2012-09

The EP-3E vs. the BAMS UAS An Operating and Support Cost Comparison

Larkins, Colin G.

Monterey, California. Naval Postgraduate School

https://hdl.handle.net/10945/17395

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

THE EP-3E VS THE BAMS UAS:
AN OPERATING AND SUPPORT COST COMPARISON

by

Colin G. Larkins

September 2012

Thesis Advisor:	Raymond Buettner
Second Reader:	William Robinette

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

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2012	**3. REPORT TYPE AND DATES COVERED** Master's Thesis

4. TITLE AND SUBTITLE The EP-3E vs. the BAMS UAS: An Operating and Support Cost Comparison	**5. FUNDING NUMBERS**
6. AUTHOR(S) Colin G. Larkins	
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. IRB Protocol number ______N/A______.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution in unlimited	**12b. DISTRIBUTION CODE** A

13. ABSTRACT (maximum 200 words)

The battlefield is constantly changing and the need for swift, persistent intelligence, surveillance and reconnaissance (ISR), has increased the focus on the use of unmanned aerial vehicles (UAVs) to help meet collection requirements. Certain UAVs can have longer dwell and on-station times than manned vehicles, with some UAVs capable of dwell times in excess of 20 hours. UAVs have an additional benefit of eliminating some of the risks associated with manned aircraft conducting ISR missions. Consequently, UAVs have been closely reviewed as a replacement craft for several manned ISR aircraft and have taken increasing roles in the world of ISR.

Given an uneven record of success in the implementation of UAS, and Congressional concerns regarding the relative cost of UAV programs, the purpose of this thesis is to reexamine, compare and analyze the Operating and Support (O&S) costs for both the EP-3E ISR aircraft with the Broad Area Maritime Surveillance (BAMS) Unmanned Aerial System (UAS) that the Chief of Naval Operations (CNO) has declared to be the primary system to replace the EP-3E capability. This comparison includes all costs from initial system deployment through the end of the platforms' service life. This thesis uses the revised O&S cost methodology in accordance with Department of Defense (DoD) Instruction 5000.2, *Operation of the Defense Acquisition System*. In addition, a typical O&S comparison, this thesis modifies the existing BAMS O&S costs to account for the additional costs of bandwidth, ground station support, collection sites, and risks as they apply to the BAMS UAS. These factors were not adequately considered in the original O&S analysis. Once the analysis and comparison is completed, a recommendation is made as to whether or not the decision to replace the EP-3E ISR system with the BAMS UAS should be revisited.

14. SUBJECT TERMS BAMS, Cost Estimations, EP-3E, Operating and Support, UAS, UAV	**15. NUMBER OF PAGES** 81
	16. PRICE CODE

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

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

THE EP-3E VS THE BAMS UAS:
AN OPERATING AND SUPPORT COST COMPARISON

Colin G. Larkins
Lieutenant, United States Navy
B.S., United States Naval Academy, 2003

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN INFORMATION
WARFARE SYSTEMS ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
September 2012

Author:	Colin G. Larkins
Approved by:	Raymond Buettner Thesis Advisor
	William Robinette Second Reader
	Dan Boger Chair, Department of Information Sciences

ABSTRACT

The battlefield is constantly changing and the need for swift, persistent intelligence, surveillance and reconnaissance (ISR), has increased the focus on the use of unmanned aerial vehicles (UAVs) to help meet collection requirements. Certain UAVs can have longer dwell and on-station times than manned vehicles, with some UAVs capable of dwell times in excess of 20 hours. UAVs have an additional benefit of eliminating some of the risks associated with manned aircraft conducting ISR missions. Consequently, UAVs have been closely reviewed as a replacement craft for several manned ISR aircraft and have taken increasing roles in the world of ISR.

Given an uneven record of success in the implementation of Unmanned Aerial System (UAS), and Congressional concerns regarding the relative cost of UAV programs, the purpose of this thesis is to reexamine, compare and analyze the Operating and Support (O&S) costs for both the EP-3E ISR aircraft with the Broad Area Maritime Surveillance (BAMS) UAS that the Chief of Naval Operations (CNO) has declared to be the primary system to replace the EP-3E capability. This comparison includes all costs from initial system deployment through the end of the platforms' service life. This thesis uses the revised O&S cost methodology in accordance with Department of Defense (DoD) Instruction 5000.2, *Operation of the Defense Acquisition System*. In addition, a typical O&S comparison, this thesis modifies the existing BAMS O&S costs to account for the additional costs of bandwidth, ground station support, collection sites, and risks as they apply to the BAMS UAS. These factors were not adequately considered in the original O&S analysis. Once the analysis and comparison is completed, a recommendation is made as to whether or not the decision to replace the EP-3E ISR system with the BAMS UAS should be revisited.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AIS	Automatic Identification System
ACS	Aerial Common Sensor
BAMS	Broad Area Maritime Surveillance
CAIG	Cost Analysis Improvement Group
CARD	Cost Analysis Requirement Description
CBO	Congressional Budget Office
CER	Cost Estimating Relationships
CNO	Chief of Naval Operations
COMINT	Communications Intelligence
COMSAT	Commercial Satellite
CNO	Chief of Naval Operations
DAB	Defense Acquisition Board
DIRSNA	Director, National Security Agency
DISA	Defense Information Systems Agency
DoD	Department of Defense
EO/IR	Electro-Optical/Infrared
ESM	Electronic Support Measures
EW	Electronic Warfare
EWOP	Electronic Warfare Operator
FY	Fiscal Year
GAO	Government Accountability Office
HALE	High Altitude Long Endurance
ISR	Intelligence, Surveillance and Reconnaissance
JCC	Joint Architecture Modernization Common Configuration
LCSP	Life Cycle Sustainment Cost
LRIP	Low Rate Initial Production
Mbps	Megabits per second
MDA	Maritime Domain Awareness
MPRF	Maritime Patrol and Reconnaissance Force

NAS	Naval Air Station
NCCA	Navy Center for Cost Analysis
NFO	Naval Flight Officer
O&S	Operating and Support
PRC	People's Republic of China
SAR	Selected Acquisition Report
SATCOM	Satellite Communications
SIGINT	Signals Intelligence
U.S.	United States
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UCLASS	Unmanned Carrier-Launched Airborne Surveillance and Strike
VAMOSC	Visibility and Management of Operational and Support Cost
VQ-1	Fleet Air Reconnaissance Squadron One
VQ-2	Fleet Air Reconnaissance Squadron Two
WBS	Work Breakdown Structure

EXECUTIVE SUMMARY

The need for persistent global ISR and maritime domain awareness (MDA) comes with a few challenges. These challenges come in the form of the use and application of UAVs to fill the collection gaps not currently being achieved by satellites and manned aircraft. UAVs present huge useful benefits to the DoD but those benefits are paralleled by costs. Presently, the DoD has over 6,000 UAVs in its inventory and that number is expected to continually increase. Congress has concerns with the rapid procurement, O&S cost and the management of UAVs despite the benefits they present.

This thesis developed a revised cost-estimation in accordance with DoD Instruction 5000.2, *Operation of the Defense Acquisition System*, for the BAMS UAS and compared it to the historical O&S cost of the EP-3E provided in the Visibility and Management of Operational and Support Cost (VAMOSC) database. The EP-3E was used because it is being replaced by the BAMS UAS. In addition to O&S costs, this thesis implemented the additional costs of satellite bandwidth, collection site personnel, infrastructure redesign at the notional BAMS UAS bases and risks costs. These costs were implemented as Congress has voiced concern about the additional program costs not only for the BAMS UAS but also for the Global Hawk of which BAMS is a variant.

The following impacts were identified.

1) Between FY14–20, the EP-3E would cost more to operate than the BAMS UAS when solely analyzing the O&S costs. However, the additional costs associated with the BAMS UAS make the EP-3E the more efficient aircraft to operate during the period analyzed by $ 1.6 billion.

2) The primary cost drivers identified between the two aircraft were personnel and maintenance costs. The BAM UAS squadron will have an estimated 32 percent lower manpower than that of a single EP-3E squadron based upon previous research conducted by the Orion Group. This 32 percent caused a difference of $522,043,549 between the two platforms between FY14–20.

Unit operations that include fuel cost were a major cost driver that separated the two systems. The BAMS UAS will maintain 24-hour global coverage that will require a minimum of three BAMS from each of the five notional bases to be airborne in their assigned operating areas at all times. Although the BAMS UAS is a single engine aircraft, the length of its missions and continued coverage severely increased fuel costs for the system. Based on the estimations calculated, the BAMS UAS unit operations cost exceed those of the EP-3E by $672,875,702.

Maintenance costs were also a significant cost driver. This cost is associated with the age of the EP-3E as it will be in service over 40 years by FY20. The system components will be expected to continually deteriorate as the aircraft approaches its completed life cycle. The maintenance cost of the EP-3E exceeded those of the BAMS UAS by $555,271,135.

Through the years compared in this thesis, the EP-3E is a more efficient platform to employ. The O&S costs of the BAMS UAS and the additional costs needed for the operation and utility of the platform exceed the costs of the EP-3E by 1.6 billion. Considering the current plan to reduce DoD spending over the next 10 years, Congress has valid concerns about the costs associated with medium to large sized UAVs and the BAMS UAS in particular. Additionally, the BAMS UAS program will continue to increase its number of BAMS until the inventory reaches 65, which will only add to the costs of the system based upon the cost trends identified in this thesis. The costs associated with the BAMS UAS program need to be revisited by Congress and the Congressional Budget Office (CBO) to ensure that the program does not run into future budget shortfalls and to possibly the use of a more efficient UAS with similar capabilities.

ACKNOWLEDGMENTS

First, I would like to that my Lord and Savior Jesus Christ.

I would also like to thank my wife, Kimberly, and my son, Carter, who were understanding and supportive during this tedious process.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

Future operations will most likely see a greater reliance on UAVs. The use of these systems creates several challenges that current and future military leadership should consider. Modern warfare has caused all services to dig deep in their vaults of thought to find ways to meet increasingly demanding intelligence requirements. UAVs have been used extensively to meet these requirements. The increased application of precision weapons and the subsequent need for more intelligence has led to UAVs becoming more and more important. From kinetics to surveillance, UAVs have played more than a substitute or backup role and are increasingly threatening the existence of manned aircraft. The Air Force suggest in its *Unmanned Aircraft Systems Flight Plan 2009-2047* that it is possible to have an entire unmanned flying force by 2047. This shift has been seen in naval leadership's view of future naval ISR aircraft. In August 2011, the Navy announced it would replace the EP-3E, the Navy's shore-based ISR aircraft primarily with the BAMS UAS. This thesis addresses an important aspect of the comparison of the two systems that should be reconsidered as the Navy's leadership proceeds with the deployment of the BAMS UAS.

A. BACKGROUND

1. Overview

The battlefield is constantly changing and the need for swift, persistent ISR has placed a focus on the use of UAVs to help meet collection requirements. UAVs have various dwell and on-station times with some exceeding those of manned vehicles. Depending on platform, some UAVs are capable of dwell times in excess of 20 hours. UAVs have an additional benefit of eliminating some of the risks inherent with manned aircraft. UAVs have been closely reviewed as a replacement craft for several manned ISR aircraft and have taken increasing roles in the world of ISR.

The war on terrorism has placed a high premium on the missions and roles of UAVs as intelligence gatherers. "Furthermore, the military effectiveness of UAVs in recent conflicts such as Kosovo (1999), Afghanistan (2001), and Iraq (2003) has opened the eyes of many to both the advantages and disadvantages provided by unmanned aircraft" (Bone & Bolkcom, 2003). All services are currently developing UAVs designed for specific mission sets and various roles with increasing capabilities in collection ability, processing and autonomy.

In early 2011, the Navy decided that it would replace its EP-3E Airborne Reconnaissance Integrated Electronic System (Aries) II, which is currently the Navy's only land-based signals intelligence (SIGINT) reconnaissance aircraft, with BAMS UAS. The EP-3E will ultimately be retired in 2020. The EP-3Es replacement is a part of an eight billion dollar investment that also includes the MQ-8B Fire Scout, and the unmanned carrier-launched airborne surveillance and strike (UCLASS) UAV over the next four years with the BAMS UAS occupying a significant portion of the investment (Trible, 2011). BAMS UAS is a modification of the U.S. Air Force RQ-4Q Global Hawk Block 10. This UAV is capable of reaching heights of 11 miles above the ground and can remain in flight over 24 hours. This thesis examines and compares the EP-3E aircraft with BAMS UAS operating and support (O&S) costs along with additional cost drivers that may cause concerns for Congress. It also provides information that the Navy can use to influence the decisions ahead in pressing forward with the replacement of the EP-3E, as well as figure out an alternative plan or keeping the EP-3E in service. The historical data for the BAMS UAS does not exist within the Navy VAMOSC database. The data does exist for the EP-3E that validates the exclusion of indirect cost associated with this cost estimate comparison. The O&S costs for the EP-3E are extended to FY20 for the cost estimate comparison.

2. Congressional UAV Issues

Today over 6,000 UAVs are in the DoD inventory, which is a dramatic difference from FY05 when the total DoD UAV inventory was just over 600. UAV procurement rates have concerned Congress for almost a decade but the pace of procurement has not diminished. Over a five-year span from FY00 to FY05, UAV procurement rose an astonishing 135 percent (Geer & Bolkcom, 2005). In FY05, the DoD spent $2.1 billion on UAV procurement. “Congress’s role in UAV development has been one of strong encouragement tempered with concern” (Geer & Bolkcom, 2005). Procurement pace is one of several issues about which Congress is concerned.

Accident rates for UAVs present a serious concern that Congress has considered as the size, sophistication and costs of UAVs continue to mount. As these unmanned systems become more complex and expensive, the tolerance for accidents and loss rates bring about more challenging considerations in regards to replacing lost systems. Loss rates are attributed to mechanical failures, landing gear malfunctions/failures, weather, electrical failures, engine failures and global positioning system communications loss. The Global Hawk has an accident rate of 9.31 accidents or every 100,000 hours, which is the highest rate of any aircraft in its size category (Geer & Bolkcom, 2005). No reason exists to suspect that the BAMS UAS, which is a Global Hawk variant, will have a lower accident rate as the Navy lost one of its BAMS UAS that represents one-fifth of its inventory, on June 11, 2012, in Dorchester County, MD (Geer & Bolkcom, 2005). At a cost of over $220 million a unit, coupled with the current accident rate, and the replacement costs associated with the system, Congress may have valid reasons for concern, as the loss of that one system will cost the Navy over $440 million total in procurement when considering the lost aircraft and its replacement.

Bandwidth costs associated with ISR UAVs is another concern. DoD bandwidth requirements continue to rise as information requirements rise. The time-sensitive information collected by the BAMS UAS is dependent upon a high bandwidth environment. Each BAMS UAS will require at least 500 megabits per second (mbps), which is over five times greater than what all U.S. forces required during Operation Desert Shield/Storm. The Defense Information Systems Agency (DISA) is currently purchasing over 80 percent of DoD’s bandwidth from commercial satellite (COMSAT) providers and industry experts project that this will increase to 90 percent in the near future (Rosenberg, 2010). The concern for Congress is not only COMSAT cost but the security of the military’s critical information as the DoD becomes more reliant on COMSAT providers.

Congress continues to probe the Air Force and the Navy about costs associated with their most sophisticated UAVs including the Global Hawk and the BAMS UAS. The Global Hawk has already suffered significant setbacks that have had a direct effect on cost increases and Congress is concerned that the Navy may face some of the same issues leading forward with the BAMS UAS. This thesis revisits the O&S cost estimate of the BAMS UAS based on concerns that stem from Congress. Other cost concerns examined are increased manning costs, and the building and redesigning of ground stations necessary to operate the BAMS UAS that while not specifically addressed by Congress will be of significant concern.

3. EP-3E History and Role

a. EP-3E History

First introduced in 1969, the EP-3E ARIES I specialized in tactical signal intelligence. The EP-3E was introduced to replace the EC-121 Super Constellation, which were used in World War II and the Korean War. The airframe has remained a relevant asset in maritime ISR due to upgrades that have enhanced collectability. The latest upgrade was approved in 2010 for the aircraft to receive Joint Architecture Modernization Common Configuration (JCC) Spiral 3. "The JCC Spiral 3 program was approved for Low Rate Initial Production (LRIP) in the spring of 2011 authorizing the modification of three additional aircraft" (Hewitt, 2011). Full Rate Production was later approved later in 2011.

The EP-3E continues to hold relevance in the fleet providing national and tactical intelligence against existing and emerging threats. The Navy has relied on the EP-3E for over 40 years as it is still requested in support of intelligence needs. The airframe has supported NATO operations in support of the Bosnian crisis, uprisings in the Middle East, and it has a constant presence in the Global War on Terror. While in the mission area, the mission the crew fuses collected time-sensitive information providing indications and warning, direct threat assessment and warning, and anti-air warfare.

The EP-3E is a proven aircraft but has been threatened with replacement on numerous occasions. In late 1992, the EP-3E program was threatened to be replaced by the Air Force RC-135 Rivet Joint (Joint Chiefs of Staff, 1993). The aim was to employ a single joint airframe to conduct signals intelligence in an effort to cut costs. However, after former Chairman of the Joint Chiefs of Staff, General Colin Powell expressed the need for both airframes, Congress allowed the EP-3E to remain in service. General Powell stated, “Eliminating either type or replacing one with the other would be costly and would contribute nothing to effectiveness” (The Joint Chiefs of Staff, 1993). The Aerial Common Sensor (ACS) was another threat to the existence of the EP-3E. Over the course of eight years, the Navy viewed ACS as a replacement option but the Navy eventually did not integrate the system.

The EP-3E has remained in the fight and in June 2011, it received another upgrade to its collection system, the JCC Spiral 3 configuration. The JCC Spiral 3 has extended the longevity of the EP-3E by increasing its collection capabilities. It has also allowed it to remain relevant to battle group commanders, joint commanders and the Director of the National Security Agency (DIRNSA).

b. EP-3 System Role

The EP-3E, is the Navy’s shore based, long-range, ISR SIGINT aircraft. It is a modification of the P-3 Orion and used for near real-time SIGINT reporting in support of battle group commanders, joint commanders and the National Security Agency. “The primary mission of EP-3E is to rapidly assess the tactical situation using a variety of onboard sensors and remote data-links, manage this multiple-source data, perform contact processing and events analysis and disseminate evaluated tactical data to the appropriate Fleet Commanders and in theatre decision makers” (IHS Janes, 2012). The aircrew onboard the EP-3E consists of 24 personnel, of which seven to eight are officers and 16 are enlisted. The positions held onboard are comprised of pilots, naval flight officers, an electronic warfare (EW) mission commander, an EW aircraft commander, a senior evaluator, EW operators (EWOP), laboratory operators, a secure communications operator, special station operators, in-flight technician, and flight engineers.

The EP-3E has been used in nearly every U.S. conflict including the Cold War, and provided battle group commanders with relevant SIGINT. The Navy has not let time diminish its effectiveness as new systems have been implemented, and replacing others that have become obsolete. The EP-3E is operated by two squadrons, Fleet Air Reconnaissance Squadron One (VQ-1) and Two (VQ-2). Both squadrons have flown the EP-3E since 1969 and provided valuable intelligence and support during multiple exercises with fleet and air units. These squadrons have flown the EP-3E in support of the evacuation of 2000 personnel from Liberia in 1990. The EP-3E had provided timely intelligence during Operations DESERT SHIELD, DESERT STORM, PROVEN FORCE and PROVIDE COMFORT (Fleet Air Reconnaissance Squadron Two VQ-2, 2011). The EP-3E possesses capabilities so relevant and effective that it is still flown off of the coast of some countries that find its presence offensive. The significance of this aircraft garnered world-wide attention in April 2001 when an EP-3E collided with a Chinese naval F-8 fighter. Since the incident, the EP-3 has played vital roles in Operations IRAQI FREEDOM AND ENDURING FREEDOM, and provided timely, relevant intelligence and indications and warning in support of ground commanders and national customers.

c. BAMS UAV History and Role

According to historians, UAVs have been used in battle for over 100 years. During the American Civil War, both sides used balloon-like explosive UAVs. “The idea was for the balloons to come down inside a supply or ammunition depot and explode” (Garamone, 2002). In World War II, the Japanese tried a similar tactic. “They launched balloon bombs laden with incendiary and other explosives” (Garamone, 2002). The idea was that easterly winds would force the balloons to the west coast of United States, descend and cause a multitude of forest fires in various locations. The other intended purpose of this tactic was to burn roadways, homes and businesses that would cause fear among the American people (Garamone, 2002). U.S. and Allied forces tried to use modified manned aircraft as UAVs but quickly realized they did not have the technology to control the aircraft fully so they were used as an alternative method. “Allied forces used the modified manned aircraft basically as cruise missiles” (Garamone, 2002).

In Vietnam, UAVs were implemented in a more sophisticated manner. Advances in technology allowed for completely radio controlled UAVs. The UAV of choice was the AQM-34 Firebee. “As a whole, Firebees flew over 3,400 sorties during the war” (Garamone, 2002). With an endurance of eight hours, they were originally used for photo operations. However, the Firebee quickly transitioned into a multi-mission UAV. Other missions included COMINT, ELINT, leaflet dropping and surface-to-air missile radar detection (Garamone, 2002). The Firebee code-named “Combat Dawn” was developed in the wake of the Navy’s EC-131 ISR aircraft being shot down by North Korea. The Firebee flew preprogrammed routes after being launched mid-air by a C-130 and had the capability to collect and relay collected SIGINT nearly 300 miles away (Teledyne-Ryan AQM-34 Combat Dawn Firebee, 2011). Since then, the roles of UAVs have increased in military action, such as Iraq and Afghanistan. UAVs are currently defined by the DoD as, “a powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle life, can fly by itself (autonomously) or be remotely piloted, can be expendable or recoverable at the end of flight, and can carry a lethal or nonlethal payload” (Elmendorf, 2011).

d. BAMS/Global Hawk History

The BAMS UAS is a variant of the United States (U.S.) Air Force RQ-4B Global Hawk Block 10. After participation in several exercises from 1999 through 2002, Northrop Grumman delivered the first Global Hawk to the Air Force for demonstration in 2003 (Hanlon, 2005). The Navy became interested in the Global Hawk and two were delivered to the Navy in 2005. The Navy’s plan was to modify the Global Hawk and deploy it in support of maritime surveillance. In 2008, Northrop Grumman was awarded a contract to build the Global Hawk variant (MQ-4C Triton (BAMS UAS), n.d.). The intent is to provide unparalleled maritime domain awareness, as well as deliver a persistent ISR capability to battle group commanders.

e. BAMS System Role

Lower cost was one of the main advantages that UAVs were originally thought to provide. Despite cost and budget increases, the DoD has shown an increase in use and the development of UAVs has continually increased to include the BAMS UAS, which has the ability to play a vital role in the future of Navy war-fighting. The BAMS UAS, "will be a forward deployed, land-based, autonomously operated system that provides a persistent maritime ISR capability using a multi-sensor mission payload (maritime radar, Electro-Optical/Infrared (EO/IR), Electronic Support Measures (ESM), Automatic Identification System (AIS) and basic communications relay)" (Naval Air Systems Command, 2012a). BAMS is designed to play a significant role in the Maritime Patrol and Reconnaissance Force (MPRF). "BAMS is an integrated System of Systems and a force multiplier for the Joint Force and Fleet Commander, enhancing battle-space awareness and shortening the sensor-to-shooter kill-chain" (Dishman, 2010).

Figure 1. BAMS UAS

The BAMS UAS has the "ability to perform persistent intelligence, surveillance and reconnaissance within a range of 2,000 nautical miles" (MQ-4C Broad Area Maritime Surveillance (BAMS), 2011). Collected imagery will be fed via a satellite feed to a Navy ground segment. The information will provide both operation and tactical customers with increased battle space awareness while maintaining the common operational and tactical picture. BAMS is tailored for maritime ISR, which consists of the collection above oceans, seas, bays, estuaries, islands and coastal areas (Conway, Roughead, & Allen, 2010). Its design will allow it to provide real-time SIGINT, perform vital roles in strike packages and communication relays while operating either in conjunction with other naval assets or independently (Poston, 2011).

The BAMS UAS will have a complex collection and communications suite consisting of, "maritime SAR and Inverse SAR, Electo-optical/Infra-red (EO/IR)/Full Motion Video, Electronic Support Measures (ESM), Automatic Identification System (AIS), a basic communications relay capability and Link-16" (Oesterguard, 2012). The communications suite will support real-time data and video transport and give afloat staff a common operating picture. To ensure 24-hour global coverage, BAMS will be located at five notional bases. The proposed bases include Marine Corp Base Hawaii (MCBH) Kaneohe, Naval Air Station (NAS) Jacksonville, FL, NAS Sigonella, Sicily, Italy, Diego Garcia, and NAS Kadena, Japan (MQ-4C Broad Area Maritime Surveillance (BAMS), 2011).

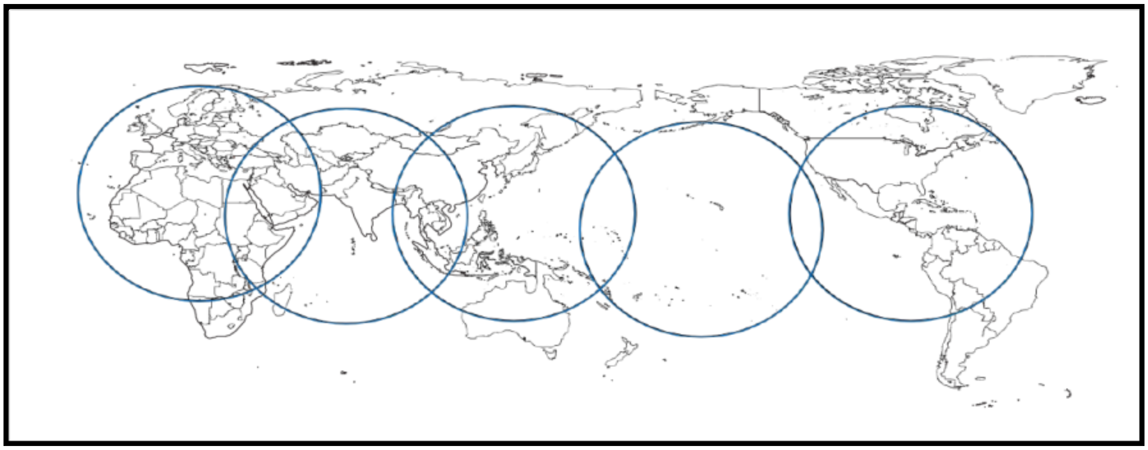


Figure 2. The BAMS UAS Radii

B. PURPOSE

Given this uneven record of success, and Congressional concerns regarding the relative cost of UAV programs, the purpose of this thesis is to examine, compare and analyze the O&S costs for both the EP-3E ISR aircraft with the BAMS UAS. This comparison includes all costs from initial system deployment through the end of the platforms' service life. This thesis uses a revised O&S cost methodology in accordance with DoD Instruction 5000.2, *Operation of the Defense Acquisition System*. This thesis modifiese these to account for the additional costs of bandwidth, ground station support, collection sites, and risks as they apply to the BAMS UAS. The original O&S analysis did not adequately consider these factors. Once the analysis and comparison is completed, the data from this thesis recommends which platform, the EP-3E or the BAMS UAS, is more cost effective from a sustainment perspective, and whether or not the decision to replace the EP-3E ISR system with the BAMS UAS should be revisited.

C. RESEARCH QUESTIONS

This thesis addresses the following research questions.

1. Primary Research Question

What are the major factors driving the cost differences between the EP-3E and the BAMS UAS and why?

2. Secondary Research Question

What are the differences in the O&S cost of the EP-3E and BAMS?

D. METHODOLOGY

For this thesis, the EP-3E was used to compare O&S cost because it is closely analogous to the BAMS UAS as the unmanned system is the primary replacement for the EP-3E. The BAMS UAS will even utilize open architecture developed for the EP-3E (Fein, 2007). The EP-3E historical O&S data will be provided by the Visibility and Management of Operating and Support Cost databases. The research questions were also addressed through the review of a substantial number of publications on the EP-3E, BAMS UAS, DoD O&S cost procedures and processes, and satellite bandwidth. Additionally, conversations were held with Pentagon (J282 and N2/N6), Naval Air Systems Command (EP-3E/P-3 and BAMS), and VIASAT personnel.

E. CHAPTER OUTLINE

This thesis contains five chapters.

Chapter I provides the topic, introduction, background, Congressional concerns, system roles, system importance, purpose and methodology.

Chapter II contains the baseline for the O&S cost as defined by the DoD, which helps understand the metrics used in the construction of this thesis.

Chapter III explains what in the O&S comparison is actually compared as the two systems differ, and develops the methodology for estimating the O&S costs used for comparison.

Chapter IV provides the analysis of the O&S comparison between the two platforms illustrated in Chapter III.

Chapter V summarizes the analysis of the data from Chapters III and IV, reports conclusion and answers the thesis research question. This chapter also provides recommendations for further research.

THIS PAGE INTENTIONALLY LEFT BLANK

II. OPERATIONS AND SUPPORT COST

A. INTRODUCTION

To understand the depths of the operating and support costs for the EP-3E and the BAMS UAS, it is essential to understand the DoD operating and support cost-estimation process. In accordance with DoD Manual 5000.4, DoD *Cost Analysis Guidance and Procedures*, all military departments and defense agencies are to perform O&S cost estimates. O&S costs are the third phase in the system life cycle process. Figure 3 depicts a notional life cycle process used as a baseline for military departments and defense agencies.

The following items are included when developing O&S estimates (Operating and Support Cost-Estimation Guide, 2007).

- Operating Cost, Maintenance and Supported Systems
  - Personnel Cost (organic or contractor)
  - Equipment
  - Supplies
  - Software
  - Operating Services
  - Modification Cost
  - Maintenance and Upgrades
  - Training
  - Any additional support cost to the DoD system

O&S costs should be presented in an annual historical form collected through VAMOSC as each military department has an established VAMSOC system (Operating and Support Cost-Estimation Guide, 2007).

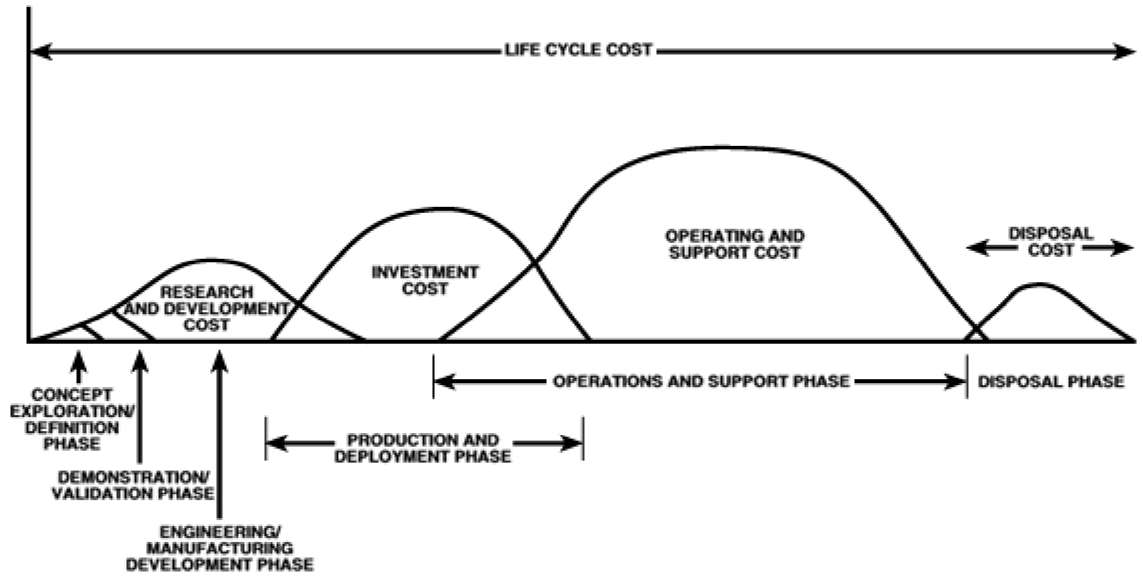


Figure 3. Life Cycle Support Cost (From Operating and Support Cost-Estimation Guide, 2007, p. 2–1)

The purpose of O&S cost estimates is to help leadership determine the affordability of the system, translate system requirements associated with programs, as well as determine if alternative systems or solutions are viable. O&S cost estimates are important to military departments because they improve the budget process providing data for required funding to ensure that the program is executable (Operating and Support Cost-Estimation Guide, 2007). “Moreover, having a realistic estimate of projected cost make for effective resource allocation, and it increases the probability of a program’s success” (Richey, Echard, & Cha, 2009, p. 33).

Military departments face challenges when developing O&S cost estimates. However, no process is perfect or error free and cost estimation requires analysis to consider multiple risks and uncertainty. Uncertainty may come from estimating the system performance, reliability and maintenance requirements that are critical factors. Other challenges include gathering enough detailed documentation and historical data, which increase the ability of the analysis to mend science and judgment of the cost estimation process.

Thus, this chapter is divided into two sections. The first section provides an overview of the DoD cost estimation process to give the reader a baseline for understanding how cost estimation is conducted by each military department and defense agency. The second section provides an overview of what O&S items will be used for the comparison in this thesis and the assumptions made in the comparison.

B. OVERVIEW OF THE O&S COST ESTIMATION PROCESS

The O&S cost estimation process is used to help determine the most efficient logistics and maintenance structure and develop methods for cost reduction. DoD Instruction 5000.02 states: “The purpose of Operations and Support Phase is to execute a support program that meets material readiness and operational support performance requirements, and sustains the system in the most cost-effective manner over its total life cycle. Planning for this phase shall begin prior to program initiation and shall be document in the LCSP.” One of its greatest strengths is that the program starts early in the acquisitions process. The process also provides the cost of the system over its total life cycle, which is another strength. These two strengths provide a budget that drives the design produced by contractors, and keeps the system affordable (Taylor & Murphy, 2012).

The O&S cost estimation process contains four forward-looking steps: Develop Approach, Cost Analysis Requirement Description (CARD), Prepare Estimate and Coordination. Due to the complexity of the O&S estimation system, several of the steps are reevaluated throughout the process. Figure 4 shows the notional framework of the O&S Cost Estimating Process.

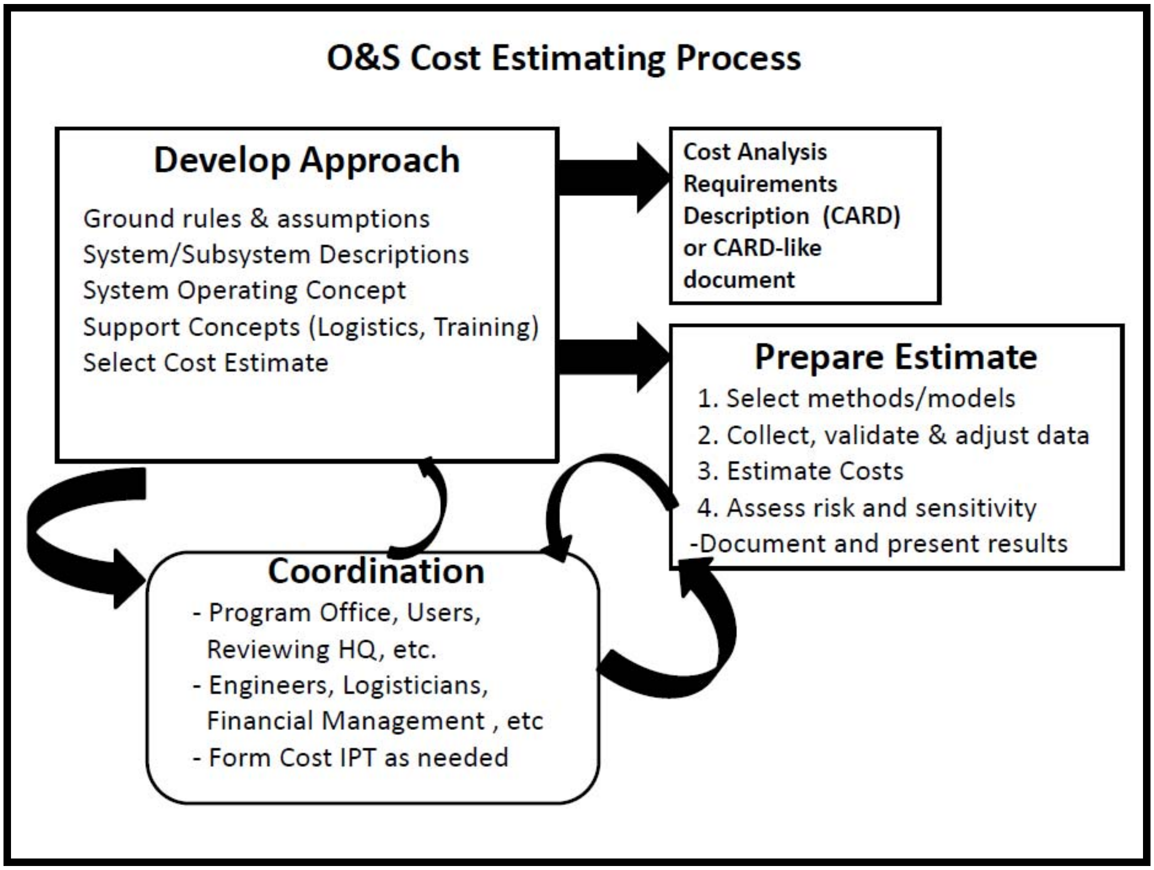


Figure 4. O&S Cost Estimating Process (From Operating and Support Cost-Estimation Guide, 2007, p. 5-1)

1. Develop Approach

Approach development requires all interested parties to conduct a well-tuned analysis for the development of the system. Baseline assumptions and risks should be established in this step. The four assumptions that are typically made during this first step are System Life/O&S Phasing, Year Dollars/Inflation Indices, War/Peace Conditions and Scope of the Estimate (Operating and Support Cost-Estimation Guide, 2007).

a. System Life/O&S Phasing

The exact life expectancy of the system may vary due to newly developed systems, reliability, and durability during a systems life (Operating and Support Cost-Estimation Guide, 2007). O&S cost estimates should cover the full life of the system.

"The O&S phasing will include a phase-in period, the period during which the system is in steady-state operations, and a phase-down period" (Operating and Support Cost-Estimation Guide, 2007, pp. 5-2).

b. Year Dollars/Inflation Indices

The costs presented in O&S estimation are presented in constant dollars. The figures are present in either fiscal or baseline year. Fiscal year O&S costs are always compared to the original O&S budget. "The indices used to adjust for inflation should be specified and documented" (Operating and Support Cost-Estimation Guide, 2007, pp. 5-3).

c. War/Peace Conditions

O&S cost normally reflect peacetime operations (Operating and Support Cost-Estimation Guide, 2007). However, some of the cost elements may be supplied at wartime levels in the event that military operations are required.

d. Scope of the Estimate

Scope sites specific costs that are directly associated, which is necessary because systems often times have unique complex operating systems that require other systems for operation (Operating and Support Cost-Estimation Guide, 2007).

Beyond assumptions, the content of the program should be described in detail. To complete the approach development step, analysts must establish the cost estimate structure for the program. The cost estimate specifically describes all elements that will be included in the O&S cost estimate (Operating and Support Cost-Estimation Guide, 2007).

2. Cost Analysis Requirements Description (CARD)

CARD is the required extensive data that is mandatory to complete the cost estimate. "The CARD is a complete description of the system whose costs are to be estimated; it is intended to define the program to a sufficient level of detail such that no confusion exist between the many parties who may be concerned with estimating the program's cost" (Azama, 2000).

3. Prepare Estimate

Selecting the proper model to estimate the costs is very important in this step. Choosing the incorrect model for a particular system may result in costs that incorrectly represent the system being described. To avoid this costly mistake, five techniques, parametric, analogy engineering estimate, actual cost and cost factors are used to ensure the most accurate cost are presented.

a. Parametric

Cost Estimating Relationships (CER) are developed using various statistical programs to include regression. "CER is an equation used to estimate a given cost element using an established relationship with one or more independent variables" (Operating and Support Cost-Estimation Guide, 2007, pp. 5–6). CERs must be relevant to the system being examined (Operating and Support Cost-Estimation Guide, 2007).

b. Analogy

An analogy uses a combination of historical data and a single data point that is accomplished by adjusting the analogous system cost (Department of Defense Instruction 5000.2, 2008). "Some adjustments can be made through the use of factors that represent differences in size performance, technology, reliability and maintainability, and/or complexity" (Operating and Support Cost-Estimation Guide, 2007, pp. 5-6).

c. Engineering Estimate

This technique evaluates manpower, maintenance and support functions. The system in question is broken down by cost based on the dollar amount expended. This process requires detailed knowledge of the system in question, to include interfaces, parts and assemblies (Operating and Support Cost-Estimation Guide, 2007).

d. *Actual Cost*

The process includes prototypes, engineering and development costs, and production items. These costs are also used to determine future costs. VAMOSC is commonly used to gather much of this data.

e. *Cost Factors*

Cost factors usually include indirect costs associated with the system, and usually include base operations, military medical care or general training, and education (Operating and Support Cost-Estimation Guide, 2007). Also included in these factors are sewage and industrial waste storage.

Uncertainty and risks estimated in O&S cost will differ. However, this uncertainty should be well documented, which will allow for seamless audits. The documentation of cost estimates should cover all aspects involved to include methods used to determine the estimates, data sources, and the actual estimates computed (Department of Defense, 2011b).

4. Coordination

The O&S cost estimation process is a complex process that requires extensive coordination from all parties involved. The parties include program manager(s), users, engineers, logisticians, and financial management. Although this list is not all inclusive, the list represents several key entities important to providing data and advice during this process. Their coordination is emphasized during this process because some of the processes will start prior to the previous process ending causing an overlap.

C. OVERVIEW OF OSD COST ANALYSIS IMPROVEMENT GROUP (CAIG) ELEMENT STRUCTURE

The CAIG advises the Secretary of Defense and The Defense Acquisition Board (DAB) on all cost related matters (Azama, 2000). This CAIG also validates cost estimation methodology, develops cost implications for individual systems, establishes guidance for preparing cost estimates, and maintains a cost analysis research program (Azama, 2000). The DAB develops the CAIG structure. The CAIG structure consists of six main categories: unit-level manpower, unit operations, maintenance, sustaining support, continuing system improvements, and indirect costs. Figure 5 provides a general description of the CAIG element structure.

Typical System and Support Descriptions

- System Characteristics
  - Performance Characteristics
  - Physical Characteristics
  - Advanced technologies/materials
- Reliability/Maintainability
- Operating Concept
  - Basing and deployment
  - Inventory and OPTEMPO
  - Organizational/Unit Structure
- Program Schedule
  - Delivery and site activation
  - System life/O&S phasing
  - Interim contractor support
- Unit-Level Manpower
  - Operations
  - Unit Maintenance
  - Other Unit-Level
- Support Concepts
  - Maintenance levels
  - Software Support plan
  - Supply strategy
  - Training concept
- Special support
  - Unique infrastructure
  - Special environmental considerations

Figure 5. CAIG Element Structure (From, Operating and Support Cost-Estimation Guide, 2007, p. 5-4)

1. Unit-Level Manpower

Unit-level manpower includes operator, maintenance and support personnel to include active and reserve military, government civilian and contractors (Operating and Support Cost-Estimation Guide, 2007), which are a direct cost to the unit that supports their assigned personnel. These costs should be based on rank and grade with civilian and government contracts cost shown separately from military personnel. The costs for military personnel should include the following items: basic pay, retired pay accrual, basic allowance for quarters/variable housing allowance, basic allowance for subsistence/subsistence-in-kind, incentive and special pays, permanent change of station, and miscellaneous expenses (Operating and Support Cost-Estimation Guide, 2007).

2. Unit Operations

Unit Operations include all cost, such as fuel, electricity, expendables stores, munitions for training, and other materials consumed at the unit level attributed to operations (Operating and Support Cost-Estimation Guide, 2007). These costs are separated into operating material (energy, training munitions/expendable stores, operating material), and support services (purchased support services and temporary duty).

3. Maintenance

Maintenance costs include all levels of maintenance associated with the primary system, simulators, training devices, and associated support equipment. These costs are further distinguished by organizational maintenance and support, consumables, repair parts, services, intermediate maintenance and depot maintenance (Operating and Support Cost-Estimation Guide, 2007).

4. Sustaining Support

Sustaining support specifically applies to the costs of training incoming personnel who will replace personnel that have reached their rotation date. Included in these costs are the cost of instructors, training devices, course material, per diem, and travel. The major contributing factors of sustaining support costs are specific operator training, support equipment replacement, operating equipment replacement, engineering and program management, and special support costs (Operating and Support Cost-Estimation Guide, 2007).

5. Continuing System Support

Continuing support applies to software and hardware replacements, and upgrades that a system may undergo after deployment to enhance performance and sustainability. “These costs include government and contract labor, materials, and overhead costs” (Operating and Support Cost-Estimation Guide, 2007, p. 6-14).

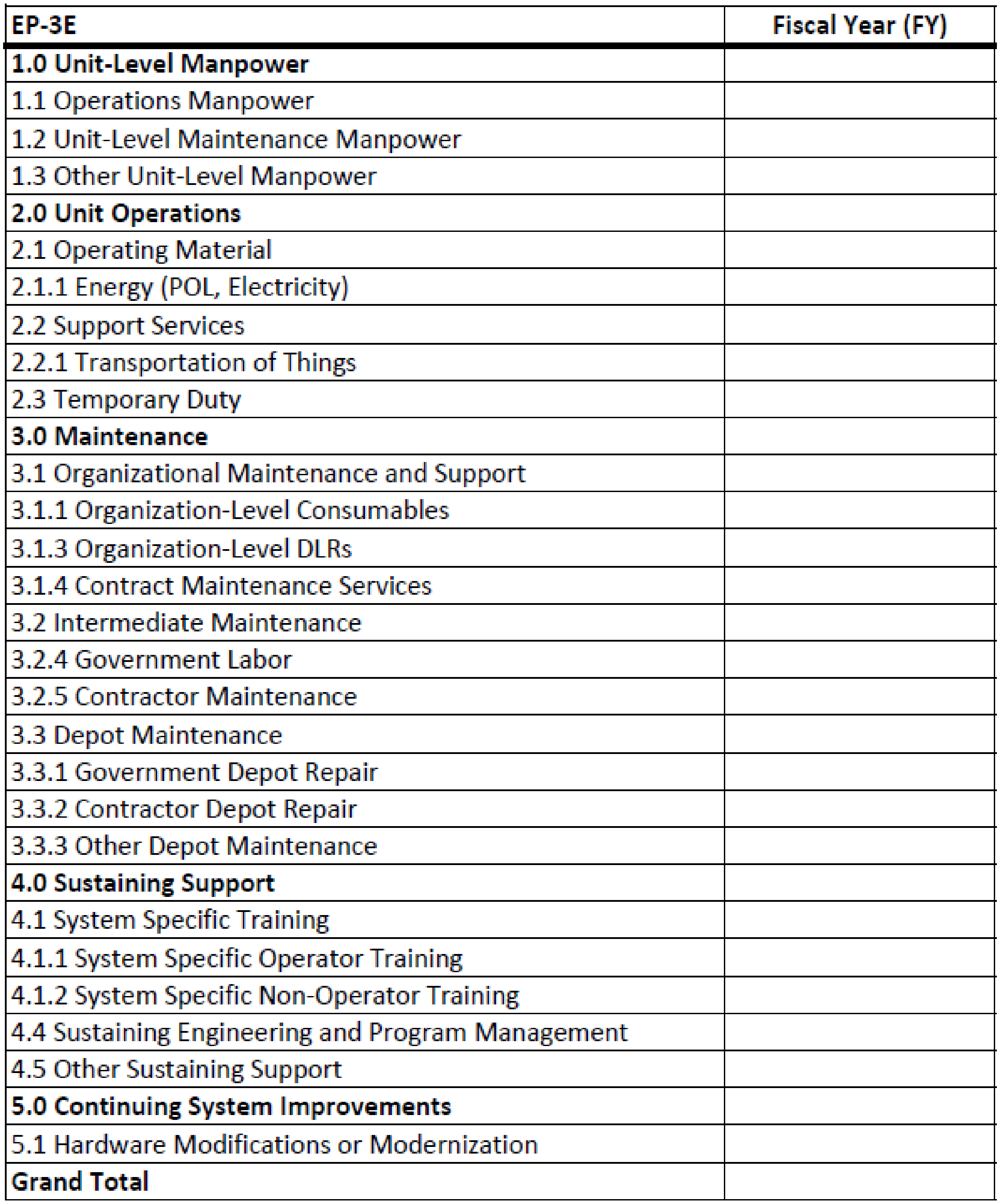
6. Indirect Support

These costs are all installation and personnel support costs that cannot fit into the previous five categories. These costs are separated because they are the costs that typically change due to the installation of a new system or equipment. They are particularly relevant is cases when manpower or installations are significantly affected (Operating and Support Cost-Estimation Guide, 2007).

D. OVERVIEW OF O&S COST COMPARISON AND ASSUMPTIONS

1. Introduction

The overview of the revised O&S cost comparison will describe the costs compared for the analysis of this thesis, which uses five of the six CAIG element structure categories for this comparison. The five categories used for this thesis are unit-level manpower, unit operations, maintenance, sustaining support, continuing system improvements. Indirect costs are excluded in this comparison because the BAMS UAS is not yet operational. Therefore, the effects that the first deployment will have on manpower and installation cannot be estimated. The chart includes the sub-categories of each of the five categories to provide a consummate level of detail. A total of 30 lines items are used for comparison. Table 1 provides a blank chart of the Work Breakdown Structure (WBS) for O&S used for this comparison. These costs form the basis of comparison for the O&S of the EP-3E to that of BAMS.



EP-3E	Fiscal Year (FY)
1.0 Unit-Level Manpower	
1.1 Operations Manpower	
1.2 Unit-Level Maintenance Manpower	
1.3 Other Unit-Level Manpower	
2.0 Unit Operations	
2.1 Operating Material	
2.1.1 Energy (POL, Electricity)	
2.2 Support Services	
2.2.1 Transportation of Things	
2.3 Temporary Duty	
3.0 Maintenance	
3.1 Organizational Maintenance and Support	
3.1.1 Organization-Level Consumables	
3.1.3 Organization-Level DLRs	
3.1.4 Contract Maintenance Services	
3.2 Intermediate Maintenance	
3.2.4 Government Labor	
3.2.5 Contractor Maintenance	
3.3 Depot Maintenance	
3.3.1 Government Depot Repair	
3.3.2 Contractor Depot Repair	
3.3.3 Other Depot Maintenance	
4.0 Sustaining Support	
4.1 System Specific Training	
4.1.1 System Specific Operator Training	
4.1.2 System Specific Non-Operator Training	
4.4 Sustaining Engineering and Program Management	
4.5 Other Sustaining Support	
5.0 Continuing System Improvements	
5.1 Hardware Modifications or Modernization	
Grand Total	

Table 1. O&S Cost Estimate Sample Chart

2. Assumptions

The BAMS UAS is being compared to the EP-3E because of the Navy's decision to replace the EP-3E with the BAMS UAS. This comparison is also valid because like the

EP-3E, in accordance with the Maritime Patrol Reconnaissance Force (MPRF) concept of operations (CONOPS), the BAMS UAS will utilize P-3C facilities. “The program planned to collocate BAMS UAS mission crews with Maritime Patrol and Reconnaissance (MPR) Forces to allow operators to closely coordinate missions and utilize common support infrastructure” (MQ-4C Broad Area Maritime Surveillance (BAMS), 2011).

Specific assumptions for this comparison include the following.

- BAMS UAS is a new system, and manning support can be expected to be at 100 percent with approximately 168 personnel (BAMS UAS Manning and Fleet Integration Strategy, 2010). The Navy has not determined if the BAMS UAS will be a stand-alone squadron but for this comparison, the cost estimates for the BAMS UAS are estimated based upon the system operating from a stand-alone squadron. The actual manning data from PMA-262 is not available due to privacy issues and program concerns. In accordance with the Navy Training System Plan for EP-3E Aircraft, the required personnel for a VQ squadron is 517 personnel (officer and enlisted). The ratio of 168 to 517 personnel is 32 percent. Due to this ratio, the manpower cost of an EP-3E squadron should be significantly higher than a BAMS UAS squadron.
- Fuel costs for the BAMS UAS may exceed those of the EP-3E. Although the BAMS UAS uses a single engine versus four engines of the EP-3E, the number of BAMS required to provide coverage of a single mission area is three. Based on Figure 6 with the BAMS UAS operating 1500 NM away from its operating bases, three BAMS will be required to be in-flight at all times per mission area plus a standby on the ground that may drive up the cost of fuel for the system. Comparable fuel costs are used for this thesis.

$$\text{Number of UAVs Required} = \left\lceil \frac{\text{Mission Cycle Time}}{\text{UAV Time On-Station}} \right\rceil \text{ x Number of UAVs required on-station} + 1 \text{ Ground Spare}$$

where:

$$\text{Mission Cycle Time} = \text{UAV Time On-Station} + \text{UAV Transit Time} + \text{UAV Maintenance Time}$$

Figure 6. Number of Required BAMS (From Lim, 2007, p. 37)

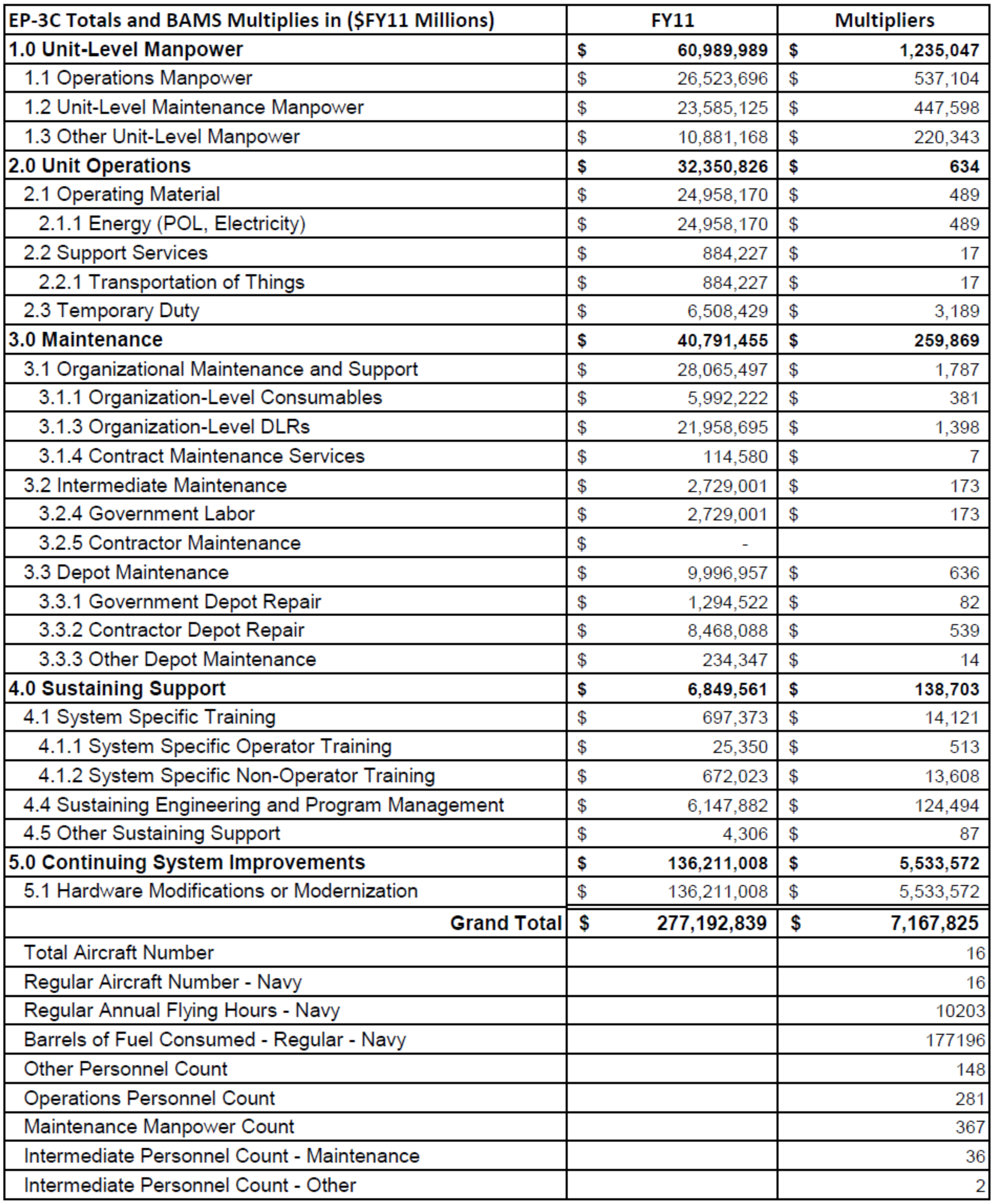
- The maintenance costs for EP-3E will significantly outweigh those of the BAMS UAS. This significant difference can be attributed to the extended service life of the EP-3E and the increased usage because of Operations IRAQI FREEDOM AND ENDURING FREEDOM. To maintain an aircraft that has been operational for over 30 years will require increasing maintenance. The BAMS UAS maintenance related costs are estimated at 65 percent lower than that of the EP-3E.
- Training costs are closely estimated to the cost of training EP-3E personnel. NAS Jacksonville will house the training facility for the BAMS UAS (Commander Navy Installations Command, 2012).
- Continuing system improvements for the BAMS UAS will be estimated at 30 percent higher than the EP-3E. The EP-3E is a retiring asset while the BAMS UAS is still in the acquisition cycle. As more BAMS UAS become operational and are successfully taking over the EP-3E mission, continuing system improvements will decrease.
- The comparison will use O&S costs from the EP-3E based upon the average increase from FY97 to FY11 in each of the five categories. This calculation will be determined using the EP-3E historical data provided by VAMOSC database.
- The thesis assumes the Navy will spend a comparable amount on the redesign of the facilities that will base the BAMS UAS. This assumption is based upon the current redesign that the Air Force is performing for the operation of its Global Hawk (Air Force Distributed Common Ground System, 2011).

- This thesis assumes the required bandwidth used by the BAMS UAS will be the same as the bandwidth required for the Global Hawk, as the actual required bandwidth required for the BAMS UAS has not been published.

III. BAMS OPERATING AND SUPPORT COST ESTIMATE

A. INTRODUCTION

The intent of this comparison is to utilize the O&S WBS data from the EP-3E provided by Naval VAMOSC and the generated O&S cost estimation data from the BAMS UAS to ascertain the major O&S cost nodes. Historical O&S costs were evaluated for cost trend analysis but the estimated cost for the BAMS UAS will based upon FY11 WBS O&S. DoD Instruction 5000.4, *DoD Cost Analysis Guidance and Procedures*, contains the mandated procedures for developing system life cycle costs of any new acquisition. System life cycle costs consist of four program phases: Research and Development, Investment, O&S and Disposal. For the purpose of this comparison and analysis, O&S costs will be solely used due to release restrictions, ongoing acquisitions and investments processes, and the fact that neither program has reached the disposal phase. The additional cost factors calculated and examined are estimations based upon the current Air Force model. Furthermore, O&S costs typically account for virtually half of the overall life cycle cost for aircraft (Valerdi, n.d.). For this reason, O&S costs were chosen for this comparative evaluation. See Table 2.



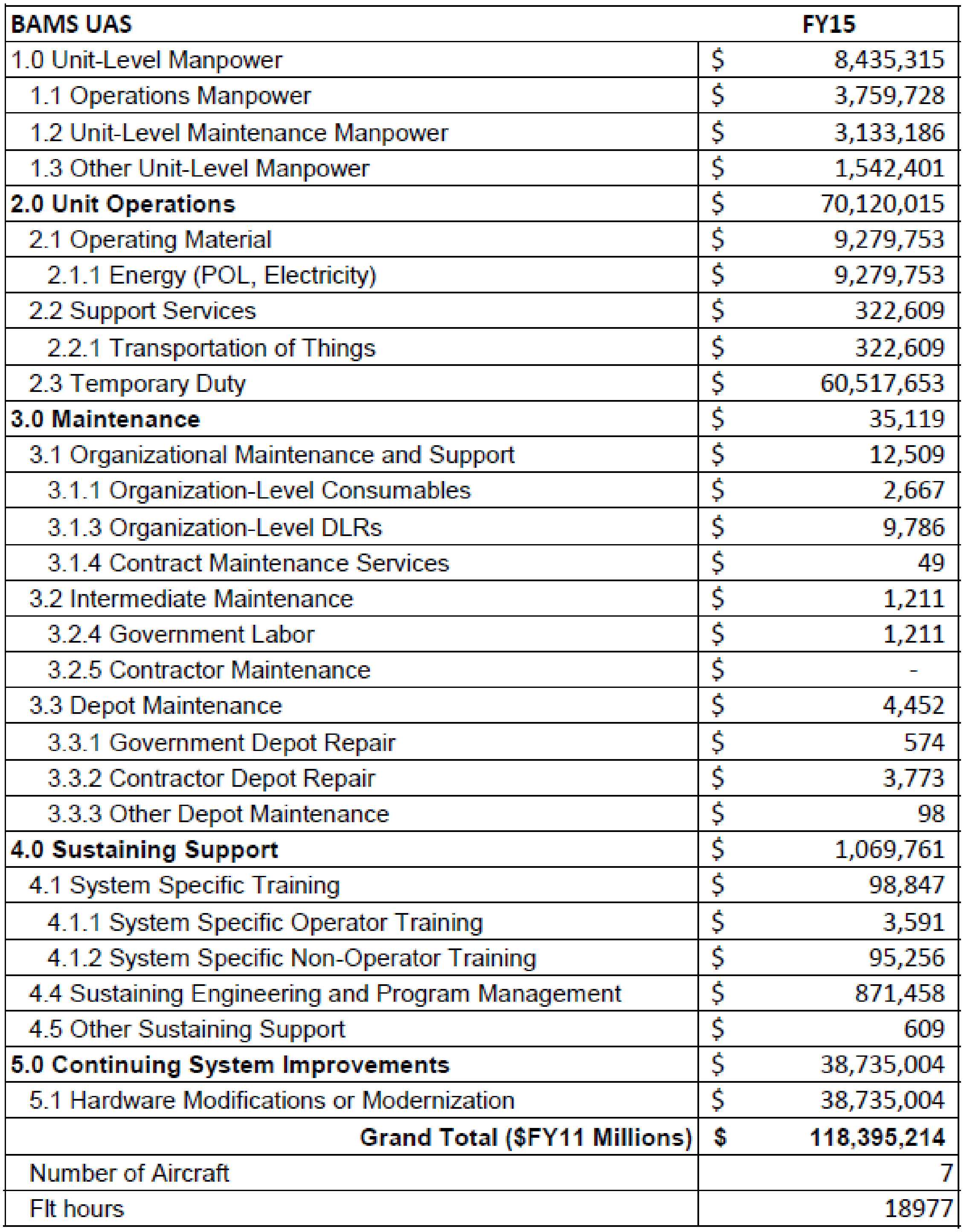
EP-3C Totals and BAMS Multiplies in ($FY11 Millions)	FY11	Multipliers
1.0 Unit-Level Manpower	**$ 60,989,989**	**$ 1,235,047**
1.1 Operations Manpower	$ 26,523,696	$ 537,104
1.2 Unit-Level Maintenance Manpower	$ 23,585,125	$ 447,598
1.3 Other Unit-Level Manpower	$ 10,881,168	$ 220,343
2.0 Unit Operations	**$ 32,350,826**	**$ 634**
2.1 Operating Material	$ 24,958,170	$ 489
2.1.1 Energy (POL, Electricity)	$ 24,958,170	$ 489
2.2 Support Services	$ 884,227	$ 17
2.2.1 Transportation of Things	$ 884,227	$ 17
2.3 Temporary Duty	$ 6,508,429	$ 3,189
3.0 Maintenance	**$ 40,791,455**	**$ 259,869**
3.1 Organizational Maintenance and Support	$ 28,065,497	$ 1,787
3.1.1 Organization-Level Consumables	$ 5,992,222	$ 381
3.1.3 Organization-Level DLRs	$ 21,958,695	$ 1,398
3.1.4 Contract Maintenance Services	$ 114,580	$ 7
3.2 Intermediate Maintenance	$ 2,729,001	$ 173
3.2.4 Government Labor	$ 2,729,001	$ 173
3.2.5 Contractor Maintenance	$ -	
3.3 Depot Maintenance	$ 9,996,957	$ 636
3.3.1 Government Depot Repair	$ 1,294,522	$ 82
3.3.2 Contractor Depot Repair	$ 8,468,088	$ 539
3.3.3 Other Depot Maintenance	$ 234,347	$ 14
4.0 Sustaining Support	**$ 6,849,561**	**$ 138,703**
4.1 System Specific Training	$ 697,373	$ 14,121
4.1.1 System Specific Operator Training	$ 25,350	$ 513
4.1.2 System Specific Non-Operator Training	$ 672,023	$ 13,608
4.4 Sustaining Engineering and Program Management	$ 6,147,882	$ 124,494
4.5 Other Sustaining Support	$ 4,306	$ 87
5.0 Continuing System Improvements	**$ 136,211,008**	**$ 5,533,572**
5.1 Hardware Modifications or Modernization	$ 136,211,008	$ 5,533,572
Grand Total	**$ 277,192,839**	**$ 7,167,825**
Total Aircraft Number		16
Regular Aircraft Number - Navy		16
Regular Annual Flying Hours - Navy		10203
Barrels of Fuel Consumed - Regular - Navy		177196
Other Personnel Count		148
Operations Personnel Count		281
Maintenance Manpower Count		367
Intermediate Personnel Count - Maintenance		36
Intermediate Personnel Count - Other		2

Table 2. Summary of EP-3E O&S Cost Elements and BAMS UAS Multipliers

Tables 3 through 9 summarize the O&S cost estimates by cost element for the BAMS UAS from FY 2014 through FY 2020.

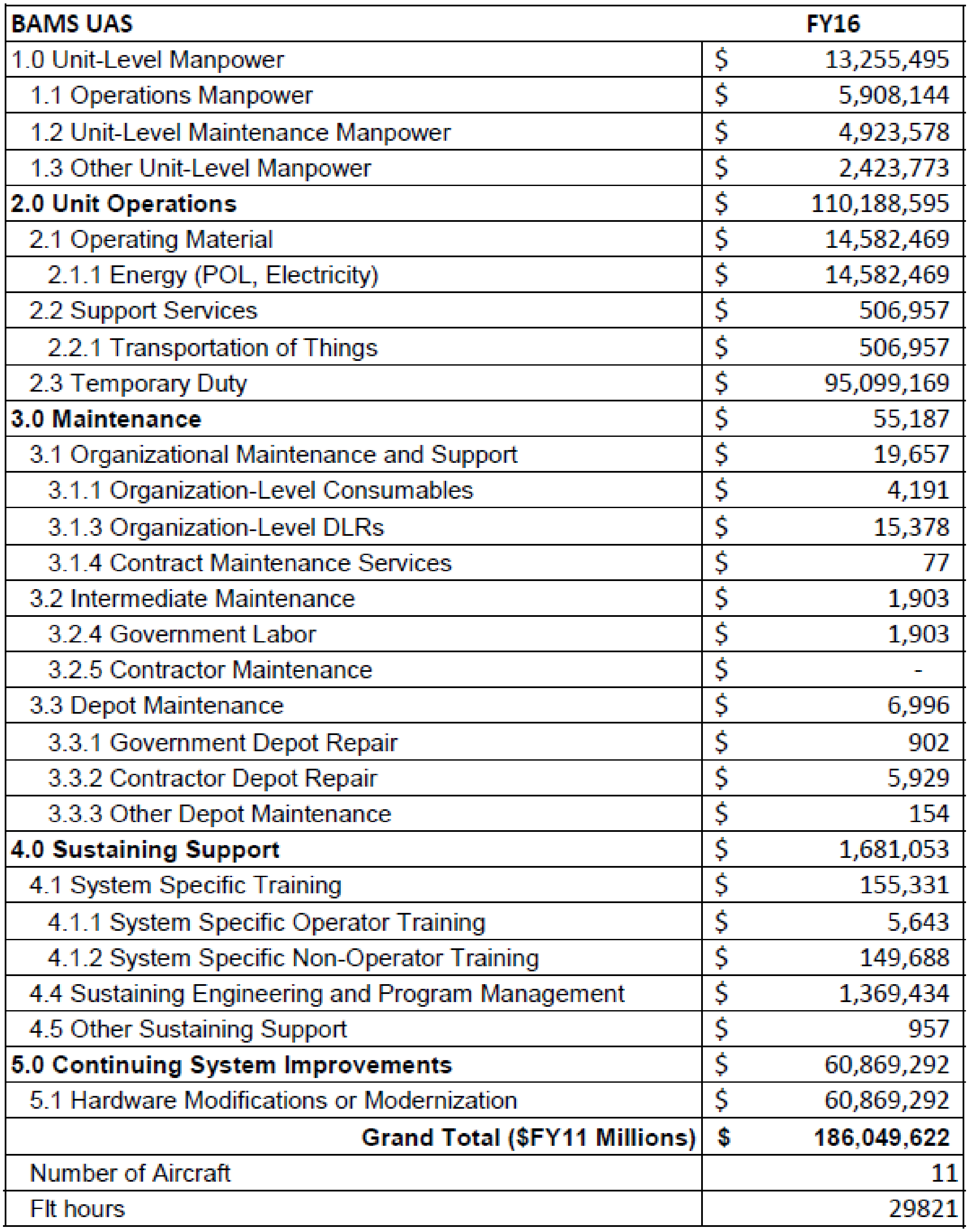
BAMS UAS		FY14
1.0 Unit-Level Manpower	$	3,615,135
1.1 Operations Manpower	$	1,611,312
1.2 Unit-Level Maintenance Manpower	$	1,342,794
1.3 Other Unit-Level Manpower	$	661,029
2.0 Unit Operations	$	30,051,435
2.1 Operating Material	$	3,977,037
2.1.1 Energy (POL, Electricity)	$	3,977,037
2.2 Support Services	$	138,261
2.2.1 Transportation of Things	$	138,261
2.3 Temporary Duty	$	25,936,137
3.0 Maintenance	$	15,051
3.1 Organizational Maintenance and Support	$	5,361
3.1.1 Organization-Level Consumables	$	1,143
3.1.3 Organization-Level DLRs	$	4,194
3.1.4 Contract Maintenance Services	$	21
3.2 Intermediate Maintenance	$	519
3.2.4 Government Labor	$	519
3.2.5 Contractor Maintenance	$	-
3.3 Depot Maintenance	$	1,908
3.3.1 Government Depot Repair	$	246
3.3.2 Contractor Depot Repair	$	1,617
3.3.3 Other Depot Maintenance	$	42
4.0 Sustaining Support	$	458,469
4.1 System Specific Training	$	42,363
4.1.1 System Specific Operator Training	$	1,539
4.1.2 System Specific Non-Operator Training	$	40,824
4.4 Sustaining Engineering and Program Management	$	373,482
4.5 Other Sustaining Support	$	261
5.0 Continuing System Improvements	$	16,600,716
5.1 Hardware Modifications or Modernization	$	16,600,716
Grand Total ($FY11 Millions)	**$**	**50,740,806**
Number of Aircraft		3
Flt hours		8133

Table 3. O&S Estimate for BAMS UAS FY14



BAMS UAS		FY15
1.0 Unit-Level Manpower	$	8,435,315
1.1 Operations Manpower	$	3,759,728
1.2 Unit-Level Maintenance Manpower	$	3,133,186
1.3 Other Unit-Level Manpower	$	1,542,401
2.0 Unit Operations	$	70,120,015
2.1 Operating Material	$	9,279,753
2.1.1 Energy (POL, Electricity)	$	9,279,753
2.2 Support Services	$	322,609
2.2.1 Transportation of Things	$	322,609
2.3 Temporary Duty	$	60,517,653
3.0 Maintenance	$	35,119
3.1 Organizational Maintenance and Support	$	12,509
3.1.1 Organization-Level Consumables	$	2,667
3.1.3 Organization-Level DLRs	$	9,786
3.1.4 Contract Maintenance Services	$	49
3.2 Intermediate Maintenance	$	1,211
3.2.4 Government Labor	$	1,211
3.2.5 Contractor Maintenance	$	-
3.3 Depot Maintenance	$	4,452
3.3.1 Government Depot Repair	$	574
3.3.2 Contractor Depot Repair	$	3,773
3.3.3 Other Depot Maintenance	$	98
4.0 Sustaining Support	$	1,069,761
4.1 System Specific Training	$	98,847
4.1.1 System Specific Operator Training	$	3,591
4.1.2 System Specific Non-Operator Training	$	95,256
4.4 Sustaining Engineering and Program Management	$	871,458
4.5 Other Sustaining Support	$	609
5.0 Continuing System Improvements	$	38,735,004
5.1 Hardware Modifications or Modernization	$	38,735,004
Grand Total ($FY11 Millions)	**$**	**118,395,214**
Number of Aircraft		7
Flt hours		18977

Table 4. O&S Estimate for BAMS UAS FY15

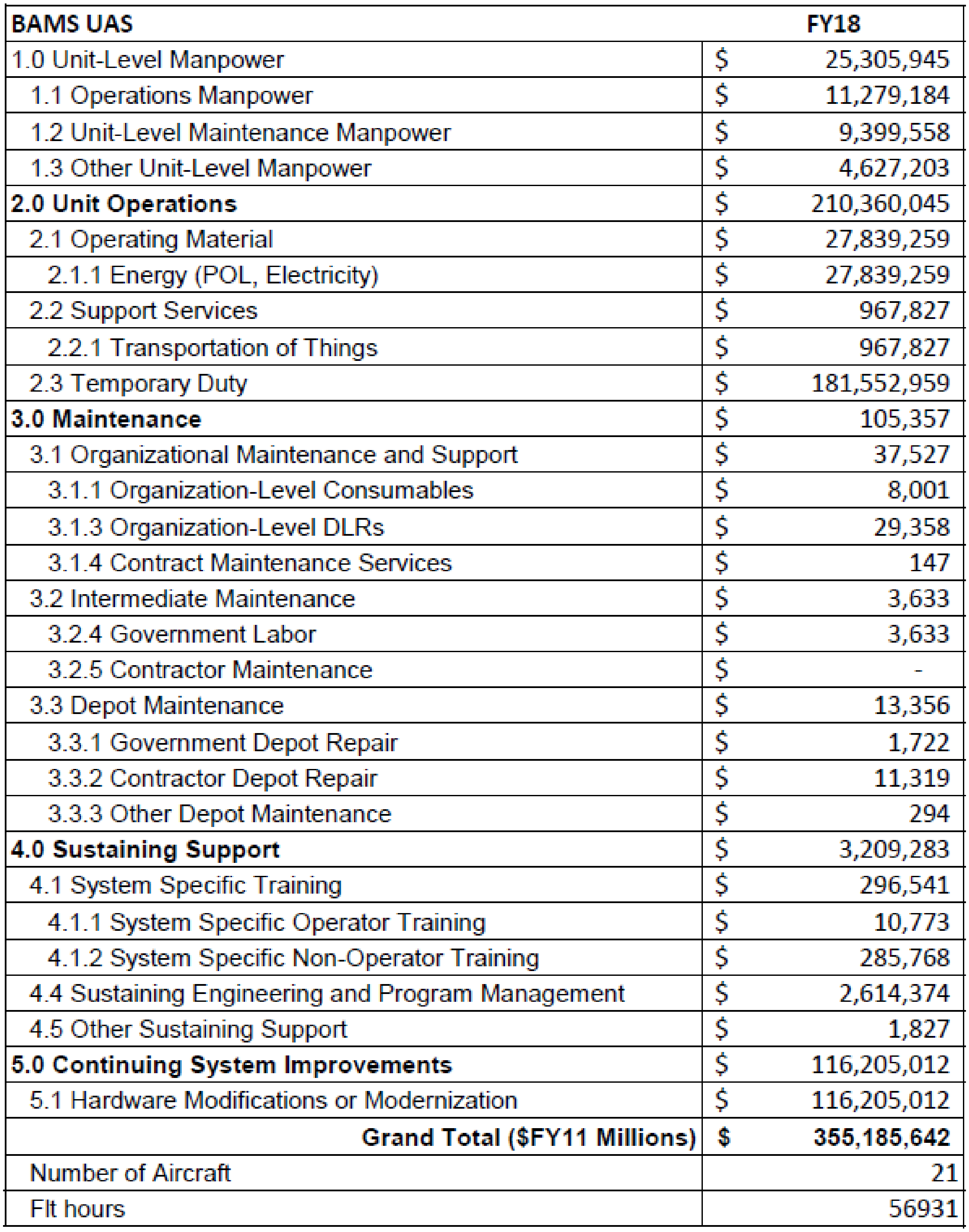


BAMS UAS		**FY16**
1.0 Unit-Level Manpower	$	13,255,495
1.1 Operations Manpower	$	5,908,144
1.2 Unit-Level Maintenance Manpower	$	4,923,578
1.3 Other Unit-Level Manpower	$	2,423,773
2.0 Unit Operations	$	110,188,595
2.1 Operating Material	$	14,582,469
2.1.1 Energy (POL, Electricity)	$	14,582,469
2.2 Support Services	$	506,957
2.2.1 Transportation of Things	$	506,957
2.3 Temporary Duty	$	95,099,169
3.0 Maintenance	$	55,187
3.1 Organizational Maintenance and Support	$	19,657
3.1.1 Organization-Level Consumables	$	4,191
3.1.3 Organization-Level DLRs	$	15,378
3.1.4 Contract Maintenance Services	$	77
3.2 Intermediate Maintenance	$	1,903
3.2.4 Government Labor	$	1,903
3.2.5 Contractor Maintenance	$	-
3.3 Depot Maintenance	$	6,996
3.3.1 Government Depot Repair	$	902
3.3.2 Contractor Depot Repair	$	5,929
3.3.3 Other Depot Maintenance	$	154
4.0 Sustaining Support	$	1,681,053
4.1 System Specific Training	$	155,331
4.1.1 System Specific Operator Training	$	5,643
4.1.2 System Specific Non-Operator Training	$	149,688
4.4 Sustaining Engineering and Program Management	$	1,369,434
4.5 Other Sustaining Support	$	957
5.0 Continuing System Improvements	$	60,869,292
5.1 Hardware Modifications or Modernization	$	60,869,292
Grand Total ($FY11 Millions)	**$**	**186,049,622**
Number of Aircraft		11
Flt hours		29821

Table 5. O&S Estimate for BAMS UAS FY16

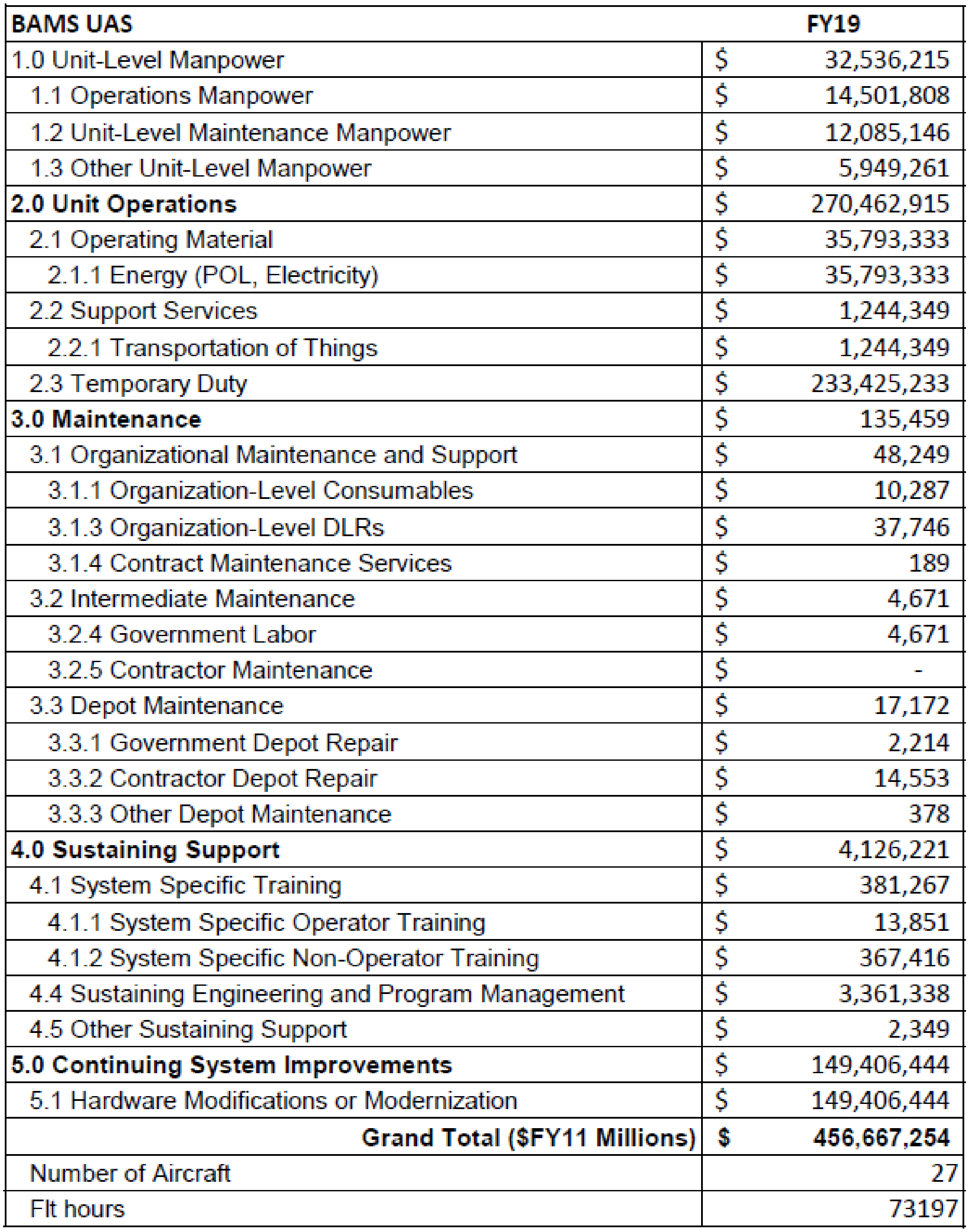
BAMS UAS		**FY17**
1.0 Unit-Level Manpower	$	19,280,720
1.1 Operations Manpower	$	8,593,664
1.2 Unit-Level Maintenance Manpower	$	7,161,568
1.3 Other Unit-Level Manpower	$	3,525,488
2.0 Unit Operations	$	160,274,320
2.1 Operating Material	$	21,210,864
2.1.1 Energy (POL, Electricity)	$	21,210,864
2.2 Support Services	$	737,392
2.2.1 Transportation of Things	$	737,392
2.3 Temporary Duty	$	138,326,064
3.0 Maintenance	$	80,272
3.1 Organizational Maintenance and Support	$	28,592
3.1.1 Organization-Level Consumables	$	6,096
3.1.3 Organization-Level DLRs	$	22,368
3.1.4 Contract Maintenance Services	$	112
3.2 Intermediate Maintenance	$	2,768
3.2.4 Government Labor	$	2,768
3.2.5 Contractor Maintenance	$	-
3.3 Depot Maintenance	$	10,176
3.3.1 Government Depot Repair	$	1,312
3.3.2 Contractor Depot Repair	$	8,624
3.3.3 Other Depot Maintenance	$	224
4.0 Sustaining Support	$	2,445,168
4.1 System Specific Training	$	225,936
4.1.1 System Specific Operator Training	$	8,208
4.1.2 System Specific Non-Operator Training	$	217,728
4.4 Sustaining Engineering and Program Management	$	1,991,904
4.5 Other Sustaining Support	$	1,392
5.0 Continuing System Improvements	$	88,537,152
5.1 Hardware Modifications or Modernization	$	88,537,152
Grand Total ($FY11 Millions)	**$**	**270,617,632**
Number of Aircraft		16
Flt hours		43376

Table 6. O&S Estimate for BAMS UAS FY17



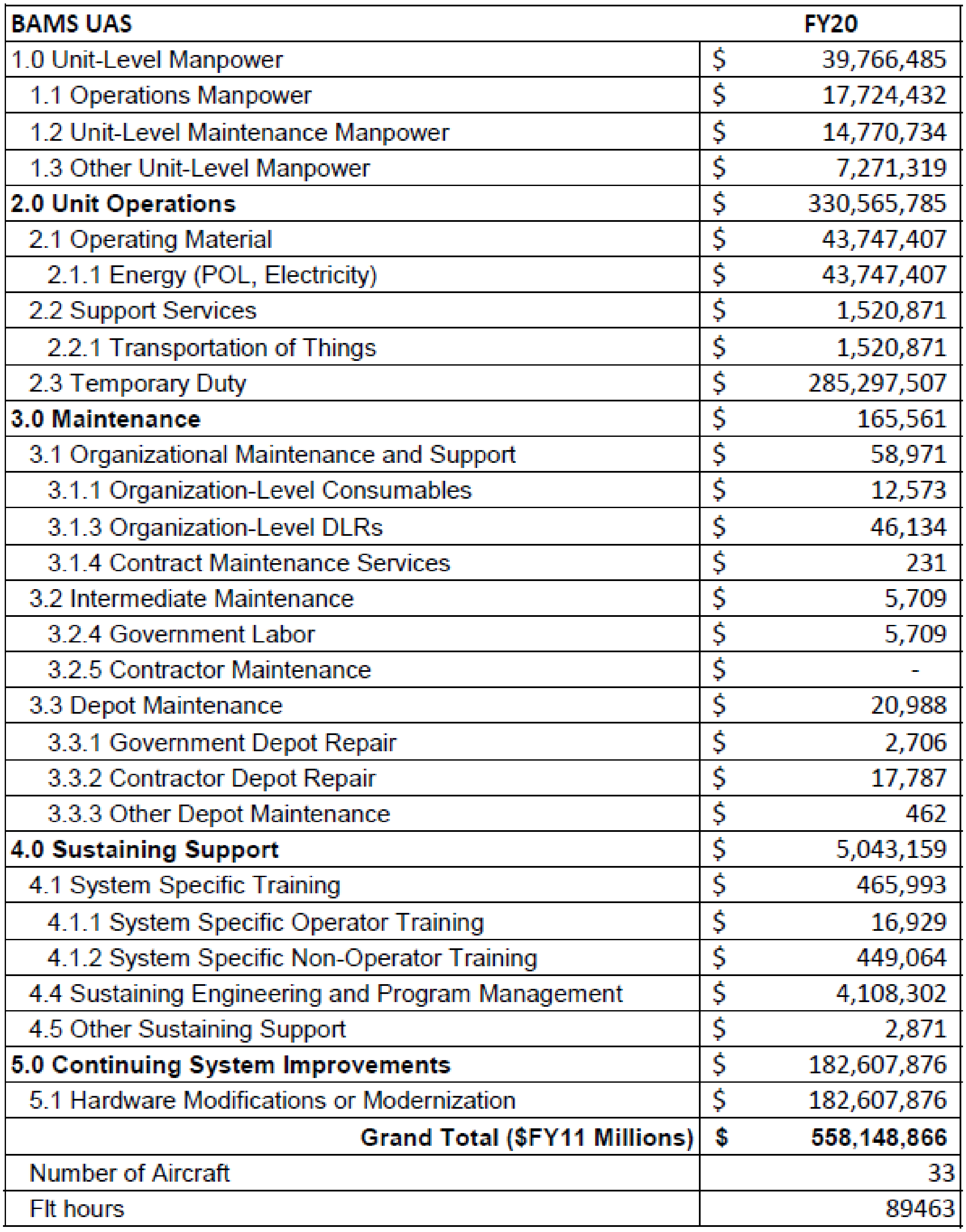
BAMS UAS		FY18
1.0 Unit-Level Manpower	$	25,305,945
1.1 Operations Manpower	$	11,279,184
1.2 Unit-Level Maintenance Manpower	$	9,399,558
1.3 Other Unit-Level Manpower	$	4,627,203
2.0 Unit Operations	$	210,360,045
2.1 Operating Material	$	27,839,259
2.1.1 Energy (POL, Electricity)	$	27,839,259
2.2 Support Services	$	967,827
2.2.1 Transportation of Things	$	967,827
2.3 Temporary Duty	$	181,552,959
3.0 Maintenance	$	105,357
3.1 Organizational Maintenance and Support	$	37,527
3.1.1 Organization-Level Consumables	$	8,001
3.1.3 Organization-Level DLRs	$	29,358
3.1.4 Contract Maintenance Services	$	147
3.2 Intermediate Maintenance	$	3,633
3.2.4 Government Labor	$	3,633
3.2.5 Contractor Maintenance	$	-
3.3 Depot Maintenance	$	13,356
3.3.1 Government Depot Repair	$	1,722
3.3.2 Contractor Depot Repair	$	11,319
3.3.3 Other Depot Maintenance	$	294
4.0 Sustaining Support	$	3,209,283
4.1 System Specific Training	$	296,541
4.1.1 System Specific Operator Training	$	10,773
4.1.2 System Specific Non-Operator Training	$	285,768
4.4 Sustaining Engineering and Program Management	$	2,614,374
4.5 Other Sustaining Support	$	1,827
5.0 Continuing System Improvements	$	116,205,012
5.1 Hardware Modifications or Modernization	$	116,205,012
Grand Total ($FY11 Millions)	**$**	**355,185,642**
Number of Aircraft		21
Flt hours		56931

Table 7. O&S Estimate for BAMS UAS FY18



BAMS UAS		FY19
1.0 Unit-Level Manpower	$	32,536,215
1.1 Operations Manpower	$	14,501,808
1.2 Unit-Level Maintenance Manpower	$	12,085,146
1.3 Other Unit-Level Manpower	$	5,949,261
2.0 Unit Operations	$	270,462,915
2.1 Operating Material	$	35,793,333
2.1.1 Energy (POL, Electricity)	$	35,793,333
2.2 Support Services	$	1,244,349
2.2.1 Transportation of Things	$	1,244,349
2.3 Temporary Duty	$	233,425,233
3.0 Maintenance	$	135,459
3.1 Organizational Maintenance and Support	$	48,249
3.1.1 Organization-Level Consumables	$	10,287
3.1.3 Organization-Level DLRs	$	37,746
3.1.4 Contract Maintenance Services	$	189
3.2 Intermediate Maintenance	$	4,671
3.2.4 Government Labor	$	4,671
3.2.5 Contractor Maintenance	$	-
3.3 Depot Maintenance	$	17,172
3.3.1 Government Depot Repair	$	2,214
3.3.2 Contractor Depot Repair	$	14,553
3.3.3 Other Depot Maintenance	$	378
4.0 Sustaining Support	$	4,126,221
4.1 System Specific Training	$	381,267
4.1.1 System Specific Operator Training	$	13,851
4.1.2 System Specific Non-Operator Training	$	367,416
4.4 Sustaining Engineering and Program Management	$	3,361,338
4.5 Other Sustaining Support	$	2,349
5.0 Continuing System Improvements	$	149,406,444
5.1 Hardware Modifications or Modernization	$	149,406,444
Grand Total ($FY11 Millions)	**$**	**456,667,254**
Number of Aircraft		27
Flt hours		73197

Table 8. O&S Estimate for BAMS UAS FY19



BAMS UAS		**FY20**
1.0 Unit-Level Manpower	$	39,766,485
1.1 Operations Manpower	$	17,724,432
1.2 Unit-Level Maintenance Manpower	$	14,770,734
1.3 Other Unit-Level Manpower	$	7,271,319
2.0 Unit Operations	$	330,565,785
2.1 Operating Material	$	43,747,407
2.1.1 Energy (POL, Electricity)	$	43,747,407
2.2 Support Services	$	1,520,871
2.2.1 Transportation of Things	$	1,520,871
2.3 Temporary Duty	$	285,297,507
3.0 Maintenance	$	165,561
3.1 Organizational Maintenance and Support	$	58,971
3.1.1 Organization-Level Consumables	$	12,573
3.1.3 Organization-Level DLRs	$	46,134
3.1.4 Contract Maintenance Services	$	231
3.2 Intermediate Maintenance	$	5,709
3.2.4 Government Labor	$	5,709
3.2.5 Contractor Maintenance	$	-
3.3 Depot Maintenance	$	20,988
3.3.1 Government Depot Repair	$	2,706
3.3.2 Contractor Depot Repair	$	17,787
3.3.3 Other Depot Maintenance	$	462
4.0 Sustaining Support	$	5,043,159
4.1 System Specific Training	$	465,993
4.1.1 System Specific Operator Training	$	16,929
4.1.2 System Specific Non-Operator Training	$	449,064
4.4 Sustaining Engineering and Program Management	$	4,108,302
4.5 Other Sustaining Support	$	2,871
5.0 Continuing System Improvements	$	182,607,876
5.1 Hardware Modifications or Modernization	$	182,607,876
Grand Total ($FY11 Millions)	**$**	**558,148,866**
Number of Aircraft		33
Flt hours		89463

Table 9. O&S Estimate for BAMS UAS FY20

B. ADDITIONAL COST CONSIDERATIONS FOR THE BAMS UAS

1. Introduction

Congress has shown concern regarding the procurement, investment and O&S costs of UAVs over the past 10 years. The concern is that the costs presented do not represent the actual expenditures that these UAVs will require to maintain operational status and utility. The Air Force Global Hawk is a classic example of the type of issues that have caused congressional skepticism. The Global Hawk program has been battered by cost overruns, production setbacks and performance issues. “The committee [Senate Armed Services Committee] is worried similar costs will show up when the Navy rolls out its Broad Area Maritime Surveillance (BAMS) unmanned spy plane, which is a derivative of the Global Hawk aircraft” (Bennett, 2011). Consequently, the Air Force announced in its 2012 budget that it would reduce the amount of Global Hawk Block 40s it would purchase by 50 percent in an effort to reduce costs (Bennett, 2011). This section addresses additional cost drivers for the BAMS UAS that may validate Congress’ concerns. The additional cost drivers selected are satellite bandwidth costs, ground station costs, collection site costs, and risks to the BAMS UAS in an operational or training environment. Although these costs were not specifically listed as concerns of Congress, they are significant costs that may cause Congress to consider them as concerns that should be addressed. These additional costs may present budgetary impediments going forward with the BAMS UAS program.

a. Satellite Bandwidth Cost

The DoD’s current UAV count exceeds 6,000 aircraft with each one providing individual unique capabilities for the end users; some are short range, while others are very complex high altitude long endurance (HALE) aircraft. However, most share the common need for satellite bandwidth. The DoD plan is to have 730 more medium to large-sized UAVs by 2020 (Congressional Budget Office [CBO], 2011). Within DoD, the Navy plans to purchase just over 30 BAMS UAS by 2020.

The number of operational UAVs directly affects satellite bandwidth costs. These costs are at times overlooked but can have a dramatic impact on operational sustainment. The BAMS UAS, like the Global Hawk, will rely heavily on the satellite bandwidth to transmit necessary time-sensitive information critical to battle groups and component commanders. In a net-centric operating environment, the satellite bandwidth availability will be increasingly critical to the success of U.S. forces. Over the past 20 years, satellite bandwidth usage has risen dramatically and costs to the DoD have increased as well. However, the amounts of bandwidth and satellite systems in orbit have not been able to keep pace with the DoD as the demand for persistent ISR continues to increase. This demand for a scarce resource typically translates into higher costs.

Since the 1980s, the intelligence community has relied on COMSAT to augment existing DoD communications systems (Rayermann, 2003–04, pp. 54–66). COMSAT provides a variety of DoD services. The demand for COMSAT has increased significantly since the 1980 that may be caused by increased demand for information. In comparison, during OPERATIONS DESERT SHIELD/STORM in 1991, the total satellite communications (SATCOM) bandwidth used by U.S. forces was 100 Mbps. During OPERATION IRAQI FREEDOM, SATCOM bandwidth use increased to 2,400 Mbps (Rayermann, 2003–04, pp. 54–66). This increase is significant because during OPERATION IRAQI FREEDOM, the force size was over 50 percent less than in OPERATIONS DESERT SHIELD/STORM. As more UAVs, such as the BAMS UAS that require high bandwidth become operational, the demand for SATCOM is expected to dramatically increase. Figure 7 shows actual and projected SATCOM needed to support all 5,000 military members.

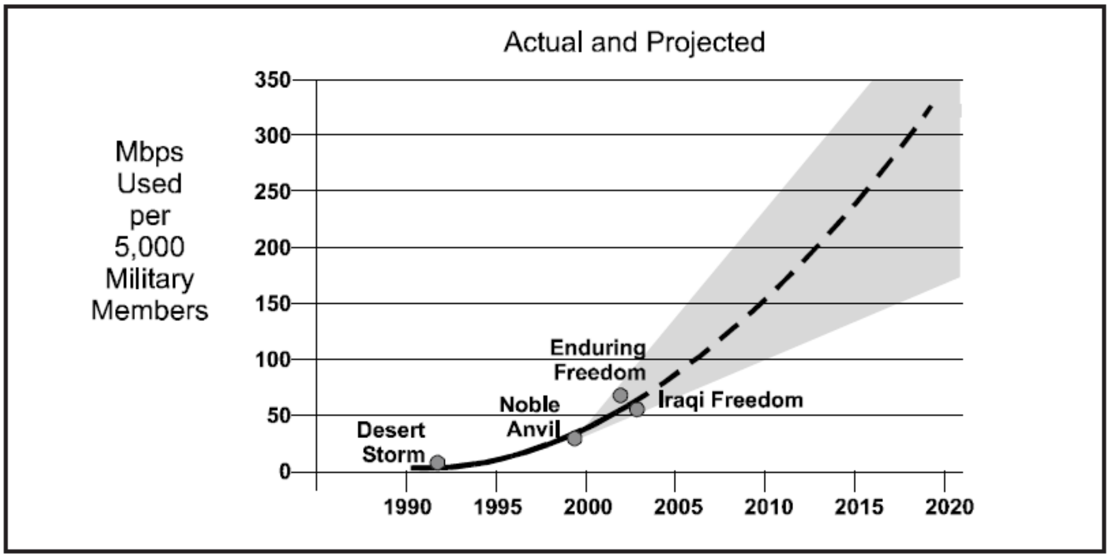


Figure 7. Growth in SATCOM Needed to Support 5,000 Military Members

The BAMS UAS is a variant of the Global Hawk Block 10. In regards to bandwidth usage, the Global Hawk uses 500 megabits per second (Mbps), which is 500 percent of the total bandwidth consumed by U.S. forces doing OPERATIONS DESERT SHIELD/STORM (Ackerman & Shachtman, 2012). Assuming the BAMS UAS will be just as or more sophisticated as the Global Hawk, it is possible to estimate that the BAMS UAS will require at least 500 Mbps while operating. This number is a conservative estimate. Previous thesis work showed that 45 Mbps is sufficient for 500 DoD military and civilian personnel (Lim, 2007). If this estimation were correct, one BAMS UAS will require enough bandwidth to support 5,500 military personnel and the BAMS fleet, if simultaneously deployed would require a total of 7,500 Mbps considering three BAMS UAS are in flight from each of the five notional bases. The DoD has spent an average of $350 million per year for SATCOM and with the implementation of the BAMS UAS alongside the Air Force existing Global Hawk fleet, expenditures for SATCOM will steadily increase, which will validate Congressional concerns. Table 10 provides a cost estimate for satellite usage for the BAMS UAS based upon the average cost from satellite service providers in the United States, the assumed BAMS UAS requirement of 500 Mbps, and the flight hours in accordance with the December 2011 BAMS UAS Selected Acquisition Report. Costs were based upon total flight hours for the fiscal year divided by the average number of hours in a month (720 hours), multiplied the average cost every month for 100 Mbps multiplied by five to account for the 500 Mbps.

Fiscal Year	Number of BAMS	Tot. Flight Hours	Costs
FY14	3	8,133	$ 41,767
FY15	7	18,977	$ 97,296
FY16	11	29,821	$ 153,196
FY17	16	43,376	$ 222,858
FY18	21	56,931	$ 292,519
FY19	27	73,197	$ 376,091
FY20	33	89,463	$ 459,663
Grand Total		**319,898**	**$ 1,643,390**

Table 10. BAMS UAS Satellite Cost FY14–20.

b. BAMS UAS Ground Station Costs

The infrastructure for the BAMS UAS basing is not complete. The Navy has decided on five notional bases discussed in Chapter I and has completed contracts for the BAMS UAS training facility in Jacksonville, FL. Assuming the Navy will use the Air Force as a model with minimal deviations, the Navy will need to redesign the five notional facilities to accommodate the complexity of the BAMS UAS. The Air Force is set to spend $200 million on ground station architecture and an additional $115 million on communications architecture at each of the bases where the Global Hawk is located (Fox, Kodzwa, Tate, & Bronson, 2011). If the Navy has similar requirements, it will incur an estimated $1.26 billion cost associated with the redesign of the five notional bases. Table 11 displays the average cost at each facility.

BAMS Notional Base Redesign	Ground Station Architecture	Communications Architecture
Marine Corps Base Hawaii Kaneohe	$ 200,000,000	$ 115,000,000
Naval Air Station Jacksonville, FL	$ 200,000,000	$ 115,000,000
Naval Air Station Sigonella, Italy	$ 200,000,000	$ 115,000,000
Naval Air Station Kadena, Japan	$ 200,000,000	$ 115,000,000
Total	**$ 800,000,000**	**$ 460,000,000**

Table 11. Notional BAMS UAS Facility Redesign Costs

c. Collection Site Manning Costs

Manning documents from previous research does not account for required intelligence analysts needed to analyze the time-sensitive information that the BAMS UAS will require. Considering that the BAMS UAS will maintain 24-hour global coverage, this thesis assumes that analysts will be placed at national collection sites (the four major sites in Georgia, Hawaii, Maryland, and Texas) that represent their respective areas of operation. This thesis places these analysts at these four sites because the typical ISR squadron only has an intelligence division of four personnel (one Officer, three Enlisted). Other assumptions made are that the watch floor will be manned 24/7, each watch will have an Officer (at least an O-2) as the lead watch officer, a senior enlisted (E-7) as the assistant watch officer, and each watch section will be comprised of 35 watch personnel. The analysts will stand three, eight-hour shifts. This thesis addresses the minimum personnel needed to accommodate this watch for a 24-hour period. Table 12 describes the watch floor personnel and the additional composite cost for manning the watch floor for one of the four sites. Tables 13 and 14 display the FY11 DoD composite costs.

Billet Title	**Grade**	**Officer**	**Enlisted**	**Composite Cost**
Watch Officer	O-2	3		$ 320,991
Asst. Watch Officer	E-7		3	$ 324,876
Intelligence Analysts	E-6		9	$ 827,109
Intelligence Analysts	E-5		60	$ 4,582,860
Intelligence Analysts	E-4		30	$ 1,889,880
Total per year		**3**	**102**	**$ 7,945,716**

Table 12. Notional BAMS UAS Watch Floor Requirement per Collection Site

Military Pay Grade	**Composite Cost**
O-10	$ 298,240
O-9	$ 295,409
O-8	$ 275,574
O-7	$ 245,980
O-6	$ 232,064
O-5	$ 193,920
O-4	$ 166,273
O-3	$ 132,959
O-2	$ 106,997
O-1	$ 85,616
WO-5	$ 191,550
WO-4	$ 162,748
WO-3	$ 139,175
WO-2	$ 117,717
WO-1	$ 103,267

Table 13. DoD Officer Composite Cost

Military Pay Grade	**Composite Cost**
E-9	$ 148,501
E-8	$ 122,739
E-7	$ 108,292
E-6	$ 91,901
E-5	$ 76,381
E-4	$ 62,996
E-3	$ 54,193
E-2	$ 49,812
E-1	$ 45,041

Table 14. DoD Enlisted Composite Cost

d. BAMS UAS Risks

"The threats to aircraft have been defined as those elements of a man-made environment designed to reduce the ability of an aircraft to perform mission-related functions by inflicting damaging effects, forcing undesirable maneuvers, or degrading system effectiveness" (Nguyen, 2002). Future operations will most likely see a greater reliance on UAVs, which will cause these vehicles to conduct operations on the frontlines of those operations closer to adversarial threats. On December 7, 2011, the world was notified that a U.S. RQ-170 Sentinel crashed in Iranian territory near the town of

Kashmar, just over 100 miles from the Afghan border (Shane & Sanger, 2011). The political response from both countries was minimal. The Iranian MP Esmaeil Kowsari stated that had it been a fighter jet vice a UAV, Iran would have carried out a military response, which shows Irans' the lack of concern for UAVs and view towards manned fighter jets. Six months later in Dorchester County, MD, a BAMS UAS crashed (Naval Air Systems Command, 2012b). Again, the political response within the United States was minimal. Hence, if the reaction to UAV losses whether on a mission or during training does not generate the same responses as losses to manned aircraft, a possibility exists that other countries may be less reluctant to shoot down a U.S. UAV as the political implications may have little or no effect.

Iran may not be considered a sophisticated potential adversary at this time. However, the likes of the People's Republic of China (PRC) and Russia are very different. Those countries may possess the ability to shoot down the BAMS UAS, deny GPS, and manipulate SATCOM feeds that would have far-reaching effects to the program due to losses of the UAS and its mission capabilities. Currently, the aircraft along with its associated systems, cost $220 million (Department of Defense, 2011a). Losing several of these UAVs could cost the program over a billion dollars when the loss and replacement costs are considered. Assuming that the BAMS UAS will have the same mishap/accident rate as the Global Hawk, the BAMS UAS program is set to incur 9.31 accidents or mishaps every 100,000-flight hours (McGarry, 2012). Using this accident rate coupled with possible reactions by adversaries showing minimal regard to the U.S. UAVs flying over or along the coast of their countries, the program may have issues providing 24-hour global surveillance. For the years evaluated in this thesis, the BAMS UAS will have an estimated 319,898 flight hours. This thesis estimates that between FY14 and FY20, at least two BAMS UAS will be lost during training and operations. and these aircraft will be replaced, which will cause the program an estimated $880 million in losses and replacement.

C. SUMMARY

The revised O&S cost estimation in Tables 3 through 9 include the assumptions and constraints explained in the previous chapter and form the basis for comparison to the Navy’s BAMS decision. The tables do not reflect decisions by naval leadership to decrease or increase manning, specific system upgrades or changes the maintenance, or collection systems. Furthermore, events, such as a surge to quell an uprising that may cause an increase in flight hours, and maintenance directly resulting in increased spending, are not factored into the estimate. However, according to the cost estimate provided, the BAMS UAS O&S costs from FY14 to FY20 increased by an average of 53 percent each year. With all cost estimations, inaccuracies are expected. For this comparison, these estimates are reasonable approximations for consideration.

IV. ANALYSIS OF O&S COSTS FOR THE EP-3E AND THE BAMS UAS

A. INTRODUCTION

In this section, the analysis of the revised O&S costs for the EP-3E and the BAMS UAS from FY14 to FY20 are based upon manpower, operations, maintenance, system support and improvements, and the additional applied costs (satellite costs, ground station costs, collection site personnel costs and aircraft risk costs). The thesis calculated approximate values for both platforms (shown in Chapter III), to give the reader a comprehensive look at the O&S costs for the years compared. These years were chosen because both platforms will be in service during this time. This analysis is important because O&S cost contribute greatly to the overall life cycle costs of aircraft systems. Acquisitions costs receive considerable attention but O&S costs typically outweigh them over the life of the system. Figure 8 provides an illustration describing the balance between the cost processes. The revised O&S cost estimate included the additional cost listed above because these additional costs associated with the BAMS UAS validate Congressional concern associated with the life-cycle costs of the system. As stated in Chapter 1, the BAMS UAS is one-third of an $8 billion dollar investment of three UAVs that will replace the EP-3E. The BAMS UAS obligates nearly half of the $8 billion investment, and based upon this research, will cost $1.6 billion more than the EP-3E over the seven years analyzed in this thesis.

Figure 8. Total Ownership Cost

B. O&S COST COMPARISON

1. Unit-level Manpower Comparison

Unit-level manpower consists of operations, maintenance and other unit support manpower costs. These costs encompass direct costs associated with the unit. They include pilots, navigators, mission specialist, unit-level maintenance personnel (military and civilian), administrative staff, security, and logistics and ordinance support (Operating and Support Cost-Estimation Guide, 2007). The unit-level manpower cost comparison is shown in Table 15.

1.0 Unit Level Manpower	**EP-3E**	**BAMS UAS**
FY14	$ 75,683,126	$ 3,615,135
FY15	$ 81,329,088	$ 8,435,315
FY16	$ 87,396,237	$ 13,255,495
FY17	$ 93,915,997	$ 19,280,720
FY18	$ 100,922,130	$ 25,305,945
FY19	$ 108,450,921	$ 32,536,215
FY20	$ 116,541,360	$ 39,766,485
Total ($FY11 Millions)	$ 664,238,859	$ 142,195,310

Table 15. Unit-Level Manpower Cost Comparison

2. Unit Operations Comparison

Unit operations includes all costs, such as fuel, electricity, expendables stores, munitions for training and other materials consumed at the unit level attributed to operations (Operating and Support Cost-Estimation Guide, 2007). The unit operations costs comparison is shown in Table 16.

2.0 Unit Operations	**EP-3E**	**BAMS UAS**
FY14	$ 52,133,010	$ 30,051,435
FY15	$ 61,120,741	$ 70,120,015
FY16	$ 62,174,462	$ 110,188,595
FY17	$ 72,893,340	$ 160,274,320
FY18	$ 85,460,152	$ 210,360,045
FY19	$ 86,933,485	$ 270,462,915
FY20	$ 88,432,218	$ 330,565,785
Total ($FY11 Millions)	$ 509,147,408	$ 1,182,023,110

Table 16. Unit Operations Cost Comparison

3. Maintenance Comparison

Maintenance costs include all levels of maintenance associated with the primary system, simulators, training devices, and associated support equipment. The maintenance cost comparison is shown in Table 17.

3.0 Maintenance	EP-3E	BAMS UAS
FY14	$ 70,487,634	$ 15,051
FY15	$ 70,558,121	$ 35,119
FY16	$ 70,628,680	$ 55,187
FY17	$ 84,754,416	$ 80,272
FY18	$ 84,771,366	$ 105,357
FY19	$ 86,466,794	$ 135,459
FY20	$ 88,196,130	$ 165,561
Total ($FY11 Millions)	$ 555,863,141	$ 592,006

Table 17. Maintenance Cost Comparison

4. Sustaining Support Comparison

Sustaining support specifically applies to the costs of training incoming personnel who will replace personnel who have reached their rotation date. Included in these costs are the cost of instructors, training devices, course material, per diem, and travel. The sustaining support comparison is shown in Table 18.

4.0 Sustaining Support	EP-3E	BAMS UAS
FY14	$ 11,960,755	$ 458,469
FY15	$ 14,403,142	$ 1,069,761
FY16	$ 17,344,263	$ 1,681,053
FY17	$ 20,885,962	$ 2,455,168
FY18	$ 25,150,875	$ 3,209,283
FY19	$ 30,286,684	$ 4,126,221
FY20	$ 36,471,224	$ 5,043,159
Total ($FY11 Millions)	$ 156,502,905	$ 5,960,097

Table 18. Sustaining Support Cost Comparison

5. Continuing System Improvements Comparison

Continuing support applies to software and hardware replacements and upgrades that a system may undergo after deployment to enhance performance and sustainability. The continuing system improvements comparison is shown in Table 19.

5.0 Continuing System Improvements	**EP-3E**	**BAMS UAS**
FY14	$ 114,548,211	$ 16,600,716
FY15	$ 115,638,568	$ 38,735,004
FY16	$ 92,510,855	$ 60,869,292
FY17	$ 78,634,226	$ 88,537,152
FY18	$ 66,839,092	$ 116,205,012
FY19	$ 56,813,228	$ 149,406,444
FY20	$ 48,291,244	$ 182,607,876
Total ($FY11 Millions)	$ 603,275,424	$ 652,961,496

Table 19. Continuing System Improvements Cost Comparison

C. SUMMARY

The cost estimate comparison was separated by unit-level manpower, unit operations, maintenance, sustaining support, and continuing system improvements. Tables 11 through 15 provide the cost comparison. The EP-3E, according to the calculated estimate, cost $505,295,718 more than the BAMS UAS FY14 through FY20 for unit-level manpower. This number supports the assumptions made in Chapter II. The BAMS UAS unit operations costs exceeded the EP-3E unit operations by $672,875,702. This cost difference is attributed to the flight hours associated with the BAMS UAS and the minimum number of aircraft needed to cover an operating area. The maintenance costs of the EP-3E severely outweighed those of the BAMS UAS. The EP-3Es maintenance cost exceed those of the BAMS UAS by $555,271,135. This number may be attributed to the fact that by FY20, the EP-3E would have over 40 years of service and maintenance costs would be expected to be significantly high. Sustaining support again was outweighed by the EP-3E. The EP-3E sustaining support costs exceeded those of the BAMS UAS by $150,542,808. Based on the cost trend, the sustaining support costs of the BAMS UAS are expected to dramatically increase as more systems become operational. Lastly, the BAMS UAS continuing system improvement costs outweighed those of the EP-3E by $49,686,072. These costs are expected to continually increase for the BAMS UAS due to system modifications and upgrades as the operational and threat environments change. Simply looking at the O&S cost estimate, the EP-3E program cost an estimated $505,295,718 more than the BAMS UAS. However, once the additional costs, costs that should be of concern for Congress of satellite bandwidth costs, ground station building costs, collection site personnel costs, and costs that may be attributed to the loss and replacement of two BAMS UAS between FY14 and FY20, the cost of the BAMS UAS outweigh the EP-3 by more than $1.6 billion. Table 20 displays all calculated costs.

Overall Cost Comparison	**EP-3**	**BAMS UAS**
Unit-Level Manpower	$ 664,238,859	$ 142,195,310
Unit-Operations	$ 509,147,408	$ 1,182,023,110
Maintenance	$ 555,863,141	$ 592,006
Sustaining Support	$ 156,502,905	$ 5,960,097
Continuing System Improvements	$ 603,275,424	$ 652,961,496
BAMS UAS ADDITIONAL COSTS		
Satellite		$ 1,643,390
Ground Stations Redesign		$ 1,260,000,000
Collection Site Personnel		$ 31,782,864
Risks and Accidents		$ 880,000,000
Total	**$ 2,489,027,737**	**$ 4,157,158,273**
Difference		**$ 1,668,130,536**

Table 20. Overall Cost Comparison

Overall, through the years compared, the EP-3E is a more efficient platform to employ, and the additional costs associated with the BAMS UAS are reason for concern and should be considered by Congress. Additionally, the costs associated with the BAMS UAS can be expected to continue to increase as more systems are added to the Navy's inventory between FY21–40. These costs were aggregate cost estimations based upon educated assumptions, cost trends, historical data from the VAMOSC database, and multipliers (calculated based upon the historical data).

An additional consideration for the BAMS UAS program is to delay the acquisition and operation of the program for another five to six years by keeping the EP-3E fully operational through FY20. This delay will permit the Navy to take advantage of technology advances, the rapid improvements in reliability, and reductions in cost associated with the explosion in UAS technologies, as well as also allow for the deployment of more efficient and cost effective satellite systems that would also lower O&S cost that the Navy will incur.

V. CONCLUSION

A. INTRODUCTION

The purpose of this research was to examine, compare and analyze the O&S costs for both the EP-3E ISR aircraft and the BAMS UAS. This comparison included all costs from initial system deployment through the end of the platforms' service life. This thesis used a revised O&S cost methodology in accordance with DoD Instruction 5000.2, *Operation of the Defense Acquisition System*. Chapter II covered the DoD O&S cost estimation process to establish the necessary background to understand the purpose of the cost estimation process. Chapter III developed an O&S cost estimation for the BAMS UAS based upon the EP-3E (closet analogous manned aircraft in which it is replacing) O&S historical data from the VAMOSC database. Chapter III also developed cost estimations for the additional cost analyzed in this research. Chapter IV analyzed modified the O&S data for comparison between the EP-3E and the BAM UAS. The cost estimates presented in Chapter IV validate Congressional concern in regards to the BAMS UAS program. The additional cost drivers proved to create significant increased costs that need to be placed in future budgets to mitigate the risk of future budget shortfalls. Additionally, Congress should revisit the BAMS UAS program in an effort to identify more efficient ways to implement the program and reduce costs. Joint investments with the Air Force may provide a solution to mitigate several of the additional cost identified in this thesis. This chapter provides answers to the research questions and suggest topics for further research.

B. PRIMARY RESEARCH QUESTION

- **What Are the Major Factors Driving the Cost Differences Between the EP-3E and the BAMS UAS and Why?**

Unit-level manpower, unit operations and maintenance costs were the three major cost factors between the two systems for the years compared in this thesis. In a one-to-one comparison between squadron sizes, an EP-3E squadron is 32 percent larger than a proposed BAMS UAS squadron. The actual manning document from PMA-262 is not available due to privacy reasons and program concerns but previous research suggest that

168 personnel would be the closest estimate. This 32-percent size difference was the major contributing factor for the EP-3E unit-level manpower costs outweighing those of the BAMS UAS so significantly. Unit operations that include fuel cost were a major cost driver that separated the two systems. As discussed in the assumptions section of Chapter II, the BAMS UAS will maintain 24-hour global coverage that will require a minimum of three BAMS from each of the five notional bases to be airborne in their assigned operating areas at all times. Although the BAMS UAS is a single engine aircraft, the length of its missions and continued coverage severely increased fuel costs for the system. The other major cost factor was maintenance costs. As described in the assumptions prior to the cost estimations, it is assumed that the aging EP-3E will require much more significant maintenance per flight hour than the BAMS UAS to remain mission ready. The EP-3E service life expands over 30 years and by FY20, 40 years. The additional costs that were the cost drivers for this thesis caused the BAMS UAS to be more expensive. Building redesign and losses to the BAMS UAS program due to adversaries and accident rate were the major cost drivers within the additional cost.

C. SECONDARY RESEARCH QUESTION

- **What Are the Differences in the O&S Cost of the EP-3E and BAMS?**

The two systems were compared from FY14 through FY20. Due to the additional costs implemented in the calculations, the EP-3E is the more cost effective platform to operate during the time period analyzed. These additional costs are important when considering future budgets for the BAMS UAS program. The addition of more BAMS UAS aircraft for the fiscal years going forward will continue and add to the costs of associated with the BAMS UAS program. More personnel may be needed at each of the BAMS UAS bases (due to increased BAMS UAS), and at the collection site to accommodate for the amount of BAMS UAS data and live streams that will be down-linked. In addition to personnel costs, maintenance and fuel costs should also increase as more systems become operational. By FY40, the O&S costs of the EP-3E program will be minimal to those of the BAMS UAS, and possibly beyond comparison. As discussed in previous chapters, cost estimations are not without error and the actual historical data eventually be provided to VAMOSC may be slightly different.

D. RECOMMENDATIONS FOR FURTHER RESEARCH

- **What is the Satellite and Bandwidth Cost Implications of the BAMS UAS from FY21 to FY40. How Many More Satellites Will Be Required to Handle the Bandwidth Requirement of the BAMS UAS?**

Bandwidth costs rise with increased UAV usage, and increases in demand are typically followed by increases in cost. The demand for satellite support is not only affected by the DoD but from the civilian sector as well. The demand for data by ground units has steadily increased since the beginning of Operations IRAQI FREEDOM AND ENDURING FREEDOM. Much of that burden is placed upon UAVs that require the use of satellites to forward most of the data they gather, and especially full motion video. By FY40, an estimated 65 BAMS UAS will be owned by the Navy, and the Air Force is set to have a comparable amount of Global Hawks as well. The increased satellite usage of these UAVs will have a dramatic effect on the costs of satellites and associated systems.

- **How Many More Satellites Constellations Will Be Required to Handle the Bandwidth Requirement of the BAMS UAS?**

In a phone conversation with a VIASAT engineering manager, Paul Cramer, the company recently launched a new 140 gigabyte Ka COMSAT that will support the increased bandwidth demand of the DoD. The satellite cost an estimated $400 million to design and another $500 million to launch. If demand for bandwidth continues at the current rate, how many more of these satellites will be needed to provide the coverage needed by DoD personnel and systems?

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Ackerman, S., & Shachtman, N. (2012, January 9). *Almost 1 in 3 U.S. warplanes is a robot*. Retrieved from Wired website: http://www.wired.com/dangerroom/2012/01/drone-report/

Air Force distributed common ground system. (2011, December 9). Retrieved from AirForce.mil website: http://af.mil/information/factsheets/factsheet.asp?id=15433

Airships from 1900–1990. (2009, November 2). Retrieved from Aeronautic Learning Laboratory for Science, Technology and Research website: http://www.allstar.fiu.edu/aerojava/balloon5.htm

Azama, S. S. (2000). *Introduction to cost analysis.* Fort Belvoir, VA: Defense Acquisition University.

Bardin, J., Covelli, D., Malvasio, J., Olson, M., & Speer, D. (2010). *BAMS UAS manning and fleet integration strategy* (master's thesis). Naval Postgraduate School, Monterey, CA.

Bennett, J. T. (2011, August 11). *Following criticism, official says spy plane costs are dropping.* Retrieved from The Hill website: http://thehill.com/news-by-subject/defense-homeland-security/176497-after-senate-criticism-official-claims-global-hawk-costs-are-dropping

Bone, E., & Bolkcom, C. (2003). *Unmanned aerial vehicles: Background and issues for Congress.* Washington, DC: Library of Congress.

Commander Navy Installations Command. (2012, September 8). Retrieved from http://www.cnic.navy.mil/jacksonville/CNICP-A295309

Congressional Budget Office (CBO). (2011, June). *Policy options for unmanned aircraft systems.*

Conway, J., Roughead, G., Allen, T. (2010). *Naval operations concept 2010*. Retrieved from United States Navy website: http://www.navy.mil/maritime/noc/NOC2010.pdf

Defense Industry Daily. (2012, March 8). Next-stage C4ISR bandwidth: The AEHF satellite program. Retrieved from http://www.defenseindustrydaily.com/nextstage-c4isr-bandwidth-the-us-militarys-aehf-program-updated-02165/

Department of defense instruction 5000.2. (2008). Retrieved from Defense Technical Information Center website: http://www.dtic.mil/whs/directives/corres/pdf/500002p.pdf

Department of Defense. (2011a). *Selected Acquisition Report (SAR) MQ-4C BAMS*.

Department of Defense. (2011b). *Unified facilities criteria: DoD facilities pricing guide*. Retrieved from Whole Building Design Guide website: http://www.wbdg.org/ccb/DOD/UFC/ufc_3_701_01.pdf

Dishman, R. (2010). *Selected acquisition report (SAR): MQ-4C UAS BAMS.* Washington, DC: Department of Defense.

Elmendorf, D.W. (2011). *Policy options for unmanned aircraft systems*. Washington, DC: Congress of the United States: Congressional Budget Office.

Fein, G. (2007, February 7). *Lockheed martin's open architecture efforts transitioning into P-3, BAMS*. Retrieved from Acquisition Community Connection website: https://acc.dau.mil/adl/en-US/135673/file/26893/Lockheed%20Martin%20_%20OA%20in%20Defense%20Daily_02.07.07.pdf

Fleet Air Reconnaissance Squadron Two VQ-2. (2011, May 5). Retrieved from GobalSecurity.org website: http://www.globalsecurity.org/military/agency/navy/vq-2.htm

Fox, J., Kodzwa, P., Tate, D., & Bronson, P. (2011, May). *Global haw: Root cause analysis of projected unit cost growth*. Retrieved from ACQWeb website: http://www.acq.osd.mil/parca/docs/IDA-Reports/Global%20Hawk-Root-Cause-Analysis-of-Projected-Unit-Cost-Growth.pdf

Garamone, J. (2002, April 16). *From U.S. civil war to Afghanistan: A short history of UAVs*. Retrieved U.S. Department of Defense website: http://www.defense.gov/news/newsarticle.aspx?id=44164

Geer, H., & Bolkcom, C. (2005, November 21). *Unmanned aerial vehicles: Background and issues for Congress.* Retrieved from Defense Technical Information Center website: http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA477738

Hanlon, M. (2005, November 10). *Global hawk UAV get bigger and more capable*. Retrieved from Gizmag website: http://www.gizmag.com/go/4831

Hewitt, M. W. (2011, October 28). *MPA community news.* Retrieved from Maritime Patrol Association website: http://www.maritimepatrolassociation.org/documents/updates/MPA_Community_News_10282011.pdf

Hollister, G. S. (2011). *UAVs to drive rapid satellite bandwidth growth.* Colorado Springs, CO: Market Info Group, LLC.

IHS Janes. (2012, March 12). Retrieved from Lockheed Martin EP-3E website: https://janes.ihs.com/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1309483&Pubabbrev=JEMA

Joint Chiefs of Staff. (1993). Roles and missions review: Steps toward jointness. *The DISAM Journal*.

Kan, S. (2001). *China-U.S. aircraft collision incident of April 2001: Assessment and policy implications.* (Congressional Report No. Order Code RL30946). Washington, DC: Library of Congress Congressional Research Service.

Lawler, P. P. (2010). *Cost implications of the broad area maritime surveillance unmanned aircraft system for the Navy flying hour program and operation and maintenance budge* (Master's thesis). Naval Postgraduate School, Monterey, CA.

Lim, T. Y. D. (2007). *A methodological approach for conducting a business case analysis of the global observer joint capability technology demonstration* (master's thesis). Naval Postgraduate School, Monterey, CA. Retrieved from edocs website: http://edocs.nps.edu/npspubs/scholarly/theses/2007/Dec/07Dec_Lim_Thiow.pdf

McGarry, B. (2012, June 18). *Drones most accident prone U.S. air force craft: BGOV barameter*. Retrieved from Business Week website: http://www.businessweek.com/news/2012-06-18/drones-most-accident-prone-u-dot-s-dot-air-force-craft-bgov-barometer

MQ-4C Broad Area Maritime Surveillance (BAMS). (2011, November 6). Retrieved from GlobalSecurity.org website: http://www.globalsecurity.org/intell/systems/bams-program.htm

MQ-4C Triton (BAMS UAS). (n.d.). Retrieved from Northrop Grumman website: http://www.as.northropgrumman.com/products/bams/index.html

MQ-4C UAS BAMS: Selected acquisition report. (2011, December 11). Arlington, VA: Defense Acquisition Management Information Retrieval.

Naval Air Systems Command (NAVAIR). (2012a). *Broad area maritime surveillance UAS*. Retrieved from Navy Air Systems Command: Aircraft and Weapons website: http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=7CD9F773-04D7-440F-AE35-653BBB7B288F

Naval Air Systems Command. (2012b). *Navy UAV crashes; No injuries or property damage*. Retrieved from United States Navy website: http://www.navy.mil/submit/display.asp?story_id=67739

Nguyen, X. T. (2002). *Threat assessment in tactical airborne environments*. Edinburgh, SA, Australia: International Society of Informatoin Fusion.

Oesterguard, J. K. (2012, May 7). *RQ-4 global hawk*. Retrieved from Aeroweb: Aerospace and Defense website: http://www.bga-aeroweb.com/Defense/RQ-4-Global-Hawk.html

Operating and support cost-estimation guide: Office of the Secretary of defense cost analysis improvement group. (2007). Retrieved from Acquisition Community Connection website: https://acc.dau.mil/adl/en-US/187960/file/32364/Operating%20and%20Support%20Cost%20Estimating%20Guide%20DTD%20Oct%202007.pdf

P-3/EP-3. (2012). Retrieved from Navy Air Systems Command: Aircraft and Weapons webiste: http://www.navair.navy.mil/index.cfm?fuseaction=home.displayPlatform&key=5B7DC7D0-C4DB-45E3-92EA-662605B57409

Poston, C. (2011, February 14). *US navy wants common ground control stations for BAMS & Global Hawk*. Retrieved from UAS Vision website: http://www.uasvision.com/?s=US+Navy+Wants+Common+Ground+Control+Stations+for+BAMS+%26+Global+Hawk

Rayermann, P. (2003–04, Winter). Exploiting commercial SATCOM: A better way. *Parameters*, *33*(4), pp. 54–66. Retrieved from U.S. Army War College website: http://www.carlisle.army.mil/usawc/parameters/Articles/03winter/rayerman.pdf

Richey, K., Echard, J., & Cha, C. General Accounting Office (GAO). (2009). *Cost estimating and assessment guide*. Washington, D.C.

Rosenberg, B. (2010, February 25). *DoD's reliance on commercial satellites hit new zenith*. Retrieved from Defense Systems website: http://defensesystems.com/articles/2010/03/11/cover-story-the-satcom-challenge.aspx

Shane S. & Sanger, D. (2011, December 7). *Drone crash in Iran reveals secret U.S. surveillance effort*. Retrieved from New York Times website: http://www.nytimes.com/2011/12/08/world/middleeast/drone-crash-in-iran-reveals-secret-us-surveillance-bid.html

Taylor, M., & Murphy, J. (2012, March–April). OK, we bought this thing, but can we afford to operate and sustain it? *Defense AT&L: Product Support*, 17–21.

Teledyne-Ryan AQM-34 combat dawn firebee. (2011, February 15). Retrieved from National Museum of the U.S. Air Force website: http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=4044

Trible, S. (2011, August 11). *US navy to replace EP-3w with unmanned aircraft*. Retrieved from Flight Global website: http://www.flightglobal.com/news/articles/us-navy-to-replace-ep-3s-with-unmanned-aircraft-360617/

Valerdi, R. (n.d.). *Cost metrics for unmanned aerial vehicles*. Retrieved from MIT website: http://web.mit.edu/rvalerdi/www/UAVcostValerdi.pdf

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California