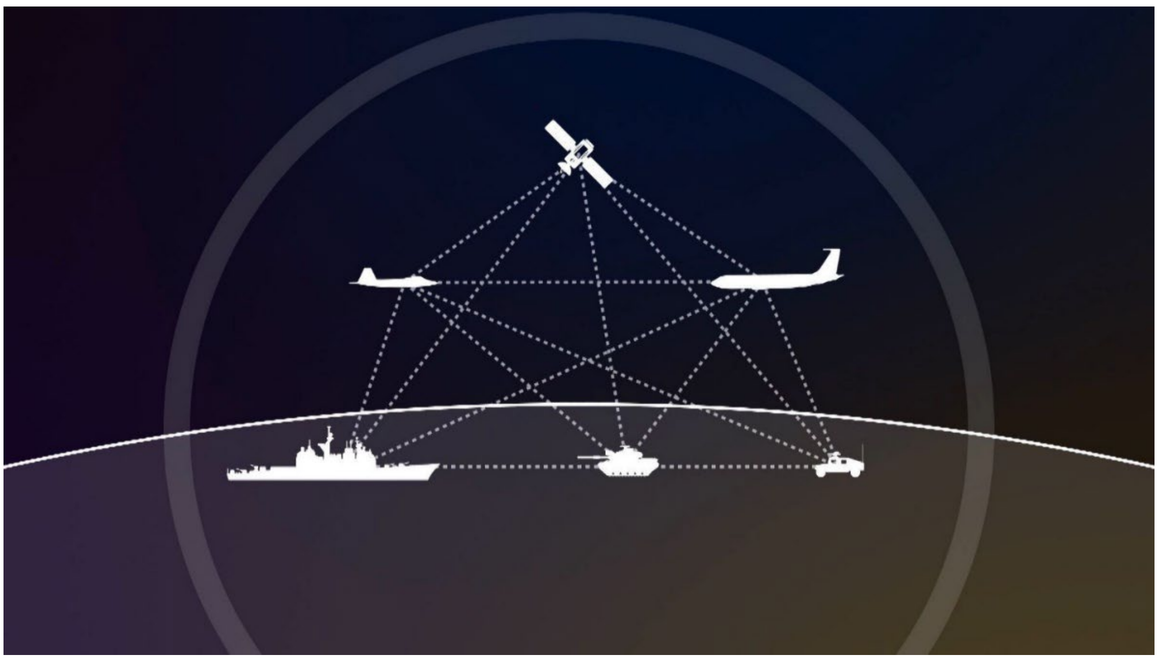

Figure 5. Project Overmatch Concept. Source: Eckstein & Demarest (2022).

To make this a reality, the Navy is evolving legacy systems like AEGIS and the ship self-defense system into a single, hardware-agnostic software, effectively creating an integrated combat system (Franchetti, 2024). The result is a battle network where surface action groups, strike groups, and entire fleets can function as a proper system of systems capable of operating independently or as a coordinated force.

2. Efforts to Support MUMT

MUMT is not just about adding unmanned platforms; it's about ensuring they integrate effectively with the existing force. Adm. Franchetti highlights three critical components: training, talent development, and force structure adaptation (Franchetti, 2024). The Navy ensures that Sailors have the knowledge and skills to operate these systems through live virtual, constructive training, ready relevant learning, and the fleet learning continuum (Franchetti, 2024). The reality is, "it's not really unmanned. The actual platform may be unmanned, but we also need to set up all the infrastructure, all of the networks, everything that can enable the unmanned technology to actually work and the people that operate it" (Franchetti, 2024). The Navy is already placing junior officers in command of Task Group 59.1 and Task Force Hopper, another AI and machine learning-focused group created in 2021, specialized units tasked with conceptualizing, testing, and operationalizing new technology (Franchetti, 2024). Additionally, the Service seeks to create a new robotics rating, ensuring that the next generation of sailors is equipped to handle sensor integration and manage platform autonomy. As the demand for autonomous and unmanned systems grows, the Navy is expanding its human force structure to adapt. This ensures the right people are in place to manage, operate, and refine these disruptive technologies (Franchetti, 2024).

CNO laid out a three-phase Future Years Defense Program (FYDP) approach to integrating unmanned systems into the fleet, as shown in Figure 6 (McGarry & Peters, 2024). This approach encompasses the entire vision for the future force structure; however, the expedited maturation of MUMT is particularly relevant to this development. Nonetheless, this phased strategy has moved from prototyping and experimentation to full-scale deployment.

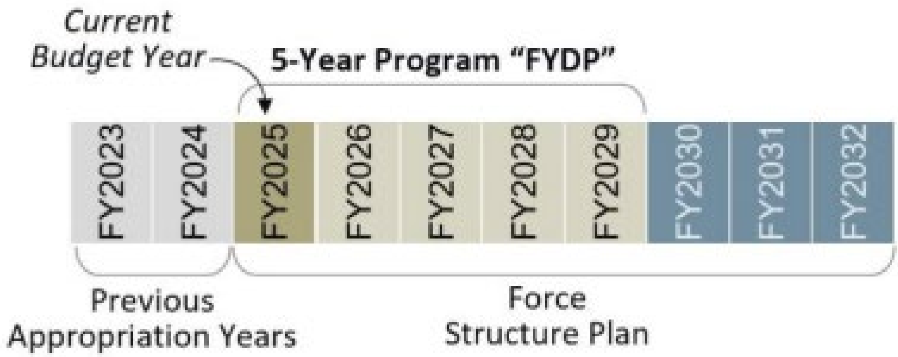

Figure 6. Future Years Defense Program. Source: McGarry & Peters (2024).

The first phase, ending in 2024, focused on prototyping and experimentation (McGarry & Peters, 2024). This means testing unmanned systems in real-world conditions while simultaneously building the networks, infrastructure, and operational enablers to allow these platforms to function as an integrated force (Franchetti, 2024). This stage involves efforts like Task Force 59's hybrid fleet operations, 4th Fleets experiments, and Pacific Fleet's aggressive battle problem exercises, refining how unmanned systems work alongside manned platforms (Franchetti, 2024). Now that the backbone is in place, the next FYDP, 2025–2029, shifts to procurement (Franchetti, 2024). This is when the Navy moves from prototypes to fleet-wide acquisitions of unmanned systems at scale. The focus will be on deploying unmanned platforms in sufficient numbers to achieve operational impact. Specifically, this phase will see the expansion of the "mesh network" concept, which is being explored by the experimental bodies mentioned (Franchetti, 2024). By the third FYDP, 2030–2035, the Navy expects these unmanned systems to operate at full scale and speed (Franchetti, 2024).

C. MUMT IN AVIATION

MUMT has slowly become a reality within the DoD and Naval Aviation, thanks to the support of the CNO and other leadership, but fundamental challenges remain in acquiring these systems. The view of acquisition within the Navy has soured due to cost and schedule overruns in programs like the F-35 and the LCS (GAO, 2023; Thomas, 2024). Experimentation with MUMT has demonstrated progress in various fleets on a smaller scale and in less congested environments compared to carrier-based operations. However, the aircraft carrier (CVN) remains the focal point of Naval operations with its supporting CVWs. The CVWs are aging, and the need for innovation for potential future conflicts remains a concern.

The Navy is actively developing and integrating large UAS: the MQ-25 Stingray, the MQ-8 Fire Scout, and the MQ-4 Triton (NAVAIR, n.d.-f). The MQ-25 and MQ-8 are the only UAS applied in carrier-based aerial MUMT, as the MQ-4 is a land-based system (NAVAIR, n.d.-e). Currently, the MQ-25 Stingray provides capabilities for the fleet and has set up a Fleet Replacement Squadron, VUQ-10, for training and support of the platform, at the same time, VUQ-11 and VUQ-12 are slated to activate as operational squadrons soon (Burgess, 2021). The MQ-8 program serves as an example of innovative concept development but lacks the necessary support and refinement for full effectiveness (Tegler, 2024).

There are divergent U.S. Marine Corps and Air Force approaches for unmanned integration. The Marine Corps is adopting an incremental method, as demonstrated by its XQ-58 Valkyrie flight test employing Link-16 for data exchange, while the Air Force is aggressively fielding 'loyal wingman' drones designed to extend the operational range and lethality of its manned platforms (Rogoway, 2025b; Trevithick, 2024b). The Marine Corps' approach is cautious yet charging ahead, as they commit to properly integrating the systems into the existing operations framework as a force multiplier rather than disrupting existing command and control protocols (Landreth et al., 2020). The Air Force's approach is to outpace adversaries and deliver unmanned capabilities as rapidly as possible (Losey, 2024). This approach yields innovation but risks scaling and integration challenges from inertia in doctrinal change to technological immaturity. The Navy has taken a more backseat approach, adopting a wait-and-watch tactic in scaling UAS and MUMT into aviation. Understandably, the vast spectrum of warfare environments the Navy encounters in undersea, surface, and air operations spreads the focus of unmanned systems very thin. The Navy is slowly developing its UAS for carriers through the MQ-25. Still, they are heavily banking on the success of this system to expand outward into other support or attachment roles for MUMT beyond aerial refueling.

Rear Adm. Michael Donnelly, the N98 director in the CNO's office at the annual Sea Air Space Symposium, made the statement, "I will tell you that we are definitely in the follow of those three services as we look to see how Air Force is developing and fielding things, quite frankly, in a more simple operational environment than what is required for a ship-based system" (Rogoway, 2025b). The Navy has committed to a more measured trajectory by grounding its pathway in the MQ-25, viewing it as a baseline architecture that supports current carrier operations and sets a standard for future unmanned integrations across the joint force.

D. SUMMARY

The way acquisition is conducted in the DoD has evolved significantly over the decades, particularly in response to rapidly increasing technological development. Reforms introduced the PPBE system, the AAF, and the JCIDS process by which current military procurement is conducted. These reforms have sought to streamline the process, but cost overruns, schedule delays, and sustainment issues remain prevalent. With a shifting focus on adopting UAS and conducting MUMT through initiatives in Task Force 59 and Project Overmatch, the Navy must strategically position itself to avoid past issues.

The challenge that MUMT with UAS poses on the military, specifically in the complex maritime environment, can be understood more thoroughly when seen through the lens of past and current programs. Some notable acquisition efforts that deserve a more in-depth historical understanding are the Coast Guard's Vertical Unmanned Aerial Vehicle (VUAV) and the Navy's MQ-8 Fire Scout, MQ-25 Stingray, and MQ-4 Triton (Magnuson, 2023; NAVAIR, n.d.-f). Analyzing the acquisition and integration of these systems, as well as understanding their successes and failures, will help inform the analysis and recommendations for effective acquisition and integration to address present capability gaps.

III. LITERATURE REVIEW

To further highlight the historical and future track of UAS and MUMT in the Navy and CVWs, significant record programs for past and current maritime systems are summarized to gather potential lessons to be learned from their shortcomings or successes that can be directly applied to future programs. The collected information helps tailor the analysis using a CBA and DOTmLPF assessment to dictate the future direction of integration. Additionally, a summary of how CBAs and DOTmLPF analysis are conducted will be introduced to guide the approach of the actual study of this capstone project.

A. SYSTEMS

1. Coast Guard VUAV

The U.S. Coast Guard's attempt to acquire the vertical-takeoff-and-landing (VTOL) unmanned aerial vehicle (VUAV), as shown in Figure 7, under the integrated deepwater system (IDS) program offers a valuable case study for assessing the challenges of unmanned system acquisitions. Key details from the Office of Inspector General's (OIG) report on the VUAV acquisition program are worth considering. UAS was envisioned as force multipliers for the U.S. Coast Guard's fleet modernization effort, and the VUAVs were expected to expand the aerial surveillance capabilities of National Security Cutters (NSCs) from 18,320 to 58,160 square nautical miles, a 68% increase (OIG, 2009). The advantage of the VUAV platform was demonstrated in its ability to provide up to 16 hours of surveillance every day, in contrast to the 4 hours of surveillance limit of manned helicopters (OIG, 2009). Without putting the VUAV into operation, the NSCs were considered no better than the aging Hamilton-class cutters, running counter to the benefits of modernizing the cutters in the first place (OIG, 2009).

The VUAV demonstrated its advantages to the Coast Guard; however, funding shortfalls posed an extreme developmental risk (OIG, 2009). Sixty-nine total VUAVs were set to be procured with initial delivery of 8 aircraft in 2006 under the Deepwater program (OIG, 2009). The program was divided into three phases: system development, component production, and vehicle assembly & demonstration (OIG, 2009). The lack of funding in fiscal year (FY) 2003 and partial funding from FY 2004 to 2006 led to delays and cost overruns (OIG, 2009). This caused funding for these distinct phases to be separated, resulting in delays via stretching the program across several budget cycles. This increased timeline caused other effects, like contract adjustment and higher personnel payments for development and oversight (OIG, 2009). This decision increased costs and extended the timeline by two years (OIG, 2009). By June 2007, after spending $113.7 million, including $90.3 million expended and $23.4 million in outstanding obligations, the Coast Guard canceled the program, citing excessive developmental risks and funding constraints (OIG, 2009).

Figure 7. Bell Eagle Eye Proposed UAV. Source: Magnuson (2023).

Significant burdens were also found in gaining regulatory approval for the unmanned system. The Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO) regulate UAS no differently than other aircraft, requiring compliance with existing regulations to classify UAS as aircraft, requiring (OIG, 2009). The VUAV did not have clear or robust guidance for integration into manned airspace, particularly for "see and avoid" capabilities required by 14 Code of Federal Regulations §

91.113(b) (OIG, 2009). The Coast Guard initially planned to install and use the Navy's High-Frequency Surface Wave Radar (HFSWR) on their cutters as a detect-and-avoid mechanism (OIG, 2009). Still, the Navy canceled this technology in 2003 due to technical issues, depriving the Coast Guard of their see and avoid capability (OIG, 2009). The Coast Guard explored alternative approaches, including the use of the air search radars of their cutters for airspace deconfliction and invoking "Due Regard" provisions under the 1944 Convention on International Civil Aviation, which would have allowed operations without meeting FAA standards (OIG, 2009). This solution failed to provide full operational capability and would make coastal operations difficult. The lack of a viable see-and-avoid system prevented the VUAV from obtaining FAA approval for unrestricted operations in national airspace (OIG, 2009).

When the VUAV program was canceled, the Coast Guard turned toward a short-term mitigation strategy through increasing manned HH-65 Dolphin helicopter flight hours (OIG, 2009). While this filled the immediate capability gap left by the VUAV cancelation, this alternative was more expensive per flight hour and diverted resources from other operations (OIG, 2009).

Two key recommendations were provided in the OIG report. First, the Coast Guard should implement a formalized documented plan for filling the surveillance gap while pursuing the addition of long-term unmanned systems and conduct fleet analyses to assess resource allocation along with mission demands (OIG, 2009). Second, compliance with FAA and ICAO regulations from the outset, in platform selection and operational planning phases, is paramount to successful implementation (OIG, 2009). The Coast Guard established an FAA Unmanned Aircraft Branch liaison officer in the summer of 2009 to help facilitate this process (OIG, 2009).

The failed VUAV acquisition yields critical insights into pitfalls in unmanned platform procurement.:

- Funding Strategy: The Deepwater program had shifting priorities and received split incremental funding, which directly contributed to cost delays and overruns, highlighting the necessity of consistent funding throughout the acquisition cycle (OIG, 2009).

- Regulatory Compliance: Compliance and coordination early on with aviation authorities is vital in preventing integration issues, especially in domestic regulated airspaces (OIG, 2009).
- Technology Readiness: Programs with unproven or immature technologies, such as the HFSWR for the VUAV, drastically increase risk (OIG, 2009). Mature and tested systems should be prioritized and integrated into systems to help mitigate these risks.

The failure to procure the VUAV in the Coast Guard illustrates the difficulty of integrating UAS into maritime operations. While the platform showed genuine promise in filling a capability gap within operations and expanding surveillance capabilities, the program faced challenges in regulations, funding, and technical immaturity.

2. MQ-8

The MQ-8 Fire Scout program, developed by Northrop Grumman, is a tactical unmanned aerial system designed to support Naval ISR, general surface warfare (SUW), and mine countermeasures (MCM) operations (DoD, 2019). It would operate primarily from LCSs but was designed for use on any surface ship and general landing pads, thereby enhancing the Navy's maritime situational awareness. The program has two variants: MQ-8B and MQ-8C, each with distinct capabilities shown in Figure 8 (DoD, 2019).

Figure 8. MQ-8C (Left) and MQ-8B (Right). Source: DoD (2019).

The MQ-8B, based on the Schweizer 333 airframe, reached Initial Operational Capability (IOC) in March 2014 and has accumulated over 17,000 flight hours (DoD, 2019). It has electro-optical/infrared (EO/IR) sensors, maritime search radar, and communications relays, supporting recon and surface warfare missions (DoD, 2019). However, its performance detecting targets was inconsistent during testing, with flight-specific factors like sea state and weather affecting radar accuracy (DoD, 2019). The MQ-8B has an endurance of over five hours, reaching 5.5 hours when carrying its maximum payload of 300 pounds (DoD, 2019). Yet, the MQ-8B is being phased out through attrition as the MQ-8C replaces it (DoD, 2019).

The MQ-8C, utilizing the Bell 407 airframe, provided enhanced endurance, range, and payload capacity. Achieving IOC in June 2019, it integrated the AN/AAQ-22D BRITE Star II sensor with EO/IR cameras and laser designation/range finding (DoD, 2019). The MQ-8C's design supports incremental payload integration. This system has three increments: the Endurance Baseline, Surface Warfare, and the Mine Countermeasure baseline (DOT&E, 2016). The Endurance Baseline Increment includes an automated identification system (AIS), which enables the tracking of friendly assets equipped with the appropriate transponders, as well as tactical ISR capabilities, referring to the endurance of the ISR sensors before they require maintenance or reset (DOT&E, 2016). The SUW Increment adds radar and an Advanced Precision Kill Weapons System, and the final MCM Increment incorporates coastal battlefield reconnaissance and analysis capabilities used for mine detection (DOT&E, 2016). Compared to the MQ-8B, the MQ-8C demonstrated a more reliable communications relay and improved AIS (DOT&E, 2016). With a 300-pound payload, it can fly for up to 12 hours and carry payloads exceeding 700 pounds, operating within a 150-nautical-mile range from its host ship (Tegler, 2024).

Both variants faced challenges during land-based assessments. The MQ-8B radar yielded inconsistent detection rates and variable target location errors, while the MQ-8C's EO/IR sensor performance was affected by environmental factors and required precise cueing, or location tasking, for effective target classification (DOT&E, 2016). Neither variant's shipboard capabilities were fully validated during these assessments. These include taking off and landing in operational conditions, data transmission and control from the control center, and procedurally handling the aircraft.

The MQ-8 Fire Scout has had a mixed operational history, with the MQ-8B and MQ-8C variants serving on various platforms. The MQ-8B accumulated over 17,000 flight hours while supporting missions aboard LCS and land-based deployments, including operations in Afghanistan (DoD, 2019). Despite inconsistent radar performance during testing, the MQ-8B demonstrated its ability to complement manned aircraft and improve maritime situational awareness. It could stay on station for long periods, freeing up MH-60s for other roles. It was able to detect and track both surface vessels to be confirmed by MH-60 and enemy personnel to be engaged by other assets (DOT&E, 2016). The MQ-8C, with its increased range, endurance, and payload capacity, was intended to replace the bravo variant through attrition (Tegler, 2024). However, the MQ-8C's operational career was short-lived.

The MQ-8C achieved Milestone C in 2017, and the Test and Evaluation Master Plan (TEMP) was approved in February 2022 (Tegler, 2024). The 2023 President's Budget removed all MQ-8Bs and stopped the MQ-8C inventory at 36 units. Of the 36, 17 are operationally deployed, two are used for testing, and 17 are mothballed at Point Mugu, California, potentially for parts (Tegler, 2024). With a unit cost of approximately $28 mil, alternative unmanned systems may offer greater capability and practicality (Tegler, 2024). Group 3 UAVs, lightweight platforms operating below 250 knots, are considered more viable options (Tegler, 2024). However, the long-term viability of the MQ-8C remains uncertain, as the Constellation-class frigates currently in development were explicitly designed to accommodate this platform. The Navy will likely seek to field more attritable UAVs, such as the RQ-21 Blackjack, and deploy them on the new frigates (Tegler, 2024). Currently, the MQ-8 program is essentially terminated, with its future role in the Navy's ISR and maritime operations uncertain (Tegler, 2024).

One major pitfall of the MQ-8 system was the integration style into the Naval fleet. The Fire Scout was integrated using a composite deployment method that forced personnel to be qualified in maintaining and operating both unmanned and manned platforms, spreading personnel even thinner and causing inefficiencies in integration (Wright & Whitsett, 2022). On top of this, composite deployment complicated logistics for maintaining the system and created competing mission priorities (Wright & Whitsett, 2022). These factors, along with the previously mentioned issues of development and sustainment, have led to the system's underutilization. Although it has demonstrated functional capability, it has failed to integrate properly into the CVW.

System Facts:

- Current Stage of Acquisition: Follow-On Test & Evaluation, SUW increment achieved, working on MCM increment for the MQ-8C only (DOT&E, 2024).
- Procurement Size: 177 desired at program start, 38 procured, two struck from service. No further procurement (Tegler, 2024).
- Total Acquisition Cost (Estimated): $3.0495 billion. 8% increase from the $2.822 billion baseline estimate in 2006, but for far fewer aircraft (DoD, 2019).
- Average Procurement Per Unit Cost: $29.931 mil Dec 2019. 176.1% increase from baseline of 10.842 Dec 2006 (DoD, 2019). Recent research suggests that $28 mil is a reasonable and easy estimate (Tegler, 2024)

- Capability Gap Addressed: LCS-based ISR, Surface Warfare radar, and mine countermeasures. Reduced need for MH-60 role in surface ship operations (DOT&E, 2024).

The troubled Fire Scout acquisition underscores critical considerations for future unmanned platform procurements:

- High Cost with Limited Capability: With a high per-unit cost, the MQ-8C was deemed too expensive for its limited operational flexibility compared to newer, more cost-effective UAVs (Tegler, 2024). The platform's sensor inconsistencies and limited shipboard validation further reduced its value, leading to its early retirement despite a decade of development and billions invested (Tegler, 2024).
- Shift Toward Attritable UAVs: The MQ-8's slow speed and predictable flight paths made it highly susceptible to modern counter-UAV systems, including electronic warfare and anti-drone munitions (DOT&E, 2016). Unlike more survivable UAVs that incorporate stealth or rapid maneuverability, the Fire Scout lacked effective defenses against adversary air defenses and electronic disruption (GAO, 2016). The Navy is prioritizing Group 3 UAVs, such as the RQ-21 Blackjack, which are cheaper, lighter, and more expendable, aligning with evolving Naval warfare strategies (Tegler, 2024). The cancellation of the MQ-8C suggests a shift toward more flexible, easily replaceable UAV platforms better suited for distributed maritime operations.
- Insufficient integration support: The approach of integrating the MQ-8 into existing manned squadrons and supporting the system through dual qualifications, unclear maintenance support, and complicated logistical chains caused the utilization of the system to be doomed at the outset (Wright & Whitsett, 2022).

3. MQ-25

The MQ-25 Stingray is the primary system developed out of the CBARS program, and it is the first large operational, carrier-based unmanned system with a primary mission of aerial refueling, as shown in Figure 9 (DoD, 2023b). Boeing and Lockheed Martin produce the system and seek to incorporate it seamlessly into the complex operational field of carrier-based aviation, including taxi, launch, and recovery (NAVAIR, n.d.-g). Carrier-based aircraft require air-to-air refueling to extend the range and duration of missions. The purpose of the MQ-25 is to expand the combat range of the F/A-18 Super Hornet, EA-18 Growler, and F-35C fighters while alleviating reliance on F/A-18E/F aircraft for tanking missions (DoD, 2023b).

Figure 9. MQ-25 Stingray Conducting Aerial Refueling Testing of an F-35C. Source: Szondy (2021).

The MQ-25 had a long and indirect path to becoming a capable system viable for Naval operations. The original carrier-based unmanned program for the Navy was the Naval Unmanned Combat Air Vehicle (O'Rourke, 2007). This program was introduced in 1999 and researched by the Defense Advanced Research Projects Agency (DARPA), initially focusing on reconnaissance and surveillance to support the air wing (O'Rourke, 2007). This program shifted into a joint program between the Air Force and the Navy in 2002, changing the program name to the Joint Unmanned Combat Air Systems (Gertler, 2015). The joint nature of the system then made the requirements broader and more tended towards the strike capabilities of the unmanned system. Again, this would change in 2006, as the Air Force began development of a new bomber and terminated its engagement with the program, while the Navy pursued the development of a longer-range carrier-based aircraft capable of air-refueling and reclassifying the program and the Naval Unmanned Combat Air System (N-UCAS) (Gertler, 2015). The Navy demonstrated the feasibility of integrating UAS into carrier operations through the Unmanned Combat Air Systems Demonstration program, leading to the UCLASS program, which sought to take lessons learned from N-UCAS and create a fully operational and integrated UAS capable of strike, defense, and ISR (Gertler, 2015).

The UCLASS program underwent significant evolution due to shifting priorities, budget constraints, and strategic reassessments. As shown in Figure 10, the program changes caused the requirements to move and the environment in which the system operated. Initially envisioned in 2010 as a stealthy, long-range UCAS for ISR and strike, the program underwent significant changes in 2012, emphasizing ISR in permissive airspace with reduced strike capability due to budgetary concerns (Gertler, 2015). Industry efforts to develop airframe designs proceeded amid ongoing debates over stealth, endurance, and mission focus. By 2014, further shifts prioritized ISR and potential aerial refueling while reducing stealth and payload requirements. After years of delays and reevaluation, in 2016, the program was restructured into the CBARS program, focusing on extending the range of carrier aircraft (Gertler, 2015). This shift culminated in the MQ-25 Stingray, with Boeing securing the contract in 2018 to deliver the Navy's first carrier-based unmanned aerial refueling platform (Gertler, 2015).

	N-UCAV, 1999	J-UCAS, 2003	N-UCAS, 2006	UCLASS ICD, 2011	UCLASS RFP, 2013
Suppression of Enemy Air Defenses (SEAD)		X	X	?	
Precision Strike		X	X	X	
Counter-terrorism					X
Intelligence, Surveillance & reconnaissance (ISR)	X	X	X	X	X
Electronic attack		X		?	
Environment	Protected airspace	Deep, denied enemy territory	High-threat areas	Highly contested	Uncontested, light strike permissive to low-end contested

Figure 10. Evolving Requirements for Navy Unmanned Combat Aerial Vehicles. Source: Gertler (2015).

According to a September 2017 GAO report to the Congressional Committees, the Navy's MQ-25 acquisition strategy, approved in April 2017, follows an evolutionary, knowledge-based approach to reduce risk and ensure program success (GAO, 2017). It emphasizes open systems standards and incremental capability upgrades, starting with aerial refueling and ISR, while allowing for future enhancements like receiving fuel and improved sensors (GAO, 2017). The Navy has established key knowledge-based milestones to assess progress and inform leadership decisions throughout the development process. To mitigate risk, the program constrains development to six to eight years, mandates that all technologies be demonstrated in a relevant environment before integration, and leverages prior design knowledge from UCLASS and prototyping efforts (GAO, 2017). Additionally, an independent cost estimate is being developed to support the Milestone B review, and the Navy plans to use a fixed-price incentive contract to control costs (GAO, 2017).

Even with this acquisition approach, the cost and schedule of the MQ-25 have slipped. Due to supplier management and manufacturing issues, the procurement schedule has been delayed, and the costs have exceeded the approved acquisition program baseline (APB) due to budget adjustments, including shifts in IOC, updated cost estimates, quantity phasing changes, tooling reuse, and added obsolescence risks (DoD, 2023b). As shown in Figure 11, the costs have increased compared to the MQ-8C but not as substantially as the increase for the MQ-4C Triton.

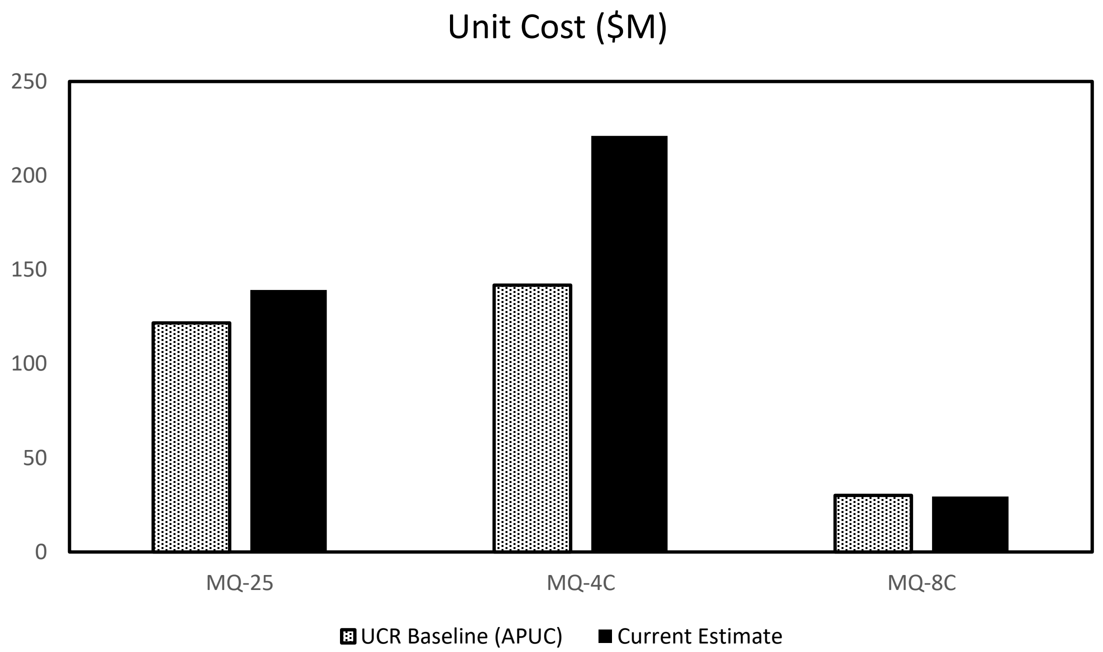

Figure 11. Bar Chart Showing Unit Cost Report Baseline and Current Estimated Costs per Program.

System Facts:

- Current Stage of Acquisition: The MQ-25 program is in the low-rate initial production (LRIP) phase. The FY 2025 budget funds three LRIP MQ-25 aircraft and advanced procurement supporting LRIP Lot 2, which includes three additional MQ-25 aircraft and expected IOC in FY 2026 (Office of the Under Secretary of Defense, 2024a).
- Procurement Size: 76 Units (DoD, 2023b).
- Total Acquisition Cost (Estimated): $17.641 billion (DoD, 2023b)
- Average Procurement Per Unit Cost: $193.963 mil (DoD, 2023b)

- Capability Gap Addressed: The MQ-25 Stingray addresses the need for carrier-based aerial refueling. The system can provide up to 500 nautical miles of range with 15,000 pounds of fuel, extending the combat range of the CVW (DoD, 2023b). It alleviates the reliance on F/A-18E/F Super Hornet aircraft for refueling missions, preserving their service life for combat operations. Additionally, future iterations of the MQ-25 will seek to provide ISR capabilities as a secondary mission, enhancing the Navy's operational flexibility (Rogoway, 2025a).

In Late August of 2024, the USS George H.W. Bush became the first aircraft carrier to incorporate a dedicated control center for the MQ-25 Stingray, as shown in Figure 12 (Ziezulewicz, 2024). This space, created through a multi-year effort during maintenance periods, features the Navy's first fully operational and integrated aviation MUMT carrier control system. The system functions as the piloting interface for the MQ-25 and is essential for its operation. At-sea testing of the control center is scheduled for early 2025. Other CVNs, including Carl Vinson, Theodore Roosevelt, and Ronald Reagan, will start implementation in late 2025 (Ziezulewicz, 2024).

The MQ-25 looks to supplement and extend manned aircraft, reducing the burden of manned flight hours for aerial refueling and extending its mission to other operational areas once the primary CBARS mission has been proven effective (NAVAIR, 2021). Given that the F/A-18 A-D Hornet has been in service for 40 years, the F/A-18 E/F Super Hornet for 25, modern MH-60 helicopters for approximately 20 years, and even the newest E-2D Hawkeye ISR aircraft for 15 years, it is evident that the Navy is nearing a need for fleet revitalization (NAVAIR, n.d.-a, n.d.-b, n.d.-c, n.d.-d). Establishing onboard control centers, like the MD-5, is the next step toward this concept. These centers allow control of unmanned aircraft and teaming with manned assets (NAVAIR, 2024). Beginning experimentation with these centers and integrating systems like the Joint Fires Network or other proprietary systems will bridge the gap between unmanned vehicles talking with each other and working with their manned counterparts.

Further support for the Stingray is demonstrated in the learned approach of integration by the failure of the Fire Scout. The Navy has established squadrons dedicated to supporting, training, maintaining, and integrating the MQ-25 through VUQ-10, a Fleet Replacement Squadron (FRS), and two planned operational squadrons, VUQ-11 and VUQ-12. The operational squadrons will directly support deployment onboard CVNs under the oversight of the Airborne Command & Control Logistics Wing, which also manages the Navy's E-2s (Burgess, 2021).

Figure 12. MD5 Ground Control Station (GCS) Aboard the H.W. Bush. Source: NAVAIR (2024).

The procurement of the MQ-25 reveals the direction of UAS procurement and the primary path for integrating MUMT into CVWs. However, some lessons that must be learned for future UAS procurements should be gleaned from its acquisition.

- Schedule Delays: Due to failures and challenges presented by supplier management and the complex Full-Size Determinant Assembly process of manufacturing, this system fell behind schedule (DoD, 2023b). This caused subsequent breaches in the APB schedule, LRIP, first CVN flight, IOT&E, IOC, and full-rate production.

- Shifts and Limitations: Shifting priorities for the system and delays have plagued this acquisition. Initially conceived in the early 2010s as the UCLASS program, it was intended to be a stealthy, long-range strike drone. Still, it was restructured into a tanker-first platform after years of debate over its mission focus (Gertler, 2015). While this shift accelerated its deployment, it also reduced its capabilities to refuel missions, potentially compromising secondary ISR missions. It is still unclear if the Stingray will be fitted for contested environments with stealth and lethality as the program's focus was tunneled only to demonstrate aerial refueling (Rogoway, 2025a). This approach should have been pursued earlier as it would have likely delivered a capable system to the fleet earlier. Providing vast requirements on systems, such as in the UCLASS program, leads to confusion and failure. By focusing the requirements on a specific and urgent capability gap, the system has been able to be built and perform as intended, with a path toward building additional capabilities being added to the system (Gertler, 2015).

4. MQ-4C

The MQ-4C Triton is a high-altitude, long-endurance (HALE) UAS developed by Northrop Grumman, based on the Air Force's RQ-4B Global Hawk (DOT&E, 2016). Designed to provide near-constant ISR, the Triton enhances battlespace awareness, is slotted to replace the capability gap of the EP-3E Aries indirectly, and complements the P-8 Poseidon patrol aircraft (DoD, 2023a). It features multi-intelligence (multi-INT) sensors, 360-degree radar coverage, EO/IR cameras, an AIS, and signals intelligence (SIGINT) capabilities (DoD, 2023a). Boasting a mission radius of over 2,000 nautical miles and an endurance exceeding 24 hours, the MQ-4C perpetually supplies Naval-relevant data so long as it can take off and land from a shore installation (DoD, 2023a). The MQ-4C system is shown in Figure 13.

Figure 13. Two MQ-4C Tritons at Northrop Grumman Test Facility in Palmdale, California. Source: DVIDS (2013).

The Triton program originated from the Broad Area Maritime Surveillance program, an initiative launched in the early 2000s to enhance U.S. Navy ISR capabilities. In April 2008, Northrop Grumman was awarded the System Development and Demonstration contract, leading its entry into acquisition (DoD, 2023a). By May 2013, the first Triton prototype conducted its maiden flight, leading to LRIP contracts in September 2016 (GAO, 2024).

Operational Assessments conducted from November 2015 to January 2016 manifested positive and negative trends (DOT&E, 2016). On the one hand, the MQ-4 exceeded target detection and classification ranges set in the capabilities development document, and sending EO/IR video to other assets via Data Link was effective (DOT&E, 2016). However, it was afflicted by lacking "Due Regard" capability to maintain a minimum distance from other aircraft, weak EO/IR sensor control, poor electronic support measures interface to track targets, and Radar overheating (DOT&E, 2016). In August

2016, in motivation from more successful capabilities than deficiencies, the TEMP was updated to Milestone C and moved to LRIP in 2016.

Between 2016 and 2019, the Triton underwent extensive operational assessments, like radar performance verification, EO/IR system calibration, and SIGINT capability testing. The MQ-4C achieved early operational capability in January 2020, with two aircraft deployed to the 7th Fleet (DoD, 2023a). However, testing delays, including sensor integration issues and electromagnetic interference challenges, postponed full operational certification (GAO, 2024).

The program was restructured in 2021, adopting an incremental development approach to maintain alignment with evolving maritime ISR needs (GAO, 2024). In simple terms, increment 1 of the program delivered the basic ISR capabilities via Inverse Synthetic Aperture Radar/Synthetic Aperture Radar, EO/IR sensors, AIS, SIGINT, LOS, and beyond-LOS communication relays, and includes Integrated Functional Capabilities (IFC) 3 and 4. IFC-3 being the iteration that adds SIGINT, 4 being the retrofitted version of the IFC-3 aircraft with functioning multi-INT going into Increment 2 (GAO, 2024). Increment 2 of the program ultimately involves bolstering the IFC-4 version (GAO, 2024). This includes advanced capabilities like ground moving target indicator radar, improving SIGINT specifically to gain geolocation capability, multi-UAV command and control, and see and avoid capability (DoD, 2023a). The Navy plans on spending $2.9 billion in fiscal year 2024 to incorporate increment 2 (GAO, 2024). SIGINT refers to the sensors that allow interception and interpretation of enemy electronic signals to locate or disrupt them. Multi-INT refers to the culmination of SIGINT sensors to intercept and classify enemy signals, which stems into tracking communication signals and detecting and geolocating electronic emissions, like enemy radar (Kritz, 2024).

The first fully equipped multi-INT MQ-4C aircraft was delivered in October 2022, supporting operations from Naval Air Station Jacksonville (DoD, 2023a). The Joint Requirements Oversight Council subsequently reduced the planned procurement from 70 to 27 aircraft, citing revised ISR demands and cost-efficiency measures (DoD, 2023a). The MQ-4C has increased in cost by 117 percent, considering the incremental costs, going from $286 million per unit in the last report to $618 million in the 2024 GAO report. The Navy achieved IOC in July 2023 with two IFC-4 aircraft, suggesting that the remaining IFC-3 variants be retrofitted. According to the 2024 GAO report, the Navy should possess seven fully functional MQ-4s by the end of 2024.

The MQ-4C Triton is operational with the U.S. Navy and Royal Australian Air Force, with additional aircraft undergoing system upgrades (GAO, 2024). Despite schedule delays and cost adjustments, the MQ-4C remains a critical component of the Navy's ISR strategy, supporting strategic intelligence collection across vast distances (GAO, 2024).

System Facts

- Current Stage of Acquisition: LRIP moved into increment 2 of development. Only IFC-3 modified to IFC-4 aircraft are to be procured (DoD, 2023a).
- Procurement Size: 70 desired, 27 procured. No further procurement.
- Total Acquisition Cost: $16.699 billion. 16% decrease since 2023, but also for much fewer aircraft (GAO, 2024)
- Per Unit Cost: $618 mil. 79% increase in fiscal base year 2024, from $286 mil to $513 mil. Considering the second increment costs expected, a 117% increase, from $286 mil to $618 mil per unit (GAO, 2024).
- Capability Gap Addressed: Indirect replacement for E-3PE Aries, complement to assist P-8 Poseidon in long-duration maritime ISR and Mult-INT (GAO, 2024).

Despite its cost overruns, like many acquisition programs, the MQ-4 has become a key asset in achieving maritime dominance, particularly in data collection and threat tracking. Several factors contribute to its continued procurement:

- Revolutionary Technology: The program's active development of multi-INT sensors has considerable value. Even from the outset, the platform effectively communicated relevant information within the data link. Through multi-INT, the MQ-4C will be able to geolocate and track targets, all while feeding a constant battlespace into an all-encompassing combat system, like the Navy is aspiring to utilize. Along with its extraordinary range capability, the MQ-4C can avoid direct harm while providing pivotal information to the users (GAO, 2024).

- Renewed Interest: The MQ-4C is here to stay. The Royal Australian Air Force's purchase of three aircraft and Congress' directive for an additional unit in FY21 helped prevent a significant production pause that could have jeopardized the program's future. With joint interest in the system, the demand for the platform's technology is ever more present. (Katz, 2022)

5. Summary

The U.S. Navy has reached a critical stage of integrating UAS into Naval operations. Significant advances have been made, and this stage represents an evolution in modernizing military techniques to meet ever-changing and emerging threats. Threats that demand more capabilities, innovation, and resilience must be countered. Systems such as the MQ-25 and MQ-4 represent the path forward in closing capability gaps. The push towards unmanned assets that complement manned assets is vital for operational readiness and improving force posture. The Navy is committed to making a more cost-effective fleet and leveraging emerging technology in this pursuit. MUMT is a clear cornerstone of this modernization, laying the groundwork for shaping the future of the Navy. But first, the Navy must understand how to approach the procurement of these systems and where the requirements need to be aligned for the proper integration and sustainment of unmanned systems in the maritime environment.

B. CAPABILITIES-BASED ASSESSMENTS

Upon reviewing existing MUMT programs, a better understanding of correctly identifying and scoping requirements is gained to fill the Navy's capability gaps within carrier aviation. The CBA is the cornerstone of the DoD acquisition process, embedded within the JCIDS. A CBA addresses where capabilities exist and where they are lacking, aligning acquisition decisions with operational priorities and setting the groundwork for creating robust requirements (AcqNotes, 2023). The term capability can be defined differently, but in the context of a CBA, it is defined as “the ability to achieve an objective in a military operation” (Joint Staff J-8 [JCS], 2021). This broadens the scope of the department’s needs to avoid labeling a precise solution to a deficiency, but instead defines it based on desired outcomes. The goal is to answer critical questions about the readiness of the DoD to meet mission objectives and whether the current force is equipped and capable of performing said mission without additional support or systems (AcqNotes, 2023). This assessment aligns the strategic vision of the Navy, CNO, and industry partners to identify what is needed and what can be created.

The CBA process is conducted through three structured analyses: Functional Area Analysis (FAA), Functional Needs Analysis (FNA), and Functional Solutions Analysis (FSA) (JCS, 2021). The FAA establishes the operational framework by defining the tasks, conditions, and standards necessary for mission success (AcqNotes, 2017a). The Tasks section provides the outline for what must be accomplished, the conditions layout of the current operational environment, and standards provide performance metrics (AcqNotes, 2017a). This is followed by an FNA, which evaluates active capabilities and ones that are planned to determine if they meet the standards set (AcqNotes, 2017b) To conclude, an FSA identifies potential solutions to the identified gaps, considering both materiel and non-materiel solutions. (AcqNotes, 2017c). These analyses are guided by a study plan that scopes the assessment, aligns it with strategic guidance, and categorizes the challenge as traditional, irregular, disruptive, or catastrophic (JCS, 2021).

The CBA is the beginning of the process of discovering what is needed to fill a capability, which will then be used to create an Initial Capabilities Document (ICD), used as the decision document to continue or stop seeking a solution (JCS, 2021). This is shown in Figure 14, with the CBA as the tip of the spear for any acquisition.

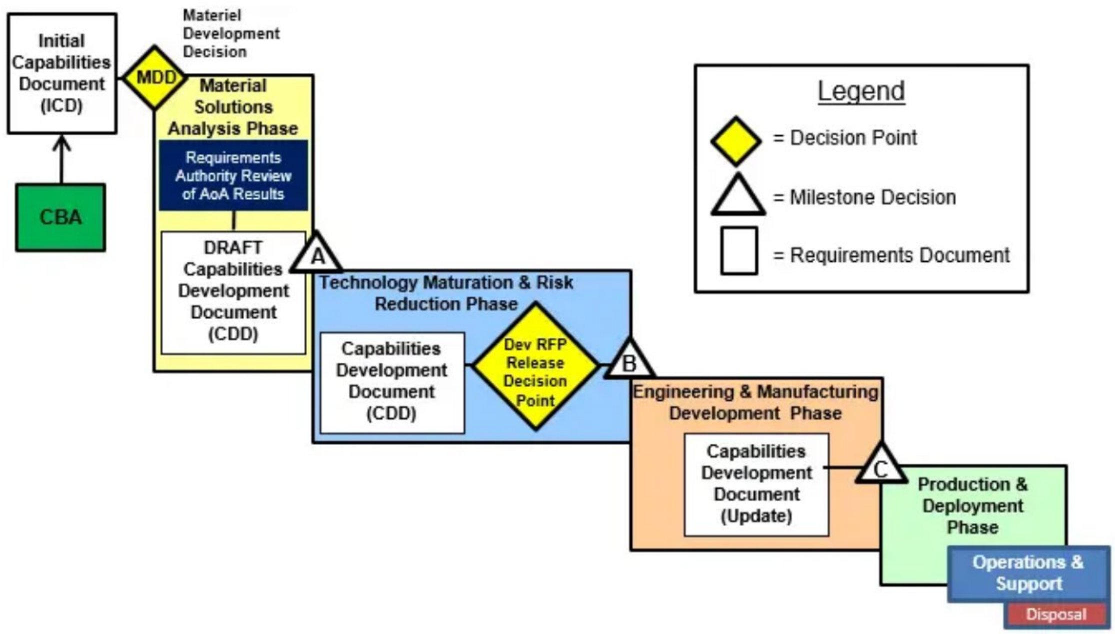

Figure 14. Defense Needs Identification and Solution Process. Source: AcqNotes (2024).

This capstone research will not provide an exhaustive CBA, as most CBAs weren't concluded for six months to four years (JCS, 2021). Depending on the scope, a CBA can take 60–180 days, with simpler assessments completed in 60–90 days and complex new missions requiring up to 180 days (Defense Acquisition University, n.d.). The CBA process is supported by a study team, often comprising a "front desk" for external coordination and a "back shop" for analysis and documentation (JCS, 2021). The team develops a study plan that incorporates six analytical elements: tasks, conditions, standards, effects, ways, and means; these provide a comprehensive framework for evaluating solutions (JCS, 2021).

The components of an ICD are, paraphrased: a short explanation of the mission and what success looks like, a list of mission areas and planning scenarios, a description of required capabilities and when they are needed, a description of the capability gaps or redundancies and how they are measured, a summary of threats and their operational environment, proposals for non-materiel solutions, and then final recommendations (JCS, 2021). These components are all developed from information found in the CBA. Simply put, the CBA articulates which military problem is to be studied, examines it, assesses how well the DoD can address it given its current ability, and then provides a general recommendation for solutions (JCS, 2021).

There are several types of CBAs depending on the context and scope of the capability gap identified, but a general process is standard: identify current capabilities, analyze capability gaps, develop solutions, prioritize requirements, and then document these findings and ultimate recommendations for leadership (JCS, 2021). The CBA User's Guide provided a taxonomy of six types of CBAs. The one relevant to our purposes is one based on perceived future needs or the failure of an existing program.

The six elements are:

1. Tasks involve formulating the concepts of operations that the solution considers: what do we want to do?
2. Conditions refer to the scenarios that can be used to test a solution in its intended operating conditions, the situation we expect.
3. Standards are the measures of effectiveness (MOEs) that will evaluate the solution.
4. Effects are capabilities the solution should have to achieve an objective.
5. Ways are the functions of that solution, whether it's battlespace awareness, logistics, etc.
6. Means assesses the type of solution that can be considered, given policy, treaties, or other limiting circumstances (JCS, 2021).

In the context of this capstone research, the CBA framework is essential for analyzing capability gaps in carrier aviation, particularly for integrating MUMT. While conducting an extensive CBA is beyond the scope of this research, the principles of FAA, FNA, and FSA will guide the assessment of Naval Aviation needs. Reviewing prior MUMT programs and applying CBA methodologies, this research aims to identify how MUMT can address operational deficiencies, ensuring recommendations are grounded in validated requirements.

C. DOTMLPF-P

Fundamentally, a DOTmLPF-P analysis evaluates whether non-materiel solutions would be viable to address a current capability gap and seeks to determine whether those solutions would have any broader implications (Non-Materiel (DOTmLPF-P) Analysis and Documentation (DCR), n.d.). Two primary purposes are served within this analysis. The first purpose is to assess whether non-materiel changes can eliminate capability gaps found in the FNA, and second, if a materiel solution is proposed, the broader implications are identified for necessary support in integration. The analysis is conducted across eight areas:

1. Doctrine: The methods of operation and combat strategy.
2. Organization: Structural arrangements for missions.
3. Training: Preparation of personnel for tactical and operational effectiveness.
4. Materiel: Equipment and tools that do not require new development.
5. Leadership and Education: Development of leadership capabilities at all levels.
6. Personnel: Availability of skilled individuals for operations.
7. Facilities: Infrastructure and installations required for operations.
8. Policy: Regulations and guidelines influencing other elements (Non-Materiel (DOTmLPF-P) Analysis and Documentation (DCR), n.d.).

Before the Materiel Development Decision, the analysis focuses on non-materiel solutions to capability gaps, typically resulting in a DOTmLPF-P Change Recommendation (DCR) document, which an ICD may accompany if a materiel solution is also being considered (Non-Materiel (DOTmLPF-P) Analysis and Documentation (DCR), n.d.)

D. SUMMARY

This chapter evaluated four significant UAS acquisition efforts to understand the approach to integrating maritime platforms. The Coast Guard VUAV revealed how funding instability, regulatory hurdles, and immature technology can derail programs. The VUAV's failure occurred nearly two decades ago. Yet, many of its pitfalls, such as inadequate integration planning and reliance on unproven technology, would resurface in later UAS programs despite the JCIDS process being intended to reverse this trend. The MQ-8, developed for ISR aboard the LCSs, delivers some operational value yet suffers from high costs, inconsistent technology performance, and poor integration planning. The MQ-25 is a more successful programmatic effort initiated after the UCLASS program. The program's focus was limited to aerial refueling, and it was looking to expand after a successful demonstration of its potential capabilities. The program leveraged open architecture, incremental upgrades, and dedicated integration infrastructure, which are now being incorporated. While delays and costs persist, it is slotted to fill a relevant capability gap and shows progress in carrier integration. The MQ-4C is intended to serve as a long-range ISR asset to supplement P-8s. Despite significant cost growth and reduced procurement size, the Triton extraordinary technology is maturing to create a key asset for persistent ISR. Its multi-INT sensors will saturate the prospective Project Overmatch with continuous, relevant data.

Understanding these programs and the initiatives to mature MUMT within the Navy, a better comprehension of the capability gap that MUMT needs to address and how it should be addressed can be gained. This will be analyzed through a shortened CBA and DOTmLPF-P assessment. The CBA seeks to identify operational deficiencies and align requirements to determine what solutions should be pursued. The DOTmLPF-P analysis complements the CBA in evaluating whether non-materiel solutions can be sought after to close the capability gap. These frameworks, conducted in the following chapter, will align acquisition with strategic needs and current capability.

IV. ANALYSIS

This chapter formally analyzes the capability gaps that exist for the United States Navy and identifies potential solutions to mitigate or eliminate these gaps through non-materiel means. Recommendations and findings from the analysis are presented to highlight areas requiring change or restructuring, providing insight into the landscape of carrier-based operations and supporting UAS roles in this field.

A. CAPABILITIES-BASED ASSESSMENT

1. Assessment

As mentioned, CBAs are conducted over months by a large interdisciplinary team. Comprehensive and detailed research on the issue at hand is conducted in conjunction with feedback from warfighters and other stakeholders to identify the capability gaps present. As discovered in the UCLASS program, scope creep is the antithesis of a successful endeavor; therefore, this study does not employ an exhaustive methodology. This analysis adopts a more conceptual approach, aiming to map the desired capabilities in the maritime environment, measure their effectiveness, and explore how they can contribute to filling an identified gap.

According to the 2024 U.S. Military Strength Index Assessment, Brent Sadler rated the U.S. Navy's overall power as "weak," highlighting its inadequate size and equipment to counter the navies of Russia and China effectively (Sadler, 2024). This assessment is critical in future conflicts, which are anticipated to emphasize long-range engagements and systems disruption. This assessment reveals the need for rapid advancement in defensive systems for the U.S. Military, particularly in aviation. If advancement isn't made, the Navy will decline further relative to its adversaries (Sadler, 2024). The fleet sits at 298 ships and is projected to decrease to 280 by 2037 (Sadler, 2024). It has also increased personnel shortages, leaving a less capable Navy (Sadler, 2024). Furthermore, adversaries are rapidly advancing, while the U.S. Navy faces an aging fleet hindered by maintenance backlogs (Sadler, 2024). With these massive obstacles ahead for the Navy, MUMT emerges as a solution that could potentially bridge the gap between an aging fleet and one with advanced operational capabilities. MUMT may represent an encompassing capability advantage that can operate in a vast array of environments, whether the contested straits of Taiwan or the vast expanse of the South China Sea.

Aside from the weakness of the current U.S. Naval capability, our adversaries, particularly China, are actively progressing their unmanned systems capabilities. At this point, China is ahead of the United States in the number of ships due to the rapid development of smaller vessels, while the United States outpaces in displacement due to larger vessels like destroyers, cruisers, and CVNs, which some argue to be the more critical factor in maritime dominance (Palmer et al., 2024). China has more frigates and corvettes, smaller ships that are better suited for large-area coverage, which the U.S. Navy recognizes it needs to expand. To make matters worse, China has 230 times the shipbuilding capability of the U.S (military and commercial) and can thus logistically support its massive Navy (Palmer et al., 2024). As of a late 2024 DoD report, China is getting close to meeting the capability of Air Force drones, with platforms like the WZ-7 Soaring Dragon, WZ-8, and GJ-11 combat air vehicle (Easley, 2024b).

By 2030, China will be able to field a range of network-centric warfare utilizing AI and machine learning for autonomous unmanned systems to provide ISR and conduct precision strikes (Easley, 2024b). Its stealth drones are potentially years ahead of the United States, with systems that use air pulses to steer fixed-wing aircraft rather than using conventional control surfaces (Potter, 2025). This drastically increases stealth capability, and on top of extraordinary advances in energy consumption, China's unmanned systems currently have more stealth and endurance than those the United States possesses (Potter, 2025). China has been developing this technology since 2021, compared to the DARPA X-65 program starting in 2023 (Potter, 2025).

Programs like the Fire Scout had significant shortcomings, putting into question how much of a reality UAS and MUMT would be for the U.S. Navy in the near future. However, these systems have positive momentum and necessitate infrastructure and monetary support. Technology needs to be implemented and appropriately sustained. MUMT offers that path forward to enhance operational effectiveness.

This CBA evaluates MUMT integration through six primary elements: Tasks, Conditions, Standards, Effects, Ways, and Means. The analysis, guided by these guidelines, provides acquisition and implementation strategies to address identified capability gaps. As seen in Figure 15, the total CBA process is extensive; however, this research includes the study plan as a precursor to a comprehensive CBA. This serves as a concise version of a CBA to identify capability gaps that MUMT can satisfy and how that will be accomplished. It also serves as an analysis of how individual UAS programs will interplay with the overarching framework of MUMT, which is the current push for the Navy.

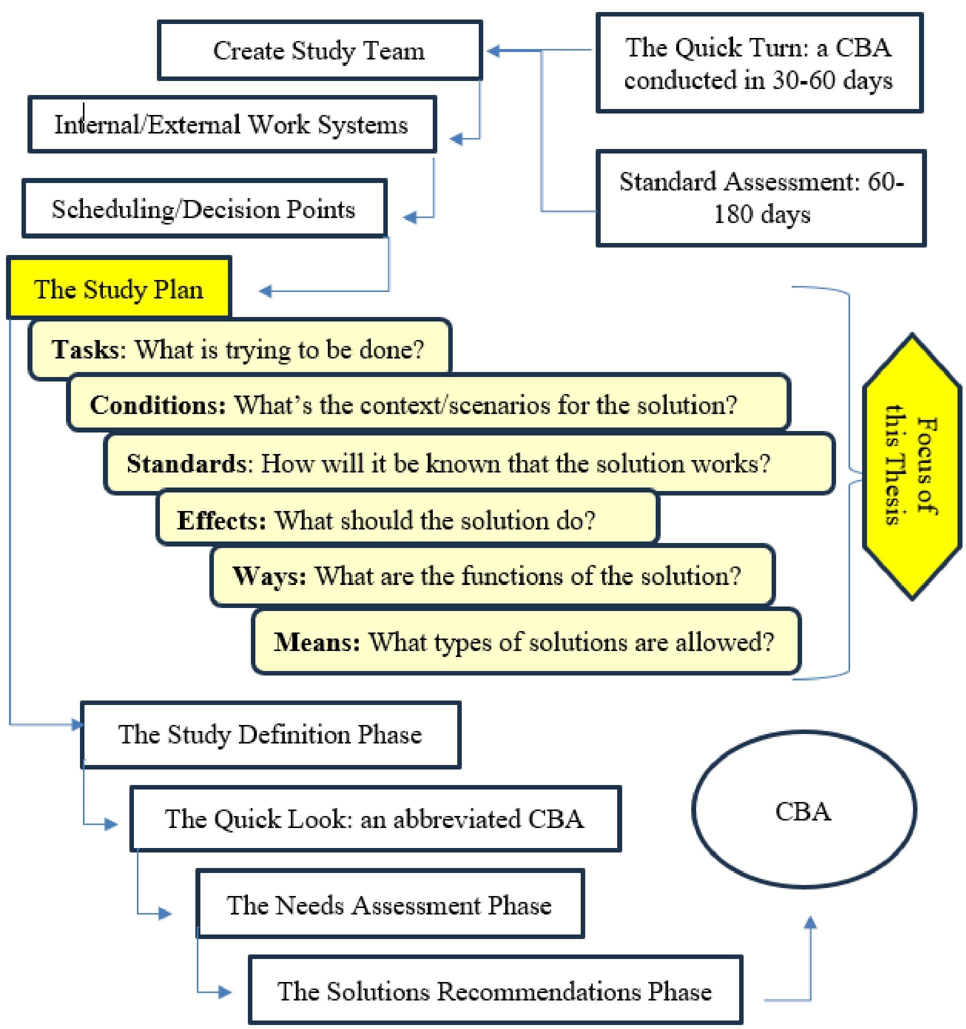

Figure 15. CBA Process and Scope for Thesis. Source: JCS (2021).

a. Tasks

The primary task of MUMT within Naval Aviation is to supplement the traditional roles of manned systems in maritime operations with UAS. The roles that will be augmented are ISR, strike, EW, ASW, and logistics support (Commander, Naval Air Force, 2025). Specific challenges must be considered in CVN airborne operations, including launch and recovery, unique maintenance and training, requirements, and effective integration into the fast-paced carrier deck operations. The goal with MUMT is to be enveloped and supported by Project Overmatch to produce a Joint All-Domain Command and Control (JADC2) with data sharing across forces for real-time decision-making (Shelbourne, 2020)

(1) Roles Within Naval Aviation

The Navy has shifted focus to incremental progress for UAS development and is leaning into role-specific platforms to simplify designs. The Unmanned Campaign Framework presents the development style of "Build a Little, Test a Little, and Learn a Lot," inspired by the AEGIS program for iterative programmatic growth (Department of the Navy [DON], 2021; Huang et al., 2012). Programs like the MQ-8 demonstrated the complexity of integrating UAS without proper guidance as to what role the system is to fill. The MQ-25 integration has taken an alternate approach that will likely pay dividends for the future capability of the system. Shifting from the massive scope creep of the UCLASS program, focusing solely on aerial refueling has allowed the system to be built and incorporated into CVNs. The systems' primary purpose is to extend the range of carrier-based aircraft, but once the concept of operations is demonstrated successfully, the open architecture of the system allows for the secondary implementation of ISR capabilities (LaGrone, 2025). "Stingray to the Fight," in future phases, could expand the Stingray's scope of operations as the system develops into more environments and capabilities (LaGrone, 2023).

At its core, the motivation for unmanned aircraft is risk mitigation. Putting a comparably cheaper asset with no risk to human life, nor minimal human error to risk, allows "additional warfighting capability and capacity to augment our traditional combatant force, allowing the option to take on greater operational risk while maintaining a tactical and strategic advantage" (DON, 2021). Unmanned systems inherently are risk-averse if they can be tasked accordingly. What they are not optimal at, as the MQ-8, VUAV, and UCLASS programs have shown, is that each vehicle provides the best operational capability and cost efficiency when it has one key role to focus development efforts and avoid requirements or scope creep. Just as normal manned assets are mostly centralized in roles, such as the Super Hornet for strike, the Growler for electronic attack, and the Hawkeye for command and control, with some cross-utilization, the unmanned components should be no different. This approach will enable focused UAV development and integration into carrier operations. After all, the target is to make the future carrier-based fleet 60% unmanned with the aid of the Air Force (Trevithick, 2023a).

(2) Integration of UAS into Carrier Ops

UAS integration will likely be delayed or fail if it is not concurrently developed with the necessary infrastructure and training systems, as seen in previous unmanned programs. The Navy has made significant progress on this front, specifically for the Stingray, by installing the world's first Unmanned Air Warfare Center (UAWC) aboard the USS George H.W. Bush (CVN 77), with the Unmanned Carrier Aviation Mission Control System and MD-5E Ground Control Station (GCS) that serves as the control room to manage MQ-25 operations (NAVAIR, 2024). Powered by Lockheed Martin's Skunk Works Multi Domain Combat System, the UAWC is the baseline for future installations on carriers like CVN 70, 71, and 76, with work beginning in FY2025 (Daigle, 2024). This allows air vehicle pilots (AVP) to control UAS aboard CVNs and integrate them into CVW operations. The Navy is working to train personnel for these systems through dedicated squadrons. However, maintenance personnel and deck crews must also become familiar with these systems in terms of handling, operating, and sustaining UAS. Simulation and virtual training tools will help prepare personnel before deploying physical systems fully. The Navy can ensure operational readiness upon MQ-25 deployment in 2026 by aligning infrastructure and training development with platform timelines (Daigle, 2024).

These issues must be understood as practical steps in integrating developed systems. Still, no task force has been commissioned to build UASs and direct the MUMT experiment. This action could significantly accelerate the process of filling this capability gap.

(3) Applying Project Overmatch

Project Overmatch, the Navy's goal of creating a joint battle network, is pivotal for UAS and MUMT to reach their full operational potential. JADC2 will drastically change how warfare is conducted, making it network-centric and equipping leadership with an enhanced wartime picture that enables better and more informed decision-making (Shelbourne, 2020). Link 16 or future JADC2 networks in development will equip UAS with seamless transmission of pertinent data, enabling them to receive commands and intelligence updates. Project Overmatch is led by Rear Admiral Doug Small, who has emphasized UAS roles in EW, where he describes their integration as a "killer app" for fleet capabilities and that it is a "growth imperative" (Demarest, 2024). The support for this battlefield network and the push to integrate this into operations was demonstrated by the contract award to EpiSci for mission autonomy through software that enables collaborative multi-domain swarming by USVs and UAVs in support of Project Overmatch (Naval News, 2024). This all works together to form a system of systems that support and operate in conjunction with one another to enhance situational awareness on the battlefield and ensure effective command and control.

b. Conditions

The broad spectrum of factors that allow for closing a capability gap is much less theoretical and, therefore, much more difficult to analyze at an unclassified level. Even with more available information, the following would be key limiters: program timelines, operational environments, budgetary limitations, system availability, and the level of implementation support.

(1) Timeline

Evaluation of what constitutes a feasible timeline for addressing a capability gap is essential. In the scope of this CBA, the practical horizon for planning and implementation is roughly 10 years to align with the Naval Aviation Enterprise's vision for the future of Naval Aviation (NAVAIR, 2021). There are three recommended phases in the timeline for MUMT integration in the Navy, adapted from the FYDP: short-term, medium-term, and long-term. The short-term phases, spanning 1–5 years, aim to deploy the MQ-25 Stingray for aerial refueling by 2026 and explore the feasibility of potential ISR capabilities (Eckstein, 2023a). The medium-term phase, spanning 5–10 years, aims to develop additional capabilities for UAS, including strike and EW capabilities. The long-term phase, 10+ years, should see the full development of MUMT using experimentation and lessons learned from the expansion of Stingray's mission roles and cooperation with other departments' development efforts in MUMT.

(2) Environments

These platforms and the MUMT system must function reliably under all weather conditions, both at night and during the day, in both open ocean and littoral environments, and seamlessly integrate into the carrier's command and control infrastructure. Operational environments are anticipated to involve high-intensity conflicts, particularly in the Indo-Pacific, characterized by anti-access/area denial (A2/AD) threats, long-range engagements, and electronic warfare (O'Rourke, 2025).

(3) Budget

It is assumed that budgeting for UAS will likely decrease due to the prioritization of Columbia class submarines and the development of the Constellation class of frigates as well (Trevithick, 2023a). The budget for unmanned vehicle research and development for the Navy in FY25 is $1.75billion (U.S Navy, 2024). The overall investment in UAS for the entire DoD in FY25 is $2.4billion (Office of the Under Secretary of Defense, 2024b). With this consideration, it is reasonable for the Navy to pursue close collaboration with the Air Force in developing MUMT while continuing to build its own UAS to meet service-specific requirements. The Navy is also requesting $139.8 million for Project Overmatch in FY2025 and $716.7 million across the future year's defense program (Harper, 2024). The United States is not alone in this effort; therefore, collaboration with industry and allies, such as Australia and the United Kingdom, could help reduce research and development costs.

(4) Availability

It is assumed that the MQ-8, MQ-25, and MQ-4 will all be utilized in the fleet, in which the MQ-25 and MQ-4 should reach LRIP within 10 years, and the MQ-25 should be integrated into MUMT within 2026 (Trevithick, 2025). However, that does not mean extensive numbers will be present in carrier air wings.

(5) Implementation Support

Another key condition closely related to availability is the applicability and integration of MUMT, specifically in carrier operations. Only the MQ-25 and MQ-8 can currently integrate into carrier operations, and trained personnel and control and administrative systems must be present to see the MUMT-carrier relationship to fruition.

c. Standards

In principle, the standards established in this CBA serve as the measures of effectiveness for evaluating potential solutions. Within this context, the primary MOE is the Navy's ability to address its identified capability gap, specifically by replacing its aging fleet with technologically advanced unmanned systems capable of countering a future near-peer threat.

(1) Inventory

Inventory size indicates preparedness and ability to fill the capability gap. Inventory goals include deploying 5–8 UASs, specifically MQ-25s, per carrier air wing by 2030 (Trevithick, 2023a).

(2) UAS Performance

Other standards include integration with carrier operations, operational reach, and success in its intended missions. Reflecting the success of the MQ-4C program, any UAS should be able to provide persistent, high-quality data and be difficult to jam. By and large, feeding constant intel that AI can interpret is an advantageous capability that MUMT can provide. UAS performance metrics will vary from system to system. It cannot be condensed into a single set of metrics unless the complete set of requirements is established and key performance parameters are developed, which is beyond the scope of this research. However, from previous system examples, some a general idea of performance parameters can be pointed out, such as parameters that encompass endurance (nearly 16 hours for the MQ-25), range extension (500 nautical miles), payload capacity (15,000 pounds for MQ-25), and overall mission success rate reliability depending on what mission set is required (DoD, 2023b; LaGrone, 2017; Rogoway, 2025a). Additionally, although not measurable at an unclassified level, modern UASs should utilize innovative design and electromagnetic wave-absorbing materiels to optimize undetectability by radar as much as feasible.

(3) MUMT Performance

MOEs for individual programs and platforms are difficult to pinpoint. However, it is essential to focus on capability-specific metrics. Initially pursuing UAS, the Navy focused on developing the individual platform rather than the overall concept. The Navy is finally shifting to an open-architecture, capability-centric approach, as seen in Figure 16.

MUMT performance, like overall UAS performance, can be measured using various quantitative and qualitative metrics. The metrics vary from system to system and depend heavily on the mission area. Some examples of performance standards would be the percentage increase in mission success rates and efficiency compared to manned-only operations, the risk reduction to manned aircraft, data latency for autonomous tasks, and times for launch and recovery (Airbus, 2025; O’Neill et al., 2022; Pandey, 2025). These MOEs ensure that MUMT meets operational requirements and enhances the capabilities of the carrier air wing.

The Navy should consider creating MOEs for the AI systems used in command systems, such as the MD-5, and for the simulators and trainers needed to implement MUMT. Other MOEs should be explicitly created for each combat role, such as strike and ISR, assuming similar or better performance than pre-existing manned assets. In addition to these, MOEs specific to MUMT performance, such as data flow rate, integration with the control system (like MD-5), and development of Naval air training and operating procedures for training purposes, could be included.

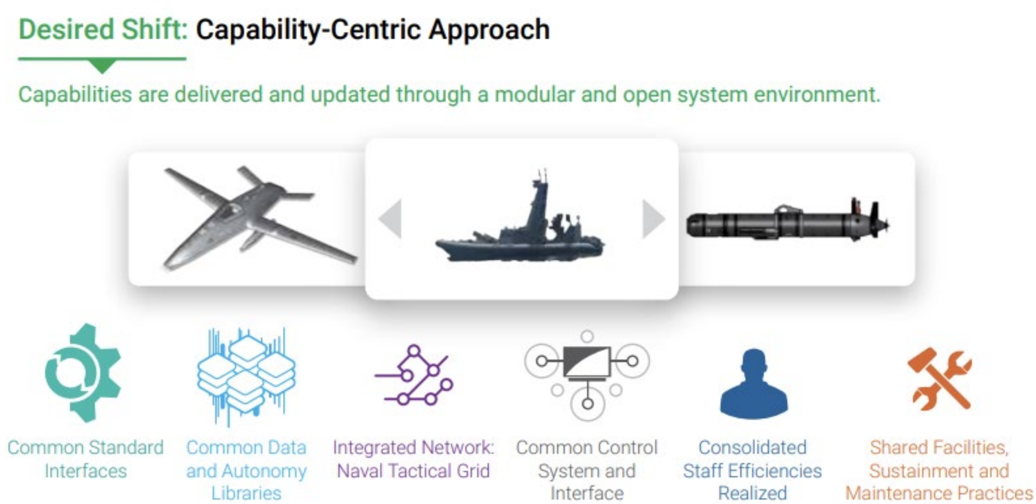

Figure 16. Capability-Centric Approach Source: DON (2021).

d. Effects

The CBA, or the desired capabilities, enables a MUMT integrating control system and UAS that can complement the combat roles of the carrier air wing. Effects include reliable system connectivity, connectivity with multiple unmanned assets, accurate AI interpretation of data, and seamless integration into carrier air wing day-to-day operations. Looking solely at what is readily available and realistic within the 10-year time frame for this CBA, vehicle-specific effects include persistent data ISR, reliable refueling, general reliable control by manned assets, correct autonomous function, and low unit cost.

The effects that MUMT seeks to achieve include extended force protection and operational distances, providing assets in contested environments with lower risk than manned assets. The MQ-25 looks to extend the CVW range by 500 nautical miles, reduce expended flight hours by pilots, and eventually provide ISR capabilities (DoD, 2023b). Coordination in MUMT operations will lead to better target engagement capabilities and increase survivability in enemy engagements, as manned aircraft will have reduced exposure. This will allow for more flexibility and support the DMO concept, emphasizing the distribution of lethality and network operations (Shelbourne, 2020).

e. Ways

Regarding this CBA, the functional means are the specific ways needed to fill the capability gap. Mimicking China's rapid expansion of unmanned and long-range weaponry (O'Rourke, 2025) is a way to ensure capability in a future conflict. Inserting MUMT into the functions of the CVW can supplement management and act as a force multiplier. Aerial refueling, provided by UAS like the MQ-25, extends the operational range and time on station for manned aircraft (NAVAIR, 2021). ISR functions involve collecting and disseminating real-time intelligence to support target identification and informed decision-making. Strike operations enable an armed UAS to conduct offensive missions independently or in coordination with manned aircraft. EW functions include jamming and deception to disrupt enemy systems. Logistics support may involve UAS delivering supplies or performing other tasks. Command and Control (C2) is facilitated by systems like the MD-5 Unmanned Carrier Aviation Mission Control System, which manages unmanned assets. Networking and data sharing, integral to MUMT, ensure seamless information flow across joint forces through Project Overmatch, which aims to create a Naval battle network for enhanced decision-making (Shelbourne, 2020). This interoperability between a central network and information sharing between vast numbers of vehicles inside will strengthen Naval Aviation's preparedness for a future conflict.

f. Means

The CBA's means of implementation are strictly focused on carrier-based means. Only the air wing can ensure that MUMT can be integrated, and only by working with industry can the best UAS development occur. Thus far, no international treaties or documentation limits the use of unmanned systems in warfare or its development in the states. Nonetheless, the domestic development of MUMT must adhere to FAA guidelines and ensure safe experimentation.

The means for MUMT integration encompass a range of resources and solutions. Key UAS platforms include the MQ-25 Stingray for aerial refueling and potential future fixed-wing UAS for strike and EW roles. Control systems, such as the MD-5, are essential for managing UAS operations from carriers, with plans to control all carrier-based UAS in the future (NAVAIR, 2024). Communication infrastructure is paramount in supporting MUMT operations, such as Link 16. Training for aircrew, deck personnel, and planning is critical for the bottom-up adoption of these systems. Budgetary allocations prioritize UAS development, with the Navy seeking significant funding for Project Overmatch (Harper, 2024). Collaboration with industry partners, such as Boeing and Lockheed Martin, and international allies, including Australia and the United Kingdom, can reduce costs and accelerate development. Adapting existing technologies, such as the MQ-4 Triton, and incorporating advanced equipment for carrier-based UAS could potentially help expedite the development of these capabilities.

2. Results

The CBA indicates that, without accelerated progress, the Navy may not be fully equipped to leverage UAS effectively in a potential future conflict. The Navy's reliance on manned platforms limits its long-range strike, air-to-air combat, and defensive capabilities against near-peer adversaries (NAVAIR, 2021). MUMT offers a scalable and flexible solution to address these gaps, with fixed-wing UAS like the MQ-25 providing superior maneuverability and adaptability for carrier operations (NAVAIR, 2021). However, budget constraints, technological readiness, and policy uncertainties must be addressed.

The debate over single-role versus multi-role UAS designs suggests a preference for specialized platforms to reduce costs and complexity. To assist in this categorization of UASs into MUMT, there should be an expansion of the ability for manned assets to directly interact with unmanned platforms, both on and off the ship. Collaboration with the Air

Force is essential for advancing MUMT while preserving Navy-specific requirements. Following the lead of the MQ-25 and MD-5 will be a step in the right direction for both Naval Aviation and the Air Force. In support of maritime strike, the Air Force and Navy are working together to ultimately develop the Collaborative Combat Aircraft (CCA), which is part of the Navy's Next Generation Air Dominance (NGAD) (Trevithick, 2023a). The CCA is slotted to be a smaller and more expendable asset that will be "picked up" by manned assets (Trevithick, 2023a). It will travel with them and provide any support role desired, ultimately extending the range and survivability of manned assets, as the CCA could either stop incoming threats or sacrifice itself (Trevithick, 2023a).

This program will see that these companion drones can operate with manned assets, specifically the NGAD platforms, and F-35s, serving as force multipliers (Trevithick, 2023a). The Air Force and Navy are standardizing four key components: autonomy, mission systems, communication architectures, and networking. This is to ensure interoperability with plans to enable cross-service control of drones (Trevithick, 2024). However, Naval Aviation faces unique challenges, including catapult launches, arrested recoveries, and operations in harsh maritime environments, necessitating tailored UAS designs. The Navy's F/A-XX program, part of NGAD, underscores this collaboration, with shared enabling technologies ensuring interoperability while maintaining carrier-specific capabilities (Trevithick, 2023a). This joint effort reduces development costs and accelerates innovation, but the Navy must vigilantly protect its operational requirements to ensure MUMT's effectiveness in carrier air wings. At the end of July 2025, an internationally contributed demonstration of the remote control of several UAVs will be held at the Woomera ranges in Australia (Trevithick, 2024a). The Boeing Australia-produced UAV depicted in Figure 17 features the MQ-28 Ghost Bat (Trevithick, 2024a). This initiative has developed a Navy prototype intended for the Royal Navy, which the U.S. Navy could consider in the future for the CCA concept.

The CCA concept is already taking shape. The Navy is planning to have these unmanned companions directly support the sixth-generation Navy jet currently in the works, the F/A-XX (Trevithick, 2024a). The concept of operation for that jet is to "quarterback" other smaller units into assisting its missions, which will most likely seek to replace the F/A-18 Super Hornets in the 2030s (Trevithick, 2024a). The Navy version of CCA would aim to be no more than $15 million per unit, with a shorter life span and lower sustainment costs (Trevithick, 2024a). The CCA program leverages MUM's advantage in harnessing advanced sensors in a compact system, allowing humans to remain farther away from the line of fire.

Figure 17. MQ-28 Ghost Bat (Left) and MQ-25 Stingray (Right). Source: Trevithick (2023b).

Through this analysis, unmanned systems, although they may branch into every role in Naval Aviation, should be further developed in ISR, maritime strike, and electronic warfare. These roles leverage their inherent strengths in powerful onboard computing, sensing capabilities, and adaptable and expendable systems. Conducting ISR in contested environments using their complex sensors, cameras, and intertwined networks is an innate advantage of unmanned systems. It can supplement Super Hornets and the Hawkeye for this role. For strike, whether using the next CCA concept and/or outfitting variants of the MQ-25 with strike capability, utilizing the expendability of unmanned systems is a risk mitigation action for combat missions.

Not based on a preexisting effort, consideration should be made to include MUMT in electronic warfare and ASW. Electronic warfare is essential for modern warfare. Yet, ironically, the E/A-18 Growler is the only offensive, "stand-in" electronic warfare capability in the entire U.S. military (Tegler, 2022). The Air Force utilizes Growler protection to help jam enemy threats and mask precise locations. Known in the Navy is that, so long as it is feasible, every mission exposed to enemy radar should have a Growler with it (Tegler, 2022). However, Growlers have half the range of Super Hornets and F-35 Lightning IIs (Tegler, 2022). The Navy's Next Generation Jammer, which would replace the Growlers ALQ-99 Tactical Jamming System, reached development and operational testing in 2022 (Tegler, 2022). Its fulfillment could pave the way for integration into unmanned systems, allowing them to effortlessly escort manned assets into combat zones and provide electronic warfare support.

Lastly, there is potential in the idea of utilizing unmanned systems for ASW. P-8 Poseidon's are the standard for above-water anti-submarine engagement (GAO, 2024). The M/H-60R is a competent ASW platform, but its range and endurance are inherently low (DOT&E, 2024) Both manned platforms are vulnerable to detection and engagement, yet their operational environments could become active patrolling engagement areas for extended periods. An unmanned platform that could extend the scanning range of either of these assets and potentially disrupt a threat headed for the manned asset could be an extraordinary opportunity to mitigate risk while enhancing ability simultaneously.

Other roles such as logistics, refueling, and MCM are advantageous areas to pursue for unmanned systems due to low-risk environments of operation. This provides a test bed outside of contentious environments for these systems. Aviation logistics is a relatively low-risk evolution easily executed by the V-22 Osprey and MH-60S manned systems (PteroDynamics, 2025). However, this pulls qualified and capable personnel away from other positions that could be filled. Though these mission areas require intricate coordination with deck crews, the proof of concept has been demonstrated, and the low-risk environment allows for complex development and integration to be honed and mastered. The Navy has already awarded PteroDynamics of Colorado Springs a contract to build a VTOL UAS for logistics (PteroDynamics, 2025). Furthermore, the MQ-25 has demonstrated the capability for refueling with certainty now, and the MQ-8, even in its limited numbers, can conduct MCM. This solidifies the ability of these systems to perform these missions, but they require full support, continued development, and sustainment for many years to come. The unique environment of logistics, refueling, and MCM have been the primary drivers for increased UAS adoption to free qualified personnel towards other Naval platforms and will likely be the first stepping stone into further integration into Naval Aviation.

With these considerations in mind, the ideal task for MUMT is to focus on one mission set at a time. Ensure that MUMT has the infrastructure to link between manned and unmanned assets. Then, develop each unmanned platform or different models for one role that can be incorporated into this system. This will ensure ease of integration and cost-effectiveness. Additionally, the Navy should consider unburdening its research and development efforts by prioritizing combat-specific roles and considering the purchase of well-developed UAS platforms, such as the MQ-28.

Regarding integration, the Navy is on its way to UAS integration with its UAWC onboard the USS George H.W. Bush, which will act as the infrastructure that enables further integration of other UAVs and MUMTs on different ships. However, greater learning for both machines and humans should be facilitated to supplement this.

These inter-asset systems must be appropriately connected to feed Link 16 or JADC2 within the overall Project Overmatch concept. Rear Admiral Stephen Tedford, Program Executive Officer for Unmanned Aviation and Stike Weapons, addressed the need for generative AI networks and, consequently, the need for vast computers as the key to testing and using the next-generation UAVs (Trevithick, 2024a). Specifically, large cloud-based computers that can simulate and run millions of test simulations are a way to support programs, such as the CCA, that feature extremely complex systems requiring autonomy (Trevithick, 2024a). Whether outsourcing this potential to industry or purchasing simulators outright, the Navy must invest in the infrastructure to control and experiment with these drones. These computers would aid in experimenting with UASs as they are developed and in incorporating them into Project Overmatch, which requires generative AI to analyze vast amounts of data (Trevithick, 2024a). The UAWC is envisioned as a direct component of Project Overmatch, where different control centers, whether ships or aircraft, can take control of and utilize unmanned assets as necessary. The Navy needs to strengthen cooperation with industry, specifically companies like Anduril, which are actively developing AI interfaces that connect different UASs and enable them to be controlled by experienced operators (Anduril Industries, 2024). The solidification of an interface for Project Overmatch is paramount not only for the Navy but also for the Air Force, enabling seamless control, comprehension, and rapid distribution of acquired data, and providing a solid, uniform base for training personnel to utilize these air vehicles.

In terms of environments, the carrier-potential UASs thus far, the MQ-8 and the MQ-25, have shown to be capable of enduring inclement weather and boasting beyond line-of-sight communication. More operational test and evaluation (OT&E), through the standard acquisition cycle, can verify and validate that these UASs, both the vehicle itself and its communication within the MUMT network, can operate in combat environments.

Another critical condition, though it cannot be accurately estimated at an unclassified level, is the general budget that should be anticipated to give MUMT the necessary vigor to be primed for a future conflict. Yet, fixed-wing UAS offers unmatched maneuverability, expendability, and adaptability, making them ideal for ISR, EW, and scalable strike capabilities against surface threats. Consequently, the Navy should consider redirecting resources from USV research and development, beyond existing small and medium platforms, toward UAS and UUVs. The MQ-4 Triton's advanced sensors, such as the Multi-Platform Radar family of systems, should be adapted for carrier-based UAS to bolster ISR capabilities, even if the MQ-4 remains land-based. Collaboration with partners is also essential.

If the Navy wants to make 60% of its entire fleet unmanned, it could be assumed that 60% of the CVW should also be unmanned. It is unlikely to be completed within a 10-year timeframe. Nonetheless, MUMT should receive a percentage of funding similar to this percentage of utilization. Utilizing the Department of the Navy FY2025 presidential budget request, 21% of the $77 billion for procurement goes to aircraft, and of the $25 billion research and development budget, 7% goes to unmanned UASs, UUVs, and USVs, so 2.3% to UASs regardless of the recommendation to prioritize UAS and UUV –12% goes to aircraft, and 10% vaguely goes to "next generation," which may be assumed as the next generation concepts like the NGAD (U.S Navy, 2024). In all, that means $16.17 billion for aviation procurement and $3.575 billion for aviation-related research and development (R&D). If the Navy is seeking a 60% unmanned force, unmanned aviation should account for roughly 60% of procurement and R&D funding, not necessarily 60% each year, over 10 years. Rounding up, that amounts to $120 billion that should be allocated to develop Naval MUMT over 10 years.

Though these funding numbers are roughly estimated, producing the results in MUMT is vital for preparing and anticipating the next conflict. Where increased funding in MUMT exists, there will be a decrease in the funding necessary for manned systems operation, including maintenance, training, and all other aspects associated with maintaining personnel. Beneficially, pooling funds with the Air Force and possibly expanding the list of stakeholders to allies like Australia, Japan, and South Korea could reduce the strain on R&D accounts. Consolidating and unifying funding to maximize potential funding for MUMT could prove pivotal and worthwhile, as opposed to the risk of not incorporating and utilizing unmanned vehicles in a future battle force. Ultra-stealth submarines and the next generations of surface ships require financial attention, though it is in the Navy's best interest to prop up MUMT like never before.

UAS and MUMT performance is intrinsically tied to the individual UAS platforms and incorporation with MUMT. The standards used to measure these are innately written in the program requirements for the individual programs. The Navy should utilize a unique development body, such as Task Force 59, that is solely responsible for incorporating MUMT into CVWs. They could work closely with industry and the Air Force to set requirements for the individual UASs and the control centers and modules to be installed on ships or aircraft.

Understanding the limited numbers of UASs being developed in carrier MUMT, none of which are in CVWs, carriers will remain largely unequipped, with UASs going into a possible near-peer conflict in 2027. The MQ-25 is a respectable platform that will be widely fielded, entering LRIP in FY25 (USNI, 2025).

Expendability is a key trait of modern UASs; hence, it is worth considering the de-prioritization of funding for the MQ-4C Triton. Its multi-INT sensors should continue to be developed, but production of additional units of the IFC-4 version should be deprioritized compared to seeking attributable UASs beneficial to CVWs. The MQ-4 can't operate well with a carrier, but a carrier-based HALE ISR platform could operate seemingly anywhere (Katz, 2022).

The MQ-8, though likely to be integrated with MUMT control systems, will likely be and should be utilized by LCSs in limited ISR and MCM capabilities. The integration of these UASs with LCSs can assist in incorporating other UASs into ships outside direct carrier operations and solidify Project Overmatch's capability and training to utilize its interface. Thus, UAS solutions will supplement the fleet with their technological advancement in affordable packages. They should be rapidly integrated into MUMT and produced in large numbers.

Following these recommendations thus far, a reasonable timeline that utilizes the 10-year timeframe can guide the future of Naval MUMT:

- Short-Term (1–5 years): Deploy MQ-25 for aerial refueling and ISR, prioritizing single-role integration.
- Medium-Term (5–10 years): Develop single-role UAS for strike and EW, leveraging Air Force CCA advancements.
- Long-Term (10+ years): Achieve full MUMT integration with autonomous operations utilizing Project Overmatch.
- Support Actions: Accelerate UAWC installations, expand simulation-based training, and deepen collaboration with industry and allies to reduce costs.

B. DOTMLPF ANALYSIS

1. Analysis

Naval Aviation is evolving to integrate MUMT into CVWs, which presents numerous challenges, particularly in the operations of CVNs. The goal is to enhance and expand the capabilities already offered by manned assets. The operational style and capability changes that come with integrating UAS affect the core of maritime aviation and require changes throughout the entire department. Applying a DOTmLPF assessment enables a structured analysis of the changes necessary to effectively integrate MUMT into CVWs.

The analysis in the context of this research focuses on the first seven functional areas of the DOTmLPF-P framework. The scope of this research is within the operational requirements of MUMT integration into Naval carrier aviation. The final functional area of policy is crucial as a foundational framework for non-materiel solutions. Still, it involves a regulatory framework that extends beyond the organizational scope of this research, precluding direct recommendations for MUMT integration. The other seven areas of analysis provide a lens of actionable recommendations for Naval Aviation.

a. Doctrine

In every military branch, the foundational principles and guiding framework will be found in its doctrine. Doctrine guides the utilization of forces in operational contexts and the employment of resources to execute their defined mission. The integration of MUMT represents a foundational shift in how all forces will operate, particularly in a maritime environment characterized by the chaotic and congested nature of CVNs. The U.S. Navy has focused on doctrinal development within the ISR and aerial refueling for the MQ-8 and MQ-25. However, there is still a lack of overall doctrinal guidance on how UAS should be deployed in other roles and how they fit into the broader landscape of Naval operations. This is especially prevalent in combat roles, as there is no clear understanding of how UAS fits into the targeting cycle and how it will interact with manned systems.

As the Unmanned Campaign Framework highlights, unmanned platforms must be aligned into key areas such as DMO and Littoral Operations in a Contested Environment (LOCE; DON, 2021). The emphasis on these strategic areas indicates that MUMT requires clear guidance on how it will be efficiently and effectively incorporated into all Naval domains. This demonstrates the strategic vision of leadership in the Navy; however, the tactics, techniques, and procedures (TTPs) required for these systems remain undeveloped. A fully developed and fleshed-out doctrine regarding system implementation requires considerable time and consideration. With MUMT in its infancy, it is understandable that the role these systems will play in the short term is unclear, but in the long term, MUMT will be a primary force capability. Without any rudimentary doctrinal guidance in the Navy, UAS are hamstrung in their deployment, as tactics remain unclear regarding how they are to operate within the current force structure (Barnhill, 2019).

This is a significant challenge to the Navy's ability to incorporate MUMT platforms. For instance, the MQ-25 Stingray has demonstrated success in aerial refueling, but doctrinal guidelines are silent on how it would potentially branch out into other roles, such as electronic warfare or (Barnhill, 2019). This may be a strategic posture to wait for system maturity to expand into other operational contexts, but the path to fleet-wide integration requires clear guidance. This is most clearly demonstrated in contested environments where clear defining roles of operation and coordination are paramount.

A doctrine that is integrated across all Naval domains and addresses the implementation of MUMT into the multitude of mission areas should be prioritized for CVW. This will directly contribute to the sustainable adoption and resilience of UAS. TTPs for current and future systems must clearly define and demonstrate how MUMT will contribute to Naval operations. The current effort to develop doctrine and the changes made in recent years demonstrate that the Navy is committed to this front, yet it is taking a slow and cautious approach. The use of prototype systems in 2023 for the surface Navy in developing tactics and procedures suggests the Navy is in the thick of changing this landscape in support of the MUMT doctrine (Holzer & Filipoff, 2024). However, it is unclear at the unclassified level as to where the Navy currently stands on doctrine, specifically regarding UAS. This cautious approach, while understandable, needs to keep pace with technological advancements to avoid introducing the risk of near-peer threats evolving faster than the U.S. Navy. For example, the slow progress in C2 doctrine for joint operations is a clear area where MUMT doctrine could be improved upon as it is pivotal for successful implementation (Cobb, 2024).

The Unmanned Campaign Framework emphasizes a foundation of MUMT doctrine that complies with the ethical principles by which the Navy operates (DON, 2021). This framework provides a solid foundation for ensuring that MUMT operations are conducted with appropriate human judgment and adherence to the Law of Armed Conflict.

Standardization with other services should be sought, as UAS and MUMT are being developed concurrently in the Air Force and Marine Corps. This could help facilitate robust TTPs for how MUMT should function in the context of a CVW.

b. Organization

The organization section of the DOTmLPF analysis is used to determine how the department organizes itself to fight. For Naval Aviation, the current structure for CVWs is primarily focused on manned platforms. Squadrons orientate around specific platforms and their specifically defined roles. There is some interplay and overlap between the different mission sets, but they are currently set as squadrons for fighters, electronic attack, airborne early warning, helicopter sea combat, and helicopter maritime strike explicitly staffed for these platforms and designed mission sets (LaGrone, 2016). These squadrons operate under the directives of the Carrier Air Wing Commander (CAG) to keep these squadrons aligned with the overarching goal of the Carrier Strike Group (CSG; Lawson, 2000). Introducing a new squadron into the CAG poses challenges. Still, the unique nature of UAS and MUMT introduces an entirely new set of hurdles for CSGs to overcome in support of these systems.

UASs have been put into operation onboard CVNs, but their role has been vague, causing the full potential of these systems to remain unrealized (Barnhill, 2019). Without a clear understanding of how these systems are to be used, they are doomed to fail from the outset. The Navy's approach to integrating the MQ-8 Fire Scout involved embedding these systems into existing manned squadrons, particularly those operating MH-60S helicopters (Wright & Whitsett, 2022). As discussed in the literature review, Stingray addressed this shortcoming by establishing dedicated support squadrons and operational squadrons to fully support, train, and advance this system, ultimately preparing it for future use. The integration challenges are acknowledged in the Unmanned Campaign Framework in terms of necessary organizational changes for efficient and successful adoption of unmanned systems (DON, 2021)

By separating manned and unmanned platforms into distinct squadrons, which require unique training and operational requirements, resources can be allocated appropriately for these systems. Additionally, qualification and maintenance can be focused on rather than the personnel needed to be qualified for multiple systems. This may also contribute to better development of C2 MUMT procedures in the CVW environment. Eventually, this may need to shift into manned squadrons adopting UAS into their operational squadrons with the development of CCA, but in its current state, MUMT necessitates a robust foundation with supporting squadrons and resources for there to be any hope of successful integration of these systems. There are other broader initiatives in place, such as the Air Test & Evaluation Squadron Two Four (UX-24), which conducts testing and research for UAS with the goal of organizational evolution at the same rate as technological advancements (DON, 2021).

While there has been significant organizational improvement, there are still areas that need improvement and those that hinder the integration of MUMT. Specific C2 procedures need to be developed for operation in contested environments in coordination with manned systems. Roles must also be clarified for how systems will be utilized beyond aerial refueling and ISR mission sets. The Navy is looking to expand the use of UAS and MUMT into CSG operational areas, but needs to lay out a pathway with supporting organizational infrastructure to adopt these systems sustainably.

c. Training

The fundamental principle in question for training is how forces are prepared to carry out the mission, from basic training to joint exercises. The U.S. Navy has established structured training programs to prepare personnel for operating unmanned systems within CVWs, with a primary focus on the Stingray. As previously mentioned, the VUQ-10 FRS is the primary training squadron for the MQ-25. The training pipeline starts with Naval Introductory Flight Evaluation, where initial aviation skills are developed, followed by primary, then intermediate and advanced flight training, where specific simulators are used in the familiarization of the system, such as Multi-Crew Simulators to hone the skills necessary for flight the UAS (Alert5, 2023). Air vehicle operators (AVO) flying UAS require different skills from traditional manned aircraft as they have vastly different informational displays (Tegler, 2021). While this flight training is unique, it is not new to the Navy as UAS has been in service utilizing specific training pipelines since its inception.

The MQ-4 provides a good example of how the training pipeline can be improved and used to support the system in the field. However, the Triton differs from the Stingray in terms of the new development of MUMT. Specific training and exercises are necessary in this developing field to expose deficiencies and areas of improvement. The Navy is incorporating exercises such as the 2022 demonstration involving the AH-1Z Viper, UH-1Y Venom, and MQ-8C Fire Scout, which focused on the coordination aspect for deploying MUMT into current maritime tactics (Hernandez, 2022).

Training for MUMT is still evolving, adapting to the framework provided by the doctrine, organization, and leadership. With rapid developments in how the military will utilize these systems and technological advancement, setting a rigid training program is complicated and ill-advised. A training pipeline that is open and variable, shifting to the current state of UAS and MUMT, would provide a foundation of support for system usage while also allowing for changing criteria and skill sets for maritime adoption. MUMT integration is highly complex and variable, making it difficult to develop standardized curricula at this early integration stage. Exercises and simulations are incredibly beneficial in this specific area. Communication protocols and joint mission planning would greatly benefit from a training syllabus emphasizing live exercises and scenario-based simulation training. Focusing on the interoperability of manned and unmanned systems during the training phase will better position both AOVs and manned system pilots to understand how communication and integration should be achieved most effectively. This curriculum should include scenarios for high-threat environments, emphasizing the reliability of communication and autonomous decision-making. Expanding the use of live virtual trainers, such as the ones pointed to in the Unmanned Campaign Framework, can build operator trust and expertise (DON, 2021).

d. Materiel

The materiel analysis examines any shortages in commercial equipment or systems that could be used to address MUMT integration without requiring a new development effort. The MQ-25 Stingray underscores why a complete-system MUMT platform cannot be procured as an off-the-shelf solution: its airframe, carrier-compatible launch and recovery systems, refueling boom, and integrated mission control are under engineering efforts that exceed the "minor modifications" scope of non-developmental items defined in Federal Acquisition Regulations 2.101 (*FAR 2.101, Definitions*, 2025). Although the Stingray leverages some commercial-derivative subsystems, its certification to operate on CVNs, integration with the Joint Precision Approach and Landing System, and development of an entirely new Unmanned Carrier Aviation Mission Control System necessitated a complete production pathway (Kunzler, 2024). However, portions of a MUMT platform can and should exploit off-the-shelf solutions to expedite capability and reduce costs. Products that can provide functionality to MUMT systems that have already been developed should be sought and integrated by a modular open systems approach mandated by National Defense Authorization Act §804 (*FAR 12.103, Commercially Available off-the-Shelf (COTS) Items*, 2025; *FAR 52.244-6 Subcontracts for Commercial Products and Commercial Services*, 2025).

e. Leadership and Education

This section aims to determine if leaders are prepared to lead this effort. The Navy is equipping its leaders with the knowledge to oversee MUMT integration through professional military education (PME). The fundamental shift in how the military operates with unmanned systems requires at least rudimentary education and knowledge in this field. New educational initiatives are underway, such as the program at the Naval War College entitled "Unmanned Systems and Conflict in the 21st Century," which seeks to provide a history that informs future applications and strategy in an ethical framework (Gomes, 2019). Additional education is offered at Naval Postgraduate School in its Autonomous Systems Track that stresses control and collaborative networks of these systems (Naval Postgraduate School, n.d.). Education is also stressed in the Unmanned Campaign Framework as a critical component of talent development (DON, 2021).

While graduate-level college courses address these issues broadly and help with leadership, specifically following those pathways, the Navy needs to be more ubiquitous in training for how these systems operate at all levels as these systems increase in number and deployment. Leadership must advocate for the acceptance and use of collaborative unmanned systems as profound cultural resistance remains, especially in the aviation community, in adopting these systems (Spataro et al., 2022). As MUMT becomes more common in the fleet, the Navy should increase PME effectiveness by incorporating MUMT-specific modules that address operational integration, C2 frameworks, and ethical considerations. Leadership should also emphasize integrating these systems to overcome cultural resistance, and training should be based on lessons learned in MUMT exercises.

f. Personnel

Personnel is used to understand if enough qualified people are in place to complete this effort. The Navy is seeking to improve its personnel dedicated to MUMT integration by establishing training units, such as VUQ-10, as previously discussed. Through initiatives like these, the first four AVPs were able to earn "Wings of Gold," marking their successful training as a Naval Aviator and denoting both a culture shift as well as proper recognition for developing specialized UAS personnel in Naval Aviation (Alert5, 2023). The Navy plans to train about 450 warrant officers as AVOs over the next six to t10 years (Tegler, 2021). Additionally, Air Test & Evaluation Squadron Two Four (UX-24) looks to further develop personnel expertise through exercises and operations. (DON, 2021).

The GAO developed a report in 2018 that highlighted many current issues with military personnel (GAO, 2018). Some of the main findings were the Navy's failure to evaluate alternatives via contracting or the civilian sector, outdated personnel requirements for the RQ-21 Blackjack, and insufficient UAS capability policies (GAO, 2018). Another concern is retention, as the civilian sector draws talent away from military departments, especially in technological sectors such as unmanned systems, due to better pay and higher job satisfaction (GAO, 2018). Several recommendations remain open from the GAO report as of March 2025, which shows that these issues persist in providing and equipping personnel to perform their duties properly (GAO, 2018).

The Navy needs to implement the GAO's recommendations to position its workforce better to integrate and maintain unmanned systems sustainably. Clarification is required for contractor and civilian sector roles, and personnel requirements need to be assessed for sustainment. Retention has been an ongoing issue in the military as a whole, particularly in technical areas that require higher levels of education or expertise, which falls beyond the scope of this analysis. However, formulating career paths that are better defined and prevent current military personnel from being spread thin, such as what happened in the Fire Scout program, could help retain qualified personnel. Lastly, partnering with industry leaders can be valuable and decrease the loss of educated individuals experienced by military branches, as talent development and support are well-established even in rapidly advancing fields in the civilian sector.

g. Facilities

This section examines whether government-owned infrastructures, such as land, buildings, and factories, are suitable for addressing this capability gap. Integrating UAS into the Naval fleet structure requires modification to the current infrastructure as systems are supported independently of each other in platform silos (DON, 2021). A new approach will be necessary to sustain MUMT systems, such as a capability-centric approach that shares standard facilities and infrastructure in an open, modular system environment (DON, 2021).

Maintenance and storage facilities on CVNs are another critical area to focus on improvement. The maintenance facilities aboard CVNs are optimized for manned platforms that are not modular. CVNs are configured to support these systems in a siloed manner with specific hangars, maintenance bays, and storage for specific platforms (DoD, 2017). While this approach has been historically feasible, it causes maintenance to be slow and cumbersome due to siloed infrastructure with dedicated, specific support systems. UAS and, consequently, personnel and the CVNs will be better positioned with shared maintenance facilities. UAS and newer platforms, such as the F-35, rely heavily on data links and sensors, which require specialized equipment and expertise but could benefit from modular integration for the use of common space.

Examining the current Stingray program, significant challenges have been encountered on the facilities side, including manufacturing delays that have pushed back the IOC date. The delays were caused by the lingering effects of COVID-19-related supply chain disruptions, issues with the development of the production line, and metal coatings failing to meet quality standards (LaGrone, 2023). The Inspector General report in 2023 pointed out a critical failure by the Navy in making production decisions before developmental testing and operation testing had been completed, thereby increasing the risk of the program in terms of cost overruns and the likelihood that requirements for the capability would not be met (Department of Defense Inspector General, 2023). This demonstrated that lessons from the UCLASS program were not heeded, which was notorious for scope creep but failed to test rigorously and adhere to stable requirements, leading to technological overreach. The IG recommends delaying production decisions until operational testing is completed to ensure the proper fulfillment of the set requirements.

The Navy has demonstrated its intention to build out the Stingray as a stepping-off point for UAS and MUMT in the future by investing heavily in its adoption aboard CVNs. The MD-5E GCS was installed onto the USS George H.W. Bush in 2024 to support the control of the aircraft from the carrier instead of land-based control stations that are used for the MQ-4 (Finnerty, 2024). This also requires bolstering with software support and maintenance to ensure the system's longevity.

While delays have hindered the MQ-25 program, there is evident progress on how the system's integration will be conducted and supported materielly. There is a clear need for investment onboard CVNs to maintain and support the operation of UAS. Still, the Navy has set a clear tone that support is available, and training facilities are in place to support these systems. While specific MUMT training remains sparse, it will be developed and increased as these systems become more ubiquitous. The primary challenge for these systems is the need to transition from platform-specific silos to a capability-centric approach. This will require investment and reconfiguration of facilities for support and maintenance but will contribute to smoother and more efficient operation. Maintenance for UAS may be less frequent on the hardware components. Still, software is the primary driving force behind these systems, requiring specialized knowledge and maintenance workflows that are unique to carrier aviation. There is a lack of public knowledge released by the Navy on this front for how these aspects are being addressed, improved, and made more efficient. This suggests that the requirements for CVNs for maintenance and support on the materiel front are still being fully defined and require attention for sustainment.

2. Results

The DOTmLPF analysis reveals a substantial number of gaps that exist in the current department structure that could be mitigated and should be addressed in the adoption of MUMT systems. These findings are summarized in Table 1.

Table 1. DOTmLPF Analysis Summary

Section	Main Findings
Doctrine	No specific MUMT doctrine for combat roles and vague guidance for integration into ISR, EW, and other mission areas besides aerial refueling.
Organization	Squadrons dedicated to UAS support will be effective for implementation into the fleet, while future integration of CCA into manned squadrons will need to be addressed. MUMT requires clear guidance for C2 in contested environments.
Training	Standardized curricula for MUMT are needed but should not be rigid as technology and tactics evolve rapidly in this field.
Materiel	Integrating commercial off-the-shelf solutions can mitigate risk but is not a primary issue for this capability gap.
Leadership and Education	MUMT-specific education is necessary for more than just specific graduate-level programs. Leadership must address cultural resistance to unmanned systems.
Personnel	Workforce development is progressing, and partnering with the industry can help expedite talent development efforts.
Facilities	The current platform-specific approach must evolve into a more flexible, capability-centric model.

The DOTmLPF framework for this analysis reveals that capability gaps exist in carrier-based UAS and MUMT that can be addressed without the need for a new program of record. Most of these recommendations and findings are based on the Stingray program, which highlights its success in development and provides an example approach to fully adopting MUMT into CVWs. However, there are areas where the implementation of the MQ-25 and the complete sustainment of future UAS, as well as the upgrade or modification of Stingrays, are necessary before this program can reach its full potential. The focus has been on aerial refueling as a milestone of development. Still, doctrinal guidance is required for other systems, such as ISR with the MQ-8 or detailed TTPs for operations in contested maritime environments. At the organizational level, dedicated unmanned squadrons will provide a better support system for UAS programs, representing an improvement over the model used by the MQ-8 for integrating these systems directly into manned squadrons. With MUMT being so interlocking within these squadrons, however, there may be a necessary shift in the future for CCA and other systems to integrate directly into existing squadrons. Procedures for C2 in contested environments need to be clarified beyond aerial refueling to expedite system integration.

Training efforts for unmanned systems operators have advanced, but the absence of a standardized MUMT curriculum limits their preparedness despite exercises that highlight the need for cohesive training in high-threat contexts. Materiel challenges do not highlight any significant capability gaps in current MUMT development. Still, risks and delays could be mitigated by incorporating off-the-shelf solutions into its open system architecture. Leadership and Education initiatives within professional military education address unmanned systems broadly; however, the lack of MUMT-specific education fails to equip leaders to overcome operational hurdles and cultural resistance within Naval Aviation. Personnel challenges, including retention difficulties and competition from the civilian drone sector, have been addressed. However, the Navy has made significant progress in developing the training and workforce necessary for UAS operations. Talent development steps should be learned from partners in the industry. Lastly, facilities require investment to sustain and improve the efficiency of deployment. The existing platform-specific infrastructure needs to be shifted to a more flexible and capability-centric model to accommodate the needs of unmanned systems without displacing infrastructure supporting currently deployed assets. Addressing these issues will help instigate long-term development and employment of unmanned assets, providing a framework for MUMT to be fully leveraged within Naval Aviation.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS

A. SUMMARY AND RESEARCH QUESTIONS

Integrating UAS and MUMT into U.S. Navy CVWs is a vast leap for maritime forces to maintain dominance in a competitive near-peer environment. By using a CBA and DOTmPLF analysis, areas of concern that need to be addressed were identified, highlighting where the Navy should focus its efforts. MUMT and UAS will be a significant force multiplier for the CVW and U.S. Navy. It will extend operational reach, enhance decision-making, and ultimately reduce the risk to pilots of manned systems. The strategic advantage these systems will supply cannot be understated and will be expanded into every mission area. The Navy is looking to align the technological efforts of MUMT innovation with the future year's defense program and continue prototyping and experimentation into 2029 (McGarry & Peters, 2024). This will lead to the procurement of UAS systems by 2030 and full-scale integration by 2035 (McGarry & Peters, 2024).

This should be bolstered by collaborative efforts among allies to expedite the development and deployment of these platforms. Collaboration with allies will ultimately help interoperability among joint forces as well. Technological advancements have been made rapidly, so the Navy must remain adaptable in its approach. Refining strategies and being realistic about goals, requirements, cost, schedule, and performance will equip the AWOTF with advanced systems capable of combating emerging threats.

Three fundamental questions directed this research. The first was: Where are the current capability gaps in CVWs that UAS or MUMT could address? Using a modified CBA, capability gaps were isolated in many maritime operational areas with a primary gap in ISR. Manned aerial platforms are struggling to meet the demands of the current Naval Aviation community. The MQ-25 is slated as the solution to the gap in endurance and range by augmenting and replacing refueling platforms, but many shortcomings remain in this high-demand environment. The ultimate purpose of UAS and MUMT is to enhance flexibility and data flow, thereby reducing risks to aviators and positioning the Navy to win future conflicts. The assessment revealed that MUMT needs to be expanded into a broader role for the CVW in a controlled, focused, and risk-tolerant manner. The Navy lacks attritable systems to act in wartime scenarios, engage in contested environments, and supply pilots with real-time information and risk mitigation. UAS will be crucial in bridging those capability gaps for the AWOTF by increasing efficiency and leveraging MUMT for increased data flow and informed decision-making.

The second question was: Do past programs provide lessons learned for actionable steps to help mitigate risk in integrating solutions that fill those capability gaps? The Coast Guard VUAV, MQ-8 Fire Scout, MQ-4C Triton, and MQ-25 Stingray programs were all reviewed better to understand the field of UAS in maritime conditions. These programs encountered many common issues for DoD acquisition, such as scope creep and integration failures. The key takeaways from this review were the need for stable requirements, realistic scoping for deliverables, and sufficient testing. Lessons have been learned on improper implementation and acquisition, guiding current programs into a better position for future use and development. Risk mitigation has been key for program success, but additional failures will arise due to the technically immature nature of these systems. However, greater risk lies in a CVW that is ill-equipped to perform in potential conflicts.

The last question was: Can a DOTmLPF framework reveal solutions for integrating MUMT into Naval operations? Every facet of the DOTmLPF framework, except the materiel section, showed areas of improvement necessary for MUMT integration.

- Doctrine: Developing MUMT-specific TTPs would help clarify integration and lay a foundation for the fast-paced adoption of UAS.
- Organization: Guidance for C2 is necessary for contested environments, and future integration paths for CCA within manned squadrons will need to be addressed.
- Training: Adaptable curricula will need to be developed with an emphasis on live exercises to increase interoperability with manned assets.
- Materiel: While COTS solutions are helpful for risk mitigation and increasing the rate of development, they are not a primary contributor to this capability gap.

- Leadership and Education: MUMT education needs to be expanded beyond graduate degree programs, and leadership must emphasize the importance of accepting this shift in how Naval Aviation operates.
- Personnel: Partnership with industry would be advantageous for developing and sustaining qualified personnel in this field. Well-defined career paths are being refined and developed, which will pay dividends in the future for these systems.
- Facilities: The main issue for maintaining these systems is monolithic platform sustainment rather than capability-centric approaches to modularly maintaining and supplying UAS.

By capitalizing on the MQ-25 Stingray's progress and addressing the identified challenges through targeted non-materiel solutions, the U.S. Navy can effectively integrate MUMT into its CVWs. This strategic evolution will close critical capability gaps, enhance operational resilience, and position the Navy to meet future challenges with a more agile, technologically advanced force. The successful adoption of MUMT will not only strengthen carrier-based operations but also reinforce the Navy's role as a leader in maritime innovation, ensuring its ability to project power and maintain superiority in an increasingly complex security landscape

B. FUTURE RESEARCH

This research laid a foundation for where MUMT and UAS need to be focused, refined, and implemented. Additional areas of study and research were made evident by pulling together many sources on the topic:

1. Long-term strategies for sustaining and supplying these systems, especially for maintenance.
2. How could a capability-centric model for integration and sustainment be implemented, specifically on a CVN, with minimal disruption to operational tempo?

3. Research how AI and autonomous decision-making can affect MUMT, such as ethical implications for contested spaces.
4. If collaboration with allies could expedite system delivery and alleviate the test burden on the United States Military.

These future research areas would build upon the foundation laid in this research to usher in a detailed picture of how MUMT will be integrated into the maritime structure and how sustainment for these systems can be achieved. The future of aviation is UAS and MUMT, and Naval Aviation is no exception. While the Navy has unique operation demands and contexts that vary from other services, the adoption of unmanned platforms will provide it with the necessary tools to combat threats of the future. To reach that goal, a strategic approach to acquisition and requirements generation must be taken to ensure that this push does not fall on its face but instead ushers in the future of U.S. Military dominance.

LIST OF REFERENCES

AcqNotes. (2017a, July 12). *Functional area analysis (FAA)*. https://acqnotes.com/acqnote/acquisitions/functional-area-analysis

AcqNotes. (2017b, July 12). *Functional needs analysis (FNA)*. https://acqnotes.com/acqnote/acquisitions/functional-needs-analysis

AcqNotes. (2017c, July 12). *Functional solutions analysis (FSA)*. https://acqnotes.com/acqnote/acquisitions/functional-solutions-analysis

AcqNotes. (2023, August 10). *Capabilities based assessment (CBA)*. https://acqnotes.com/acqnote/acquisitions/capabilities-based-assessment-cba

AcqNotes. (2024, February 10). *Joint Capabilities Integration and Development System (JCIDS) Process Overview*. https://acqnotes.com/acqnote/acquisitions/jcids-overview

AFCEA International, & U.S. Naval Institute. (2024, February 13). *WEST conference and exhibition*. WEST 2024. https://www.westconference.org/WEST24/Public/Content.aspx?ID=104249&sortMenu=101002

Airbus. (2025). *Manned-unmanned teaming*. https://www.airbus.com/en/products-services/defence/uas/manned-unmanned-teaming-mum-t

Alert5. (2023, May 26). *First four AVPs to earn their "wings of gold."* https://alert5.com/2023/05/26/first-four-avps-to-earn-their-wings-of-gold/

Anduril Industries. (2024, April 8). *IBP 24–1: Command and control*. https://www.anduril.com/article/ibp-24-1-command-and-control/.

Axe, D. (2022, November 20). Ukraine's drone boats are winning the black sea Naval war. *Forbes*. https://www.forbes.com/sites/davidaxe/2022/11/20/the-ukrainian-Navy-has-no-big-warships-its-winning-the-Naval-war-anyway-with-drones/

Barnhill, D. (2019). The manned-unmanned team: Where's the doctrine? *U.S. Naval Institute*, *145*(3), Article 1393.

Burgess, R. R. (2021, August 2). Navy to stand-up 2 fleet MQ-25 squadrons to deploy detachments. *Seapower*. https://seapowermagazine.org/Navy-to-stand-up-2-fleet-mq-25-squadrons-to-deploy-detachments/

Cobb, J. (2024). The Navy is not prepared for the joint fight in IndoPaCom. *U.S. Naval Institute*, *150*(3), Article 1453.

Commander, Naval Air Force. (2025). *Naval Aviation Playbook 2025*. Department of Defense. https://www.airpac.Navy.mil/Portals/53/Naval%20Aviation%20Playbook%202025.pdf

Daigle, L. (2024, August 19). Uncrewed air warfare center installed on U.S. Navy aircraft carrier. *Military Embedded Systems*. https://militaryembedded.com/unmanned/test/uncrewed-air-warfare-center-installed-on-us-Navy-aircraft-carrier

Defense Acquisition University. (n.d.). Capabilities based assessment (CBA). In *ACQuipedia*. Retrieved April 18, 2025, from https://www.dau.edu/acquipedia-article/capabilities-based-assessment-cba

Defense Systems Management College (DSMC). (2024, September 17). *Guide to Program Management Business Process*. Defense Acquisition University (DAU).

Defense Visual Information Distribution Service. (2013, May 21). *Triton successfully completes first flight*. https://www.dvidshub.net/image/938945/triton-successfully-completes-first-flight

Demarest, C. (2024, April 11). Project overmatch's small says EW is "killer app" for unmanned tech. *C4ISRNET*. https://www.c4isrnet.com/unmanned/2024/04/11/project-overmatchs-small-says-ew-is-killer-app-for-unmanned-tech/

Department of Defense. (2017). *Unified facilities criteria: Aircraft maintenance hangers* (No. UFC 4–211-01). https://www.wbdg.org/FFC/DoD/UFC/ufc_4_211_01_2017_c3.pdf

Department of Defense. (2019). *MQ-8 fire scout unmanned aircraft system (MQ-8 fire scout)* [Selected Acquisition Report]. Freedom of Information Act (FOIA) Reading Room. https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2019_SARS/20-F-0568_DOC_60_MQ-8_Fire_Scout_SAR_Dec_2019_Full.pdf

Department of Defense. (2020). *DoD instruction 5000.02: Operation of the adaptive acquisition framework* (No. DoDI 5000.02). Department of Defense. https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodi/500002p.PDF

Department of Defense. (2023a). *MQ-4C Triton unmanned aircraft system (MQ-4C Triton)* [Modernized Selected Acquisition Report]. https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/MQ-4C_Triton_MSAR_Dec_2023_v2_Cleared.pdf

Department of Defense. (2023b). *MQ-25 Stingray (MQ-25)* [Modernized Selected Acquisition Report]. https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/FY_2023_SARS/MQ-25%20MSAR%20Dec%202023.pdf

Department of Defense Inspector General. (2023). *Audit of the Navy's management of the MQ-25 Stingray program* (No. DODIG-2024-026). Department of Defense. https://www.dodig.mil/reports.html/Article/3594541/audit-of-the-Navys-management-of-the-mq25-stingray-program-dodig-2024-026/

Department of the Navy. (2021). *Unmanned campaign framework*. https://www.Navy.mil/Portals/1/Strategic/20210315%20Unmanned%20Campaign_Final_LowRes.pdf

Director, Operational Test and Evaluation. (2016). *2016 DOT&E annual report*. Department of Defense. https://www.dote.osd.mil/Portals/97/pub/reports/FY2016/other/2016DOTEAnnualReport.pdf?ver=2019-08-22-105134-547.

DOT&E. (2024). *2023 DOT&E annual report*. Department of Defense. https://www.dote.osd.mil/Portals/97/pub/reports/FY2023/other/2023annual-report.pdf?ver=d7gusiIrcbYmxM0oDkPSFg%3d%3d

Easley, M. (2024a, January 11). *Navy's 4th fleet sets sights on command center upgrades for drone ops*. DefenseScoop. https://defensescoop.com/2024/01/11/Navy-4th-fleet-command-center-ai/.

Easley, M. (2024b, December 18). *China's drone modernization efforts close to "matching U.S. standards," Pentagon report says*. DefenseScoop. https://defensescoop.com/2024/12/18/chinas-drone-modernization-efforts-close-to-matching-us-standards-pentagon-report-says/

Eckstein, M. (2021, March 12). *As USS Gerald R. Ford nears shock trials, carrier remains busy with testing, fleet support*. USNI News. https://news.usni.org/2021/03/12/as-uss-gerald-ford-nears-shock-trials-carrier-remains-busy-with-testing-fleet-support

Eckstein, M. (2023a, April 12). U.S. *Navy aims to field manned-unmanned fleet within 10 years*. Defense News. https://www.defensenews.com/Naval/2023/04/12/us-Navy-aims-to-field-manned-unmanned-fleet-within-10-years/

Eckstein, M. (2023b, June 16). *Congressman wants faster drone testing, fielding to fill inventory gap*. C4ISRNET. https://www.c4isrnet.com/Naval/2023/06/16/congressman-wants-faster-drone-testing-fielding-to-fill-inventory-gap/.

Eckstein, M., & Demarest, C. (2022, December 8). *Project overmatch: U.S. Navy preps to deploy secretive multidomain tech*. Defense News. https://www.defensenews.com/outlook/2022/12/05/project-overmatch-us-Navy-preps-to-deploy-secretive-multidomain-tech/

Eide, P. K. (2011). *The more things change, acquisition reform remains the same* (No. ADA560205). U.S. Army War College. https://apps.dtic.mil/sti/pdfs/ADA560205.pdf

FAR 2.101, Definitions. (2025, January 17). Aquisition.Gov. https://www.acquisition.gov/far/2.101

FAR 12.103, commercially available off-the-shelf (COTS) items. (2025, January 17). Aquisition.Gov. https://www.acquisition.gov/far/12.103

FAR 52.244-6 subcontracts for commercial products and commercial services. (2025, January 17). Aquisition.Gov. https://www.acquisition.gov/far/52.244-6

Finnerty, R. (2024, August 16). U.S. *Navy installs first MQ-25 control station on aircraft carrier*. FlightGlobal. https://www.flightglobal.com/military-uavs/us-Navy-installs-first-mq-25-control-station-on-aircraft-carrier/159605.article

Fox, J. R. (2011). *Defense acquisition reform 1960–2009: An elusive goal*. Center of Military History. https://history.defense.gov/Portals/70/Documents/acquisition_pub/CMH_Pub_51-3-1.pdf

Franchetti, L. (2024, February 13). *CNO delivers keynote address at WEST 2024*. U.S. Navy. https://www.Navy.mil/DesktopModules/ArticleCS/Print.aspx?PortalId=1&ModuleId=698&Article=3676251

Gertler, J. (2015). *History of the Navy UCLASS program requirements: In brief* (No. R44131). Congressional Research Service. https://sgp.fas.org/crs/weapons/R44131.pdf

Gomes, D. (2019, January 21). Game of drones. *The Newport Daily News*. https://www.newportri.com/story/news/local/2019/01/22/retired-Navy-captain-explores-impacts-ethics-of-drones-in-new-book/6235274007/

Government Accountability Office. (2016). *Assessments of selected weapon programs* (No. GAO-16-329SP). https://www.gao.gov/assets/gao-16-329sp.pdf

Government Accountability Office. (2017). *Navy unmanned aerial refueling system: Acquisition addresses validated requirements and reflects a knowledge-based approach* (No. GAO-17-647). https://www.gao.gov/assets/gao-17-647.pdf

Government Accountability Office. (2018). *Military personnel: Actions needed to better position the Navy and the Marine Corps to support expanding unmanned systems operations* (No. GOA-18-162). https://www.gao.gov/products/gao-18-162

Government Accountability Office. (2023). *F-35 joint strike fighter: More actions needed to explain cost growth and support engine modernization decision* [GAO-23-106047]. https://www.gao.gov/products/gao-23-106047

Government Accountability Office. (2024). *Weapon systems annual assessment* [GAO-24-106831]. https://www.gao.gov/assets/gao-24-106831.pdf

Harper, J. (2024, March 11). *Navy plans to spend more than $700M on secretive Project Overmatch across FYDP*. DefenseScoop. https://defensescoop.com/2024/03/11/Navy-project-overmatch-funding-2025/

Hernandez, J. (2022, March 15). *USMC and U.S. Navy demonstrate manned-unmanned teaming*. Naval News. https://www.Navalnews.com/Naval-news/2022/03/usmc-and-us-Navy-demonstrate-manned-unmanned-teaming/

Holzer, R., & Filipoff, D. (2024, March 1). U.S. Navy in review. *U.S. Naval Institute*, *150*(3), Article 1453.

Huang, P. M., Knuth, A. A., Krueger, R. O., & Garrison-Darrin, M. A. (2012, May 1). Agile hardware and software systems engineering for critical military space applications. *Sensors and Systems for Space Applications V*. SPIE Defense, Security, and Sensing 2012, Baltimore, Maryland. https://doi.org/10.1117/12.919303

Indo-Pacific Command. (2023, December 13). *U.S. INDOPACOM joint mission accelerator directorate reaches initial operating capability*. https://www.pacom.mil/Media/News/News-Article-View/Article/3615783/us-indopacom-joint-mission-accelerator-directorate-reaches-initial-operating-ca/.

Joint Staff J-8. (2021). *MANUAL FOR THE OPERATION OF THE JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM*. Joint Chiefs of Staff. https://www.dau.edu/cop/iam/documents/dod-jcids-manual-oct-21

Katz, J. (2022, April 5). How the Navy, Northrop avoided “strategic pause” in MQ-4C production line. *Breaking Defense*. https://breakingdefense.com/2022/04/how-the-Navy-northrop-avoided-strategic-pause-in-mq-4c-production-line/

Katz, J. (2025, February 5). *Navy’s 4th fleet to start operation focused on unmanned systems countering illicit trafficking*. Breaking Defense. https://breakingdefense.com/2025/02/Navys-4th-fleet-to-start-operation-focused-on-unmanned-systems-countering-illicit-trafficking/.

Kritz, D. J. (2024, June 8). *What is signals intelligence? Understanding SIGINT*. American Military University. https://www.amu.apus.edu/area-of-study/intelligence/resources/what-is-signals-intelligence/.

Kunzler, J. (2024, September 21). *Boeing MQ-25 Uncrewed Carrier-Based Refueler: U.S. Navy JPALS Test Successful*. Simple Flying. https://simpleflying.com/boeing-mq-25-uncrewed-carrier-based-refueler-us-Navy-jpals-test/

LaGrone, S. (2016, April 28). *Inside the carrier air wing*. USNI News. https://news.usni.org/2016/04/28/the-basics-inside-the-carrier-air-wing

LaGrone, S. (2017, August 31). *MQ-25 Stingray unmanned aerial tanker could almost double strike range of U.S. carrier air wing*. USNI News. https://news.usni.org/2017/08/31/mq-25-stingray-unmanned-aerial-tanker-almost-double-strike-range-u-s-carrier-air-wing

LaGrone, S. (2023, April 4). *MQ-25A Stingray IOC pushed to 2026 following manufacturing delays*. USNI News. https://news.usni.org/2023/04/04/mq-25a-stingray-ioc-pushed-to-2026-following-manufacturing-delays

LaGrone, S. (2025, January 30). *MQ-25A Stingray 2026 debut will unlock unmanned aviation for carrier strike group, say officials*. USNI News. https://news.usni.org/2025/01/29/mq-25a-stingray-2026-debut-will-unlock-unmanned-aviation-for-carrier-strike-group-say-officials

Landreth, J., Ochs, S. A., & Riloff, M. (2020). The Marines and the future of unmanned systems. *Defense Aquisition University*, *May-June 2020*, 23–26.

Lawson, R. L. (2000). *Carrier air group commanders: The men and their machines*. Schiffer.

Losey, S. (2024, September 16). *How the Air Force averted a major flaw in its drone wingmen approach*. Defense News. https://www.defensenews.com/digital-show-dailies/afa-air-space/2024/09/16/how-the-air-force-averted-a-major-flaw-in-its-drone-wingmen-approach/

Magnuson, S. (2023). *Why the Coast Guard lags when it comes to unmanned systems*. National Defense. https://www.nationaldefensemagazine.org/articles/2023/7/7/why-the-coast-guard-lags-when-it-comes-to-unmanned-systems

McGarry, B. W., & Peters, H. M. (2024). *Defense primer: Future years defense program (FYDP)* (No. IF10831). Congressional Research Service. https://sgp.fas.org/crs/natsec/IF10831.pdf

Mrusek, B., Kiernan, K., & Clark, P. (2018). UAS Maintenance: A critical component in maintaining airworthiness. *International Journal of Aviation, Aeronautics, and Aerospace*, *5*(5). https://doi.org/10.58940/2374-6793.1274

NAVAIR. (n.d.-a). *E-2D Advanced Hawkeye (AHE)*. Retrieved May 8, 2025, from https://www.navair.Navy.mil/product/E-2D

NAVAIR. (n.d.-b). *F/A-18 A-D Hornet*. Retrieved May 8, 2025, from https://www.navair.Navy.mil/product/FA-18-D-Hornet

NAVAIR. (n.d.-c). *F/A-18E/F Super Hornet*. Retrieved May 8, 2025, from https://www.navair.Navy.mil/product/FA-18EF-Super-Hornet

NAVAIR. (n.d.-d). *MH-60R Seahawk*. NAVAIR. Retrieved May 8, 2025, from https://www.navair.Navy.mil/product/MH-60R-Seahawk?utm_source=chatgpt.com

NAVAIR. (n.d.-e). *MQ-4C Triton*. Retrieved May 7, 2025, from https://www.navair.Navy.mil/product/MQ-4C

NAVAIR. (n.d.-f). *Unmanned*. Retrieved May 8, 2025, from https://www.navair.Navy.mil/ProductContent?field_related_products_target_id=unmanned

NAVAIR. (n.d.-g). *Unmanned carrier aviation*. Retrieved May 8, 2025, from https://www.navair.Navy.mil/product/Unmanned-Carrier-Aviation

NAVAIR. (2021). *Navy aviation vision 2030–2035*. Department of Defense. https://media.defense.gov/2021/Oct/27/2002881262/-1/-1/0/NAVY%20AVIATION%20VISION%202030-2035_FNL.PDF

NAVAIR. (2024, August 15). *Navy completes install of first MQ-25 unmanned air warfare center aboard USS George H.W. Bush (CVN 77)*. NAVAIR News. https://www.navair.Navy.mil/news/Navy-completes-install-first-MQ-25-Unmanned-Air-Warfare-Center-aboard-USS-George-HW-Bush-CVN

NAVAIR. (2025). *Naval Aviation north stars*. Naval Air Systems Command. https://www.navair.Navy.mil/North-Stars

Naval Forces Central Command Public Affairs. (2024, January 16). *Task force 59 launches new unmanned task group 59.1*. United States Navy. https://www.Navy.mil/Press-Office/News-Stories/Article/3645647/task-force-59-launches-new-unmanned-task-group-591/

Naval News. (2024, June 11). *EpiSci selected by U.S. Navy for project overmatch's mission autonomy proving grounds*. https://www.Navalnews.com/Naval-news/2024/06/episci-selected-by-us-Navy-for-project-overmatchs-mission-autonomy-proving-grounds/

Naval Postgraduate School. (n.d.). *Autonomous systems track*. Retrieved May 5, 2025, from https://nps.edu/web/ast

Non-Materiel (DOTmLPF-P) Analysis and Documentation (DCR). (n.d.). Retrieved October 29, 2024, from https://www.dau.edu/acquipedia-article/non-materiel-dotmlpf-p-analysis-and-documentation-dcr

Office of Inspector General. (2009). *U.S. Coast Guard's acquisition of the vertical-takeoff-and-landing unmanned aerial vehicle* (No. OIG-09-82). Department of Homeland Security. https://www.oig.dhs.gov/sites/default/files/assets/Mgmt/OIG_09-82_Jun09.pdf

Office of the Under Secretary of Defense. (2024a). *Program acquisition cost by weapon system*. Department of Defense. https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2025/FY2025_Weapons.pdf

Office of the Under Secretary of Defense. (2024b). *United States Department of Defense fiscal year 2025 budget request*. Department of Defense. https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2025/FY2025_Weapons.pdf

O'Neill, T., McNeese, N., Barron, A., & Schelble, B. (2022). Human–autonomy teaming: A review and analysis of the empirical literature. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *64*(5), 904–938. https://doi.org/10.1177/0018720820960865

O'Rourke, R. (2007). *Unmanned vehicles for U.S. Naval forces: Background and issues for Congress* (No. RS21294). Congressional Research Service. https://crsreports.congress.gov/product/pdf/RS/RS21294/14

O'Rourke, R. (2025). *China Naval modernization: Implications for U.S. Navy capabilities—Background and issues for Congress* [RL33153]. Congressional Research Service. https://www.congress.gov/crs_external_products/RL/PDF/RL33153/RL33153.285.pdf

Palmer, A., Carroll, H. H., & Velazquez, N. (2024). *Unpacking China's Naval buildup*. Center for Strategic and International Studies. https://www.csis.org/analysis/unpacking-chinas-Naval-buildup

Pandey. (2025, January 9). *Manned-unmanned teaming: Enhancing lethality*. Centre for Joint Warfare Studies. https://cenjows.in/manned-unmanned-teaming-enhancing-lethality/

Phua, B. K. (2022). *An operational effectiveness analysis on manned-unmanned teaming using weaponized unmanned vehicles in urban terrain* [Master's Thesis, Naval Postgraduate School]. NPS Archive: Calhoun. https://hdl.handle.net/10945/71023

Potter, R. (2025, March 31). *"Pentagon in shock": China's next-gen stealth drones are now leagues ahead of DARPA's, says explosive new study*. Sustainability Times. https://www.sustainability-times.com/reports/pentagon-in-shock-chinas-next-gen-stealth-drones-are-now-leagues-ahead-of-darpas-says-explosive-new-study/

PteroDynamics. (2025, February 19). *PteroDynamics awarded U.S. Navy contract to develop next-gen autonomous transwing VTOL UAS*. UAS Magazine. https://uasmagazine.com//articles/pterodynamics-awarded-us-Navy-contract-to-develop-next-gen-autonomous-transwing-vtol-uas

Rogoway, T. (2025a, April 7). *MQ-25 Stingray's extreme range gives it massive potential far beyond a tanker*. The War Zone. https://www.twz.com/air/mq-25-stingrays-range-gives-is-massive-potential-far-beyond-a-tanker

Rogoway, T. (2025b, April 7). *Navy won't scramble to field loyal wingman drones like the air force*. The War Zone. https://www.twz.com/air/Navy-isnt-scrambling-to-field-loyal-wingman-drones-like-the-air-force

Sadler, B. (2024). *2024 U.S. Military strength index assessment* (pp. 441–456). The Heritage Foundation. https://static.heritage.org/2023/Military_Index/pdf_%24folder%242024_IndexOfUSMilitaryStrength_ASSESSMENT_POWER_NAVY.pdf

Shelbourne, M. (2020, October 29). Navy's "Project Overmatch" Structure Aims to Accelerate Creating Naval Battle Network. *USNI News*. https://news.usni.org/2020/10/29/Navys-project-overmatch-structure-aims-to-accelerate-creating-Naval-battle-network

Shelbourne, M. (2022, March 24). A Generational Change in Naval Aviation Has Begun Amidst Tight Budgets, Fighter Gaps. *USNI News*. https://news.usni.org/2022/03/24/a-generational-change-in-Naval-aviation-has-begun-amidst-tight-budgets-fighter-gaps

Shelbourne, M., & Lagrone, S. (2024, February 14). *Navy will stand up lethal drone unit later this year, first replicator USVs picked*. USNI News. https://news.usni.org/2024/02/14/Navy-will-stand-up-lethal-drone-unit-later-this-year-first-replicator-usvs-picked.

Spataro, N., Phillips-Levine, T., & Tenbusch, A. (2022, January 10). *Winged luddites: Aviators are the biggest threat to carrier aviation*. War on the Rocks. https://warontherocks.com/2022/01/winged-luddites-aviators-are-the-biggest-threat-to-carrier-aviation/

Szondy, D. (2021, September 14). *MQ-25 Stingray drone refuels F-35C mid-air for the first time*. New Atlas. https://newatlas.com/military/mq-25-stingray-drone-aerial-refueling-f-35c-lightning-ii-fighter-first-time/

Tegler, E. (2021, January 12). *Developing The MQ-25's ground control station means thinking like a mission commander—Not a pilot*. Forbes. https://www.forbes.com/sites/erictegler/2021/01/12/developing-the-mq-25s-ground-control-station-means-thinking-like-a-mission-commandernot-a-pilot/

Tegler, J. (2022, October 7). *Questions emerge after Congress prohibits growler divestment*. National Defense Magazine. https://www.nationaldefensemagazine.org/articles/2022/10/7/questions-emerge-after-congress-prohibits-growler-divestment

Tegler, J. (2024, May 30). U.S. *Navy's MQ-8C fire scouts fly into retirement just two Years after entering operational service*. Flight Global. https://www.flightglobal.com/helicopters/us-Navys-mq-8c-fire-scouts-fly-into-retirement-just-two-years-after-entering-operational-service/158500.article

Thomas, R. (2024, May 22). U.S. Navy LCS programme reaches end of road with USS Pierre. *Naval Technology*. https://www.Naval-technology.com/news/us-Navy-lcs-programme-reaches-end-of-road-with-uss-pierre/?cf-view

Trevithick, J. (2023a, April 5). *Navy carrier-based drones will be able to be controlled by the Air Force*. The War Zone. https://www.twz.com/Navy-carrier-based-drones-will-be-able-to-be-controlled-by-the-air-force

Trevithick, J. (2023b, May 25). *First image of MQ-28 ghost bat in the United States*. The War Zone. https://www.twz.com/first-image-of-mq-28-ghost-bat-in-the-united-states

Trevithick, J. (2024a, April 10). *Navy's vision for disposable carrier-based loyal wingman drones comes into focus*. The War Zone. https://www.twz.com/air/Navys-vision-for-disposable-carrier-based-loyal-wingman-drones-comes-into-focus

Trevithick, J. (2024b, September 26). *Third marine XQ-58 Valkyrie flight test uses link 16 for control*. The War Zone. https://www.twz.com/air/third-marine-xq-58-valkyrie-flight-test-uses-link-16-for-control

Trevithick, J. (2025, January 29). *Carrier air wing's key priorities to win in future pacific fight laid out by Navy*. The War Zone. https://www.twz.com/sea/carrier-air-wings-key-priorities-to-win-in-future-pacific-fight-laid-out-by-Navy

Tucker, P. (2024, February 16). *Navy envisions "hundreds of thousands" of drones in the Pacific to deter China*. Defense One. https://www.defenseone.com/threats/2024/02/Navy-envisions-hundreds-thousands-drones-pacific-deter-china/394266/.

U.S Navy. (2024, March 11). *Department of the Navy FY 2025 president's budget*. https://www.Navy.mil/Press-Office/Press-Releases/display-pressreleases/Article/3703469/department-of-the-Navy-fy-2025-presidents-budget/

USNI. (2025, April 18). *Report to Congress on MQ-25 Stingray unmanned aircraft*. USNI News. https://news.usni.org/2025/04/18/report-to-congress-on-mq-25-stingray-unmanned-aircraft

Vincent, B. (2023, January 10). *Navy's task force 59 reaches full operational capability as it works to build a "digital ocean" of connected assets*. DefenseScoop. https://defensescoop.com/2023/01/10/Navys-task-force-59-reaches-full-operational-capability-as-it-works-to-build-a-digital-ocean-of-connected-assets/.

Wickert, D. P., Turner, M. D., & Shipe, R. (2016). *Innovation lost: The tragedy of UCLASS*. The Eisenhower School for National Security and Resource Strategy. https://www.jcs.mil/Portals/36/Documents/Doctrine/Education/jpme_papers/turner_m.pdf?ver=2017-12-29-142159-597

Wright, M., & Whitsett, D. (2022, May 1). Create a Naval unmanned aviation community. *U.S. Naval Institute*, *148*(5), Article 1431.

Xinhua. (2019). *China's national defense in the new era* (First). Foreign Languages Press Co. Ltd. https://english.www.gov.cn/archive/whitepaper/201907/24/content_WS5d3941ddc6d08408f502283d.html

Ziezulewicz, G. (2024, August 21). *Aircraft carrier Bush gets first-ever stingray drone control room*. NavyTimes. https://www.Navytimes.com/news/your-Navy/2024/08/21/bush-aircraft-carrier-gets-first-ever-stingray-air-drone-control-room/.

Acquisition Research Program
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net