NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

EXPLORING THE POTENTIAL USE OF LONG-RANGE UNMANNED AERIAL SYSTEMS TO ADDRESS CAPABILITY GAPS IN THE UNITED STATES COAST GUARD

by

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December 2023

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REPORT DOCUMENTATION PAGE				*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2023	**3. REPORT TYPE AND DATES COVERED** Master's thesis

4. TITLE AND SUBTITLE
EXPLORING THE POTENTIAL USE OF LONG-RANGE UNMANNED AERIAL SYSTEMS TO ADDRESS CAPABILITY GAPS IN THE UNITED STATES COAST GUARD

5. FUNDING NUMBERS

6. AUTHOR(S) Jeffrey C. Henkel

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT (maximum 200 words)

There is a growing threat to international order, specifically in the maritime environment. The United States Coast Guard (USCG), with its unique authorities, is perfectly positioned to respond to these threats in means that can avoid undesired conflict. Increased mission demand for intelligence, surveillance, and reconnaissance coupled with an ever-aging fleet of aircraft, reveal an expanding capability gap in the USCG's resources. There is an opportunity for the USCG to leverage the capabilities of current and future unmanned aerial systems (UAS), which can be strategically utilized in specific, key mission sets to augment the service's existing and evolving fleet. By utilizing Department of Defense acquisition frameworks and methods, a standardized approach is employed to analyze the potential benefits and costs of adding UAS capabilities into the USCG's aviation portfolio, which includes a capabilities based assessment (CBA), DOTmLPF-P analysis, and an analysis of alternatives (AoA). The study found that a capability gap of approximately 13,000 flight hours will come about in the next decade. This gap can be met with commercial materiel UAS solutions that are able to provide persistent surveillance and detection abilities in contested maritime environments.

14. SUBJECT TERMS
unmanned aerial systems, UAS, long-range unmanned aerial systems, LR-UAS, unmanned aerial vehicles, UAV, Coast Guard, ISR, search and rescue, capabilities based assessment, acquisition

15. NUMBER OF PAGES
103

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
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LIST OF ACRONYMS AND ABBREVIATIONS

ALMIS	asset logistics management information system
AoA	Analysis of Alternatives
ATON	aids to navigation
AUVSI	Association for Uncrewed Vehicle Systems International
BLOS	beyond line of sight
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CBA	capabilities-based assessment
CBO	Congressional Budget Office
CBP	Customs and Border Protection
CER	cost estimating relationship
COCO	contractor-owned, contractor-operated
COMINT	communications intelligence
CONOPS	concept of operation
CoOp	continuity of operations
COTS	commercial off the shelf
DAS	Defense Acquisition System
DHS	Department of Homeland Security
DOD	Department of Defense
EEZ	exclusive economic zone
ELT	enforcement of laws and treaties
EOIR	electro-optical/infrared
FASA	Federal Acquisition Streamlining Act
FY	fiscal year
GOCO	government-owned, contractor-operated
GOGO	government-owned, government-operated
GOTS	government off the shelf
HALE	high-altitude long endurance
IFF	identification friend or foe
ISR	intelligence, surveillance, and reconnaissance

IUU	illegal, unreported, and unregulated
JCIDS	Joint Capabilities Integration and Development System
JIATF-South	Joint Interagency Task Force-South
LMR	living marine resources
LRCCA	long-range command and control aircraft
LRS	long-range surveillance
LR-UAS	long-range unmanned aircraft system
MALE	medium-altitude long endurance
MGTOW	maximum gross takeoff weight
MOE	measure of effectiveness
MOSA	modular open systems architecture
MRR	medium-range recovery
MRS	medium-range surveillance
MR-UAS	medium-range unmanned aircraft system
NASEM	National Academies of Sciences, Engineering, and Medicine
NAVAIR	Naval Air Systems Command
NDI	non-developmental items
NGLH	next generation light helicopter
NGMH	next generation medium helicopter
NM	nautical miles
NSC	National Security Cutter
NSS	National Security Strategy
PoR	program of record
PPBES	Planning, Programming, Budgeting, and Execution System
PRC	People's Republic of China
PWCS	port, waterways, and coastal security
R&D	research and development
RDT&E	research, development, test, and evaluation
SAR	search and rescue
SIGINT	signals intelligence
SOCOM	Special Operations Command
SRR	short-range recovery

sUAS	small unmanned aircraft system
UAS	Unmanned Aircraft System
USCG	United States Coast Guard
USMC	United States Marine Corps
USRD	Uncrewed Systems & Robotics Database
UxS	unmanned systems
VTOL	vertical takeoff and landing

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I. INTRODUCTION

A. MOTIVATION

The missions of the United States Coast Guard (USCG) are vital to the nation's interests. From protecting the nation's economic lifeblood through the enforcement of maritime security to responding to crises at sea, the USCG performs "diverse missions in a maritime domain that encompasses more than 100,000 miles of coastline and inland waterways and the largest exclusive economic zone in the world, covering some 4.5 million square miles of sea from Puerto Rico to Guam and from the Arctic Circle to American Samoa, south of the equator" (National Academies of Sciences, Engineering, and Medicine [NASEM], 2020, p. 7). To accomplish its missions, the USCG employs 259 cutters (defined as any vessel that is equal to or greater than 65 feet in length), over 1,600 boats (less than 65 feet in length), and 200 aircraft (Coast Guard, 2023c). The Service's aircraft inventory is comprised of 57 fixed-wing and 143 rotary-wing assets, the former of which are differentiated in three programs of record: Long-Range Surveillance (LRS) Aircraft (fulfilled by the HC-130), Medium-Range Surveillance (MRS) Aircraft (fulfilled by the HC-144 and C-27), and Long-Range Command and Control Aircraft (fulfilled by the C-37 and primarily used for personnel transport). While the USCG continues to acquire LRS assets, the MRS program is in the Department of Homeland Security's (DHS's) support phase of the acquisition program life cycle (analogous to the Department of Defense's operations and support phase) with no ongoing airframe acquisitions. As the USCG's aviation fleet, specifically the MRS assets, continues to age, it is vital that the Service seriously consider unmanned aircraft systems (UAS) as a supplement to and/or replacement of capabilities.

Likening the current state of world affairs to those preceding World War II, in their 2020 tri-Service strategy, the Service Chiefs of the U.S. maritime forces proclaimed, "The rules-based international order is once again under assault" (Department of Defense [DOD], 2021, p. ii). They further called for a modern response:

> We are at an inflection point. Our integrated Navy, Marine Corps, and Coast Guard must maintain clear-eyed resolve to compete with, deter, and, if

> necessary, defeat our adversaries while we accelerate development of a modernized, integrated all-domain naval force for the future. Our actions in this decade will shape the maritime balance of power for the rest of this century. (DOD, 2021, p. iv)

As maritime missions evolve, so must the USCG's capabilities. The USCG's diverse mission set may benefit from the advantages of UAS.

B. RESEARCH PROBLEM

Stretched thin and with an ever-aging fleet of aircraft, there is an opportunity for the USCG to leverage the capabilities of current and future UAS; however, there is little movement on this front. DHS's Fiscal Year (FY) 2024 USCG budget request does not include funding for the acquisition of USCG UAS in neither the budget overview nor the unfunded priorities list (Coast Guard, 2023a). While the FY2024 Congressional Justification does include a request for $4.1 million to "assess and evaluate UAS and unmanned maritime vehicles," there is no mention of long-range assets that could fill and/or supplement the role of current MRS aircraft (Coast Guard, 2023a).

The end-of-service-life of the HC-144 and the risks of sustaining the C-27 together place the MRS program, the USCG, and the nation as a whole in a precarious position. Without these assets, there will be a considerable capability gap in multiple USCG mission areas, which are of high importance to national and Service-level strategies.

If a materiel solution is warranted, there is a wide range of UAS options that could fill the capability gaps. These include commercial-off-the-shelf platforms, non-developmental items that are already in government inventory, and developmental programs. Each of these solutions will vary in their effectiveness and affordability.

This study examines USCG statutory missions and strategies to determine whether there will be a future capability gap within the fixed-wing aircraft inventory. By applying acquisition techniques, including a capabilities-based assessment, a DOTmLPF-P analysis, and an analysis of alternatives, recommendations to improve the Service's acquisition strategy are presented.

C. OBJECTIVES AND RESEARCH QUESTIONS

The objective of this thesis is to provide decision-makers with a well-researched argument for the investment into UAS. It is important to note that UAS solutions are not a one-for-one replacement of any current USCG program of record (PoR), but rather can be strategically utilized in specific, key mission sets to augment the capabilities of the existing and evolving fleet. By reviewing Service and national strategies alongside current capabilities, an analysis of a future capability gap is presented. Various approaches, including UAS materiel solutions, are analyzed for their ability to address the future capability needs of the Service.

This research attempts to answer the following two research questions:

1. What is the future capability gap in USCG missions?

2. Is there a UAS materiel solution that can affordably fill the capability gap?

D. METHODOLOGY

1. Research Approach

By utilizing Department of Defense (DOD) acquisition frameworks and methods, a standardized approach is employed to analyze the potential benefits and costs of integrating UAS capabilities into the USCG's aviation portfolio. To do so, background information on the missions, Service strategies, and current PoRs is first presented. A literature review of UAS follows, which includes a description of their functionality, government and commercial uses, and payload considerations. After this groundwork has been laid, an opportunity-based Capabilities-Based Assessment (CBA) is attempted that uncovers an emerging operational need. In alignment with the DOD's Joint Capabilities Integration and Development System (JCIDS) processes, a DOTmLPF-P analysis is then completed to determine if a materiel solution is warranted. Finally, commercial-off-the-shelf (COTS) platforms, non-developmental items, and developmental programs are analyzed to determine their effectiveness at and cost of addressing the capability gap. Differing operating approaches are presented that compare the benefits of government ownership and operation vice commercial and combinations thereof.

2. Research Limitations

The scope of this research is limited to long-range, fixed-wing, UAS alternatives to current, manned operations. It is also limited to only those solutions that are actively marketed today and does not account for future advancements in technology. The research findings were intended to be unclassified and therefore some operational data could not be included. The research was limited to publicly available information, and operational flight hour data supplied by the Coast Guard. Within the analysis of alternatives, UAS performance specifications were taken from published manufacturer data. The reported technical characteristics would likely be affected by mission system payloads. It was further assumed that UAS platforms and commercial payloads have an open or compatible architecture that enables technology integration. Further research to validate the performance characteristics was outside of the scope of this report but would greatly enhance its argument.

E. SUMMARY

During the past two decades, every DOD Service and numerous federal agencies have heavily invested in UAS technology. Their employment of these systems has steadily increased as "[UAS] capabilities, commercial availability, reliability, and affordability have grown" (NASEM, 2020, p. 8). Meanwhile, the USCG has yet to seriously invest in these systems. As the USCG's fixed-wing fleet ages, there is an opportunity to investigate the capabilities of UAS as they apply to USCG statutory missions and strategic plans. This study captures the capability gap and presents potential solutions that can enable the USCG to remain *Semper Paratus*, always ready, to protect and defend the United States of America.

This chapter introduced the need for research into UAS alternatives in the USCG and posed specific research questions. The next two chapters provide background information and a literature review covering UAS platforms and payloads. Chapter 4 then utilizes the DOD frameworks of a CBA, DOTmLPF-P analysis, and an analysis of alternatives to recommend a path forward.

II. BACKGROUND

A. U. S. COAST GUARD STATUTORY MISSIONS

The USCG, one of 22 agencies within DHS, is the only armed force of the United States that falls outside the DOD. As such, its role and missions are distinct. While the DOD is primarily focused on national defense at a global scale, DHS and the USCG are responsible for public security to protect the United States within and around its borders. Due to this organizational structure and focused role, the USCG operates under different legal authorities than the DOD, each of which defines the Service's various missions. USCG recruiting succinctly distills the USCG mission into three words: "Our mission is simple yet powerful: Protect. Defend. Save" (Coast Guard Recruiting, n.d.). This overarching mission is in complete alignment with the Coast Guard Ethos, which states,

> In Service to our Nation
> With Honor, Respect, and Devotion to Duty
> We protect
> We defend
> We save
> We are Semper Paratus
> We are the United States Coast Guard (Coast Guard Recruiting, n.d.)

The USCG's daily work is key to the national interests of the United States and its citizens. With almost 100,000 miles of coastline and an exclusive economic zone (EEZ) of nearly 3.4 million square miles, "maritime interests are critical to our nation's security, economy, and prosperity" (Coast Guard Recruiting, n.d.). These tenets of the USCG contributory role are derived from the following 11 statutory missions:

1. Port, Waterways, and Coastal Security
2. Drug Interdiction
3. Aids to Navigation
4. Search and Rescue
5. Living Marine Resources
6. Marine Safety
7. Defense Readiness
8. Migrant Interdiction
9. Marine Environmental Protection
10. Ice Operations

11. Other Law Enforcement (NASEM, 2020, p. 14)

A description of each of these 11 missions is presented, with a focus on the role that aviation plays in completing them.

1. Port, Waterways, and Coastal Security

The Port, Waterways, and Coastal Security (PWCS) mission involves the protection of population centers, vessels, and critical infrastructure in the maritime domain (NASEM, 2020, p. 15). Specifically, this mission oversees the security of 361 U.S. ports and 95,000 miles of waterways ("Missions of the United States Coast Guard," n.d.). Example activities that align to this mission area include enforcing security zones, escorting high-interest vessels such as those carrying dangerous cargo or a large number of passengers, conducting harbor patrols including vessel boardings, performing vulnerability assessments, and enforcing compliance with security plans (NASEM, 2020, p. 15). In the decade between 2011 and 2020, 22% of the Service's operating budget was spent on the PWCS mission, the highest of all statutory missions (Government Accountability Office [GAO], 2021, p. 7). Aviation assets play a role in this mission as they provide aerial surveillance and deterrence during routine patrols and high-interest events.

2. Drug Interdiction

As the lead federal agency in maritime drug interdiction, the USCG's role is crucial in disrupting the flow of illegal drugs into the United States via maritime routes. The USCG utilizes its law enforcement authorities on the high seas to conduct at-sea interdictions and seize illegal substances and their traffickers. In FY2011 to FY2020, the drug interdiction mission was the highest of all missions in combined vessel and aircraft operational hours with roughly 1.3 million hours expended (GAO, 2021, p. 4). One of the major efforts in the execution of this mission is the USCG's involvement in Joint Interagency Task Force –South (JIATF-South), comprised of numerous U.S. and international agencies, which are responsible for detecting, monitoring, and interdicting illegal drug trafficking in the transit zone between South America and the United States. Through the conduct of aerial and surface patrols, interception and boarding of suspicious vessels, seizure of illegal substances, and intelligence gathering, the multiagency task force disrupts and dismantles drug trafficking organizations and prevents illegal drugs from reaching U.S. shores. All USCG aircraft play a critical role in the drug interdiction mission at large. The LRS and MRS fixed-wing aircraft provide surveillance and detection capabilities from both within the United States and from forward operating bases in Central America and the Caribbean. The USCG's rotary-wing assets, the ship-deployable MH-65 and the MH-60, each support this mission through surveillance, detection, and disruption of drug traffic.

3. Aids to Navigation

The Aids to Navigation (ATON) mission "promotes the safe, economic, and efficient movement of military, commercial, and other vessels" (NASEM, 2020, p. 16). To do so, the USCG maintains a system of more than 50,000 buoys, beacons, and other fixed or floating aids. This mission also includes responding to ATON emergencies, such as replacing damaged or misplaced buoys after the passage of a major hurricane. While largely a surface function, fixed-wing aviation assets can assist in the surveillance of ATON devices.

4. Search and Rescue

Perhaps most well-known for its maritime search and rescue (SAR) role, the USCG is the nation's lead agency for this mission. As designated in the *National Search and Rescue Plan*, the USCG is the federal SAR coordinator for U.S. aeronautical and maritime SAR regions in U.S. waters (Coast Guard Deputy Commandant for Operations, 2016, p. 7). Overland aeronautical SAR is assigned to the U.S. Air Force. The USCG "executes this mission by planning, coordinating, and conducting SAR efforts using its own surface and airborne units, as well as those of other federal, state, and local responders" (NASEM, 2020, p. 16). The SAR mission accounted for 11% of the USCG's operating expenses from FY 2011 to FY2020 (GAO, 2021, p. 7). For comparison of expenditures by mission, a graphic from the 2021 GAO report is included in Figure 1. All aviation platforms play a significant role in the SAR mission as they provide advanced detection and recovery capabilities to effect the rescue of those in peril.

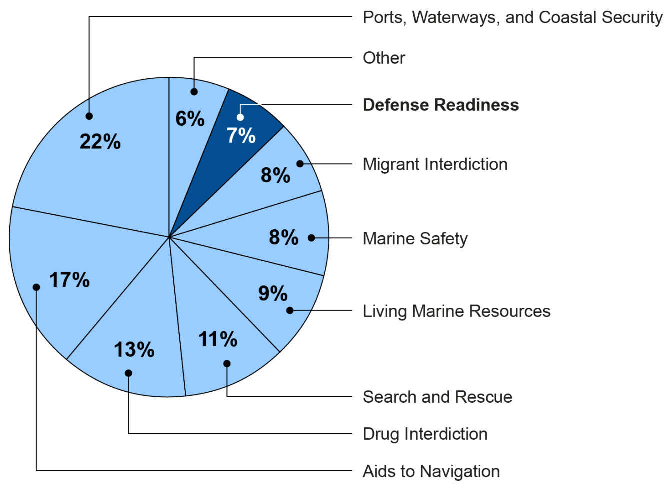

Figure 1. Share of the USCG's Total Estimated Operating Expenses by Statutory Mission, FY2011–FY2020. Source: GAO (2021).

5. Living Marine Resources

The Living Marine Resources (LMR) mission of the USCG focuses on the protection of marine life and their ecosystems. The Service accomplishes the LMR mission through international agreements and at-sea enforcement of U.S. and international fisheries laws. Some key aspects of the LMR mission include (1) fisheries enforcement, which aims to prevent overfishing, protect endangered species, and promote sustainable fishing practices, (2) marine mammal protection, (3) protected species conservation, and (4) environmental response to pollution incidents. While these activities are carried out to preserve and protect U.S. waters, there has been an increased focus on both international waters and those of allied nations, especially in the Pacific. Through international partnerships, the USCG aims to be the partner of choice for underdeveloped nations that do not have the resources to counter the threats posed by illegal, unreported, and unregulated (IUU) fishing. Aviation resources, specifically fixed-wing platforms, play a major role in the intelligence and surveillance component of this mission. Working in concert with U.S. and/or foreign end-game surface vessels, the information gained by aerial platforms assists to prioritize vessel boardings.

6. Marine Safety

The Maritime Safety mission is aimed at preventing maritime issues before they occur. Activities of this mission include inspections of vessels and facilities, mariner credentialling, vessel documentation, and educational programs. This mission also involves the investigation of maritime accidents to find root causes and prevent future occurrences. Aviation assets are not significantly employed in fulfillment of this mission.

7. Defense Readiness

The USCG is unique in that it is the only branch of the armed forces that falls outside of the DOD. In times of war, however, or when directed by the president, the department under which the USCG operates can be transferred from DHS to the Navy per 14 U.S.C. § 103. It is important, therefore, to maintain a state of readiness to function in a military capacity. Training and capability must be maintained to support interoperability with DOD branches, especially with U. S. Navy assets (GAO, 2021, p. 1). This is carried out through exercises and operations including the USCG's role in securing the National Capital Region airspace, which surrounds Washington, DC. USCG aviation assets incorporate interoperability requirements such as Identification Friend or Foe (IFF) and secure communications into their platforms to support defense readiness.

8. Migrant Interdiction

Through the detection and interdiction of undocumented migrants at sea, the USCG utilizes its law enforcement authorities to enforce U.S. immigration laws (NASEM, 2020, p. 18). This mission ensures the safety and security of the U.S. maritime borders by preventing and responding to illegal migration as well as human trafficking. Approximately 8% of the FY2011 to FY2020 operating budgets came from execution of the migrant interdiction mission (GAO, 2021, p. 7). USCG aviation assets, both fixed-wing and rotary-wing, play a significant role in this mission. Through both routine patrols of maritime borders and responding to specific intelligence reports, air assets are crucial to the detection and identification of suspected migrant vessels.

9. Marine Environmental Protection

The USCG protects not only those at sea but also the sea itself. The USCG's Marine Environmental Protection mission aims to safeguard and preserve the nation's waters from pollution and other ecological threats. This mission is aimed at preventing, detecting, and responding to marine pollution incidents and the introduction of invasive species into the marine environment (NASEM, 2020, p. 18). While the smallest of missions when it comes to operational hours and operating expenditures, the response element to incidents can gain global attention. For example, the infamous BP Deepwater Horizon oil spill in 2010 had lasting implications for the nation's economy and ecosystems that are still being felt today. USCG capabilities, aviation assets included, are critical to responding to these unanticipated pollution events.

10. Ice Operations

The USCG's Ice Operations mission spans from the Arctic to the Antarctic and is aimed at ensuring safe and efficient maritime operations while protecting national interests. By maintaining navigable seas and lakes through icebreaking, the USCG enables maritime commerce in these areas. The Service conducts scheduled international ice patrol missions via fixed-wing aircraft, to detect navigation hazards and warn mariners of iceberg danger.

11. Other Law Enforcement

This last mission of the USCG, Other Law Enforcement, encapsulates the other unique maritime authorities of the Service that do not fall into other mission areas. One of these focus areas is the deterrence, detection, and interdictions of foreign flagged vessels that encroach or enter the nation's EEZs (NASEM, 2020, p. 19). While vessel traffic can be monitored via electronic, satellite-based communications systems, there are often dark targets that are not transmitting their activities and may be conducting illegal operations. Aircraft and surface vessel patrols are executed to counter this activity and protect sovereign rights to U.S. waters as well as those of allied nations.

B. STRATEGIC PLANS AND VISION

A review of national, DOD, USCG, and mission-specific strategies have an interwoven theme: the world and each of the organizations above find themselves at an inflection point. As President Biden stated in the 2022 *National Security Strategy* (NSS), the U.S. finds itself in a "strategic competition to shape the future of the international order" (The White House, 2022, p. 2). The strategy highlights how there are escalating geopolitical tensions that result from non-democracies, such as the Russian Federation and the People's Republic of China (PRC), who are challenging established norms. President Biden's national strategy is clear and concise: "We want a free, open, prosperous, and secure international order" (The White House, 2022, p. 10). To accomplish this goal, the NSS further provides three lines of effort, which include strengthening American power and influence, partnering with allies, and modernizing the armed forces. Within these efforts, integrated deterrence is a key competency that must be exploited to out-compete and constrain adversaries.

The leaders of the 2020 U.S. maritime forces—General Berger, Commandant of the Marine Corps; Admiral Gilday, Chief of Naval Operations; and Admiral Schultz, Commandant of the Coast Guard—declared in their tri-Service strategy that an integrated all-domain naval power that leverages the authorities and capabilities of each of their Services is crucial to obtaining a free and open, rules-based order (DOD, 2021, p. i). Further, they call for the maritime forces to modernize though innovation and the utilization of emerging technologies in response to the rapidly changing battlefield. As the nation formulates responses to adversaries, the Service Chiefs acknowledged the impetus to field a "multi-domain portfolio of shore-launched and sea-launched unmanned platforms with urgency" (p. 18). Intelligence, surveillance, and reconnaissance (ISR) platforms, they claimed, "will add capability to monitor, record, and report instances of coercive behavior, providing evidence suitable for diplomatic engagement and public audiences" (p. 18). The NSS and the tri-Service strategy each emphasize that the actions of this decade will shape the next century. These actions include not only diplomatic efforts but investments in capability.

The USCG serves a unique role in its service to the American people. The Service's focus on maritime governance and cooperative engagements are key competencies that can assist in accomplishing the national strategies introduced above. The USCG uses its law enforcement authorities to bridge the gaps between DHS, the Department of State, and the DOD. These tenets are strewn throughout the Service's 2022 strategic outlook, within which Admiral Fagan, Commandant of the Coast Guard, opened:

> As a maritime nation, the United States depends on a strong and agile Coast Guard to enhance the Nation's maritime safety, security, and economic prosperity. For 232 years, we have applied our broad authorities and capabilities to save lives, protect our waters, and defend our national interests. (Coast Guard Headquarters, 2022, p. 1)

Fagan further acknowledged the risks introduced by the rapid pace of geopolitical change and called for the Service to respond and adapt.

> Now is the time to move our Service forward. … We will sharpen our competitive edge by driving a culture of innovation to integrate new technology and provide our people with reliable assets, systems, and infrastructure. And we will advance our mission excellence by pioneering new operating concepts while enhancing our readiness. (Coast Guard Headquarters, 2022, p. 1)

The USCG finds itself in a unique position as it frequently engages with the nation's adversaries in the course of its daily missions. For example, the USCG routinely encounters vessels from PRC during LMR and law enforcement patrols within the Indo-Pacific. Recent USCG strategies are anything but shy in addressing the threats to international order on the seas, specifically calling out the aggressive actions of PRC. For example, the global food markets and economic security of maritime nations are under attack from destructive commercial fishing practices. To counter IUU fishing in particular, the USCG, in their 2020 IUU fishing strategic outlook implementation plan, identified unmanned systems as an enabler to perform ISR missions that span large and remote areas of the maritime domain (Coast Guard Headquarters, 2020, p. 27).

The Arctic has become an area of increased strategic focus for the USCG and the nation. With significant investments in the Polar Security Cutter, congressional and executive leadership have recognized the crucial role that the USCG plays in this domain.

With the abundance of energy, mineral, fishery, and other commercial resources present in the Arctic, persistent physical presence in the region is paramount to protecting national security and economic prosperity (Coast Guard Headquarters, 2019, p. 2). To meet this demand, the USCG's 2019 Arctic strategic outlook calls for an investment in systems, including unmanned and autonomous systems that are capable of operating in the harsh and remote environments of the region (Coast Guard Headquarters, 2019, p. 26).

A review of national and maritime forces' mission-level strategies reveals that there is a growing threat to international order, specifically in the maritime environments. The USCG, with its unique authorities, is perfectly positioned to protect and respond to these threats in diplomatic means that can avoid unwanted conflict. To be effective in this challenge, however, numerous USCG strategies call for investments in capability. Unmanned assets such as UAS can provide the persistent ISR capability that will be required to enhance maritime domain awareness.

C. USCG PROGRAMS OF RECORD

USCG acquisition PoRs are aligned into three major domains—surface, aviation, and Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR)—each of which delivers mission capability to the Service. The aviation portfolio is divided into fixed-wing, rotary-wing, mission system, and unmanned system areas, which are further decomposed into specific programs, including

- Long-Range Surveillance Aircraft
- Medium-Range Surveillance Aircraft
- Long-Range Command and Control Aircraft
- Medium-Range Recovery Helicopter
- Short-Range Recovery Helicopter
- Minotaur Mission System
- Unmanned Aircraft Systems

1. Long-Range Surveillance Aircraft

The USCG LRS Aircraft PoR is currently comprised of legacy HC-130H and modernized HC-130J assets. The HC-130H is beyond its designed service life and remains operational at only one unit: Air Station Clearwater, FL. With only five assets remaining in USCG inventory, these are all scheduled to be decommissioned in FY2024 (Coast Guard, 2023a, p. 57). The USCG is currently acquiring to meet a PoR of 22 HC-130J aircraft that will continue to fulfill long-range maritime patrol requirements. Historically acquired at approximately one aircraft per year, the USCG accepted its 16th HC-130J aircraft in FY2022 (Coast Guard, 2023a, p. 196). This aircraft, as shown in Figure 2, features the standardized Minotaur mission system, which incorporates an advanced, 360-degree multimode surface search radar and electro-optical/infrared (EOIR) sensors fused with real-time tracking information "to enhance [the] common operating picture and maritime domain awareness" (Coast Guard, 2023b). With a range of 4,900 nautical miles (NM) and an endurance of 20+ hours, this asset carries out a wide array of missions, including SAR, cargo and personnel transport, law enforcement, and international ice patrol (Coast Guard, n.d.b). The initial service life of the HC-130J is projected out to the 2050s (Eckhause et al., 2020, p. 26). These aircraft currently operate from USCG air stations in Kodiak, AK; Barbers Point, HI; and Elizabeth City, NC.

Figure 2. USCG HC-130J Aircraft. Source: Coast Guard (n.d.b).

2. Medium-Range Surveillance Aircraft

The USCG MRS Aircraft PoR is currently comprised of two models of aircraft, the HC-144 Ocean Sentry and the C-27J Spartan. The MRS program was established in 2002 and was initially envisioned to be comprised of 36 HC-144 aircraft (Mackin, 2015, p. 7). However, due to a congressional mandate in 2014, DHS directed that the USCG restructure their acquisition plan to include an addition of 14 C-27J aircraft (Mackin, 2015, p. 9). These aircraft, while new to the USCG, were resurrected from a preservation status after the Air Force, which had acquired 21 airframes in total, had canceled the acquisition in 2012 (Mackin, 2015, p. 4). The addition of the 14 C-27 aircraft reduced the HC-144 planned fleet down to 18.

The HC-144, shown in Figure 3, has extensive sensor capabilities, including a multimode search radar and EOIR sensors, which enable it to perform a wide array of USCG missions. With a maritime communications suite and the cross-platform Minotaur mission system, the aircraft performs exceptionally well in the role of on-scene commander during homeland security missions. With a range of 2,100 NMs and an endurance of 10+ hours, this platform can execute the same types of ISR missions as the HC-130J, although not at the ranges and endurance of the LRS assets. A 2020 RAND study found that the HC-144 had fleetwide challenges with deicing capabilities and fuel storage (Eckhause et al., 2020, p. 28). The Service has also requested funding in their FY2024 budget request for airframe analysis studies, implying that there may be upcoming structural concerns with these aircraft (Coast Guard, 2023a, p. 216). These aircraft currently operate from USCG Air Stations Cape Cod, MA; Miami, FL; Mobile, AL; and Corpus Christi, TX.

Figure 3. USCG HC-144 Aircraft. Source: Coast Guard (n.d.c).

Despite beginning operations with un-missionized C-27Js in Sacramento, CA, in 2017, as of 2023, the first C-27 is only just completing its prototype developmental testing for missionization (Coast Guard, 2023a, p. 194). Once missionized, they will feature the standardized Minotaur mission system and a suite of sensors similar to those aboard the HC-130J and HC-144. The regeneration and missionization process for these assets has been behind schedule and over budget. At program inception, all 14 C-27s were estimated to be missionized by 2022 at an acquisition cost of $600 million (Mackin, 2015). As of the FY2024 budget request, no aircraft have yet to fully complete the missionization process, and they have already surpassed the initial cost estimate (Coast Guard, 2023a, p. 194). The USCG is battling numerous issues with the aircraft, including parts obsolescence, access to technical data, and poor airframe conditions found during regeneration. Despite these delays and conditions, the USCG is transitioning one its largest aviation units, Air Station Clearwater, from the HC-130H to C-27J in FY2024. The C-27 aircraft have a range of 2,675 NMs with an endurance of 12 hours (Coast Guard, n.d.c). The C-27 aircraft is pictured in Figure 4.

Figure 4. USCG C-27 Aircraft. Source: Coast Guard (n.d.c).

3. Long-Range Command and Control Aircraft

The USCG operates two Long-Range Command and Control Aircraft (LRCCA), shown in Figure 5, for the sole means of transporting DHS and USCG leadership. These are baseline commercial Gulfstream aircraft that transition to a C-37B after being missionized with specialized equipment and sensors to ensure continuity of operations (Coast Guard, n.d.a).

Figure 5. USCG Long Range Command and Control Aircraft. Source: Coast Guard (n.d.a).

4. Rotary-Wing PoRs

The USCG maintains two rotary-wing PoRs: Short-Range Recovery (SRR) and Medium-Range Recovery (MRR). Both programs are in the Support Phase of the DHS acquisition life cycle. The SRR PoR is filled by 98 MH-65 helicopters, shown in Figure 6, that have been operating in USCG inventory since the early 1980s (Coast Guard, n.d.e). These aircraft have received numerous upgrades, which include engine and avionics replacements, and have undergone service-life extension projects lengthening the service life from 10,000 hours to 30,000 hours. These aircraft are no longer in production by the manufacturer and will begin to reach their service life within the next decade.

Figure 6. USCG MH-65 Helicopter. Source: Coast Guard (n.d.e).

To ease supply chain pressures and maintain readiness of the fleet, the SRR program is slowly being reduced as it is replaced by the MH-60, the asset of the MRR PoR (Coast Guard, 2023a, p. 59). The MH-60 Jayhawk helicopter, shown in Figure 7, supports all mandated USCG missions and is specifically adept at rapid response efforts (Coast Guard, n.d.d). In USCG operational service since 1990, these are aging airframes as well and are currently undergoing a service-life extension project (Coast Guard, n.d.d). As the existing rotary-wing fleet transitions from the MH-65 to the larger MH-60, response capabilities, specifically in relation to range and endurance, should increase.

Figure 7. USCG MH-60 Helicopter. Source: Coast Guard (n.d.d).

5. Minotaur Mission System

The Minotaur Mission System "incorporates sensors, radar and command, control, communications, computers, cyber, intelligence, surveillance and reconnaissance equipment and enables aircrews to gather and process surveillance information that can be transmitted to other platforms and units during flight" (Coast Guard, n.d.f). The system, which is open architecture and government-owned, was originally developed by the Navy and is used across multiple DOD and DHS platforms. The system provides increased situational awareness for operators and supports interoperability both within and outside the USCG.

6. Unmanned Aircraft Systems

The USCG has a dedicated UAS acquisition program that is focused on evaluating and implementing cost-effective UAS solutions to meet both cutter and land-based requirements. The USCG has achieved success with its small Unmanned Aircraft System (sUAS), which addresses "the operational need for a persistent airborne surveillance capability" (Coast Guard, n.d.g). This capability, ISR services, was initially procured for a single National Security Cutter (NSC) in 2016 via a contract to Insitu for contractor-owned, contractor-operated (COCO) systems that utilized the ScanEagle medium-range UAS, pictured in Figure 8 (Eckhause et al., 2020, p. 105). This acquisition strategy has been expanded to outfit all NSCs (and plans to do the same with the medium-class Offshore Patrol Cutters) with sUAS capability.

Figure 8. USCG ScanEagle sUAS. Source: Coast Guard (n.d.g).

Regarding long-range UAS (LR-UAS) capability, the USCG has "validated a mission need for land-based UAS to significantly enhance ocean surveillance in support of the Service's operations" (Coast Guard, n.d.g). The USCG's FY2022 and FY2023 budgets included $3.4 million and $4.1 million respectively for research and development projects spanning unmanned air, surface, and subsurface systems (Coast Guard, 2023a, p. 260). A similar request was made in the FY2024 budget. Outside of these requests, there is no indication of upcoming investment in LR-UAS.

D. SUMMARY

USCG aviation assets are aging. With the exception of the HC-130J, there are no ongoing acquisitions of airframes that are used to carry out the 11 statutory missions of the USCG. The MRS program assets, the HC-144 and HC-27, each have significant challenges that are likely to accelerate their end of useful life, as early as within the next decade. As the rotary-wing fleet transitions to a single model, the MH-60, the capabilities of the aviation enterprise will change. The USCG has demonstrated the ability to successfully integrate UAS into their concept of operations with sUAS but have yet to invest in LR-UAS.

III. LITERATURE REVIEW

A. UNMANNED AIRCRAFT SYSTEMS

In its simplest form, a UAS can be defined as an aircraft whose aircrew has been replaced by computers and a communications link (Austin, 2010). The aircraft, however, is only one part of the greater system that comprises a UAS. Reg Austin, in his 2010 text, *Unmanned Aircraft Systems*, described these subsystems as including the aircraft, its payloads, the control station(s), launch and recovery systems, support systems, and transport systems. This entire system is displayed in Figure 9.

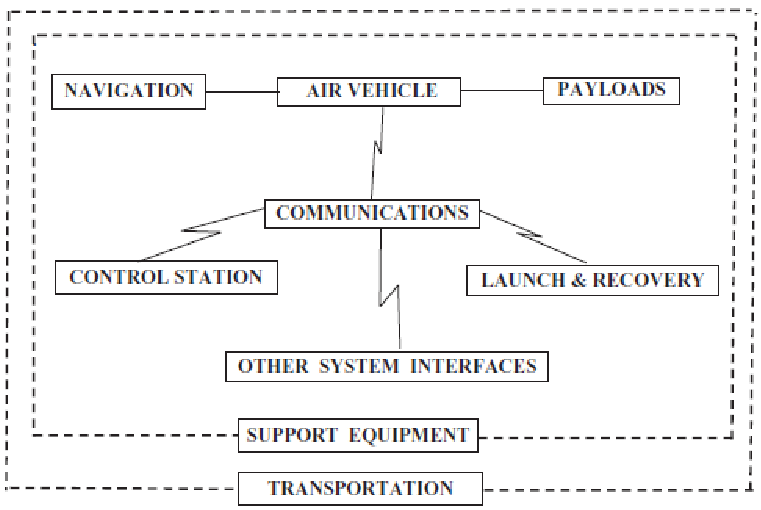

Figure 9. UAS Subsystems. Source: Austin (2010).

Austin (2010) further made some distinctions between commonly used UAS terms. An unmanned aircraft vehicle (UAV) is the single aircraft subsystem of the greater UAS. Therefore, the UAS is a broader term that enables UAV operations (Garg, 2021). Different authors prefer to use the term *aerial* in lieu of *aircraft*, but there is no distinction. Other terms that are synonymous with UAV and appear in literature include *remotely piloted aircraft*, *unmanned air vehicle*, *unmanned aerospace vehicle*, *uninhabited aircraft vehicle*, *unmanned airborne vehicle*, *unmanned autonomous vehicle*, *uncrewed aircraft systems,* and *aerial robots*, to name a few (Garg, 2021). Austin (2010) made an important differentiation, however, between a drone and a UAV. While a drone can operate beyond line of sight from the operator, it has zero intelligence. It does not communicate with the operator, and data from the mission, such as imagery, are not retrieved until its recovery (Austin, 2010). A UAV, however, employs automatic intelligence that enables data communication between itself and an operator (Austin, 2010). These data, coming from both the UAV and its payload subsystem, can include primary state information such as position, airspeed, heading, and altitude; condition information such as fuel state and engine performance; and imagery or radar tracks from onboard sensors.

The history of drones and UAVs dates to the French Revolutionary Wars in the 1800s when soldiers used hot air balloons to bomb the enemy (Garg, 2021). Interest continued in World War I with the invention and testing of systems including an automatic airplane and unmanned aerial torpedoes (Garg, 2021). It wasn't until the Vietnam War, however, that UAS, including the AQM-34 Firebee, was employed in a combat role (Hoehn & Kerr, 2022). This vehicle, pictured in Figure 10, was launched from a DC-130 Hercules and served as a low-altitude photographic reconnaissance drone. After its flight mission, it would return to a programmed location, complete an engine shutdown, deploy a parachute, and then be recovered either from the air via helicopter or from the sea after splashdown (Pima Air & Space Museum, n.d.).

Figure 10. AQM-34 Firebee. Source: Pima Air & Space Museum (n.d.).

UAS technology continued to advance with a major development in the late 1990s when the MQ-1 Predator, shown in Figure 11, first entered military service. Operated by the Air Force, the MQ-1 Predator "was designed in response to a Department of Defense requirement to provide to the warfighter persistent intelligence, surveillance, and reconnaissance information combined with a strike capability" (Air Force, n.d.). The Predator was a developmental program in which General Atomics Aeronautical Systems was contracted to produce systems via an Advanced Concept Technology Demonstration. This UAS continues to serve the military with missions that include armed reconnaissance, airborne surveillance, and target acquisition.

Figure 11. U.S. Air Force MQ-1 Predator. Source: Air Force (n.d.).

UAVs can be classified into various categories based on their characteristics, including size, payload, endurance, range, altitude, and capabilities (Jha, 2017). Garg (2021) provided seven distinct categories of UAVs, which are presented, along with their salient characteristics, in Table 1. These categories include micro, mini, small, tactical, medium-altitude long endurance (MALE), high-altitude long endurance (HALE), and strike/combat.

Table 1. Categories of UAVs and their Salient Characteristics. Source: Garg (2021).

Category	Weight of UAV (kg)	Operating Altitude (m)	The Radius of Mission (km)	Endurance (hr)	Typical Uses
Micro	< 2	250	< 5	1	Reconnaissance, inspection, surveillance
Mini	2–20	150–300	< 25	1–6	Surveillance, data gathering
Small	20–150	Up to 5000	50	8–24	Surveillance, data gathering
Tactical	150–600	Up to 10,000	300	> 24	Surveillance, data gathering
MALE	> 600	14,000	> 1,000	> 24	Surveillance, cargo transportation
HALE	> 600	Up to 65,000	> 1,000	> 24	Surveillance, data gathering, signal relay
Strike/ Combat	> 600	Up to 65,000	> 1000	Days/weeks	Surveillance, data gathering, signal relay

The USCG sUAS program currently employs the Insitu ScanEagle platform, which aptly falls into Garg's small category of UAS. This system has a maximum takeoff weight of 26.5 kilograms, endurance of 18 hours, and a ceiling of 5,950 meters (Insitu, n.d.). With EOIR sensors, the ScanEagle is capable of providing video and communications data links for its surveillance missions (Insitu, n.d.).

The USCG's validated mission need for a long-range UAS is defined as a wide-area surveillance platform that incorporates beyond radio line of sight communications, a 24-hour endurance, and operating altitude around 25,000 feet (Coast Guard, n.d.g). These desired characteristics align with the MALE category. Austin (2010) elaborated on HALE and MALE UAS, describing how HALE aircraft carry out transglobal reconnaissance and surveillance and are operated by air forces from fixed bases. Austin (2010) explained how MALE aircraft also launch from fixed, land-based locations and perform similar functions as HALE aircraft, yet at smaller ranges. The broader-term, long-range UAV includes both MALE and HALE aircraft.

For UAS mission execution, the payload is equally as important as the air vehicle itself. The mass of the payload, in combination with the desired endurance and range characteristics, determines many of the requirements for the UAV, some of which include wingspan, propulsion, and power (Jha, 2017). Austin (2010) decomposed payloads into two distinct types: those that remain with the vehicle, such as sensors and cameras, and those that are dispensable, such as armament. Possible USCG uses for dispensable payloads include typical SAR gear such as pumps, inflatable life rafts, and datum marker buoys. Non-dispensable payloads include electro-optic systems, radar systems, laser designators, communications relay packages, pollution-detection equipment, public address systems, and electronic intelligence, to name a few (Austin, 2010). Of specific importance for USCG missions are the imagery and radar systems.

Electro-optic systems integrate daylight cameras, low-light cameras, and thermal imagers to provide either still or moving images at a resolution that is high enough to perform the intended mission (Austin, 2010). USCG applications of electro-optic systems require a high resolution that can result in identification, which goes beyond detection and recognition. Austin (2010) explained the difference between these levels: *detection* means something is there; *recognition* means differentiating between objects such as a vessel, buoy, or sea life; and *identification* means the ability to differentiate among vessels such as a purse seiner or trawler. The USCG would also benefit from higher resolutions that allow the reading of hull numbers and determination of flags.

B. UAS IN OTHER ARMED SERVICES

Where the USCG falls short in research and development, the DOD certainly compensates. The DOD's *Unmanned Systems Integrated Roadmap 2017–2042* provides strategic guidance to coalesce Service efforts toward the continued expansion of unmanned systems. The report highlights four areas that will continue to advance the effectiveness of unmanned systems in the military, which include interoperability, autonomy, network security, and human–machine collaboration. These topics of continued research and development are being exploited by the DOD, industry, and academia (Office of the Assistant Secretary of Defense for Acquisition, 2018). In contrast, the USCG, as the National Academies of Sciences, Engineering, and Medicine (2020) points out, “is a user, not a developer, of technologies” (p. 11). The USCG should, therefore, closely monitor these areas of development and allow the DOD to continue its research efforts.

The Army, Navy, Air Force, and Marine Corps all have well established LR-UAS programs, which will be introduced in this section. A majority of the information regarding these programs was published in a 2022 Congressional Research Service report that analyzed DOD-selected acquisition reports for current UAS programs.

1. U.S. Army’s MQ-1C Grey Eagle

Per the program’s December 2019 Selected Acquisition Report, the U.S. Army’s MQ-1C Grey Eagle UAS program was initiated at Milestone B in 2005 as a replacement for the Hunter UAS. The same report noted that the program completed Milestone C in 2010 and the first Grey Eagle Company was deployed in 2012 in support of combat operations in Afghanistan. With a total of 204 vehicles, the program achieved full operational capability in 2019 after fielding all of the desired 15 companies (Army, 2019). As of 2019, the Grey Eagle had logged nearly 500,000 flight hours while maintaining 92% combat operational availability (Army, 2019). According to the Army (2019), the Grey Eagle “provides reconnaissance, surveillance, target acquisition, command and control, communications relay, signals intelligence, electronic warfare, attack, battle damage assessment, and manned-unmanned teaming capabilities” (p. 7). The average procurement unit cost as reported in the Selected Acquisition Report was $92.895 million (in 2010 U.S. dollars [USD]). The aircraft has a gross weight of 3,600 pounds and is operated by a propeller system that enables speeds of 150 knots, an endurance of 27 hours, and a maximum altitude of 25,000 feet (Hoehn & Kerr, 2022). The MQ-1C Grey Eagle is shown in Figure 12.

Figure 12. U.S. Army’s MQ-1C Grey Eagle. Source: Hoehn and Kerr (2022).

2. U.S. Air Force’s MQ-9 Reaper

The U.S. Air Force’s MQ-9 Reaper was a replacement for the successful MQ-1 Predator program. Similar in design to the MQ-1, the MQ-9 is slightly larger and more powerful than its predecessor, which enables it to reach 50,000 feet and operate for 24 hours (Hoehn & Kerr, 2022). According to the Air Force (2019), the MQ-9 “provides a unique capability to perform strike, coordination, and reconnaissance against high-value, fleeting, and time-sensitive targets” as both an intelligence collection asset and an armament equipped vehicle. In 2019, the MQ-9 surpassed 2 million U.S. flight hours and, when combined with the MQ-1, surpassed 4 million flight hours in the same year (Air Force, 2019). Per the program’s 2019 Selected Acquisition Report, the MQ-9 began developmental efforts in 2001, received its Milestone B decision in 2004, and began early fielding in 2007. In 2019, estimates advertised a total quantity of 414 aircraft, with an average procurement unit cost of $20.755 million (USD 2008; Air Force, 2019). This propeller-driven aircraft has a maximum gross weight of 10,500 pounds and can operate at speeds up to 240 knots (Hoehn & Kerr, 2022). The MQ-9 Reaper is shown in Figure 13.

Figure 13. U.S. Air Force’s MQ-9 Reaper. Source: Air Force (n.d.).

3. U.S. Navy’s MQ-4C Triton

The U.S. Navy operates the MQ-4 Triton, an autonomous UAS that provides persistent maritime ISR capabilities (Naval Air Systems Command [NAVAIR], n.d.a). The UAV was based off the Air Force’s RQ-4B Global Hawk but utilized non-developmental sensors that were already in DOD inventory (NAVAIR, n.d.a). According to the Navy’s 2021 Selected Acquisition Report, the MQ-4C is optimized for maritime SAR and “will provide surveillance when no other naval forces are present and will support operations in the littorals” (Navy, 2021, p. 3). This program began at Milestone B in 2008 but has reported schedule breaches and has yet to achieve initial operating capability (Navy, 2021). While the initial program of record included 70 aircraft, the Navy’s FY2024 budget request only accounts for two additional aircraft over the next 5 years for a total program of only 22 aircraft (Assistant Secretary of the Navy [Financial Management & Comptroller], 2023). This jet engine aircraft operates at 320 knots, at an altitude of up to 50,000 feet, and at an endurance of 24 hours (Hoehn & Kerr, 2022). The average procurement unit cost as reported in the 2021 Selected Acquisition Report was $147.45 million (USD 2016). The MQ-4C is pictured in Figure 14.

Figure 14. U.S. Navy's MQ-4C. Source: NAVAIR (n.d.a).

4. CBP's MQ-9 Predator B

U.S. Customs and Border Protection (CBP), another of the 22 agencies of DHS, operates a fleet of MQ-9 Predator B aircraft that provide increased domain awareness in both land and maritime environments (Customs and Border Protection, 2021). While the aircraft are owned and managed by CBP, they are operated in a joint program office in a partnership between CBP and the USCG (NASEM, 2020). As CBP guards both land and maritime borders, their fleet of 10 MQ-9 aircraft have varying configurations: five are configured for land missions, two are configured for maritime missions (Guardian variant), and the remaining three can operate in either environment (Office of Inspector General, 2014). The Guardian variant Predator B utilizes Raytheon's SeaVue marine search radar alongside EOIR sensors for persistent surveillance in maritime environments (Eckhause et al., 2020). According to CBP's fact sheet, their Predator B has a maximum gross weight of 10,500 pounds, reaches speeds of up to 240 knots, and can operate for up to 20 hours with a service ceiling of 50,000 feet (Customs and Border Protection, 2021). A 2014 DHS report from the Office of the Inspector General estimated the average procurement unit cost at $17 million (assumed as USD 2009 as the acquisitions occurred between 2005 and 2013) per UAS. The MQ-9 Predator B Guardian variant is pictured in Figure 15.

Figure 15. CBP's MQ-9 Predator B Guardian
Source: Customs and Border Protection (2021).

5. USMC's MQ-9A Extended Range

In 2018, the U.S. Marine Corps (USMC) took a different acquisition approach to gaining UAS capability and did so through a COCO agreement that was to provide persistent surveillance over Marine operations both in the United States and in Afghanistan (Trevithick, 2018). With the MQ-9A, General Atomics Aeronautical Systems Inc. provided "long-range intelligence, surveillance, and reconnaissance capability in support of expeditionary advanced based operations, littoral operations in contested environments, and maritime domain awareness" (NAVAIR, 2022). The success of this program led to a FY2022 contract award worth $135.8 million (USD 2022) to the same manufacturer for the purchase of eight MQ-9A Extended-Range systems (NAVAIR, 2022). This equates to $16.975 million (in USD 2022) per UAS. Similar to other Predator variants, the USMC MQ-9A has a maximum airspeed of 240 knots and can reach an altitude of 50,000 feet (NAVAIR, n.d.b). The USMC's MQ-9A is pictured in Figure 16.

Figure 16. USMC's MQ-9A. Source: NAVAIR (n.d.b).

C. STUDIES OF USCG USE OF UAS

LR-UAS can perform a variety of naval roles. Some of the roles, as explained by Reg Austin (2010), that could be applicable to USCG missions include fleet detection and shadowing, port protection, over-beach reconnaissance, fisheries protection, detection of illegal imports, electronic intelligence, and maritime surveillance. These mission areas, he explained, can be carried out more efficiently, reliably, and economically through the employment of UAS. This thesis examines USCG-funded studies alongside DOD frameworks and the current state of technology of UAS and payloads to analyze their readiness and applicability for the USCG.

A 2020 study by the National Academies of Sciences, Engineering, and Medicine examined the USCG's current and potential use of unmanned systems (UxS), which include aerial, surface, and underwater vehicles. The study reviewed capabilities, affordability, reliability, and versatility of UxS along with an examination of current policies, procedures, and protocols to further promote their incorporation. This study did not provide detailed technical assessments of alternatives but focused on strategic visions and planning for changes to culture, processes, and investments. To do so, the National

Academies of Sciences, Engineering, and Medicine (2020) evaluated the potential impact of UxS technologies on each of the 11 USCG missions. In their analysis, they included LR-UAS, medium-range UAS (MR-UAS), short-range UAS, and vertical takeoff and landing (VTOL) UAS as aerial alternatives. They specifically found that LR-UAS has a high mission impact in law enforcement drug interdiction and migrant interdiction missions; a low impact in SAR; and a potential impact in PWCS, defense readiness, and marine environmental protection. The study, however, omitted the LR-UAS impacts to the LMR, ATON, and ice operations missions, which can all benefit from the ISR capabilities of UAS. The report concluded that "to remain responsive and fully relevant to its many missions, it is imperative that the USCG take a more strategic and accelerated approach to exploit the capabilities of existing and future unmanned systems" (NASEM, 2020, p. 102). It further determined that current budgets are insufficient to meet the need for UxS and called for augmentation by Congress and DHS. To address their call for action, the National Academies of Sciences, Engineering, and Medicine (2020) provided five recommendations, which include (1) issuing a high-level strategy, (2) designating a senior UxS champion, (3) creating a UxS program office, (4) expanding experimentation, and (5) addressing funding needs. Three years following the publication of this report, in March 2023, the USCG Deputy Commandant for Operations published the *Unmanned Systems Strategic Plan*, the first step in the path toward addressing the complex challenges that lie ahead (Coast Guard Deputy Commandant for Operations, 2023).

A 2020 study conducted by the RAND Corporation's Homeland Security Operational Analysis Center sought to conduct an examination of the USCG's aviation fleet to present varying mixes of manned and unmanned air assets to execute missions for the next 30 years. This report acknowledged the aging status of the current fleet and recommended that the USCG consider UAS as a "potential major element of the future aircraft fleet" (Eckhause et al., 2020, p. xix). The study created five future demand scenarios against which 17 potential future fleet mixes were assessed. The five demand scenarios included those listed in Table 2.

Table 2. RAND Demand Scenarios. Adapted from Eckhause et al. (2020).

Demand Scenario	Explanation
Migrants, Fish, and Drugs	Addresses an increased demand for maritime law enforcement operations
Another 9/11	Addresses an increased demand for PWCS and Defense Readiness missions to counter terror threats
National First Responders	Addresses the ability to provide surveillance and logistical support during disaster response
We're Here to Help	Addresses increased demand for joint homeland security operations
Rome Burning	Incorporates the above four scenarios into one extreme condition

The future fleet mixes that RAND proposed are comprised of different combinations of current assets, including the MH-65, MH-60, HC-130, HC-27, and HC-144, along with materiel investments including a next-generation light helicopter (NGLH), next-generation medium helicopter (NGMH), MR-UAS, and LR-UAS. A description of each of RAND's 17 proposed alternatives is presented in Table 3 with recommended fleet sizes presented in Figure 17.

Table 3. RAND Proposed Future Fleet Alternatives.
Adapted from Eckhause et al. (2020).

Future Fleet Alternatives	Explanation
Current	Status quo of only manned assets
Low Investment	As aircraft reach end of service life, fleet comprised primarily of MH-60 and HC-130J manned assets
Base + UAS 1	Maintain existing aircraft and add LR-UAS capability
Base + UAS 2	Maintain existing aircraft and add MR-UAS capability
Rotary-Wing Offset 1	Similar to Base + UAS 1 but incorporates a replacement short-range helicopter for the MH-65
Rotary-Wing Offset 2	Similar to Base + UAS 2 but incorporates a replacement short-range helicopter for the MH-65
Transition	Maintain current manned assets and invest in replacement helicopters for both the MH-60 and MH-65; no UAS
Many of Few 1	Rapid transition of current manned fleet to only NGMH and HC-130Js plus the addition of LR-UAS

Future Fleet Alternatives	Explanation
Many of Few 2	Rapid transition of current manned fleet to only NGMH and HC-130Js plus the addition of MR-UAS
Super UAS 1	Replaces end-of-life aircraft with UAS to arrive at a fleet of reduced MH-65, MH-60, and HC-130s with many LR-UAS
Super UAS 2	Replaces end-of-life aircraft with UAS to arrive at a fleet of reduced MH-60 and HC-130s with many LR-UAS and MR-UAS
Limited Buy UAS 1	Similar to Super UAS 1 with less LR-UAS and some MR-UAS
Limited Buy UAS 2	Similar to Super UAS 2 with less LR-UAS and MR-UAS
Rotary-Wing Recap 1	Maintains manned fixed-wing assets with new NGLH and NGMH with more NGLH; no UAS
Rotary-Wing Recap 2	Maintains manned fixed-wing assets with new NGLH and NGMH with more NGMH; no UAS
Rotary-Wing Recap + UAS 1	Manned rotary-wing assets replaced by new NGLH, NGMH, LR-UAS, and MR-UAS; HC-130J and HC-144 are retained
Rotary-Wing Recap + UAS 2	Manned rotary-wing assets replaced by new NGLH, NGMH, and MR-UAS; HC-130J and HC-144 are retained

Aircraft	Current	Low Investment	Base + UAS		RW Offset		Transition	Many of Few		Super UAS		Limited-Buy UAS		RW Recap		RW Recap + UAS	
			1	2	1	2		1	2	1	2	1	2	1	2	1	2
MH-65	98	31	94	94	—	—	31	—	—	41	—	—	—	—	—	—	—
NGLH[a]	—	—	—	—	31	31	31	—	—	—	—	—	—	91	29	29	29
MH-60	45	82	52	52	52	52	52	—	—	52	62	82	82	—	—	—	—
NGMH[a]	—	—	—	—	—	—	52	109	109	—	—	—	—	52	93	93	93
HC-130H	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
HC-130J	11	26	31	31	25	25	41	35	35	22	22	22	22	25	25	25	25
HC-27	14	—	14	14	14	14	14	—	—	—	—	14	14	14	14	—	—
HC-144	18	—	18	18	18	18	18	—	—	—	—	—	—	18	18	18	18
MUAS[b,c]	—	—	—	205	134	205	—	—	212	—	410	103	205	—	—	134	212
LUAS[b]	—	—	41	—	10	—	—	23	—	103	103	21	21	—	—	10	—

Figure 17. Fleet Sizes of RAND Proposed Alternatives.
Source: Eckhause et al. (2020).

The RAND study (2020) evaluated the 17 different fleet alternatives in each of their proposed demand scenarios on the criteria of performance of mission scenario, utilization rate, operations and support cost, and rotary-wing coverage. The study concluded that if there is not much change to current mission demand, Rotary-Wing Recap 1 and 2 are preferred alternatives. It has been well established, however, via the numerous national, departmental, and Service strategies presented in Chapter 2, that the maritime missions are changing and require an increased, persistent ISR capability to enhance maritime domain awareness. Taking this mission change into consideration, RAND proposed fleet alternatives that address the increased demand for ISR capability with UAS provide more value. The study found that while each of the Super UAS and Limited Buy UAS alternatives fared well in performance for ISR-reliant missions, they did so at a high cost and reduced capability across other demand scenarios. When examining all demand scenarios, the Many of Few 1, Many of Few 2, and RW Recap + UAS 1 arise as attractive alternatives. Commonalities among these alternatives are investments in next-generation helicopters along with a mix of manned and unmanned fixed-wing platforms.

D. BENEFITS OF UAS COMPARED TO MANNED AIRCRAFT

Unmanned systems have their advantages over their counterpart manned systems, especially when it comes to certain mission characteristics. It is widely cited that unmanned systems offer their advantages in the 3 Ds: the dull, the dirty, and the dangerous. Users of unmanned systems eliminate the risk of human loss of life in missions that have these attributes. Austin (2010) added "covert, diplomatic, research, and environmentally critical roles" to this list (p. 5). The National Academies of Sciences, Engineering, and Medicine (2020) further expanded the list to include "distant and exhausting" (p. 84). While the USCG may not often find itself in dirty or dangerous missions, many of the reconnaissance missions that are performed by current manned aircraft fall into the categories of dull, covert, distant, and exhausting. It is in these areas specifically where the Service can benefit from the capabilities of UAS.

Conventional wisdom would lead one to conclude that unmanned aircraft are less expensive to both acquire and operate than their manned counterparts. While this is often true, the life-cycle cost savings are not as dramatic as one would assume. The Congressional Budget Office (CBO) completed an analysis of nine Navy and Air Force aircraft to better understand the costs of manned versus unmanned assets (Keating et al., 2021). This study considered both acquisition and recurring costs to compare life-cycle costs per flying hour and found that the cost advantage may not be as large as conventionally thought. Much of its comparison, however, lies between the Air Force's

RQ-4 Global Hawk and the Navy's P-8 Poseidon aircraft. Specifically, the CBO calculated that the RQ-4's life-cycle cost per flying hour was 17% less than the P-8. While the capabilities of both aircraft likely exceed those that the USCG requires, it can be concluded that unmanned aircraft with comparable capabilities will cost slightly less to operate and acquire than their manned counterparts. This is in line with Austin (2010), who offered that when considering the cost of unmanned vehicles and their control stations, UAS costs tend to be 40% to 80% of similar manned systems. One caution that the CBO (2021) offered when comparing life-cycle costs was to consider the increased accidental destruction rate of unmanned aircraft over manned aircraft. Several explanations for the significantly higher rates could be due to the reliance on a single engine, lower design standards, and reliance on communications connectivity (Keating et al., 2021).

E. FUTURE OF UAS

1. Demand Forecast

Global demand for UAS increased by 60% between the first two decades of this century, and there is significant evidence that suggests that this trend will continue (Sanders et al., 2023). The rapid evolution of UAS can be attributed to advancements in electronics, optics, computer science, and energy storage (Garg, 2021). As these components of the system continue to improve, and with the integration of machine learning and artificial intelligence, new applications of UAS are sure to follow. The Teal Group, which specializes in UAV market analysis, believes that the worldwide UAS market will continue to see growth over the next decade with a 41% increase in research, development, test, and evaluation (RDT&E) and procurement (Zaloga et al., 2022). A 10-year forecast, shown in Figure 18, displays increases from about $13.2 billion in FY2023 to $18.7 billion in FY2032.

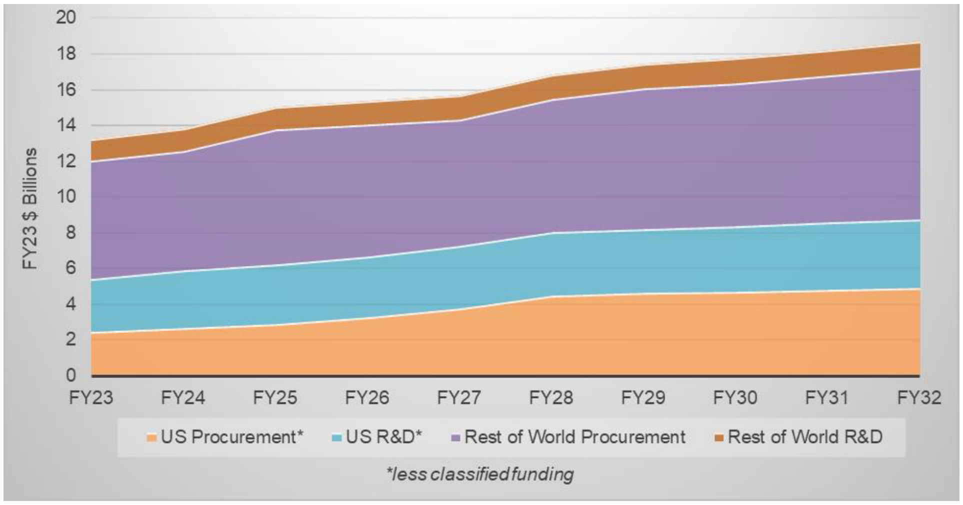

Figure 18. World Military UAS Budget Forecast for Research and Development (R&D) and Procurement. Source: Zaloga et al. (2022).

2. Future Utilization

Sigala and Langhals (2020) conducted a research study to better understand the future of the utilization of UAS in the conduct of military operations and the relevant challenges that may hinder the employment of their capability. This is a beneficial area of study, they argued, as it can inform acquisition managers and planners as they develop system requirements and make resource decisions. By employing the Delphi method, a research tool for forecasting the impact of technology on warfare, the researchers surveyed experts from operations, acquisitions, and academia to predict the capabilities and challenges that UAS may experience over the next 20 years. Their study utilized two rounds of questioning, the first of which "assessed how panelists viewed current UAS missions and their level of autonomy as well as possible future missions, expected levels of autonomy, and associated challenges" (Sigala & Langhals, 2020, p. 6). The subsequent round addressed future UAS mission areas and rated the potential and likelihood of challenges over the next 20 years. The Delphi study ultimately predicted "an increased number of UAS mission areas over the next 20 years with a corresponding increasing level of autonomy for each mission area" (Sigala & Langhals, 2020, p. 13). They further focused their discussion on ISR mission capabilities, as these were identified as most likely to expand and incorporate autonomous behavior.

3. Payload Integration

Key to ISR mission capabilities is the successful integration of sensor payloads with the UAV itself. To gain a better understanding of current and future payload technologies, information was collected from subject matter experts with extensive UAS sensor industry experience and from a government perspective at the U.S. Army's Program Executive Office for Intelligence Electronic Warfare and Sensors.

Two critical payloads for maritime patrol operations include a radar and a multispectral imaging sensor that incorporates EOIR capability. Concerning radar technology, the most practical solution for USCG application is likely maritime surveillance radar, which, while large in size, weight, and power requirements, is specially designed for detection of targets at sea (R. Walker, personal communication, June 21, 2023). When considering EOIR sensors for UAS application, it is vital to ensure that they cover long-wave, mid-wave, and short-wave spectrums, each of which have their advantages for discriminating through varying environmental conditions and providing imagery at an appropriate resolution for the mission (R. Walker, personal communication, June 21, 2023). Additional payloads that could improve the capability of USCG UAS are signals intelligence (SIGINT) and communications intelligence (COMINT), which can allow the system to intercept and analyze signals and data of adversaries (R. Walker, personal communication, June 21, 2023). No matter the payload, it is crucial that the USCG not be the sole user of a product (C. Keller, personal communication, June 19, 2023).

4. Modular Open System Architectures

As UAS continue to evolve to meet capabilities, there has been a recent focus on modular open system architectures (MOSA). "Modularity refers to the segmenting of systems into tightly integrated systems or components that are loosely coupled with one another," and "openness means that key interfaces instead use an architecture that is freely available and ideally in widespread use" (Sanders & Holderness, 2021, p. 1). By utilizing MOSA, the government attempted to simplify the integration between the vehicle and its payloads. MOSA is believed to increase competition and reduce integration complexity and cost (Sanders & Holderness, 2021). The U.S. Special Operations Command (SOCOM) has standardized the interfaces between UAVs and their payloads with their *Modular Payload Design Standard for UAS, Manned Aircraft and Small Maritime Vessels* (R. Walker, personal communication, June 21, 2023). As the USCG considers UAS and their payloads, selecting an open system architecture will likely reduce cost and risk while increasing capability.

F. SUMMARY

A review of current and past UAS solutions presents non-developmental capabilities that are currently executing military and governmental missions. External studies have consistently found that the introduction of UAS in the USCG can provide significant capability, specifically in ISR missions. As the UAS market continues to grow and payload technology advances, the USCG should pay particular attention to payload integration and those that utilize standardized interfaces designed with MOSA.

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IV. ANALYSIS

A. CAPABILITIES-BASED ASSESSMENT

1. What Is a CBA?

The DOD acquisition system is comprised of three processes: JCIDS; the Planning, Programming, Budgeting, and Execution System (PPBES); and the Defense Acquisition System (DAS). These processes work together to identify requirements, allocate resources, and develop/acquire the capability, respectively. The JCIDS process was established in 2003 and introduced the "[CBA] as the starting point in identifying the DOD's needs and recommending solutions" (Joint Chiefs of Staff, 2009, forward). The CBA specifically "identifies capabilities and operational performance criteria" that are needed to execute missions (Joint Chiefs of Staff, 2009, p. 4). It examines existing systems to determine shortfalls and operational risks and examines both materiel and non-materiel solutions to address the capability gap. While this thesis will not complete a full CBA, it uses the JCIDS framework to analyze future capability gaps within the USCG's aviation portfolio.

The 2009 *CBA User's Guide* offers a taxonomy of CBAs in which six different types are introduced. The CBA type that most closely aligns with this thesis is one based on perceived future needs. This type of CBA forecasts future needs and includes the failure of current programs in the analysis.

The 2009 *CBA User's Guide* further scopes the CBA into six elements: tasks, conditions, standards, effects, ways, and means, each of which is described in further detail below (Joint Chiefs of Staff, 2009). Tasks are the range of concepts of operation (CONOPs) that will be considered. Conditions are the scenarios utilized to test capabilities against adversaries and operating conditions. Standards are the measures of effectiveness that are used to evaluate capabilities. Effects are capabilities desired to achieve an objective. Ways are the functions considered, and means are the types of solutions considered. The overall study definition process is depicted in Figure 19. Each of these elements will be examined to determine whether a future capability gap will exist within USCG aviation.

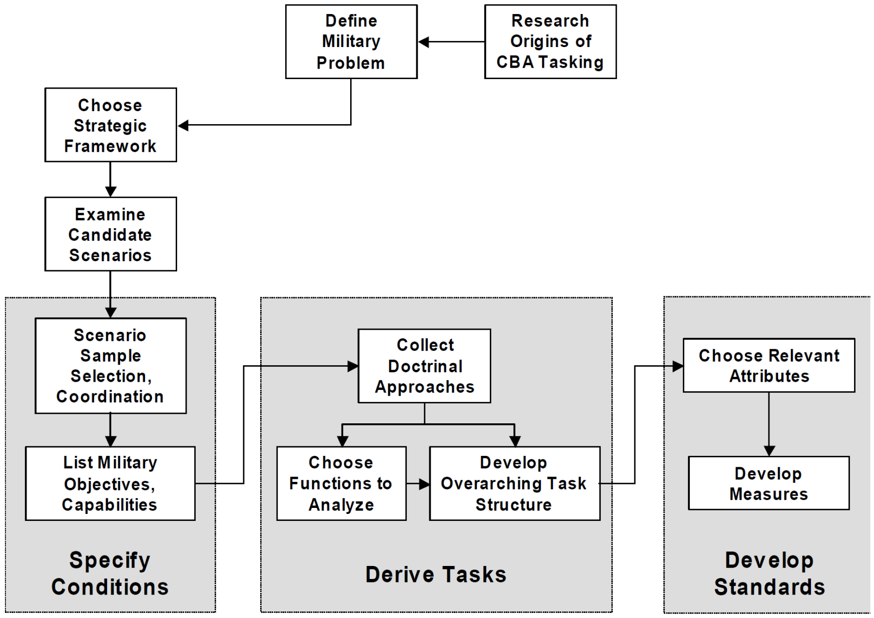

Figure 19. CBA Study Definition. Source: Joint Chiefs of Staff (2009).

2. Conditions, Tasks, and Standards

The conditions of this CBA assume a future USCG, approximately 10 years from now, similar in size and resources, in which there are no major changes to the Service's statutory missions, which are executed primarily with a fleet of surface and aviation assets. As the LRS asset, the HC-130J, is still being acquired and with a projected end of service life of at least 2050, this platform is expected to be in service and fully in the support phase of the system's life cycle. The MRS assets, however, are not assumed to be a viable, long-term solution much past the period of study, 10 years in the future. The HC-144's airframe structural issues, coupled with the C-27's obsolescence and supportability concerns hypothetically come to a head in the next decade. As an alternative to replacing these manned platforms, UAS solutions could supplement the LRS fleet to meet the needs of the USCG.

The tasks of the future USCG are derived from a study of the national and Service strategies presented in Chapter 2. They are an evolution of today's USCG mission set that has an increased demand for ISR missions. The escalating geopolitical tensions in the western Pacific and the aggressive actions of PRC call for increased maritime domain awareness. The future fixed-wing demand for law enforcement missions, therefore, is expected to increase.

The rotary-wing fleet is expected to slowly transition from a predominantly SRR fleet of MH-65 aircraft to a larger MRR fleet of MH-60 aircraft. With greater range, endurance, and load capacity, the MRR assets should alleviate a portion of the fixed-wing SAR demand that currently falls just outside the capability of the SRR platform. The fixed-wing SAR demand, therefore, is expected to decline.

The standards of this CBA are the measures of effectiveness against which evaluation will occur. For the USCG to continue to "ensure the Nation's maritime safety, security, and economic prosperity, [it is imperative that they] sharpen [their] competitive edge [,] … advance [their] mission excellence [,] … and enhance [their] readiness" (Coast Guard Headquarters, 2022, p. 1). The future aviation fleet must then meet the demands of the future USCG, which include a capability to absorb the gap incurred after losing the current MRS assets.

The USCG utilizes the Asset Logistics Management Information System (ALMIS) for both surface and aviation operations. In addition to maintenance tracking and inventories, the system is the primary means for logging asset utilization. Flight hours for both the MRS and LRS assets were obtained for the 10-year period of FYs 2013–2022 and are presented in Figure 20. The LRS program logged over 15,000 annual flight hours on average, with the MRS program logging close to 17,000 average annual flight hours. Combined, the fixed-wing assets, on average, flew over 32,000 annual flight hours.

ALMIS provides for mission employment categories; however, these do not align perfectly with the 11 statutory missions of the USCG. As seen in Figure 20, the largest employment category for each of the fixed-wing assets was enforcement of laws and treaties (ELT). This mission category includes the statutory missions of drug interdiction, living marine resources, migrant interdiction, marine environmental protection, and other law enforcement. ELT missions alone accounted for 12,500 annual fixed-wing flight hours. The next two highest mission categories were training and SAR.

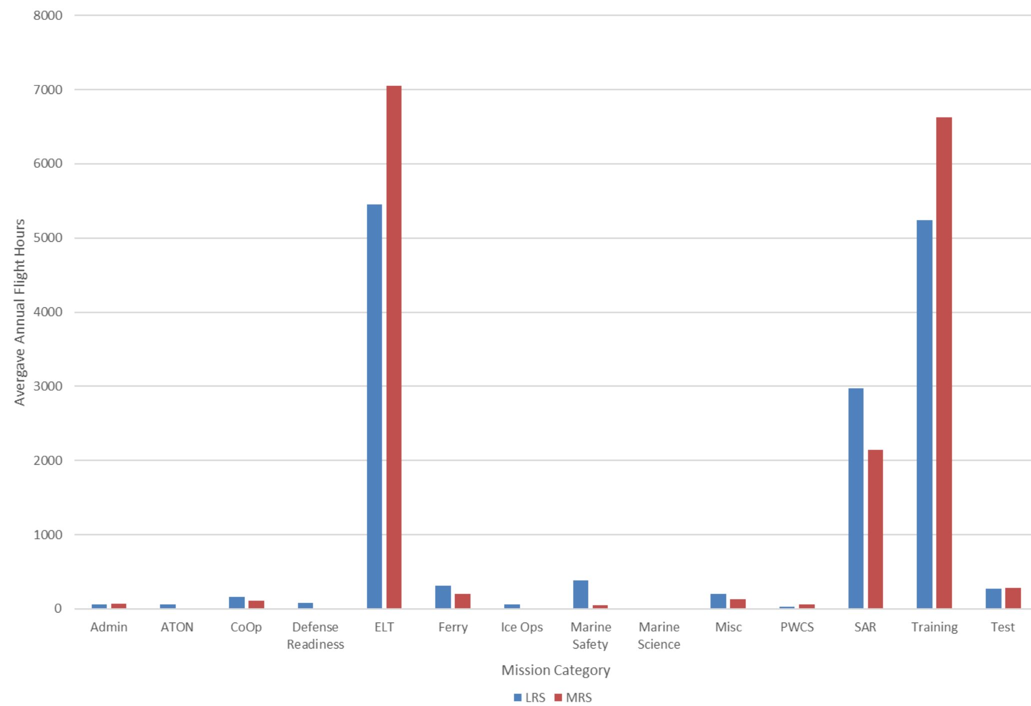

Figure 20. Average Annual Flight Hours by Mission for USCG Fixed-Wing Aircraft, FY2013–FY2022.

Aside from the top three mission categories (ELT, training, and SAR), all other mission categories combined accounted for less than 10% of the flight hours for fixed-wing platforms. The test and training mission categories are specific to each asset and are not candidates for transfer between the LRS and MRS programs. The remaining mission categories—admin, ATON, Continuity of Operations (CoOp), defense readiness, ferry, ice operations, marine safety, marine science, miscellaneous, and PWCS—are candidates for transfer between the two programs. For simplicity, these categories just listed can be consolidated into a new category named *other missions combined*. This reaggregation is displayed in Figure 21.

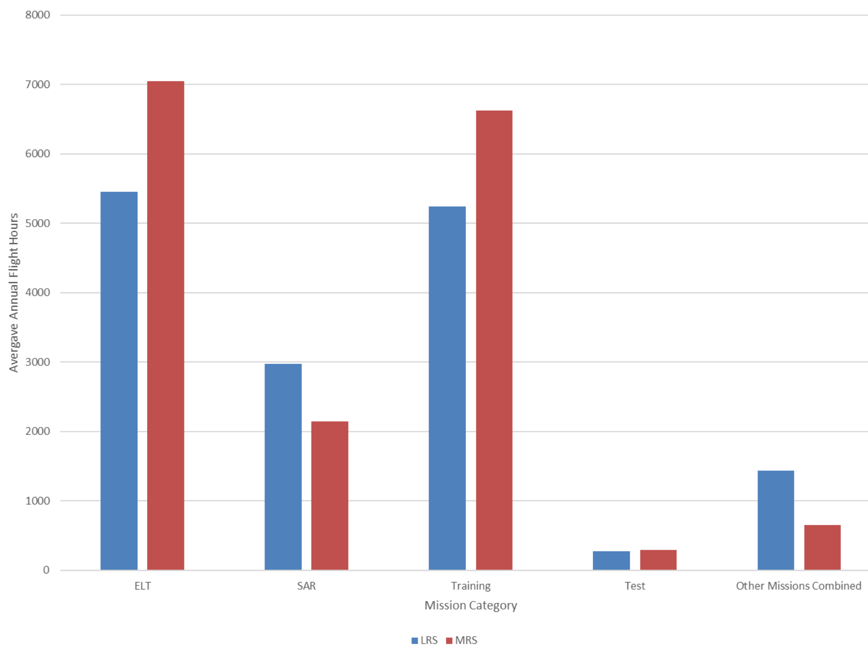

Figure 21. Average Annual Flight Hours by Mission Consolidated for USCG Fixed-Wing Aircraft, FY2013–FY2022.

In a future USCG where the MRS program is dissolved, its flight hours would have to be assumed by a combination of current and yet to be acquired future assets. While some of the MRS SAR hours could be transferred to the MRR helicopter, the LRS program would likely have to fulfill the remainder of SAR hours. The other missions combined category could be transferred from MRS to LRS as well. Moving the SAR and other missions combined would increase the LRS annual hours by approximately 2,800 hours. A capability gap then begins to emerge. This gap must fully assume the MRS ELT flight hours, account for training and test hours, and assume a portion of the ELT hours of the LRS program to balance the redistribution of missions. A new platform must also consider the increased demand for ELT missions as suggested by the strategic guidance and policy reviewed in Chapter 2. A theoretical redistribution of flight hours from MRS to LRS, along with a 25% increase in ELT hours, is shown in Figure 22.

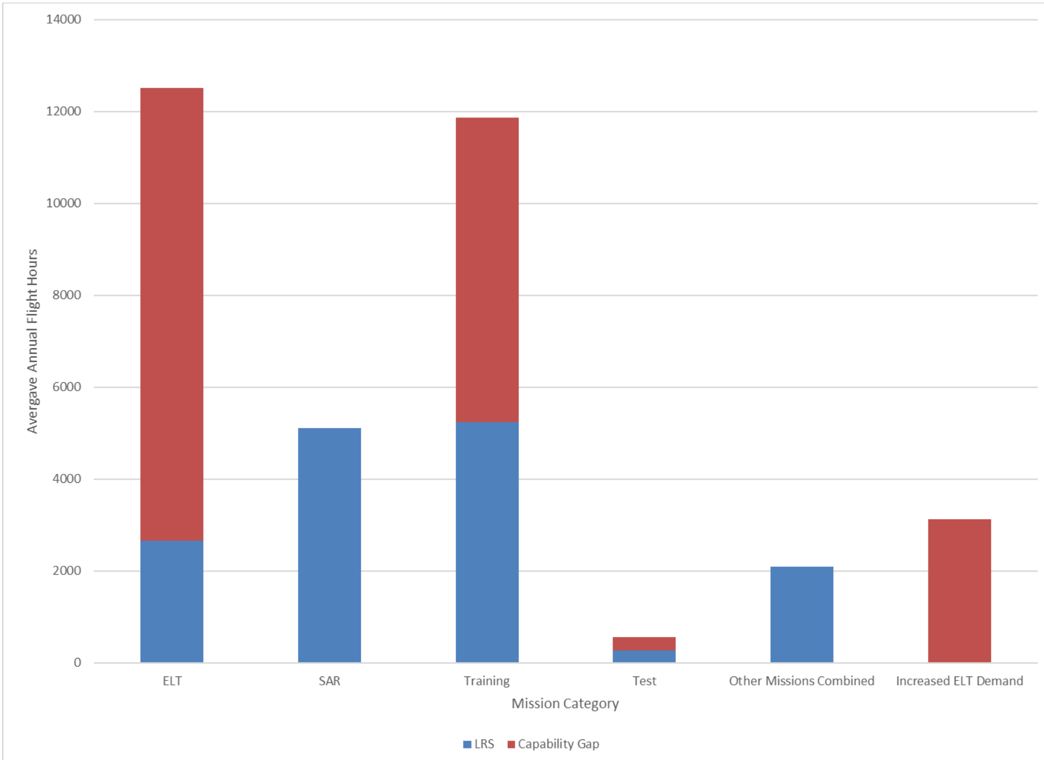

Figure 22. Theoretical Redistribution of Annual Flight Hours After Dissolving MRS Platform.

After the redistribution of hours, a capability gap of approximately 20,000 flight hours (as flown by current platforms) exists. If excluding training and test hours, the operational capability gap is reduced to 13,000 annual flight hours. This distinction is important as a Government Owned-Government Operated (GOGO) capability would need to include training and test hours, whereas a COCO solution might not.

3. Effects, Ways, and Means

Effects are the desired capabilities to achieve the objective of the scenario (Joint Chiefs of Staff, 2009). After redistributing the annual fixed-wing flight hours and accounting for increases in ELT missions, the capability gap of the future USCG can be largely distilled into one that is solely focused on ELT missions. The desired capabilities, therefore, are those that enable this ISR-laden mission. Effects such as persistent wide area surveillance, increased range and endurance, and data transmission are key performance parameters that must be considered.

The ways of the CBA is determining the functional means to be considered in the assessment (Joint Chiefs of Staff, 2009). While the capability gap could be addressed via other technological means such as satellite surveillance, the functions to be considered will involve long-range aerial surveillance provided by aircraft.

Finally, the means of the CBA restricts the types of solutions that will be considered (Joint Chiefs of Staff, 2009). As the USCG already has a PoR for sUAS that is employed on surface assets, the means under consideration are long-range aircraft that are both launched and recovered from land bases, possibly from existing USCG MRS air stations.

B. DOTmLPF-P ANALYSIS

The DOD's JCIDS process includes an assessment to ensure that non-materiel alternatives are considered in addressing capability gaps prior to developing or acquiring a materiel solution (Joint Chiefs of Staff, 2021). This analysis is referred to as DOTmLPF-P, which requires sponsors to consider doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy. Each of these areas will be examined against the capability gap.

1. Doctrine

Doctrine, or the "fundamental principles that guide the employment" of Service forces, should be considered to determine whether it is sufficient (Joint Chiefs of Staff, 2021, p. B-G-F-2). The high-level doctrines that guide USCG aviation operations are the 11 statutory missions, its designation as the U.S. maritime SAR coordinator, and its authority under Title 14 U.S.C. § 522 that authorizes the USCG to enforce U.S. federal laws. These doctrines are distinct to the USCG and vital to the safety and security of the nation. To alleviate the capability gap from a doctrinal approach would require the transfer of authorities and missions to another Service or entity. While technically feasible, this effort would require changes to federal law and CONOPS of the gaining Services. The effort to change the doctrine would be far more cumbersome than other means of addressing the gap.

2. Organization

The organization consideration of the JCIDS process asks if "current organizational structures allow the capability to be used to its fullest potential" (Joint Chiefs of Staff, 2021, p. B-G-F-3). The operational structure of the USCG is broken down into two Areas, Atlantic and Pacific, each of which is further decomposed into a handful of geographic Districts. These districts are then decomposed into several Sectors. Operational control of assets is managed at the Area and District level. As the capability gap is not isolated to a single organizational element, reorganization of current assets or control would not address the capability gap.

3. Training

Training of personnel, units or staff could improve the efficiency of mission execution, but it is highly unrealistic that this approach would address the capability gap. The future flight-hour gap is simply too large for the LRS program to fill alone.

4. Materiel

"Materiel refers to increased quantities, modifications, improvements, or alternate applications of existing materiel or the purchase of [commercial off the shelf (COTS)/government off the shelf (GOTS)/non-developmental items (NDI)]" (Joint Chiefs of Staff, 2021, p. B-G-F-4). This strategy is in alignment with the Federal Acquisition Streamlining Act (FASA) of 1994, which created a preference for the acquisition of commercial items for the DOD, the USCG, and NASA (Federal Acquisition Streamlining Act of 1994, 1994). The DOD accepts a developmental program only after non-materiel solutions and COTS/GOTS/NDI are considered. While a developmental program that could provide the USCG with a solution to meet the gap would likely result in a superior performance capability, it would require significant research and development costs. As the National Academies of Sciences, Engineering, and Medicine (2020) reasoned, the USCG is not in the business of developing technologies. This is especially true in aerospace applications. With a relatively small program of record, the USCG should not pursue developmental efforts in the UAS market. As will be demonstrated in the following analysis of alternatives (AoA), there are numerous COTS/GOTS/NDI solutions that can address the capability gap.

5. Leadership and Education

As has been discussed with other considerations, the professional development of Service leaders would not address the future capability gap. While leadership can influence the employment of assets, this type of engagement would not address the proportionally high number of flight hours that need to be met.

6. Personnel

Revisiting the qualifications of personnel would likewise not address the capability gap. While personnel qualifications will dramatically shift with a transition from manned assets to unmanned capabilities, the operators will still require physical aircraft platforms to meet the law enforcement demand.

7. Facilities

Real property is not currently a constraint on fixed-wing operations, and reimagining the USCG's facilities would not address the capability gap for mission execution.

8. Policy

The final consideration in the DOTmLPF-P analysis is to examine Service, interagency, and international policies that affect the performance of the capability (Joint Chiefs of Staff, 2021). The USCG has numerous agreements that drastically affect aviation law enforcement missions. For example, it is through a number of bilateral international agreements that the USCG is able to provide MDA capabilities to allied and underdeveloped nations for the enforcement of fishing practices. Other agreements include the USCG's participation in multinational drug interdiction initiatives that combat the trafficking of illegal narcotics on the high seas. These agreements are vital to both the international order that is under threat as well as the nation's overall national security.

While revisiting the necessity of these agreements may reduce the law enforcement demand on aviation assets, their cancellation conflict with Service and national strategies.

C. ANALYSIS OF ALTERNATIVES

1. Acquisition Strategy

There are several differing operating approaches that the USCG could employ in a transition from manned to unmanned systems to close the capability gap. These vary in levels of ownership and operation by the government and contractors. In a government-owned, government-operated (GOGO) model, the USCG would acquire and operate the UAS. This would require the greatest upfront investment but would also provide the greatest control over the program. This model also reduces security concerns as there is minimal reliance on outside entities. On the other end of the spectrum would lie a contractor-owned, contractor-operated (COCO) model in which the USCG would contractually acquire UAS capability as a service. This model is currently employed by the USCG for the sUAS program and was successfully utilized by the USMC's MQ-9A program. Advantages of the COCO model include reduced investment cost, increased ability to upgrade technology, and reduced manpower burden on the government. The USCG would, however, lose some control over the program. Lying between these two models is the government-owned, contractor-operated (GOCO) model in which the government procures the systems and contracts out the operation and/or maintenance.

Some government and industry experts in UAS technologies recommended that the USCG introduce an LR-UAS capability via a COCO model. This strategy would provide flexibility as it would not lock the USCG into a single solution (D. Fields, Chief Technology Officer of Logos Technologies, personal communication, July 11, 2023). Additionally, the COCO model can be flexible to allow technology insertion as it continually advances (D. Rombough, Vice President, Business Development, Logos Technologies, personal communication, July 11, 2023). Contracts can also be crafted to provide multiple option years that would allow the USCG to continue successful programs, while at the same time, provide an off-ramp should the program not meet their expectations (D. Rombough, Vice President, Business Development, Logos Technologies, personal communication, July 11, 2023). This model also would mitigate some of the common barriers to implementation of new technologies, such as personnel training, something that the Army mightily struggled with when they introduced UAS (R. Walker, personal communication, June 21, 2023). Regardless of the strategy selected, the USCG will still need to evaluate platform alternatives that can meet the capability gap.

A decision matrix was utilized to analyze the three approaches. This tool allows comparison between multiple alternatives among which multiple variables affect the recommendation. The variables considered for this recommendation include acquisition cost, operating cost, security vulnerability, upgradability, government manpower requirements, and contract flexibility. Each of the operating approaches, GOGO, COCO, and GOCO, were evaluated and ranked for their performance in each of the variables from best to worst where the best option received the lowest score. When two of the alternatives were equal in their ranking, an average score was applied. The results of this multivariable decision analysis are presented in Table 4.

Table 4. Multivariable Decision Matrix for UAS Operating Approaches.

(lowest is best)	**Acquisition Cost**	**Operating Cost**	**Security Concerns**	**Upgradability**	**Government Manpower Requirement**	**Contract Flexibility**	**Option Scores**
GOGO	2.5	1	1	2.5	3	2.5	12.5
COCO	1	2.5	3	1	1	1	9.5
GOCO	2.5	2.5	2	2.5	2	2.5	14

This analysis revealed that the COCO operating approach is most desirable. It was followed by the GOGO approach with the GOCO approach being the least favorable. This analysis, however, assumes that each of the variables is equally weighted. In reality, certain variables such as cost, upgradability, and contract flexibility would likely be more important considerations than security and manpower requirements. A sensitivity analysis can be applied to the same criteria that weighs these variables accordingly. Acquisition and operating costs combined were determined to be four times as important than security concerns and manpower requirements. Upgradability and contract flexibility were evaluated to be twice as important as security concerns and manpower requirements. The result of applying criteria weighting to these variables is shown in Table 5.

Table 5. Multivariable Decision Matrix with Sensitivity Analysis for UAS Operating Approaches.

(lowest is best)	**Acquisition Cost**	**Operating Cost**	**Security Concerns**	**Upgradability**	**Government Manpower Requirement**	**Contract Flexibility**	**Option Scores**
criteria weighting	*2*	*2*	*1*	*2*	*1*	*2*	
GOGO	2.5	1	1	2.5	3	2.5	12.5
weighted	**5**	**2**	**1**	**5**	**3**	**5**	**21**
COCO	1	2.5	3	1	1	1	9.5
weighted	**2**	**5**	**3**	**2**	**1**	**2**	**15**
GOCO	2.5	2.5	2	2.5	2	2.5	14
weighted	**5**	**5**	**2**	**5**	**2**	**5**	**24**

After applying the sensitivity analysis, the weighted option scores still favored the COCO model, followed by the GOGO model, and lastly the GOCO model. This result aligns with the recommendation received from subject matter experts. This type of analysis is beneficial to decision makers as they can alter the criteria weighting as they deem appropriate to reevaluate the alternatives.

2. Commercial or Developmental

The DOTmLPF-P analysis determined that COTS/GOTS/NDI solutions should be able to sufficiently address the capability gap. While developmental systems could yield a custom solution with the greatest capability tailored to USCG mission objectives, the cost of developing such a system would significantly outweigh the benefits. A qualitative analysis of the cost versus effectiveness for each of these solutions was generated. This comparison among commercial and developmental solutions first analyzed the effectiveness of each solution. A developmental system, while it takes longer to implement, offers a high degree of customization as the user can tailor the solution to its requirements. This results in higher technical performance and user satisfaction. This would offer the highest measure of effectiveness when considering capabilities. In contrast, a commercial solution (COTS/GOTS/NDI) would be quicker to implement but would require tradeoffs when considering capabilities since they were not developed specifically to the USCG requirements. These solutions and their normalized measure of effectiveness are shown in Table 6. The analysis simply shows that developmental solutions would be more effective than commercial solutions. However, developmental solutions have higher acquisition and support costs which must be considered. These costs include research and development, test and evaluation, regulatory compliance, manufacturing, and operations and support all of which are typically higher for developmental programs. This data is likewise presented in Table 6. The results are graphically displayed in Figure 23, which shows the comparative life cycle costs of developmental systems versus commercial solutions and the corresponding measures of effectiveness. These comparisons are not to scale, but simply used to show the relative cost and effectiveness of each option.

Table 6. Data Table for Analysis of Developmental versus Commercial Alternatives

	Developmental	**COTS**	**GOTS**	**NDI**
Measure of Effectiveness *higher is better*				
Technical Performance	4	2	2	2
User Satisfaction	4	2	2	2
Normalized MOE	1	0.5	0.5	0.5
Cost *higher is costlier*				
Research and Development	4	2	2	2
Test and Evaluation	4	2	2	2
Regulatory Compliance	4	2	2	2
Manufacturing	4	2	2	2
Operations and Support	4	1	2	3
Normalized Cost	1	0.45	0.5	0.55

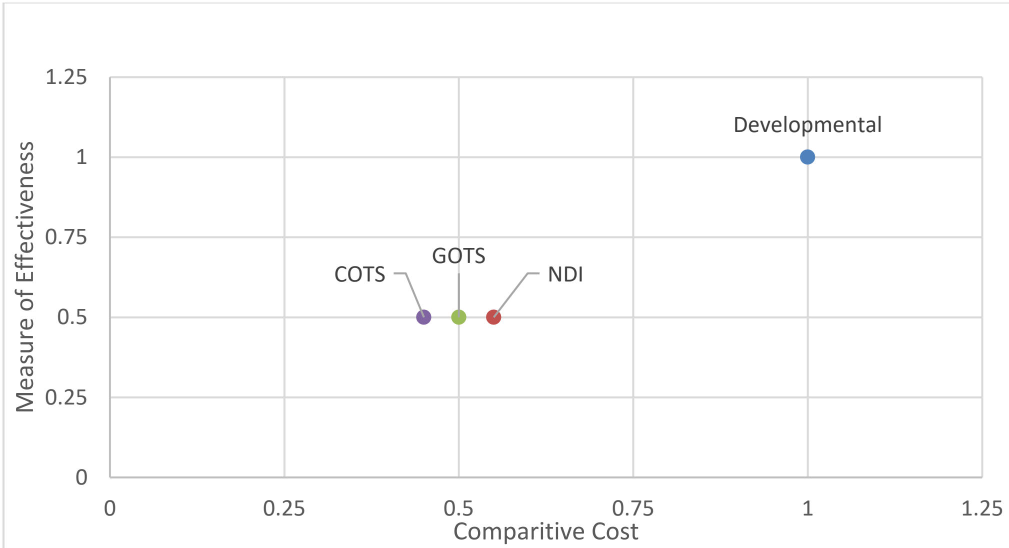

Figure 23. Relative Analysis of Developmental versus Commercial Alternatives.

This analysis shows that while a developmental system may provide additional capability, the total cost of ownership would be significantly higher than other options. On the other hand, a COTS, GOTS, or NDI solution is likely to offer acceptable capability at a reduced cost. The marginal increase in effectiveness for a developmental system does not justify the marginal increase in cost. Based on this analysis, COTS, GOTS, and NDI payloads and platforms will be further analyzed.

The CBA above revealed that there is a future capability gap of 13,000 flight hours. A direct substitution of unmanned for manned flight hours, however, is not appropriate as the flight characteristics, such as airspeed and endurance, between the platforms differ. At a basic level, the UAS alternative should be able to cover the same distance that the MRS platforms currently do. These values are shown in Table 7.

Table 7. Maximum Range and Maximum Endurance for MRS Assets. Adapted from Coast Guard (n.d.c).

MRS Platform	Max Range (NM)	Max Endurance (hrs)
C-27	2675	12
C-144	2100	10

3. Payload Considerations

The literature review revealed that payload integration is a crucial consideration when discriminating between UAS platforms. Two vital payloads for a USCG UAS alternative include a maritime surface search radar and an optical system. This section presents some commercial payload alternatives that would competitively meet the government's anticipated requirements. The presented payload systems are not intended to be inclusive but rather a benchmark for payload weights from which to select the appropriate UAS platform. Table 8 presents some maritime search radars and their associated weights. The radar weights range from 24 to 165 lbs.

Table 8. Commercial Maritime Search Radar Alternatives. Adapted from Manufacturer Data.

	Developer	Weight	Source
Eagle Eye	General Atomics	137 lbs.	General Atomics Aeronautical Systems (2022)
Lynx Multi Mode Radar	General Atomics	137 lbs.	General Atomics Aeronautical Systems (2023)
RDR-1700G(v)2	Telephonics	82 lbs.	Telephonics Corporation (n.d.)
I-Master	Thales	66 lbs.	Thales Group (2023)
ELTA Systems EL/M-2022U	IAI	165 lbs.	Israel Aerospace Industries (2014)
Selex ES Seaspray 5000E	Finmeccanica	105 lbs.	Selex ES Ltd (2014)
NSP-7	IMSAR	24 lbs.	IMSAR LLC (2023)
Osprey MM	Leonardo	62 lbs.	Leonardo Company (2016)

Similarly, Table 9 presents some EOIR systems that can meet the government's anticipated requirements. The optical sensor weights range from 38 to 260 lbs.

Table 9. Commercial EOIR Alternatives. Adapted from Manufacturer Data.

	Developer	Weight	Source
FLIR Systems Star SAFIRE 380-HD	Teledyne	100 lbs.	Teledyne FLIR (2022)
L3Harris WESCAM MX-25	L3Harris	260 lbs.	L3Harris (n.d.)
FLIR Systems SeaFLIR	Teledyne	41 lbs.	Teledyne FLIR (2023)
Rafael Toplite	Rafael	143 lbs.	Rafael Ltd (2019)
BlackKite	LogosTech	38 lbs.	Logos Technologies LLC (n.d.)

The combined radar and EOIR weights of surveyed commercial payload alternatives range from 62 to 425 lbs. Any UAS that is below this range would likely not meet requirements, and those that are capable of payloads in excess of the range are unnecessary.

4. Estimating Costs

While the acquisition and operating costs of some UAS such as the Predator and Global Hawk are known, many of the commercial alternatives that could likely meet the USCG's requirements do not have published prices to allow for comparison of costs. Cost estimating relationships (CERs) are models that utilize aircraft characteristics to parametrically estimate the acquisition cost of platforms. One standard for cost estimating relates cost to empty platform weight. The DOD's *UAS Roadmap 2005–2030* presented two relationships that link empty weight and payload weight to cost. The costs utilized in this relationship are aircraft average unit acquisition costs without sensor systems and weights do not include fuel or payloads. This is shown graphically in Figure 24.

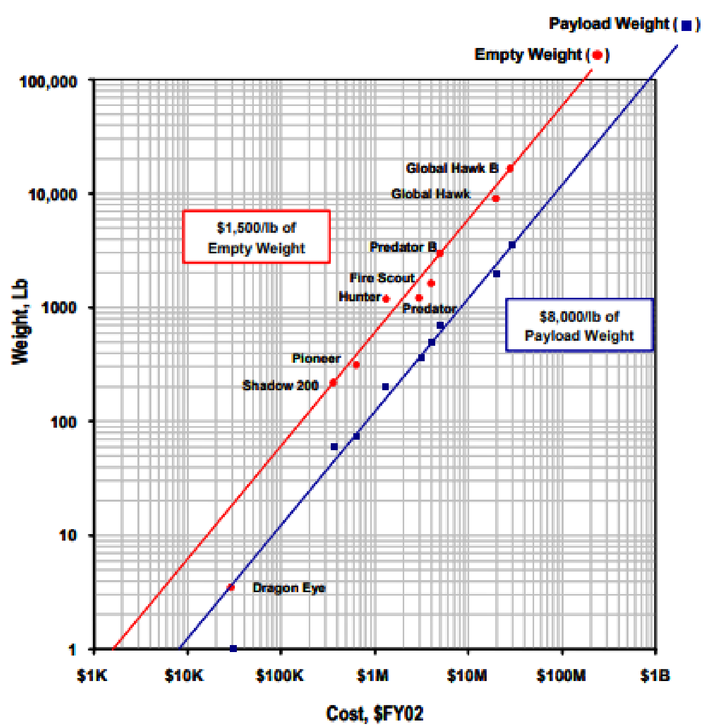

Figure 24. UAS CER Utilizing Empty Weight or Payload Weight. Source: Office of the Secretary of Defense (2005).

While most CERs use aircraft weight as the primary cost driver, this model fails to accurately capture the technological complexities of payload systems, which can include sensors, relays, weapons, and cargo (Malone et al., 2013). The DOD's *UAS Roadmap 2005–2030* introduced another useful CER for UAVs that utilizes payload weight capability and endurance to estimate costs. This model, which compares various DOD systems, is shown in Figure 25.

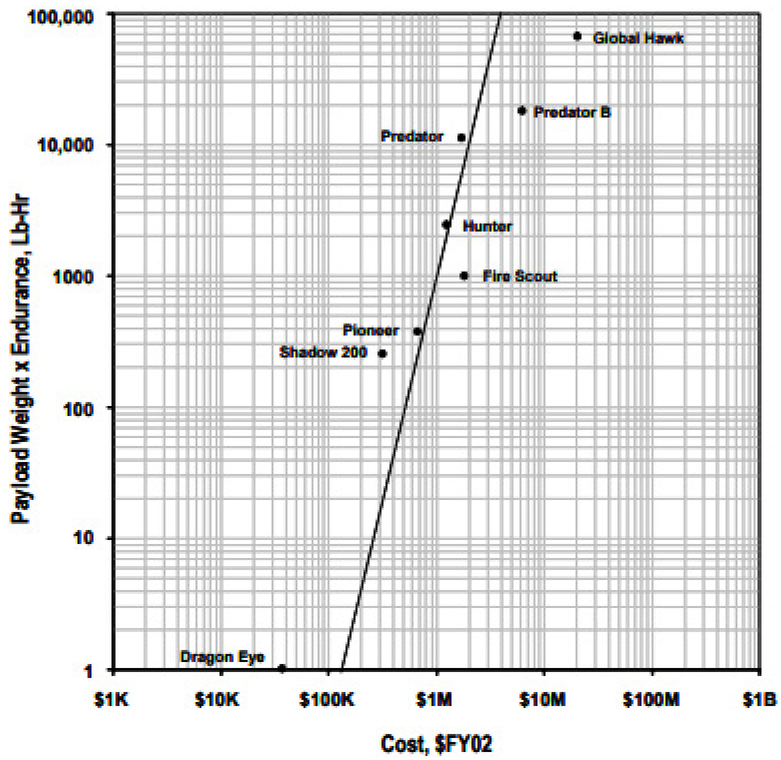

Figure 25. UAS CER Utilizing Payload Weight and Endurance. Source: Office of the Secretary of Defense (2005).

5. Commercial Alternatives

The Uncrewed Systems & Robotics Database (USRD) of the Association for Uncrewed Vehicle Systems International (AUVSI) provides over 10 years of data in uncrewed and autonomous technologies in civil, commercial, and military markets. The USRD includes over 4,500 air platforms from over 1,350 manufacturers. This database was used to review UAS specifications and capabilities to determine whether they can meet the

USCG's future requirements. Some of the candidate systems that are actively marketed are presented.

a. Albatross 2.2

UAVOS Inc, a U.S.-based manufacturer, has developed the Albatross 2.2 UAV, a MALE UAS that was designed for long-endurance missions in conditions of high turbulence (UAVOS, n.d.). This UAS is a converted Pipistrel Sinus motorglider that has been reinforced to endure additional loading. It contains a proprietary autopilot that enables automated takeoff, flight, and landing with beyond line of sight (BLOS) operation. The aircraft, shown in Figure 26, is specifically marketed for maritime and coastal patrol, SAR, and disaster response missions. The Albatross 2.2 specifications are included in Table 10.

Figure 26. Albatross 2.2. Source: UAVOS (n.d.).

b. Antares E2

The Antares E2 UAV is a product of Germany-based Lange Research Aircraft. This aircraft is unique in its hybrid design that offers an electric drivetrain consisting of fuel cells and six electric motors that offer high endurance and high reliability (Lange Research Aircraft, n.d.). While this all-weather UAS, shown in Figure 27, has impressive range and endurance characteristics, it offers a moderate payload capability that would limit the sensor package. This could be a viable alternative, especially if green initiatives are a priority. The Antares E2 specifications are included in Table 10.

Figure 27. Antares E2. Source: Lange Research Aircraft (n.d.).

c. *Bayraktar Akinci*

The Turkish manufacturer, Baykar Makina, offers the Bayraktar Akinci UAV, which was developed to conduct operations typically performed by fighter jet aircraft (Baykar Tech, n.d.). The system, pictured in Figure 28, uses two turboprop engines that enable a large payload capacity of over 2,900 lbs. with high endurance and range characteristics.

Figure 28. Bayraktar Akinci. Source: Baykar Tech (n.d.).

d. Centaur

Centaur is unique in that it is an optionally piloted aircraft, which enables both manned and unmanned operations. It is a conversion airframe offered by Aurora Flight Sciences, that is based off the popular Diamond DA42 commercial aircraft and is shown in Figure 29. This aircraft has impressive range and payload characteristics, 2,300 NM and 800 lbs. when considering its maximum gross takeoff weight (MGTOW) of under 4,000 lbs. (Aurora Flight Sciences, n.d.). After completing developmental testing, operational testing, and a lease agreement with the Swiss military, Aurora Flight Sciences completed an international sale to armasuisse, their procurement agency in 2021 (Aurora Flight Sciences, 2021).

Figure 29. Centaur. Source: Aurora Flight Sciences (n.d.).

e. ISR-ONE

The ISR-ONE platform from the Cubic Corporation provides next-generation autonomous ISR capabilities that compete with those offered by Group 4/5 systems with the cost and logistics footprint of a smaller, Group 3 system (Cubic ISR Systems, 2019). While limited in its payload capacity of 220 lbs., the ISR-ONE, shown in Figure 30, has an impressive maximum range for its low MGTOW. Cubic Corporation advertises a COCO model that delivers high-performance ISR capability as a service.

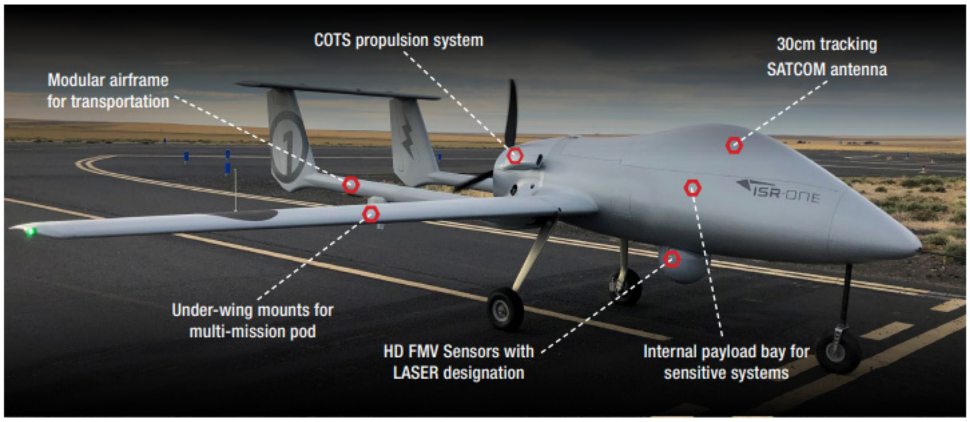

Figure 30. ISR-ONE. Source: Cubic ISR Systems (2019).

f. MQ-4C Triton

The MQ-4C Triton, a Navy program of record was introduced in Chapter 3. A maritime version of the Air Force's Global Hawk program, this UAS has a payload capacity and range that likely far exceeds the USCG's future requirements. With a MGTOW higher than most other alternatives, this system would come at a significant cost.

g. MQ-9A Reaper

The MQ-9A Reaper, as operated by the Air Force, and the extended range variant, as operated by the Marine Corps, were also introduced in Chapter 3. These are very capable systems that boast a high payload capacity that exceeds 3,500 lbs. These systems are approximately one-third of the MGTOW of the MQ-4C Triton but are still about three to four times as heavy as some of the lighter systems presented.

h. MQ-9B SeaGuardian

General Atomics Aeronautical Systems, recently built upon their successful MQ-9A experience to offer the MQ-9B SeaGuardian UAS. This is an all-weather, maritime-focused platform that was designed to fly over the horizon for over 30 hours to perform

ISR missions (General Atomics Aeronautical Systems, 2020). Specifically developed for USCG and Navy missions, this platform would likely provide some of the highest capabilities that the commercial market has to offer. With over 5,000 lbs. of payload capacity, a range that exceeds 5,000 NM, and an airspeed of over 200 knots, the MQ-9B SeaGuardian, pictured in Figure 31, is a highly capable platform.

Figure 31. MQ-9B SeaGuardian. Source: General Atomics Aeronautical Systems (2020).

i. Patroller-M

The French manufacturer, Safran Electronics and Defense, markets the Patroller-M UAS, a variant of the Patroller UAV family that was specifically designed for maritime operations. It was tailored for coastal missions including surveillance and SAR (Safran Electronics and Defense, 2022). The system, as pictured in Figure 32, is capable of large payloads with a capacity that exceeds 550 lbs. in a lightweight platform that has a MGTOW of only 2,315 lbs. With an airspeed of only 70 knots, however, the Patroller-M would take longer to complete large search area missions.

Figure 32. Patroller-M. Source: Safran Electronics and Defense (2022).

6. Specifications of Alternatives

Utilizing publicly available manufacturer data and specifications obtained from the USRD, the alternatives presented above can be compared against each other. The results are shown in Table 10.

Table 10. Specifications and Characteristics of Alternatives. Adapted from Manufacturer Data and USRD.

Name	MGTOW (lbs.)	Wingspan (ft)	Endurance (hrs.)	Range (NM)	Max Altitude (ft)	Cruise Speed (kts)	Payload (lbs.)
Albatross 2.2	1,210	49	20	1,401	23,600	110	551
Antares E2	3,638	75	40	3,355	20,000	100	440
Bayraktar Akinci	12,125	66	24	3,107	40,000	150	2,976
Centaur	3,935	44	24	2,301	27,500	160	800
ISR-ONE	1,300	31	15	2,302	18,000	120	220
MQ-4C Triton	32,250	131	24	9,436	56,500	322	5,602
MQ-9A Reaper	10,500	66	27	1,323	50,000	200	3,850
MQ-9B SeaGuardian	12,500	79	30	5,000	40,000	210	4,750
Patroller-M	2,315	59	30	1,243	25,000	70	551

These alternatives provide a wide range of capabilities that are not intended to be all-inclusive but rather a representation of commercial solutions that are currently marketed that may meet future USCG requirements. The data in Table 10 will be qualitatively compared against possible future USCG UAS requirements and categorized according to the legend in Figure 33.

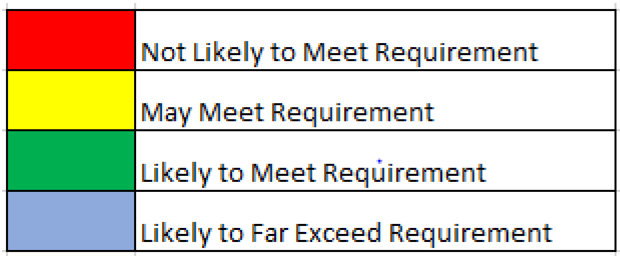

Figure 33. Legend for Likelihood of Meeting Future USCG UAS Requirements.

Wingspans of UAS alternatives were compared against the footprint of the current MRS assets, which are shown in Table 11. This is an important factor when regarding facility requirements as implementation of UAS would be simplified if they could utilize the same hangar space as current MRS platforms. The only alternative that exceeds the wingspan of current MRS platforms is the MQ-4C Triton. This is depicted in Table 12.

Table 11. MRS Platform Characteristics. Source: Coast Guard (n.d.c).

MRS Platform	**Wingspan (ft)**	**Range (NM)**	**Endurance (hrs.)**	**Cruise Speed (KTAS)**
C-27	74	2675	12	290
C-144	70	2100	10	210

Table 12. Qualitative Analysis of Likelihood of Meeting Future USCG UAS Requirements.

Name	MGTOW (lbs)	Wingspan (ft)	Endurance (hrs)	Range (NM)	Max Alt (ft)	Cruise Speed (kts)	Payload (lbs)
Albatross 2.2	1210	49	20	1401	23600	110	551
Antares E2	3638	75	40	3355	20000	100	440
Bayraktar Akinci	12125	66	24	3107	40000	150	2976
Centaur	3935	44	24	2301	27500	160	800
ISR-ONE	1300	31	15	2302	18000	120	220
MQ-4C Triton	32250	131	24	9436	56500	322	5602
MQ-9A Reaper	10500	66	27	1323	50000	200	3850
MQ-9B SeaGuardian	12500	79	30	5000	40000	210	4750
Patroller-M	2315	59	30	1243	25000	70	551

Maximum endurance factors from manufacturer specifications are likely for minimal or zero payloads as their additional weight and drag counter the efficiency of the aircraft. Nonetheless, these specifications can be compared to offer a relative ranking of endurance. While the maximum endurance of MRS platforms is over 10 hours, they accomplish this at a higher airspeed than the lighter and more efficient UAS alternatives and can thereby cover more range per sortie. Some UAS alternatives, as can be seen in Table 12, advertise over 24 hours of endurance, which would likely far exceed any USCG requirement. This capability would require a significant increase in operators, thereby increasing operating expenses. There are multiple alternatives that fall at or just short of 24 hours' endurance that would likely meet a USCG requirement. The ISR-ONE platform is on the lower end of endurance, and when combined with its slower cruise speed, may not be sufficient for USCG missions.

Range is a significant comparative performance metric, as any replacement or supplement to the USCG's fleet should meet or increase capability. The UAS alternatives should then be capable of ranges similar to those of the MRS platforms, as shown in Table 11. The MQ-4C Triton and MQ-9B SeaGuardian each offer impressive ranges that far exceed the capability of the MRS aircraft. Conversely, the Albatross 2.2, MQ-9A Reaper, and Patroller-M UAS alternatives advertise ranges that are significantly lower than MRS platforms. Four of the platforms, as seen in Table 12, offer ranges comparable to those of MRS aircraft.

All the UAS alternatives are capable of altitudes that would likely meet USCG requirements. While ISR missions can be either covert or overt, they are typically conducted at the highest altitude that allows for sufficient radar coverage and image resolution.

Cruise speed is another important discriminator when selecting a UAS alternative for USCG missions. There is a trade-off that occurs between cruise speed and the probability of detection. As cruise speed increases, the search track distance per hour also increases; however, the probability of detection at higher speeds decreases with fewer radar sweeps over the same area. The UAS alternatives that were in the 100–210 kt range would likely be able to meet a USCG probability of detection requirement.

Payload capacity is the last comparative specification that was examined and is one of the most important. It was assumed that all of the alternatives employed a MOSA to which any payload could easily integrate. The ability of the UAS platform to integrate sensor payloads is crucial and solutions that do not allow flexibility in this requirement should be heavily scrutinized. The USCG UAS alternative must be able to carry the appropriate sensors, which, as previously discussed, would likely fall in the range of 62 to 425 lbs. One of the platforms, ISR-ONE, fell within this range, which would limit the sensors that could be installed. Four alternatives fell slightly above the range of payload sensors, and four additional alternatives offer payload capacities well above the needs for USCG missions. If cost is a constraint, as it is likely to be, payload capacity that far exceeds the USCG requirement would likely make these systems unaffordable.

If considering the UAS Roadmap 2005–2030 CERs, payload capacity, platform weight, and endurance are significant drivers of platform cost. Each of these variables resulted in separate CERs which were introduced in Figure 24 and Figure 25. They will be applied to the UAS alternatives as CER 1, CER 2, and CER 3 where CER 1 is the relationship between basic aircraft weight and acquisition cost, CER 2 is the relationship between payload weight and acquisition cost, and CER 3 is the relationship between payload x endurance and acquisition cost. Each of these CERs was adjusted for inflation between 2002 and 2023 utilizing a Bureau of Labor Statistics consumer price index. The three relationships were utilized to estimate platform acquisition costs for each alterative, the results of which are presented in Table 13. Each of the CERs are shown, along with an average of the three results. For some alternatives, a wide range of cost estimates was observed. Each estimate was grouped into low, medium, and high cost for visualization purposes.

Table 13. Application of CERs to Alternatives.

Name	**CER 1** *Empty Weight ($M USD 2023)*	**CER 2** *Payload Weight ($M USD 2023)*	**CER 3** *Payload x Endurance ($M USD 2023)*	**Average of 3 CERs** *($M USD 2023)*
Albatross 2.2	2.1	7.4	18.6	9.4
Antares E2	6.4	5.9	29.7	14.0
Bayraktar Akinci	25.1	40.2	120.7	62.0
Centaur	7.6	10.8	32.4	17.0
ISR-ONE	2.3	3.0	5.6	3.6
MQ-4C Triton	73.5	75.7	227.2	125.5
MQ-9A Reaper	12.7	52.1	175.7	80.1
MQ-9B SeaGuardian	12.4	64.2	240.8	105.8
Patroller-M	4.1	7.4	27.9	13.1

Red	High Cost (>$80M per aircraft)
Yellow	Medium Cost ($20-80M per aircraft)
Green	Low Cost (<$20M per aircraft)

When considering the best value platform for USCG missions, the Service should evaluate the qualitative characteristics of UAS platforms as shown in Table 12 against the cost of platforms. Other evaluation factors, such as maintainability, reliability, and operating costs, to name a few, will surely be important and should also be considered. Analyzing Table 12 and Table 13, it seems that the ISR-ONE, which may be the lowest cost platform, could potentially meet USCG requirements but be limited in its payload capacity. It must also be determined what the effect of a full payload will have on performance properties such as range, endurance, and speed. The remaining low-cost options are the Albatross 2.2, Centaur, Antares E2, and Patroller-M. Of these, the Antares E2 and Centaur platforms seem to offer the most capability for comparatively similar costs. The remaining medium and high-cost options, the Bayraktar Akinci, MQ-4C Triton, MQ-9A Reaper, and MQ-9B SeaGuardian all offer capabilities that likely exceed USCG mission requirements and are equally likely to be significantly more expensive to acquire and operate than other options.

Alternatively, a quantitative approach can be applied where platform characteristics are converted into measures of effectiveness. This method was applied and examined the following specifications: size/weight as a function of MGTOW and wingspan, endurance, range, cruise speed, and payload capacity. Each of these variables was scaled to arrive at a measure of effectiveness (MOE) that ranged from 0 to 1. The alternative with the highest MOE received a score of 1 and the lowest a score of 0 with bounded alternatives receiving a scaled score between these two extremes. Each of these MOEs was then averaged to arrive at an overall MOE for each alternative. The results of this quantitative MOE analysis are shown in Table 14.

Table 14. Measures of Effectiveness of Alternatives.

higher is better	Size/ Weight MOE	Endurance MOE	Range MOE	Cruise Speed MOE	Payload MOE	Overall MOE
Albatross 2.2	0.91	0.20	0.02	0.16	0.06	0.27
Antares E2	0.74	1.00	0.26	0.12	0.04	0.43
Bayraktar Akinci	0.65	0.36	0.23	0.32	0.51	0.41
Centaur	0.89	0.36	0.13	0.36	0.11	0.37
ISR-ONE	1.00	0.00	0.13	0.20	0.00	0.27
MQ-4C Triton	0.00	0.36	1.00	1.00	1.00	0.67
MQ-9A Reaper	0.68	0.48	0.01	0.52	0.67	0.47
MQ-9B SeaGuardian	0.58	0.60	0.46	0.56	0.84	0.61
Patroller-M	0.84	0.60	0.00	0.00	0.06	0.30

Increases in capability, however, typically coincide with increases in cost. Utilizing the cost estimation analyses introduced in Table 13 and the overall MOEs for each alternative from Table 14, this relationship can be presented in a cost effectiveness analysis, as shown in Figure 34.

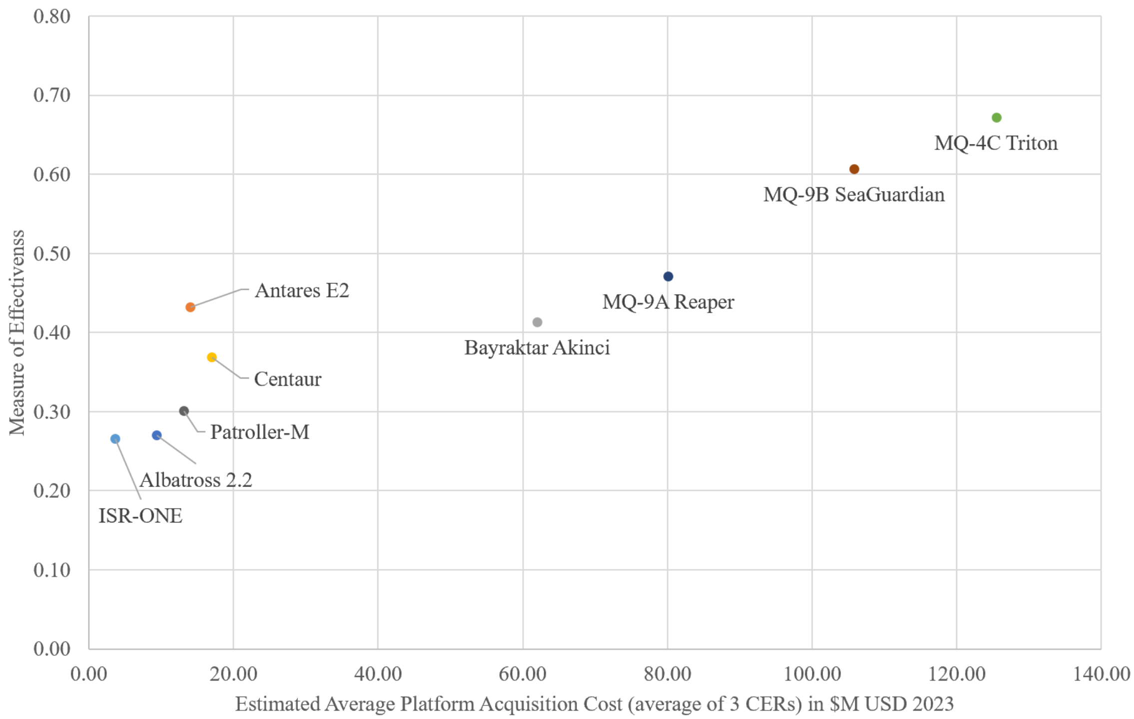

Figure 34. Cost Effectiveness Analysis of Alternatives.

The cost effectiveness analysis reveals that for the most part, increased capability, as depicted by a higher measure of effectiveness, is linked to increased cost. There is one exception in that that Antares E2 provides a higher MOE at a lower cost than the Centaur. The USCG can use an analysis such as this to weigh each marginal increase in MOE with the marginal increase in cost. A clear solution is not readily apparent, therefore the USCG needs to narrowly define their requirement and select the alternative that best meets the mission.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. SUMMARY

As maritime missions evolve, so must the USCG's capabilities. This thesis sought to determine if the USCG's diverse mission set can benefit from the advantages of UAS. To do so, it asked two research questions which focused on the identification of a future capability gap in USCG missions and if there are materiel UAS solutions that can affordably address the gap. Three DOD frameworks were utilized to determine if UAS could affordably meet a perceived capability gap: a CBA, a DOTmLPF-P analysis, and an Analysis of Alternatives.

Utilizing the JCIDS CBA process and USCG operational data, the past 10 years of USCG fixed wing employment flight hours were analyzed. In a theoretical future where the MRS program was dissolved, the MRS mission hours were redistributed among the LRS and rotary wing platforms. After the redistribution of hours, a capability gap of approximately 13,000 annual flight hours (20,000 hours if training and test are included) emerged, all of which were in the execution of the ELT mission. This ISR mission set specifically, is one that is most suited toward the capability of UAS.

A DOTmLPF-P analysis was then completed to examine if the capability gap could be addressed through changes to doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy. It was determined that a materiel solution, specifically a commercial solution vice developmental, is warranted.

An AoA that compared a sample of nine currently marketed UAS platforms that represent the wide range of capabilities that the commercial market can offer was presented. Qualitative and quantitative analyses were completed that revealed the ability of each alternative to meet the USCG capability gap. Measures of effectiveness for each alternative as well as estimated costs were then compared to present a cost effectiveness analysis. As the systems evaluated are actively marketed, actual pricing data for non-military platforms was not readily available, nor were manufacturers willing to disclose them. Although dated, three cost estimating relationships were utilized to provide a range of acquisition cost estimates for each alternative. While these estimates do not reflect the current advancements in UAS and sensor technologies they were used as a general guide to group UAS alternatives into low, medium, and high-cost systems.

B. CONCLUSIONS AND RECOMMENDATIONS

A review of the USCG's 11 statutory missions revealed that the capabilities of UAS are well aligned with the Service's mission requirements. It is also clear from national, Service, and mission-level strategies that there is a threat to international order in the maritime domain and that the United States is at an inflection point. All strategies point to the criticality of investments in capability, and many mention a need for increased autonomous systems to provide persistent surveillance and detection abilities in these contested maritime environments.

While the USCG currently completes a majority of its missions with manned aircraft, there is doubt to whether the MRS platforms will be able to continue to affordably meet mission demand. With the exception of the LRS program, there are no ongoing acquisitions into the fixed-wing and rotary-wing programs. As these platforms continue to age, a future concept of operations, one that likely incorporates UAS, will come about.

UAS are not new to military operations and have made significant advances over the past few decades. External studies consistently found that UAS can increase capability for the USCG, especially in ISR missions. With advancements in size, power, and weight characteristics of ISR payloads, significant capability can be achieved at a relatively low payload weight requirement. This opens up new possibilities to execute USCG missions with smaller, more efficient, and less costly platforms.

Some of the platforms evaluated, including the Predator as used by CBP for border surveillance and likewise evaluated by external studies, offer considerably higher capability than is likely needed for USCG ISR missions. If these missions can be completed by a much smaller, and thereby less costly platform, this could provide significant financial benefits to the decision. While not all-inclusive, there are multiple alternatives that are likely to meet but not significantly exceed future USCG requirements. This market should, in theory, provide for ample commercial competition in a future procurement.

Concerning acquisition strategies, analysis recommended that a COCO model would best suit the USCG in its initial fielding of a LR-UAS capability. This model will allow the Service to adapt to future technology changes while growing the organic knowledge and experience with the systems. If successful, future investments and a transition to GOGO UAS assets may then be examined.

C. FUTURE RESEARCH

This field of study is ripe for future research from multiple perspectives. First, a complete revisioning of the USCG concept of operations from an operations research lens would be beneficial to understand how emerging technologies can play a role in the Coast Guard of the future. This thesis, for example, did not delve into the capabilities of low earth orbit satellites or ship-tethered ISR platforms. A future USCG that incorporates surface, air, and space capabilities can revolutionize operations and will likely look vastly different from the manned surface fleet and manned aviation fleets that we use today. Additional operational impacts to manning would result from incorporating UAS into the USCG fleet. While some manning requirements, such as UAS operators could grow, others would likely decrease. The manning requirements should be fully understood and planned for well before any radical shifts in operations.

Secondly, further research into the payload and connectivity requirements for UAS operations is warranted. Any systems of interest for the USCG should be evaluated for their ability to employ a MOSA. These inputs will significantly shape the future requirements for UAS platforms and, if significantly overestimated, may filter out some capable platforms that can execute the mission at a reduced investment and operating cost.

Finally, further research into the UAS market can help in decision-making and the requirements writing process for the USCG. There are many alternatives with a wide range of capability. A deep understanding of what the market has to offer and at what cost will surely benefit decision-makers as they make initial investment decisions into USCG capabilities.

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