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Business Case Analysis of Cargo Unmanned Aircraft System (UAS) Capability in Support of Forward Deployed Logistics in Operation Enduring Freedom (OEF)

31 October 2011

by

Capt. Troy M. Peterson, USMC, and

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Abstract

Based on our analysis, K-MAX is an attractive alternative to current methods of resupply. These findings led to our conclusion that the K-MAX is a program worthy of DoD investment and of becoming a program of record.

The concept for the utilization of unmanned aircraft system (UAS) capability in support of logistics in Operation Enduring Freedom (OEF) is in response to a United States Marine Corps urgent needs requirement. This capability significantly decreases the ground convoy requirement. In addition, the introduction of UAS would reduce American forces' exposure to exterior enemy threats while conducting resupply missions.

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The purpose of this study is to estimate potential cost savings in the form of resource human life valuations. This study conducts a business case analysis (BCA) comparing the estimated costs of the UAS program to the current methods for providing logistical support through traditional ground convoys and fixed and rotary wing assets.

Keywords: Business Case Analysis (BCA), Cargo Unmanned Aircraft Systems (CUAS), Operation Enduring Freedom (OEF)

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List of Acronyms and Abbreviations

ACE	Aviation Combat Element
AO	Area of Operations
AV	Air Vehicle
BCA	Business Case Analysis
COA	Courses of Action
CONOPS	Concept of Operations
COPs	Combat Outposts
CUAS	Cargo Unmanned Aircraft System
DAU	Defense Acquisition University
DOS	Days of Supply
DO	Distributed Operations
DoD	Department of Defense
ECO	Enhanced Company Operations
FOB	Forward Operating Base
GCS	Ground Control Station
GCE	Ground Combat Element
GPS	Global Positioning System
HMMWV	High Mobility Multipurpose Wheeled Vehicle
ICUAS	Immediate Cargo Unmanned Aircraft System
IED	Improvised Explosive Device
IRR	Internal Rate of Return
JPADS	Joint Precision Airdrop System
JUONS	Joint Urgent Operational Need Statement
LCC	Life Cycle Cost
MCCDC	Marine Corps Combat Development Command
MOB	Mobile Operating Base
MOS	Military Occupation Specialty
MTVR	Medium Tactical Vehicle Replacement
NAVAIR	Naval Air Systems Command

OAD	Operations Analysis Division
O&M	Operations and Maintenance
OCO	Overseas Contingency Operations
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
PAX	Personnel
PBs	Patrol Base
QRA	Quick Reaction Assessment
R&D	Research and Development
RDT&E	Research Development Test and Evaluation
RPG	Rocket Propelled Grenade
UAS	Unmanned Aircraft System
USMC	United States Marine Corps
VAMOSC	Visibility and Management of Operating and Support Costs
VMUs	Unmanned Aerial Vehicle Squadrons

I. Introduction

A. Purpose of the Study

This study provides a business case analysis (BCA) that compares the estimated costs of procuring, operating, and sustaining either the Boeing A160T Hummingbird or the Lockheed Martin K-MAX unmanned aircraft systems (UASs) with the costs of the status quo of cargo replenishment currently used by the United States Marine Corps in support of Operation Enduring Freedom (OEF). In the types of operations these Marines are currently conducting, “there is an unusual and compelling urgency for a cargo unmanned aircraft systems [CUAS] capability in support of the Marine Corps forces engaged in [OEF]” (Director, Combat Development and Integration, 2010).

The enemy’s use of improvised explosive devices (IEDs) has greatly affected truck mobility throughout the battlefield and has been successful in disrupting current replenishment procedures. Replenishment procedures have slowed down due to lengthy, deliberate routes and time-consuming IED clearance tactics. In addition, these delays increase the time Marines are exposed to enemy attack. One extreme example follows: “a recent [Marine Expeditionary Brigade Alpha] MEB-A resupply convoy consisting of 30 vehicles took 54 hours and struck three IEDs, each causing the loss of a vehicle—two [mine resistant ambush protected] MRAPs vehicles and one [logistics vehicle system] LVS” (Marine Forces Central Command, 2009).

As requested by Program Management Naval Air Systems Command (NAVAIR) 266 (PMA-266), the tactical unmanned aerial system program office at NAVAIR, we accomplish the following in this study:

- develop realistic scenarios similar to those in Afghanistan.

- examine the reduction of time Marines spend vulnerable to attack, asset re-allocation, cost savings, and additional associated benefits gained by the acquisition and operation of CUAS in theater;
- conduct a BCA with a baseline analysis, sensitivity analysis, and risk analysis;
- compare the performances of the armored medium tactical vehicle replacement (MTVR), high mobility multipurpose wheeled vehicle (HMMWV), CH-53E, and KC-130J with joint precision airdrop system (JPADS) against both the Lockheed Martin K-MAX and the Boeing A160T Hummingbird in five operational scenarios performing resupply every three days, as well as estimate life cycle costs that will include investment costs and operating costs; and

As stated by a NAVAIR representative in CRUSER News in May 2011, the current effort will result in one system being deployed following a Quick Reaction Assessment (QRA) in August 2011. The requirement for a CUAS is based on a joint urgent operational need to counter risks from IEDs. The intent is to reduce the number of trucks delivering supplies to forward operating bases (FOBs). Following the QRA, one supplier will be fielded for a six-month military utility assessment in Afghanistan where CONOPS will be refined and the system's operation value will be evaluated (Pratson, 2011, p. 4).

B. Problem Statement

There is continuing pressure for the Department of Defense (DoD) to cut costs and contribute to reducing the national debt. The fiscal year (FY) 2012 President's Budget requests $670.9 billion for the DoD, including $553.1 billion in base funds and $117.8 billion in overseas contingency operations (OCO) funds. This is a decrease of $37.3 billion from FY 2011 and will require further scrutiny and management of program acquisitions to ensure that only the best programs are funded (DoD, 2011).

Life cycle costs are one of the most important measures in determining whether or not to pursue new technologies. CUAS falls into this new technologies category and should be discontinued if performance does not outweigh costs.

Whereas the introduction of CUAS technology will not completely replace all current cargo capabilities, it may serve as a supplement or as a viable complement to existing capabilities, which has the potential to save lives and money.

1. High Cost of Current Cargo Replenishment in OEF

Cargo replenishment of forward operating bases (FOBs) is dependent on the number of Marines stationed at those FOBs, how far away those FOBs are, and the level of threat expected en route to those FOBs. All supply materials will be sent from the main operating base (MOB) and replenish the FOBs in a hub-and-spoke supply chain. Each of these variables alone plays a major role in the cost of replenishment operations.

All cargo systems use fossil fuel, but the use of manpower differs greatly between rotary and ground convoys. For instance, if ground convoys require three HMMWV, three MTVR, and 18 Marines in a medium-security convoy, in a high-security convoy eight HMMWVs, four MTVRs, and 36 Marines are needed. If CUAS can replace some of these armored vehicles, then cost savings might well occur.

C. Logistics

As is the case with any major war, operational needs drive all facets of support. Logistics and an efficient supply chain are major combat enablers in OEF. Simply stated, the only way to render proper support to forward locations is to have a supply chain that is constantly evolving in response to changing conditions and changing threats.

D. Logistical Delivery Methods

Several cargo delivery capabilities currently exist at mobile operating bases (MOBs), including

- ground convoy transport, including HMMWVs and MTVRs;
- aerial sling delivery with CH-53E;
- fixed-wing aircraft using JPADS, which is a guided parachute delivery system that uses a Global Positioning System (GPS) to distribute supplies accurately; and

All of these capabilities can be combined to resupply forward operating units. Finally, in this study we investigate the best role for CUAS technology as a means of replenishment.

E. Scenario Development

A study has been developed by the Mission Area Analysis Branch, Operations Analysis Division (OAD), Marine Corps Combat Development Command (MCCDC) as part of a study on CUAS capabilities. We used this study as our baseline for analysis because it presents a realistic situation and it has been endorsed by PMA-266 for our BCA. We describe this study in detail in Chapter II. In this study, we investigate what operational conditions would be conducive to effective use of CUAS systems.

In our analysis, we follow the logic displayed in Figure 1. We analyze the distance between the FOB and the MOB, the number of personnel and vehicles required to support the FOB, the total resupply in pounds, the platform providing support, and the threat level to provide support.

Figure 1 shows the distances from MOB to FOB, the total resupply in pounds, and the time required by ground and rotary platforms.

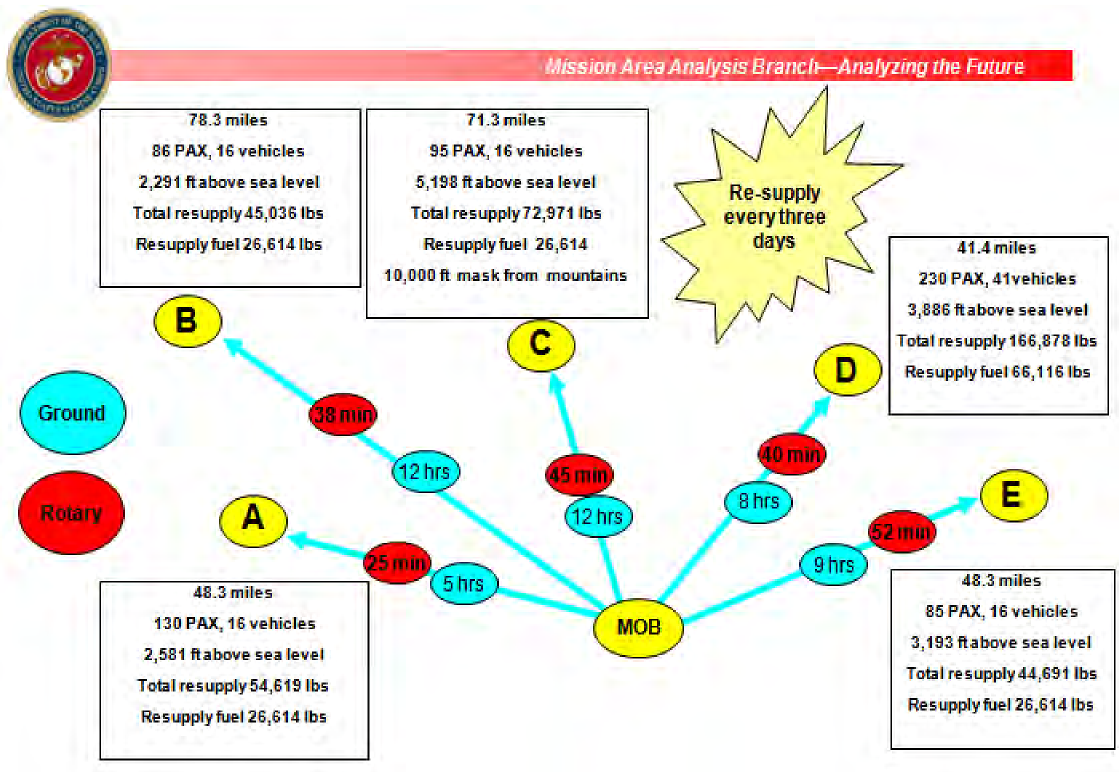

Figure 1. OEF Battalion Scenario
(T. J. Merkle, personal communication, June 9, 2011)

F. MBA Project Scope and Organization

Our primary purpose in this project is to analyze the cost and capability of CUAS as it is used with all of the other previously discussed cargo capabilities. Our analysis indicates if and where CUAS can benefit replenishment operations employed in conjunction with existing ground and aerial delivery methods. Furthermore, in this project we discuss how the development of CUAS technologies can impact and likely benefit the Marines serving in austere conditions in Afghanistan.

This project is organized into five chapters: Chapter I—Introduction, Chapter II—Background, Chapter III—Methodology, Chapter IV—Data Analysis, and Chapter V—Conclusions and Recommendations.

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II. Background

A. Concept of Operations in Operation Enduring Freedom

The vast and rugged terrain in Afghanistan poses significant challenges to standard logistics resupply missions. On the ground, Afghanistan's road networks restrict vehicle movement to narrow passages. Accordingly, vehicle convoys within the area of operation (AO) predominantly utilize foot patrols and helicopter assaults to escort the vehicle convoys (Merkle, 2010, p. 2).

The fluid operating environment, harsh climate, and tough terrain create the significant problem of how to properly supply dispersed forces. Marines who are constantly moving throughout the AO create a logistical challenge. Because Marine forces need to be light and agile in Afghanistan, they no longer maintain large stockpiles of supplies in support of combat operations (Merkle, 2010, p. 5).

To overcome these challenges, the Marine Corps has instituted the concept of distributed operations (DO). DO can be defined as "deliberate use of separation and coordinated, interdependent, tactical actions enabled by increased access to functional support, as well as by enhanced combat capabilities at the small-unit level" (Conway, 2005, p. 1). By delegating tactical decision-making to the dispersed platoon level, there has been an increase in the capacity for coordinated action within the AO (Merkle, 2010, p. 2). This employment means that smaller units have been empowered to move freely within the battle space while working in concert with the commander's intent.

As the war in Afghanistan has worn on, enhanced company operations (ECO) have been developed. ECO can be defined as "an approach to the operational art that maximizes the tactical flexibility offered by true decentralized mission accomplishment, consistent with commander's intent and facilitated by improved command and control, intelligence, logistics and fires capabilities" (Conway, 2008, p. 1). Much like DO, ECO is a significant change in sustained independent unit operations (Merkle, 2010, p. 11). ECO seeks to reduce the level of sustained independent operations to the company level (Conway, 2008, p. 1). The increased level of independent operations at the company level is accomplished by adding new enlisted Marines with specific Military Operational Specialties (MOSs) in logistics, administration, and communications to the Marine infantry company (Merkle, 2010, p. 11). This increase in capability at the company level allows greater freedom of movement in a larger AO. ECO places the responsibility of command on the company-level leadership and decision-making is delegated to the lowest level. Like DO, the key tenets for ECO are rapid decision-making and the ability for units to move quickly and freely throughout the AO.

In support of DO and ECO, several methods have enhanced the resupply of Marines at forward locations in Afghanistan. For this project, we analyzed the effectiveness of all methods but took a close look at the CUAS method for resupply. We investigate the capability of CUAS to provide the logistical reach to effectively support dispersed and independent company and platoon-size elements (Merkle, 2010, p. 2).

B. Requirements for CUAS Capability in Support of OEF

Current United States Marine Corps (USMC) units deployed to Afghanistan in support of OEF require an organic, precision resupply capability to minimize loss of personnel, equipment, and supplies on ground resupply missions. There is an additional requirement to provide an alternate means of aerial delivery when weather, terrain, or enemies pose an unsuitable risk to conventional rotary wing assets (E. N. Pratson, personal communication, June 12, 2011). One potential method for implementing improvements in the resupply mission is through the employment of CUAS.

In the paragraphs that follow in this section, we discuss the following information:

- background on the CUAS approach, along with specific discussion on the Concept of Operations (CONOPs) for this new technology;
- implications and costs of the UAS development process, specifically the requirements for the UAS capability, specifications for the two companies that have received contract awards for prototype airframes, and the resident contract structure and program schedule; and
- considerations and factors facing Navy leadership with regard to the future employment and application of the UAS technology.

At present, a UAS capability is desired to augment existing ground and air logistics operations and supplement current rotary wing assets. In addition to supplementing traditional methods of resupply, UAS will reduce Marine exposure to improvised explosive devices (IEDs), as well as reduce potential delays in resupply missions caused by weather, fuel availability, equipment maintenance, and flight crew rest.

IEDs have been specifically responsible for claiming the lives of hundreds of Marines tasked with providing security for traditional ground convoys en route to replenishing FOBs with basic classes of supply. Figure 2 provides a graphical display of projected CONOPS for CUAS employment. As depicted in Figure 2, the UAS will utilize a hub-and-spoke method for resupply. In other words, the UAS will have an established hub that will be co-located with major logistical distribution centers in theater and will use this hub to load and deliver to the spokes from which the Marines will be operating at FOBs, combat outposts (COPs), and patrol bases (PBs; Marine Forces Central Command, 2009).

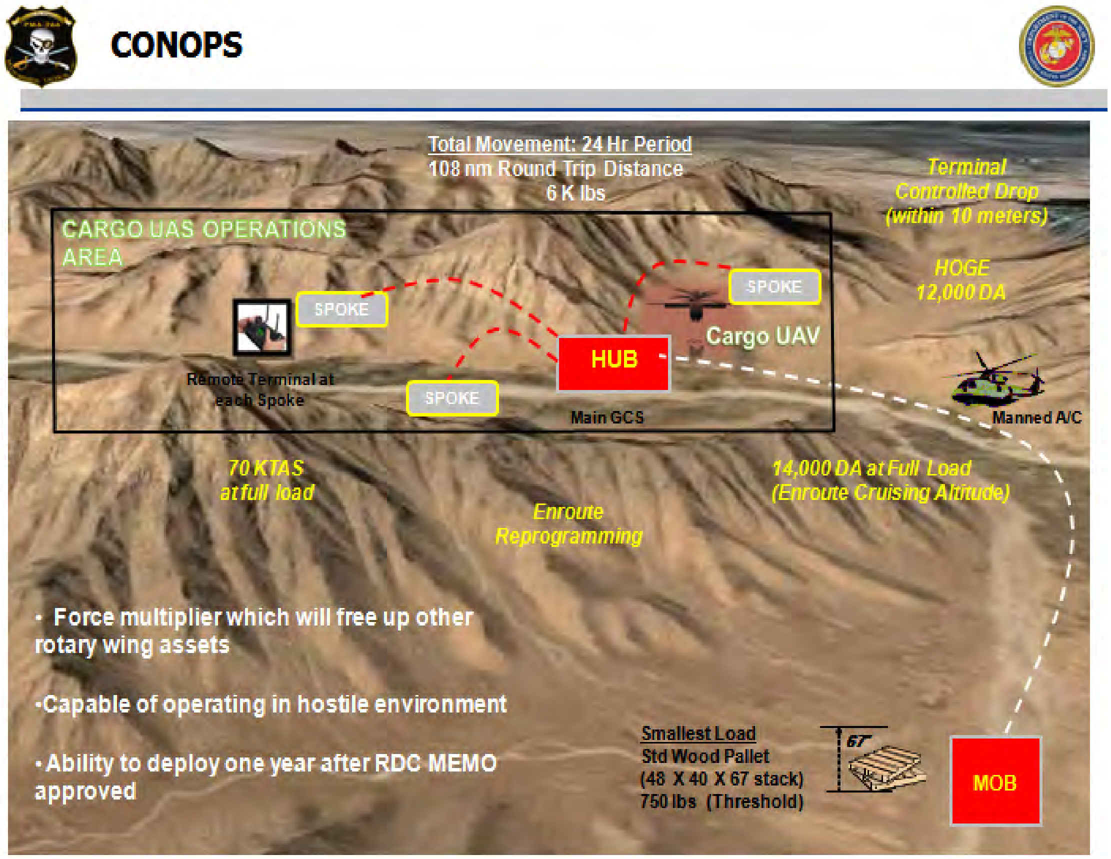


Figure 2. UAS CONOPS
(E. N. Pratson, personal communication, June 12, 2011)

CUAS development started in FY 2009 and will continue through FY 2011, to include follow-on deployments in support of OEF. The Navy conducted a Quick Reaction Assessment (QRA) in the summer of 2011 to decide which contractor's in-country service option would be exercised. Armed with this information, the Marine Corps plans to deploy the CUAS capability in support of OEF in the fall of 2011 (Robson, 2010).

Depending on the results of the QRA, the Marines will be testing the capabilities of the Boeing A160T Hummingbird or the Lockheed Martin K-MAX helicopters in an operational environment. Upon completion of initial deployment, Navy and Marine Corps leadership will determine the value of this capability and decide if a contract extension or re-compete is warranted (Robson, 2010). Figure

3 identifies items that will be tracked or watched by Navy leadership. As depicted in Figure 3, some of the key cargo performance measures that Navy leadership will monitor are

- the ability to deliver a minimum of 6,000 pounds of cargo in a 24-hour window and
- the ability of the CUAS capability to complement ground convoys by reducing the number of trucks on the road by two, thus taking six Marines off of the road each day, which leads to the reduction of overall risk to human life (E. N. Pratson, personal communication, June 12, 2011).

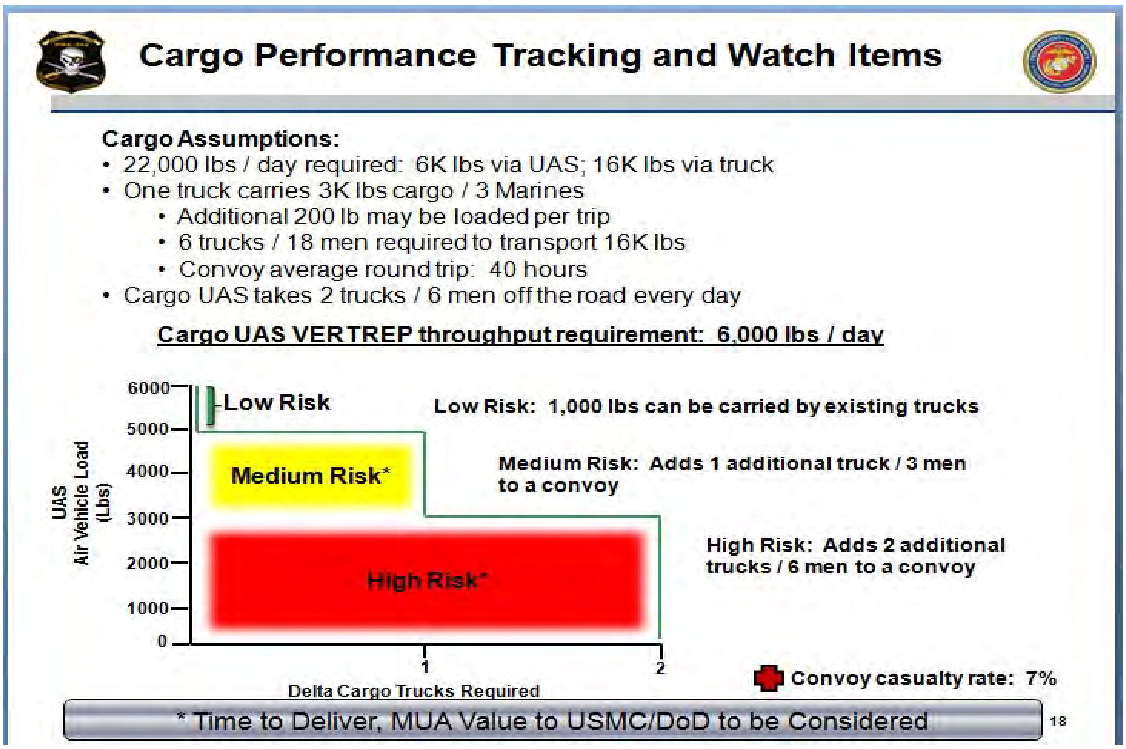


Figure 3. Cargo Tracking and Watch Items
(E. N. Pratson, personal communication, June 12, 2011)

The possible employment of the CUAS will address the Marine Corps need as described in the Joint Urgent Operational Need Statement (JUONS). The CUAS program is an initiative being developed by the Naval Air Systems Command (NAVAIRSYSCOM; NAVAIR, 2009). Figure 4 provides a graphical depiction of a CUAS organizational chart. As displayed in Figure 4, Captain Tim Dunigan is the CUAS program manager and he has a traditional supporting staff, including experts in acquisition, cost estimating, contracting, testing and evaluation, engineering, and logistics. It is apparent by looking at this figure that the Marine Corps have taken a keen interest in CUAS by investing many resources to develop and monitor the progress of this program.

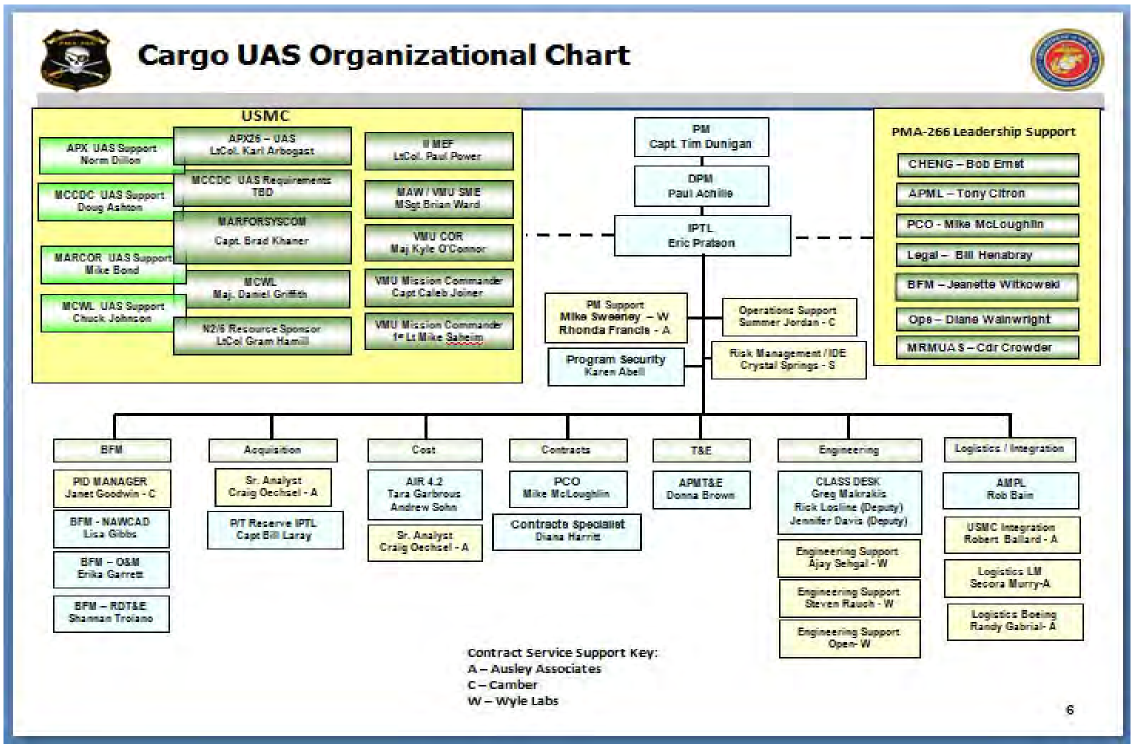


Figure 4. CUAS Organizational Chart
(E. N. Pratson, personal communication, June 12, 2011)

The CUAS demonstration project is a government-owned and contractor-operated program. It will be managed by organic unmanned aerial vehicle squadron (VMU) detachments to support U.S. Marine Corps Infantry Battalions (E. N. Pratson, personal communication, June 12, 2011). In December 2010, the Navy announced the award for two fixed-price contracts to Boeing and Lockheed

Martin for CUAS technology. Both contracts include the development of two aircraft systems, three remote ground control stations, and a QRA. Each contract includes a fixed-price option for a six-month deployment to OEF (Mortimer, 2010).

Figures 5–7 provide amplifying information on the acquisition background, program schedule, recent accomplishments, and test and training periods. As displayed, the Marine Corps original statement of need for this program was issued in October 2008, PMA-266 was assigned to the acquisition effort in January 2009, and the deployment of a CUAS capability is scheduled for October 2011. In addition, as depicted, the contracts issued have used full and open competition and both Lockheed Martin and Boeing have been advised that they must successfully pass the QRA scheduled for August 2011. Depending on the results, one company will deploy its two CUASs in support of the Marines in OEF.

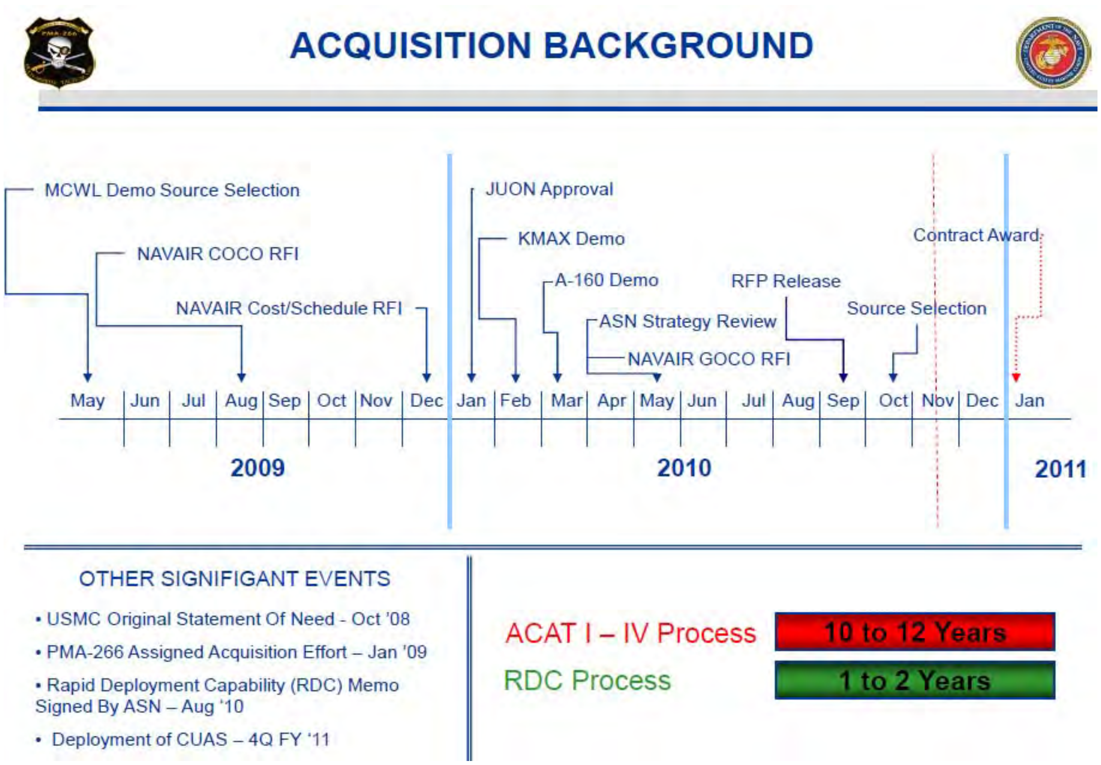


Figure 5. Acquisition Background
(E. N. Pratson, personal communication, June 12, 2011)

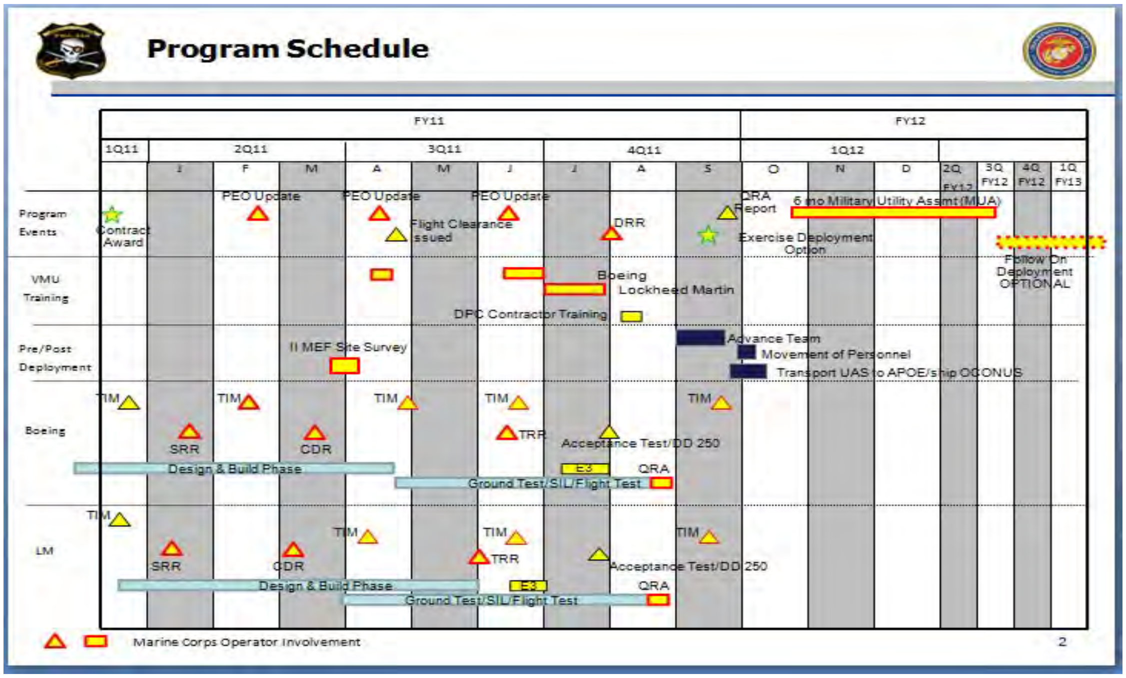


Figure 6. Program Schedule
(E. N. Pratson, personal communication, June 12, 2011)

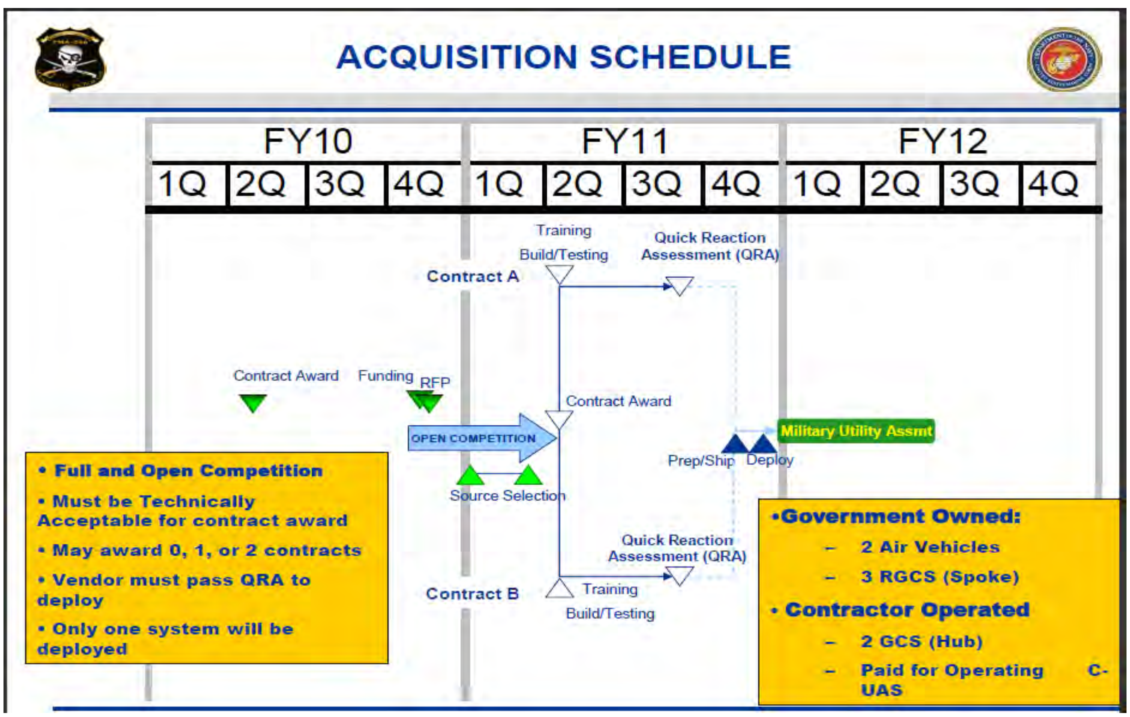


Figure 7. Acquisition Schedule
(E. N. Pratson, personal communication, June 12, 2011)

One or more deployments (depending on feedback from the Marine leadership in Afghanistan) will be funded by Research Development Testing and Evaluation (RDT&E) for the air vehicles, hardware, deployment preparation, and operational assessment. The deployed services will be funded by Operations and Maintenance (O&M). The total cost is estimated for a six-month period of service. This period is due to the fact that this program will be a performance-based service. The total cost of the air vehicles is included in the contract price (E. N. Pratson, personal communication, June 12, 2011).

Figures 8 and 9 contain the following NAVAIR CUAS cost estimates and budget information:

- the total cost for RDT&E for both contracts is approximately $51 million, and the O&M cost is close to $61 million (E. N. Pratson, personal communication, June 12, 2011); and
- the UAS total budget for FY 2011 is $68 million, $54 million in 2012, and $105 million in 2013 (E. N. Pratson, personal communication, June 12, 2011).

Immediate Cargo UAS Deployment Cost Estimate (ROM)						
Contractor Activities		**FY10 OCO RDT&E Supplemental (per contract)**	**FY10 OCO RDT&E Supplemental (2 contract)**	**Qty**	**FY11 OCO O&M,MC per Contract**	**Total FY11 OCO O&MN,MC**
Air Vehicles Cost	**2**	24,200,000	48,400,000			
Air Vehicles Quantity		2				
Nonrecurring Kr Manpower				2	6,875,000	13,750,000
Other Nonrecurring Costs				2	4,840,000	9,680,000
In-Theater Services					23,386,880	23,386,880
Total Contractor Costs		**24,200,000**	**48,400,000**		**35,101,880**	**46,816,880**
Gov't Expenses						
Test & Evaluation	**2**	900,000	1,800,000			
OEF Taxes					1,500,000	1,500,000
NAVAIR Team		300,000	300,000	2	2,900,000	5,800,000
Risk/MR Set-aside		1,000,000	1,000,000	2	3,400,000	6,800,000
Total Gov't Expenses		**2,200,000**	**3,100,000**		**7,800,000**	**14,100,000**
Total Project Cost		**$ 26,400,000**	**$ 51,500,000**		**$ 42,901,880**	**$ 60,916,880**

Figure 8. Immediate CUAS Deployment Cost Estimate
(E. N. Pratson, personal communication, June 12, 2011)

Cargo UAS Budget

	FY10	FY11	FY12	FY13	FY14	FY15	FY16	Total
R&D ($M) PE 0305204N, Pr Cde 3332*								
CUAS, (OCO)	51.5	0.0	0.0	0.0	0.0	0.0	0.0	**51.5**
R&D ($M) PE 0604402N, Pr Cde 3332**								
CUAS, (OCO)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
R&D ($M) PE 0603128N***								
CUAS, (Base)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
CUAS, (OCO)	0.0	36.0	0.0	57.9	0.0	0.0	0.0	**93.9**
Operations and Maintenance ($M)								
1A1A, PE 0206312M, (OCO)	2.3	32.0	0.0	0.0	0.0	0.0	0.0	**34.3**
1D4D, PE 0708017N, (Base)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
1D4D, PE 0708017N, (OCO)	0.0	0.0	53.9	46.9	0.0	0.0	0.0	**100.8**
Total ($M)	**53.8**	**68.0**	**53.9**	**104.8**	**0.0**	**0.0**	**0.0**	**280.5**

- *FY10 OCO funds are in a MIP PE. Decision made by OSD comptroller to keep funds in PE for FY10 .
- **N2/N6-designated temporary PE.
- ***Unique non-MIP Cargo UAS PE (approved Nov 10).
- FY10 RDT&E,N: $26.5M + $25.0M (SOCOM) 1415-3 ATR, FAD cut on 18 Nov.
- FY11 OMMC: $32M forward funded by USMC for 2 Dec 2010 award.
  - $36M recolored to RDT&E.N 11 Feb 2011 HAC appropriation bill.

Figure 9. CUAS Budget
(E. N. Pratson, personal communication, June 12, 2011)

The program will be considered a Pre-Acquisition Category (ACAT) Technology Project for demonstration and initial fielding of the system under one or more services contracts. Following the testing and field evaluation, the requirement to continue to support the project in an operational environment may transition the program into the equivalent of an ACAT program. This evaluation would ultimately lead to the development of an appropriate strategy to enter the formal acquisition cycle (E. N. Pratson, personal communication, June 12, 2011).

The CUAS capability can make significant contributions to the following related operational objectives:

- enhance rotary-wing and tilt rotor assault support transport (AST) capabilities;
- reduce risks to the rotary-wing and tilt rotor force, providing an additional alternative for surface transportation; and

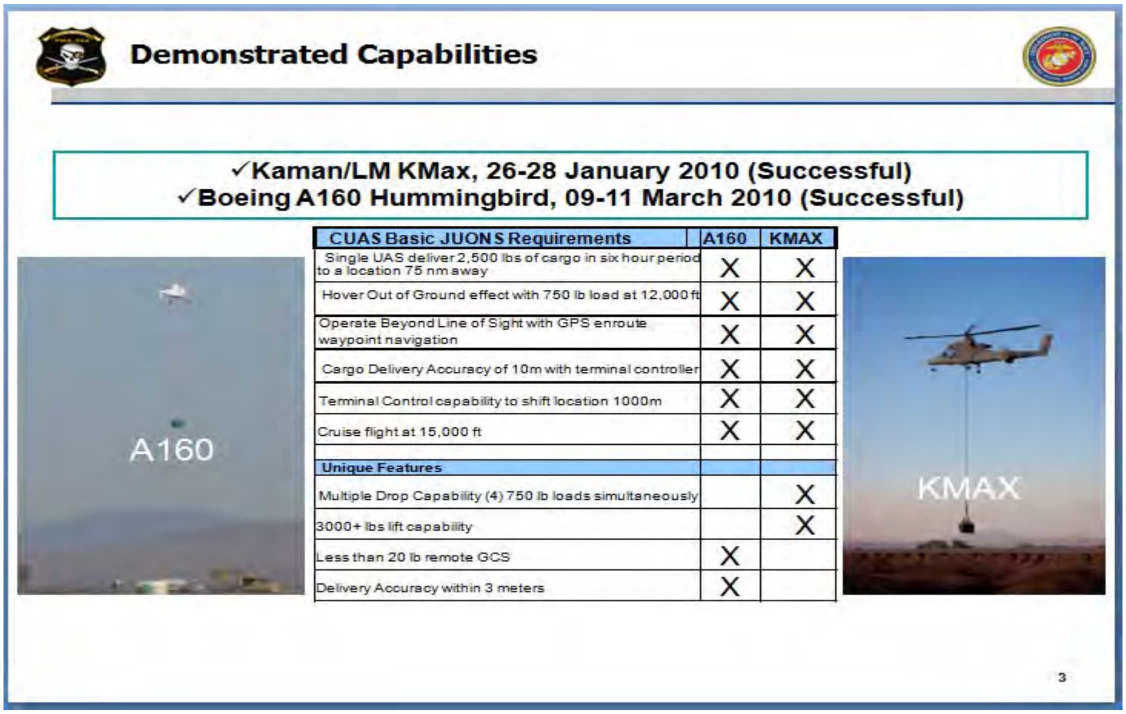
- remove a significant number of vehicles from exposure to enemy threats, such as IEDs.

The desired hardware manifestation of the UAS program is a platform that is capable of carrying 6,000 pounds of cargo delivered over a round-trip distance of 150 nautical miles within a 24-hour period, with a minimum lift of 2,500 pounds in six hours.

Other requirements include the ability to hover at 12,000–15,000 feet and fly at 18,000–20,000 feet with a full cargo load (E. N. Pratson, personal communication, June 12, 2011).

The Marines' key interest in the program is the ability to have a system that can operate autonomously beyond line of sight with GPS en route waypoint navigation and that can be controlled remotely at designated cargo delivery locations. It is anticipated by our research that the CUAS will provide affordable, reliable, effective, and safe resupply missions. Figure 10 provides the capabilities of the Lockheed Martin K-MAX and the Boeing A 160T Hummingbird aircraft variants.

As depicted in Figure 10, both the K-MAX and the A160T have successfully demonstrated the ability to accomplish the following: deliver 2,500 pounds of cargo in a six-hour period to a location 75 nautical miles away, hover with 750-pound loads at 12,000 feet, operate beyond line of sight with GPS en route navigation, deliver cargo with the accuracy of 10 meters with terminal controller, terminal control capability to shift location 1,000 meters, and maintain a cruise flight of 15,000 feet.



CUAS Basic JUONS Requirements	A160	KMAX
Single UAS deliver 2,500 lbs of cargo in six hour period to a location 75 nm away	X	X
Hover Out of Ground effect with 750 lb load at 12,000 ft	X	X
Operate Beyond Line of Sight with GPS enroute waypoint navigation	X	X
Cargo Delivery Accuracy of 10m with terminal controller	X	X
Terminal Control capability to shift location 1000m	X	X
Cruise flight at 15,000 ft	X	X
Unique Features		
Multiple Drop Capability (4) 750 lb loads simultaneously		X
3000+ lbs lift capability		X
Less than 20 lb remote GCS	X	
Delivery Accuracy within 3 meters	X	

Figure 10. UAS Demonstrated Capabilities
(E. N. Pratson, personal communication, June 12, 2011)

The K-MAX's unique features include a multiple drop capability of four 750-pound loads simultaneously and a lift capability of over 3,000 pounds. The A160T's unique features include a ground control station that weighs less than 20 pounds and that has a terminal delivery accuracy of less than three meters (E. N. Pratson, personal communication, June 12, 2011).

Figures 11–13 provide additional specifics about individual company acquisition schedules.

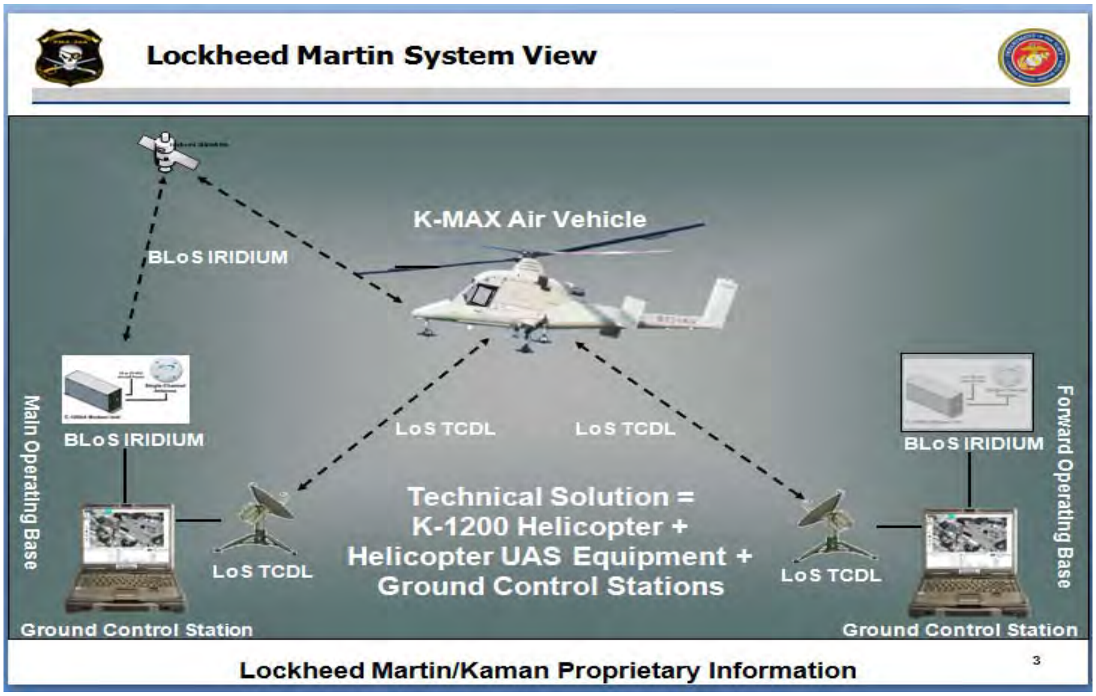


Figure 11. Lockheed Martin System View
(E. N. Pratson, personal communication, June 12, 2011)

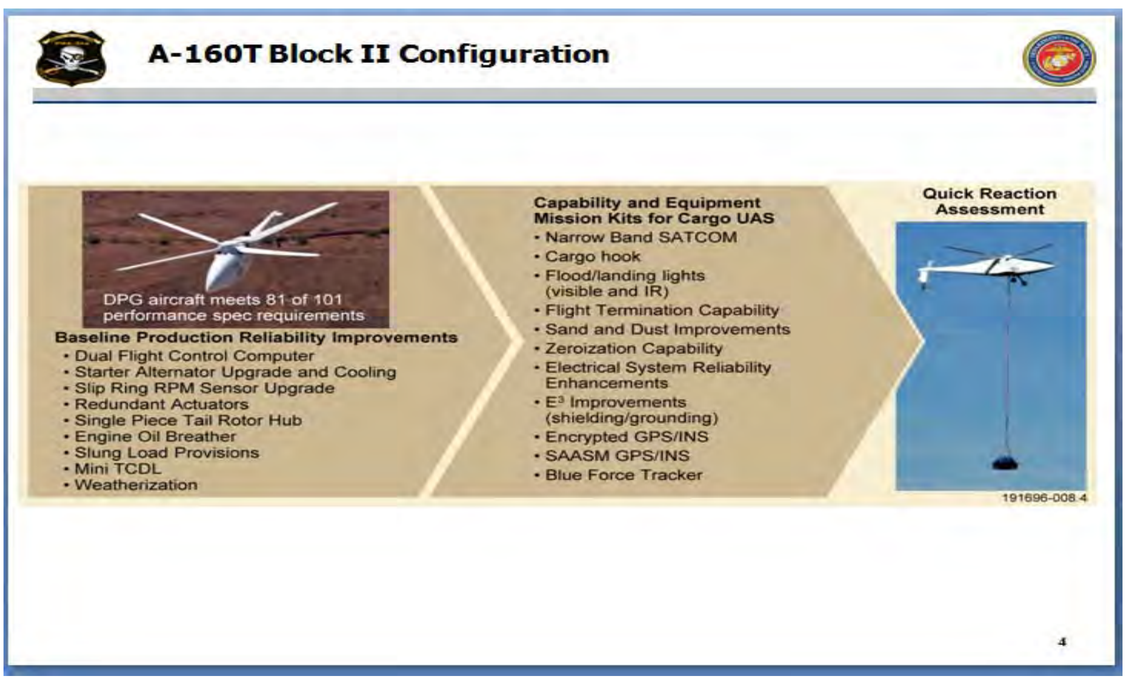


Figure 12. A160T Block II Configuration
(E. N. Pratson, personal communication, June 12, 2011)

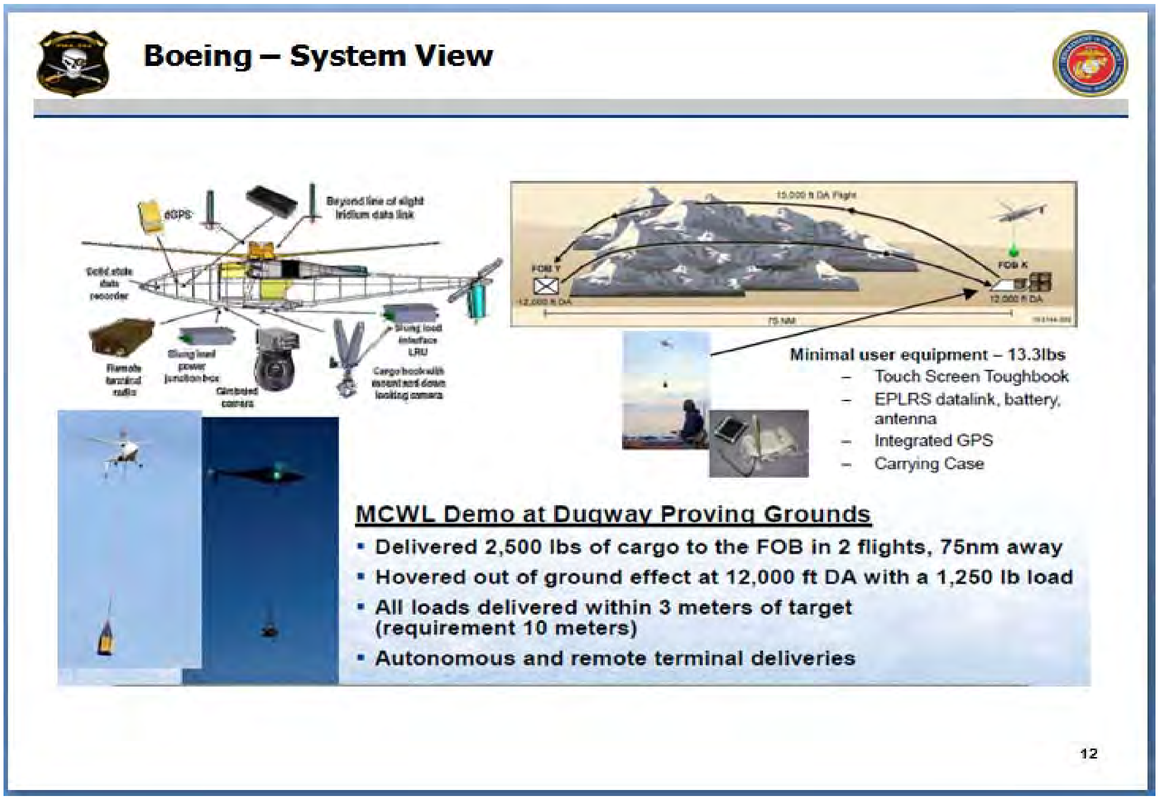


Figure 13. Boeing System View
(E. N. Pratson, personal communication, June 12, 2011)

Upon the completion of all evaluation and field testing, the Navy and Marine leadership's next objective is to determine the best logistical resupply procedures for supporting the Marines at forward locations in Afghanistan. Senior Marine and Navy leadership must make five preliminary decisions: (1) determine if the CUAS capability is a good idea for logistical operations in Afghanistan; (2) determine if UAS integration and employment fits with the current Marine operational strategy in OEF; (3) determine the Marine Corps' capacity to employ UAS working in concert with established doctrine; (4) determine if it makes sense from a resource perspective in the form of timeliness of support, supply mission reliability, and level of casualty risks encountered; and (5) determine if UAS supply vehicles make sense from a technological and operational vantage point.

C. Prior Analysis of CUAS Capability

There have been several in-depth studies previously completed on the topic of CUAS. In this project, we extensively use one study conducted by the Marines and one study conducted by the U.S. Army. The Marine study was completed by the Operations Analysis Division (OAD), Marine Corps Combat Development Command (MCCDC), in 2010. The Army study was completed by the U.S. Army Logistics Innovation Agency in 2011.

The Marine study looked at how the capabilities of CUAS compared to current ground vehicle and assault support aircraft capabilities. The researchers designed the study to evaluate under what conditions employment of unmanned aerial cargo delivery systems would enhance operational capabilities. They also looked at the metrics and data required for inclusion in an operational setting. This study was heavily dependent upon risk analysis. As previously discussed, the current cargo carriers include the Armored MTVR, CH-53E, and KC-130J. CUAS carriers include the K-MAX and the A160T. JPADS cargo carrier includes the Ultra Light (S. R. Parker, personal communication, August 1, 2011).

By way of methodology, the Marine study used data and assumptions from an OEF battalion scenario and an analysis presented to Commanding General, MCCDC in December 2008. Figure 14 provides a graphical depiction of the scenario. As noted previously, we used this scenario as a baseline for our analysis in our project. The scope of the previous Marine study was to investigate resupply support to five FOBs. The researchers in this study specifically looked at the locations of FOBs, the number of personnel at each FOB, the number of vehicles required to resupply each FOB, the total resupply requirement in pounds, the elevation at the FOB, the current logistics concept of operations associated with Afghanistan, and the selected planning factors.

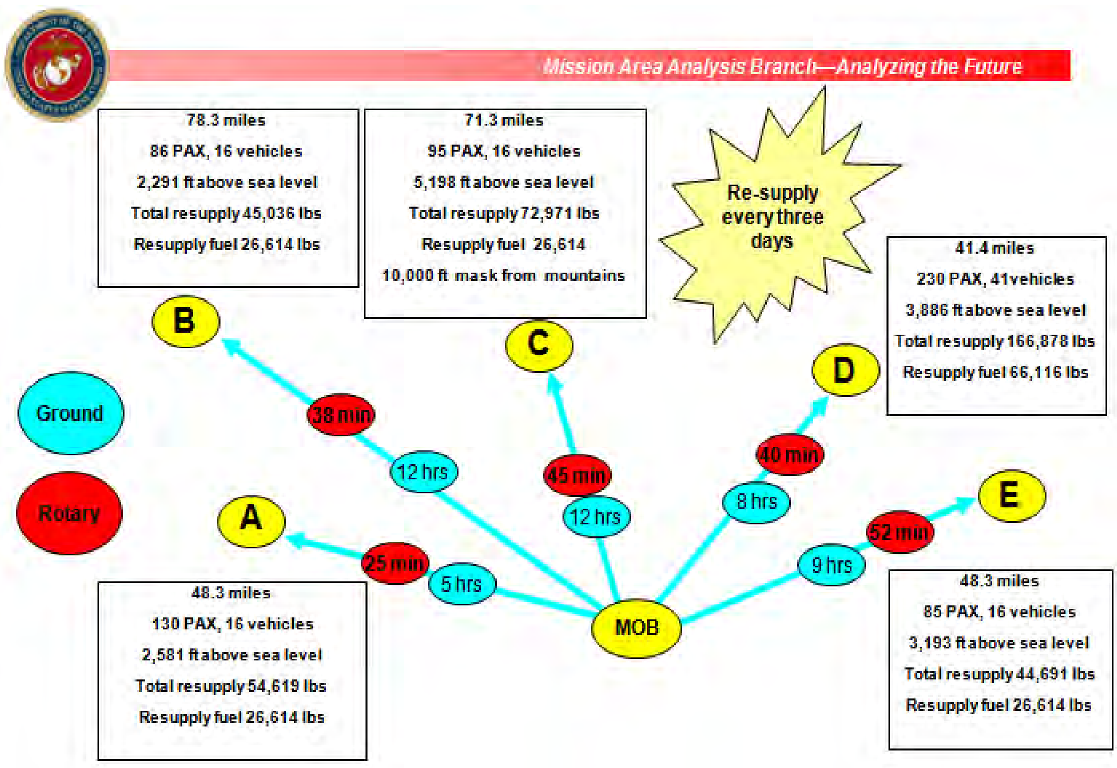


Figure 14. OEF Battalion Scenario
(T. J. Merkle, personal communication, June 9, 2011)

One important baseline assumption for the Marine study was that resupply would be conducted every three days or three days of supply (DOS). Some additional considerations included supply consumption, supply storage, vehicle capabilities, vehicle manning, vehicle availability, vehicle cargo lift capacity, and operating altitude constraints (T. J. Merkle, personal communication, June 9, 2011).

The Marine study developed several important quantifiable measures of effectiveness (MOE) for resupply missions. These MOEs included

- the number of sorties to deliver supplies (three DOS),
- the time to accomplish resupply measured in days,
- the total fuel consumed to deliver supplies measured in gallons,

- the supplies delivered per fuel consumed measured in pounds per gallon,
- the mission man-hours measured per 1,000 pounds of supply,
- the cargo throughput capacity measured in tons per day, and
- the throughput utilization measured in percentage of cargo throughput capacity (T. J. Merkle, personal communication, June 9, 2011).

Key conclusions from the study included the following findings:

- CH-53E or KC-130J options have the current capacity to deliver 100% of required supplies;
- increasing UAS operating hours is critical to obtaining a decisive advantage as it pertains to cargo effectiveness;
- measures other than fuel consumption need to be considered when determining the delivery efficiency of a particular resupply method;
- the amount of security and support for ground convoys has a significant effect on results because it accounts for 46% of fuel consumed in a medium-security convoy and 60% of fuel consumed in a high-security convoy;
- all UAS platforms achieved fuel economy over convoy; and
- cargo capacity, speed, fuel consumption, vehicle availability, and number in crew are all factors that need to be considered when evaluating the delivery effectiveness of any resupply method (T. J. Merkle, personal communication, June 9, 2011).

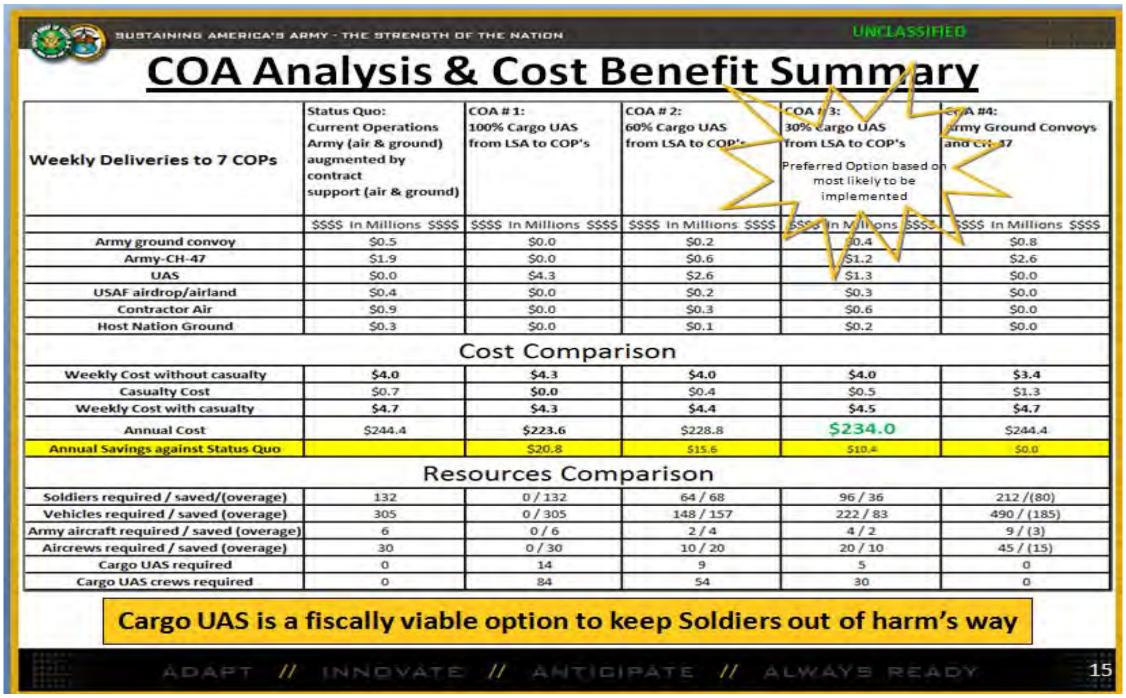
Now that we have looked at the Marine Corps study, we will transition to the Army study. The main goal for this study was to find an affordable resupply alternative that would reduce the risk to soldiers performing resupply operations through traditional means. The Army researchers conducted their analysis using a detailed cost benefit analysis (CBA). The scope of their study was to provide resupply support to seven combat outposts (COPs). Decision criteria for the study included personnel costs, operations costs, maintenance costs, fuel consumption, and casualties. The study used five courses of action (COAs) including status quo, 100% CUAS, 60% CUAS, 30% CUAS, and all Army assets—air and ground (U.S. Army Logistics Innovation Agency, 2011).

Key assumptions for the study included the following:

- further research and development (R&D) for UAS will not be required;
- no acquisition cost will be associated with UAS, only replacement cost;
- no critical or emergency requirements will be used for analysis, only routine resupply;
- manned assets (ground and air) will be available when required; and
- required ground handling equipment and ramp space will be available for staging supplies (U.S. Army Logistics Innovation Agency, 2011).

There were several important CBA cost methods for the various methods of resupply including ground convoy, CH-47, UAS, United States Air Force (USAF) assets, contract air, and contract ground. Ground convoy cost = fuel + manpower + maintenance + attrition + casualty. CH-47 cost includes mission hour cost + personnel cost + attrition + casualty. UAS cost = mission hour cost + personnel cost + attrition. Fixed wing cost = mission hours per week * O&M cost per hour. Contract air cost = mission hour per week * contractor cost. Contract ground cost = number of days per mission per week * contractor daily cost (U.S. Army Logistics Innovation Agency, 2011).

The Army CBA reached a few important conclusions, including that CUAS capability is fiscally viable, reduces the number of soldiers required, takes trucks off the road, and keeps soldiers out of harm's way (U.S. Army Logistics Innovation Agency, 2011). Based on the analysis performed, the Army study concluded that a CUAS is affordable when compared with the other courses of action. Additionally, the study discovered that the Army can expedite the flow of goods and material while at the same time reducing the number of personnel and trucks that would have to handle the same amount of cargo through various nodes (MOBs, FOBs, COPs). Due to the emerging and incremental nature of CUAS technology, this study does not recommend immediate acquisition and operation of CUAS into the Army resupply inventory. The Army study recommends a short-, mid-, and long-term approach to using and making CUAS capability a reality. Figure 15 provides a summary of the Army's CBA.



SUSTAINING AMERICA'S ARMY - THE STRENGTH OF THE NATION

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COA Analysis & Cost Benefit Summary

Weekly Deliveries to 7 COPs	Status Quo: Current Operations Army (air & ground) augmented by contract support (air & ground)	COA # 1: 100% Cargo UAS from LSA to COP's	COA # 2: 60% Cargo UAS from LSA to COP's	COA # 3: 30% Cargo UAS from LSA to COP's Preferred Option based on most likely to be implemented	COA #4: Army Ground Convoys and [illegible]47
	$$$$ In Millions $$$$	$$$$ In Millions $$$$	$$$$ In Millions $$$$	$$$$ In Millions $$$$	$$$$ In Millions $$$$
Army ground convoy	$0.5	$0.0	$0.2	$0.4	$0.8
Army-CH-47	$1.9	$0.0	$0.6	$1.2	$2.6
UAS	$0.0	$4.3	$2.6	$1.3	$0.0
USAF airdrop/airland	$0.4	$0.0	$0.2	$0.3	$0.0
Contractor Air	$0.9	$0.0	$0.3	$0.6	$0.0
Host Nation Ground	$0.3	$0.0	$0.1	$0.2	$0.0
Cost Comparison					
Weekly Cost without casualty	$4.0	$4.3	$4.0	$4.0	$3.4
Casualty Cost	$0.7	$0.0	$0.4	$0.5	$1.3
Weekly Cost with casualty	$4.7	$4.3	$4.4	$4.5	$4.7
Annual Cost	$244.4	$223.6	$228.8	$234.0	$244.4
Annual Savings against Status Quo		$20.8	$15.6	$10.4	$0.0
Resources Comparison					
Soldiers required / saved/(overage)	132	0 / 132	64 / 68	96 / 36	212 /(80)
Vehicles required / saved (overage)	305	0 / 305	148 / 157	222 / 83	490 / (185)
Army aircraft required / saved (overage)	6	0 / 6	2 / 4	4 / 2	9 / (3)
Aircrews required / saved (overage)	30	0 / 30	10 / 20	20 / 10	45 / (15)
Cargo UAS required	0	14	9	5	0
Cargo UAS crews required	0	84	54	30	0

Cargo UAS is a fiscally viable option to keep Soldiers out of harm's way

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Figure 15. COA Analysis and Cost Benefit Summary
(U.S. Army Logistics Innovation Agency, 2011)

D. Business Case Analysis

A BCA is a tool used by managers to assess (inter alia) how a new technology compares to an existing technology that performs the same function. The goal of a BCA is to help management decide whether to invest in the new technology and if that new technology will bring sufficient additional value to the table to justify its costs. The BCA provides a justification for proceeding with a given project. A BCA is best presented in a well-structured, written document and typically describes the background of the project, the expected business benefits, the options considered, the expected costs of the project, the impact to stakeholders, and the expected risks (Defense Acquisition University [DAU], 2011). A BCA typically determines the following:

- the relative cost versus benefits of different support strategies,
- the methods and rationale used to quantify benefits and costs,
- the impact and value of performance/cost/schedule/sustainment tradeoffs,
- the data required to support and justify a performance-based logistics strategy,
- the sensitivity of the data to change,
- the analysis and classification of risks, and
- a recommendation and summary of the implementation plan for proceeding with the best value alternative (DAU, 2011).

BCAs typically continue throughout the life cycle process of the project and are updated as necessary to reevaluate the project because life cycle costs and other improvements may change. Due to this notion, there are no two BCAs that are exactly the same and they are formatted and customized to each specific project. As illustrated in Figure 16, the four steps of a BCA are definition, data collection, evaluation analysis, and results presentation.

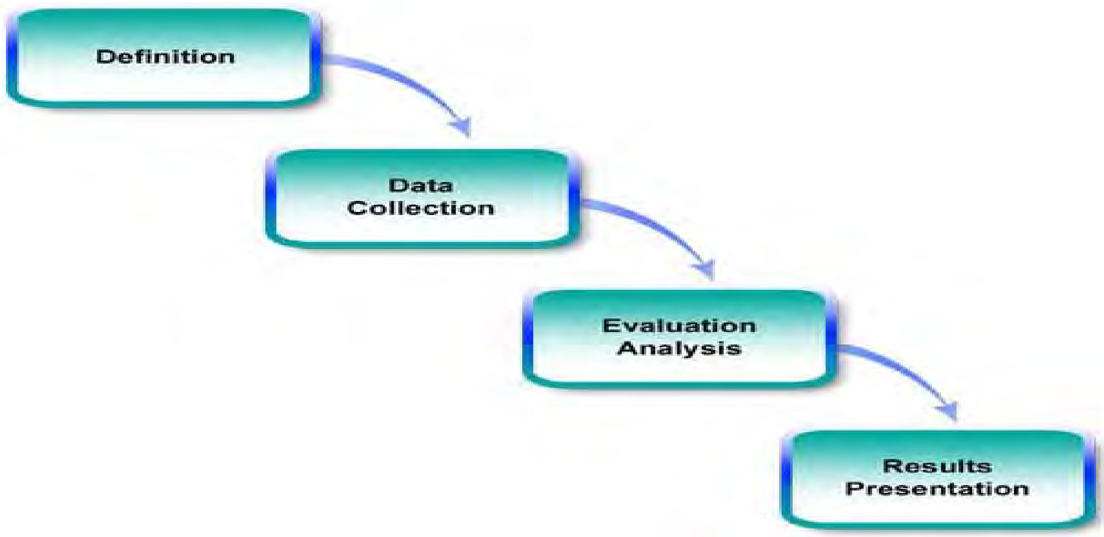

Figure 16. Steps in BCA Process
(DAU, 2011)

1. Definition

In the definition stage of the BCA, managers describe the scope of the analysis and set assumptions, constraints, and scenarios that will direct the analysis. During this stage, the managers identify the groundwork for the BCA and communicate to decision-makers the reasons why the analysis is needed. All alternatives identified are considered and compared to the status quo (DAU, 2011).

2. Data Collection

In the data collection stage, managers identify the types of data that will be necessary to complete the analysis and classify that data into categories. They identify data sources and all relevant data, including cost data, as well as performance data. Managers estimate any data that is not available and describe the approach to that estimation. They normalize all data and scrutinize for accuracy. Data normalization ensures that "apples are being compared to apples" (DAU, 2011).

3. Evaluation Analysis

In the evaluation analysis, managers use the data collected in the second stage of the BCA and begin the applicable calculations using both quantitative and qualitative data. They compare each scenario against the other to determine which alternative has the lowest cost and the best performance. Managers then identify an optimal combination of low cost and high performance to find the best value alternative. They also conduct a risk and sensitivity analysis, identify potential risks, and determine ways of mitigating those risks. Sensitivity analysis determines the effect that changes in particular inputs and constraints will have on the analysis (for example, changes in fuel costs or lower costs of the new alternative may change the solution; DAU, 2011).

4. Results Presentation

The results presentation is the final stage and is where managers communicate the results of the analysis to the decision-makers. Managers construct their conclusions around the objectives of the analysis that they stated earlier in the case. They use charts and graphs to communicate the results of all quantitative data along with a narrative description to ensure that the results are easily interpreted. They also discuss any unexpected results, outliers, or easily misinterpreted results. Finally, they identify a recommended course of action and state support for that recommendation to bring closure to the analysis (DAU, 2011).

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III. CUAS Business Case Analysis Methodology

The purpose of this analysis is to compare the benefits of the CUAS to the existing delivery methods for cargo resupply missions in Afghanistan. As discussed in the background chapter, we analyzed two CUAS helicopter systems: Boeing's A160T Hummingbird and Lockheed Martin's K-MAX. For the status quo, we analyzed four methods for resupply: medium-security ground convoy, high-security ground convoy, CH-53E, and KC-130J with JPADs.

In this chapter, we describe the five representative scenarios used to assess CUAS as a method of resupply. Using the BCA we compare the costs of these platforms performing various logistical resupply missions. We explain the composition of required personnel and assets for each method of resupply in Section A. We explain the individual characteristics and capabilities for each method of resupply in Section B, the scenarios in Section C, the known cost drivers in Section D, and the models used in the analysis in Section E.

In Chapter IV, we present the analysis of the available data. In Section A of Chapter IV, we present a linear programming transportation model that takes account of routine resupply missions and risk exposure. This is followed by a computation of baseline and alternative solutions for resupply optimization in Sections B and C. Section D is comprised of the internal rate of return. In Section E, we describe sensitivity analysis with respect to the cost of human life. In Section F, we illustrate risk analysis.

A. Composition of Required Personnel and Assets for Methods of Resupply

For planning purposes, medium-security ground convoys require 18 personnel, including three armored HMMWVs and three armored MTVRs. The number of personnel is calculated based on each vehicle having a driver, a vehicle commander, and a gunner. High-security ground convoys require 36 personnel, including eight armored HMMWVs and four armored MTVRs. CH-53Es require four personnel, including two pilots and two aircrew members. KC-130Js with JPADS require four personnel, including two pilots, a flight engineer, and a loadmaster. Both variants of CUAS require zero pilots but they do require eight Marines, including one contracting officer representative (COR), two mission commanders (naval aviators or air traffic controllers), and five unmanned aerial vehicle squadron (VMU) enlisted air vehicle operators. There will be a ground control station (GCS) located at the MOB, as well as a GCS located at each of the FOBs (T. J. Merkle, personal communication, June 9, 2011).

B. Characteristics of Assets for Resupply

In our scenarios, only MTVRs were used to carry cargo in the medium- and high-security ground convoys. HMMWVs were used as maneuver and security vehicles. Characteristics of an armored MTVR include a payload with trailer of 21,400 pounds, a fuel consumption rate of 13.3 gallons per hour, an average speed in scenario of 9.7 miles per hour, and 12 hours of operational use per day. Thus, a medium-security ground convoy has a maximum payload of 64,200 pounds with a fuel consumption rate of 57.9 gallons per hour and a high-security ground convoy has a maximum payload of 85,600 pounds with a fuel consumption rate of 102.2 gallons per hour (T. J. Merkle, personal communication, June 9, 2011).

Characteristics of a CH-53E include a maximum payload with sling of 17,125 pounds, fuel consumption with external load of 573.5 gallons per hour, a maximum altitude of 18,480 feet, and a cruising speed of 120 knots (T. J. Merkle, personal communication, June 9, 2011).

For our analysis, we looked at the employment of precision-guided air delivery through the employment of JPADS from the KC-130J platform. Characteristics of a KC-130J include a maximum payload of 35,000 pounds, fuel consumption of 800 gallons per hour, a maximum altitude of 28,000 feet, a cruising speed of 240 knots, and a maximum of five JPAD systems. JPADS characteristics include an ultra light weight (ULW) variant payload of 250–700 pounds (S. R. Parker, personal communication, August 1, 2011).

K-MAX characteristics include a maximum payload of 4,915 pounds, a maximum altitude of 15,000 feet, egress cruising speed (no sling) of 100 knots, ingress cruising speed (sling) of 80 knots, a fuel consumption rate for egress of 73.5 gallons per hour, and a fuel consumption rate for ingress of 102.9 gallons per hour (T. J. Merkle, personal communication, June 9, 2011).

A160T characteristics include a maximum payload of 1,250 pounds, a maximum altitude of 20,000 feet, egress cruising speed (no sling) of 94.9 knots, ingress cruising speed (sling) of 56.7 knots, a fuel consumption rate for egress of 21.1 gallons per hour, and a fuel consumption rate for ingress of 22.4 gallons per hour (T. J. Merkle, personal communication, June 9, 2011).

C. Operational Scenarios

The operational scenario we created for this analysis is based on a strategic employment plan to provide responsive logistics to Marines operating in austere forward deployed detachments. Specifically, the scenario depicts an infantry battalion operating in Afghanistan with five FOBs. These five FOBs are operationally realistic and were chosen by MCCDC to represent the variance in number of forces, total resupply requirements, and distances to the FOBs from the MOB. The period between resupply missions is three days. The requirement of pounds per Marine varies based on the mission being conducted at each respective FOB. For instance, an FOB that possesses a weapons company will require more pounds per resupply mission compared to a rifle company. These scenarios are used in our analysis to estimate the life cycle costs of the resupply methods. The following five FOBs were used to develop the tasking requirements for the analytical scenarios:

- FOB A is located 48.3 miles from the MOB and the total resupply required is 54,619 pounds for 130 Marines,
- FOB B is located 78.3 miles from the MOB and the total resupply required is 45,036 pounds for 86 Marines,
- FOB C is located 71.3 miles from the MOB and the total resupply required is 72,971 pounds for 96 Marines,
- FOB D is located 41.4 miles from the MOB and the total resupply required is 168,878 pounds for 230 Marines, and
- FOB E is located 48.3 miles from the MOB and the total resupply required is 44,691 pounds for 85 Marines (T. J. Merkle, personal communication, June 9, 2011).

1. CUAS Operating Base (MOB)

For the purpose of comparison, it is assumed that both CUAS and status quo methods of resupply missions may be launched from Camp Bastion, where the MOB is located.

2. Time Calculations for Resupply Missions by Platform

Time required per resupply mission was given for ground convoys, as well as fixed and rotary wing. For each ground convoy, we used the miles from the MOB to the FOB to drive our cost analysis. For each air platform, we first converted its cruising speed with payload from knots to miles per hour, then found the correct cruising speed, and finally multiplied by the number of miles traveled. For example, the following calculations are for a CH-53E for FOB A resupply:

- CH-53E cruising speed with payload converted to miles per hour (120 knots * 1.150 = 138.1 miles/hour), and
- cruising speed (138.1 miles/hour) multiplied by the number of miles to FOB A (48.3 miles) = 0.35 hours.

Table 1 provides a summary of distances and times required to conduct resupply missions to various FOBs.

Table 1. Summary of Distance and Time to Conduct Resupply Missions to FOBs

Location	Distance to FOB's	#Trucks High Security	#Trucks Medium Security	Hours CH-53E	Hours KC-130J	Hours A160T	Hours K-MAX
FOB A	96.6	12	6	0.70	0.65	1.11	0.93
FOB B	156.6	12	6	1.13	1.05	1.80	1.51
FOB C	142.6	12	6	1.03	0.95	1.64	1.38
FOB D	82.8	12	6	0.60	0.55	0.95	0.80
FOB E	96.6	12	6	0.70	0.65	1.11	0.93

D. Known Cost Drivers

1. Platform Procurement/Replacement Costs

Due to the nature of military employment, we know that there will be a rate of attrition, which means replacing assets that are destroyed through enemy engagements or other mishaps. We estimated the replacement costs for each resupply platform. These costs are described in more detail in our discussion related to risk exposure. Table 2 provides a summary of these procurement and replacement costs.

Table 2. Summary of Replacement and Procurement Costs

Platform	Procurement Costs/Replacement Costs	Data Source
CH-53E	$26,100,000	Global Security, 2011a
KC-130J	$52,000,000	Global Security, 2011b
MTVR	$230,000	Deagel, 2011
HMMWV	$143,632	Army-Guide, 2011
A160T	$12,020,928	E. N. Pratson, personal communication, June 12, 2011
K-MAX	$11,105,912	E. N. Pratson, personal communication, June 12, 2011
GCS FOB (Lockheed Martin)	$410,715	E. N. Pratson, personal communication, June 12, 2011
GCS FOB (Boeing)	$300,881	E. N. Pratson, personal communication, June 12, 2011
GCS MOB (Lockheed Martin)	$1,000,000	E. N. Pratson, personal communication, June 12, 2011
GCS MOB (Boeing)	$1,637,000	E. N. Pratson, personal communication, June 12, 2011
JPADS	$12,000	E. N. Pratson, personal communication, June 12, 2011

2. Platform Operating and Support Costs

We estimated operating and support costs for each resupply platform using dollars per mile for ground convoys and dollars per flight hour for air platforms. The calculations for ground convoy costs include fuel/mile + manpower/mile + maintenance/mile + personnel risk exposure/mile + platform risk exposure/mile. The calculations for CH-53E are fuel/hour + manpower/hour + maintenance/hour + personnel risk exposure/hour + platform risk exposure/hour. The calculations for KC-130J are fuel/hour + manpower/hour + maintenance/hour + personnel risk exposure/hour + platform (KC-130J) risk exposure/hour + platform (JPADS) risk exposure/hour. The calculations for JPADS costs include 0.05 * $12,000 (replacement costs). This cost is based on the assumption that 95% of the JPADS will be recovered (GPS and associated sensitive equipment) for each evolution, whereas the canopy will not always be recovered in a reusable manner. The calculations for both variants of CUAS costs included fuel/hour + maintenance/hour + GCS manpower/hour + risk exposure platform/hour. Table 3 provides a summary of these platforms' operating and support costs.

Table 3. Summary of Platform Operating and Support Costs

Platform	Fuel Costs	Manpower Costs	Maintenance Costs	Personnel Risk Exposure	Platform Risk Exposure	Total ($)	Data Source
MTVR (per mile)	$4.11	$18.38	$6.20	$1,393.20	$26.00	$1,447.89	U.S. Army Logistics Innovation Agency, 2011
HMMWV (per mile)	$1.86	$18.38	$6.20	$1,393.20	$16.00	$1,435.64	U.S. Army Logistics Innovation Agency, 2011
CH-53E (per flight hour)	$1,031.73	$5,794.83	$18,460.08	$619.20	$673.00	$26,578.84	VAMOSC, 2011
KC-130J (per flight hour)	$2,708.04	$4,179.47	$4,707.88	$619.20	$1,342.00	$13,556.59	VAMOSC, 2011
JPADS	N/A	N/A	N/A	N/A	$600.00	$600.00	S. R. Parker, personal communication, August 1, 2011
A160T (per flight hour)	$20,720			N/A	$1,298.00	$22,018.00	Defense Acquisition Management Information Retrieval, 2011
K-MAX (per flight hour)	$20,720			N/A	$1,199.00	$21,919.00	Defense Acquisition Management Information Retrieval, 2011

3. Personnel Risk Exposure

In order to incorporate risk exposure into our BCA, we made an assumption that the cost of life for each Marine killed is $6 million. This figure is based on life insurance, survivor benefits, loss of earnings, lost human capital, and welfare lost to society. The DoD does not publically place a value on human life. However, other U.S. government agencies do place a value on human life. For example, the Department of Transportation and the Federal Aviation Administration use $3 million, the Environmental Protection Agency uses $6.1 million, the Food and Drug Administration uses $6.5 million, and the Consumer Products Safety Commission uses $5 million (Silny, Little, & Remer, 2010). All of these values are based on year 2006 U.S. dollars and were used as a reference for our $6 million value.

In order to properly account for the loss of a Marine killed, we used the following calculation: rate of loss of personnel due to enemy or mishap * number of personnel exposed to risk per platform * $6,000,000. The loss rate of ground personnel was determined by using the 2008 joint IED defense office study, which stated that on average

- ground convoys are attacked every 808 miles and there would be one killed in action (KIA) out of every 16 attacks;
- assumption of a one-year deployment resulted in 122 ground convoys (365/3=122);
- 122 convoys multiplied by the total miles traveled for one complete replenishment of all five FOBs equaled 575.2 miles;
- 122 convoys * 575.2 miles resulted in 70,175 total miles per year;
- total miles per year divided by miles per attack resulted in 87 attacks (70175/808 = 87 attacks);
- 87 total attacks per year divided by every 16 attacks resulted in one KIA per 5.43 attacks (87/16 = 5.43);

- total miles traveled divided by attacks resulted in a KIA rate of 0.0000774 (5.43/70,175 = 0.0000774); and
- attack rate multiplied by the $6,000,000 cost of human life, resulted in a $1,393.20 per mile per truck cost. (General Dynamics, 2010)

The loss rates for fixed and rotary wing aircraft were calculated from statistics taken from the Naval Safety Center (2011). They were calculated by the number of Class A (property damage over $2 million and/or fatality or permanent disability) mishaps divided by the total flight hours per platform. Once these calculations were completed, we added the associated costs to the operating costs for each ground and air platform. Table 4 provides a summary of these personnel risk exposure costs.

Table 4. Summary of Personnel Risk Exposure Costs

Personnel	Loss of Personnel Due to Enemy or Mishap (Rate)	Number of Personnel Exposed	Value of Human Life	Total ($)	Source of Data
CH-53E (per flight hour)	0.0000258	4	$6,000,000	$619.20	Naval safety center, 2011
KC-130J (per flight hour)	0.0000258	4	$6,000,000	$619.20	Naval safety center, 2011
MTVR (per mile)	0.0000774	3	$6,000,000	$1,393.20	General Dynamic, 2010
HMMWV (per mile)	0.0000774	3	$6,000,000	$1,393.20	General Dynamic, 2010

4. Platform Risk Exposure

We also investigated losses that were associated with each method of resupply as follows: rate of loss of resupply platform due to enemy or mishap * replacement costs for platforms. The loss rate of ground personnel was determined by using the 2008 joint IED defense office JIEDDO as stated in the General Dynamics AR-5 study, 2010. This study stated that

- on average, ground convoys are attacked every 808 miles;
- one ground convoy prevented from completing its resupply mission for every 11 attacks;
- assumption of a one-year deployment resulting in 122 ground convoys (365/3 = 122) multiplied by the total miles traveled for one total replenishment of all five FOBs equaling 575.2 miles resulting in 70,175 total miles per year;
- total miles per year divided by miles per attack (70175/808 = 87 attacks) resulted in 87 attacks;
- 87 total attacks per year divided by every 11 attacks resulting in one resupply mission being prevented (87/11 = 7.91) resulted in a rate of 7.91 attacks;
- rate of attacks resulting in resupply missions being prevented was then divided by total miles (7.91/70,175 = 0.000113) resulting in a rate of 0.000113;
- attack rate is then multiplied by the procurement cost of ground vehicles and provides a per mile cost for each ground platform;
- loss rates for manned fixed and rotary wing aircraft were taken from the Naval Safety Center and are the same calculation as previously stated for the risk exposure of personnel; and
- unmanned loss rates were taken from the average loss rates of the MQ-9 Reaper (Air Force Safety Center, 2008). They were calculated by dividing the total Class A Mishaps by the total flight hours.

Once these calculations were completed we added the associated costs to the operating costs for each platform. Table 5 provides a summary of these platform risk exposure costs.

Table 5. Summary of Platform Risk Exposure Costs

Platforms	Loss of Asset Due to Enemy or Mishap (Rate)	Replacement Cost of Asset	Total ($)	Source of Data
CH-53E (per flight hour)	0.0000258	$26,100,000	$673	Naval safety center, 2011
KC-130J (per flight hour)	0.0000258	$52,000,000	$1,342	Naval safety center, 2011
MTVR (per mile)	0.000113	$230,000	$26	General Dynamic, 2010
HMMWV (per mile)	0.000113	$143,632	$16	General Dynamic, 2010
A160T (per flight hour)	0.000108	$12,020,928	$1,298	Air Force safety center, 2010
K-MAX (per flight hour)	0.000108	$11,105,912	$1,199	Air Force safety center, 2010
JPADS (per flight hour)	0.05	$12,000	$600	S. R. Parker, personal communication, August 1, 2011

E. Model Development

In order to conduct our analysis, we used a linear programming transportation model. The objective function minimizes cost during resupply missions, while the constraints are total pounds required for each FOB, time required for resupply, platform payload capacities, and operating and support costs. Our analysis looked at both routine resupply missions and risk exposure. The next section is a detailed description of the optimization model.

1. Routine Resupply Mission Model

Decision Variables:

X_{ijk} = the number of deliveries transported from MOB *i* to FOB *j* via platform *k*.

where:

i = MOB (M)

j = FOB (A, B, C, D, E)

k = GMS (ground medium security), GHS (ground high security), CH (CH-53E), C (KC- 130J), HUM (A160T Hummingbird), MAX (K-MAX)

Objective Function:

Minimize total transportation costs =

$$64290X_{MAGMS} + 85600X_{MAGHS} + 17125X_{MACH} + 35000X_{MAC} + 1250X_{MAHUM} + 4915X_{MAMAX} + 64290X_{MBGMS} + 85600X_{MBGHS} + 17125X_{MBCH} + 35000X_{MBC} + 1250X_{MBHUM} + 4915X_{MBMAX} + 64290X_{MCGMS} + 85600X_{MCGHS} + 17125X_{MCCH} + 35000X_{MCC} + 1250X_{MCHUM} + 49151X_{MCMAX} + 64290X_{MCGMS} + 85600\mathrm{MCGHS} + 17125\mathrm{MDCH} + 35000\mathrm{MDC} + 1250X_{MCHUM} + 4915X_{MDMAX} + 64290X_{MEGMS} + 85600X_{MEGHS} + 17125X_{MECH} + 35000X_{MEC} + 1250X_{MEHUM} + 4915X_{MEMAX}$$

Subject to constraints:

$X_{MAGMS} + X_{MAGHS} + X_{MACH} + X_{MAC} + X_{MAHUM} + X_{MAMAX} \geq$ 54,619 pounds (FOB A Demand)

XMBGMS + XMBGHS + XMBCH + XMBC + XMBHUM + XMBMAX ≥ 45,036 pounds (FOB B Demand)

XMCGMS + XMCGHS + XMCCH + XMCC + XMCHUM + XMCMAX ≥ 72,971 pounds (FOB C Demand)

XMDGMS + XMDGHS + XMDCH + XMDC + XMDHUM + XMDMAX ≥ 166,878 pounds (FOB D Demand)

XMEGMS + XMEGHS + XMECH + XMEC + XMEHUM + XMEMAX ≥ 44,619 pounds (FOB E Demand)

Xmagms + Xmaghs + Xmach + Xmac + Xmahum + Xmamax > 54,619 + 20% pounds (FOB A Demand)

Xmbgms + Xmbghs + Xmbch + Xmbc + Xmbhum + Xmbmax > 45,036 + 20% pounds (FOB B Demand)

Xmcgms + Xmcghs + Xmcch + Xmcc + Xmchum + Xmcmax > 72,971 + 20% pounds (FOB C Demand)

Xmdgms + Xmdghs + Xmdch + Xmdc + Xmdhum + Xmdmax > 166,878 + 20% pounds (FOB D Demand)

Xmegms + Xmeghs + Xmech + Xmec + Xmehum + Xmemax > 44,619 + 20% pounds (FOB E Demand)

XMAGMS + XMBGMS + XMCGMS + XMDGMS + XMEGMS ≤ 4 (Sorties/Convoys)

XMAGHS + XMBGHS + XMCGHS + XMDGHS + XMEGHS ≤ 4 (Sorties/Convoys)

XMACH + XMBCH + XMCCH + XMDCH + XMECH ≤ 8 (Sorties/Convoys)

XMAC + XMBC + XMCC + XMDC + XMEC ≤ 2 (Sorties/Convoys)

XMAHUM + XMBHUM + XMCHUM + XMDHUM + XMEHUM ≤ 8 (Sorties/Convoys)

XMAMAX + XMBMAX + XMCMAX + XMDMAX + XMEMAX ≤ 8 (Sorties/Convoys)

All variables ≥ 0 (non-negativity)

The decision variables for this linear programming model resulted in 30 potential methods of delivering supplies to the FOBs due to the fact that there are five destinations and six platforms capable of completing the resupply missions. Decision variables denote the flow of supplies between two nodes in the transportation network. For simplicity, the flows of supplies are represented by a triple-subscripted decision variable. The first subscript represents the origin of the supplies. The second subscript represents the destination of the supplies. The third subscript represents the platform that was used to transport the supplies. The objective function for this model seeks to minimize the total transportation costs associated with the platform or platforms used in that resupply mission.

The demand constraints represent the total demand of supplies that are necessary at each FOB. The convoy/sortie constraints represent the total number of convoys or sorties that are available at the time when resupply missions are required. The convoy/sortie constraint also takes into account the payload of each platform and ensures that the platforms chosen do not exceed their payload capacity (Balakrishnan, Render, & Stair, 2007, pp. 191–193).

IV. Cargo UAS Business Case Analysis Data Analysis

A. Utilization of Crystal Ball's OptQuest Application for Linear Optimization

We used a linear programming transportation model to conduct our data analysis. The objective function was to minimize total transportation cost during resupply missions. These missions were constrained by total pounds required for each FOB, time required for resupply, platform payload capacities, and operating and support costs. Initially, we attempted in our analysis to utilize Excel's Solver Application, but we quickly found that the Solver Application was not able to provide feasible solutions. This was in large part due to the complexity of the constraints, specifically the requirement for specified pounds per FOB. The main issue that arose was that Solver was not maximizing on the utilization of the K-MAX UAS as compared to ground convoys. Upon encountering this issue, we transitioned our transportation model to Crystal Ball's OptQuest application due to its more powerful optimization capability. Thus, we were able solve the model and obtain feasible solutions.

B. Baseline/Status Quo for Resupply Optimization

1. Baseline 1 (GMS, CH-53E, AND KC-130J)

In order to develop the potential benefits of CUAS, we need to establish baseline costs by capturing the true costs of only utilizing status quo platforms for resupply. We created two baselines: Baseline 1 assumes a moderate security threat and uses ground medium security along with CH-53E and KC-130J; Baseline 2 assumes a high security threat and uses ground high security along with CH-53E and KC-130J. Using OptQuest, Baseline 1 was found to have a total minimized transportation solution of $1,766,641. A graphical depiction of Baseline 1 is represented in Figure 17.

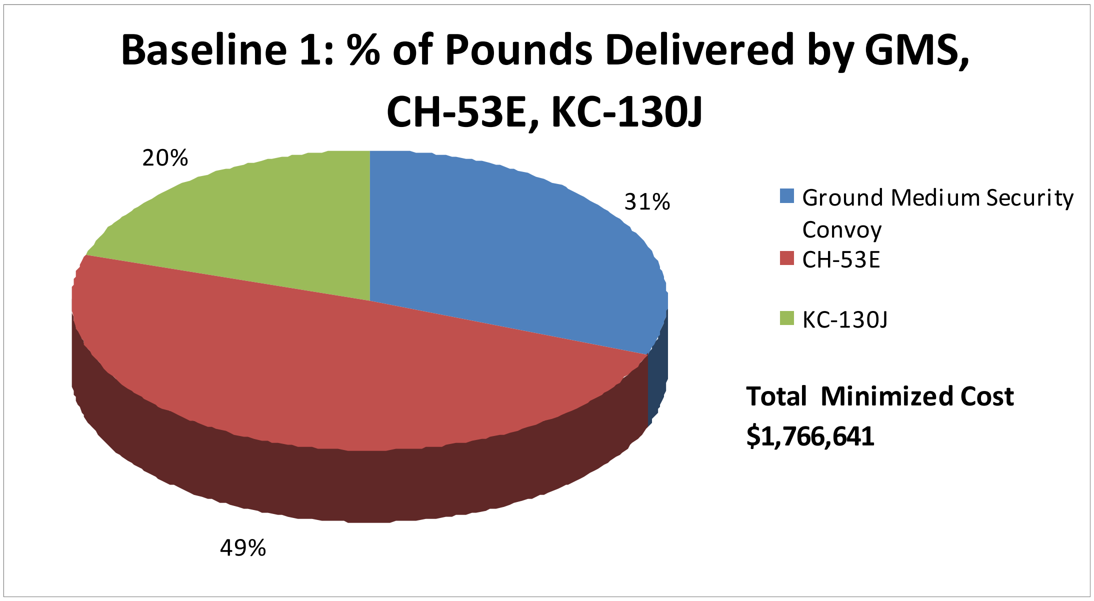

Figure 17. Baseline 1

2. Baseline 2 (GHS, CH-53E, AND KC-130J)

Baseline 2 assumes a high security threat and uses ground high security along with CH-53E and KC-130J. Using OptQuest, Baseline 2 was found to have a total minimized transportation solution of $3,141,644. A graphical depiction of Baseline 2 is represented in Figure 18.

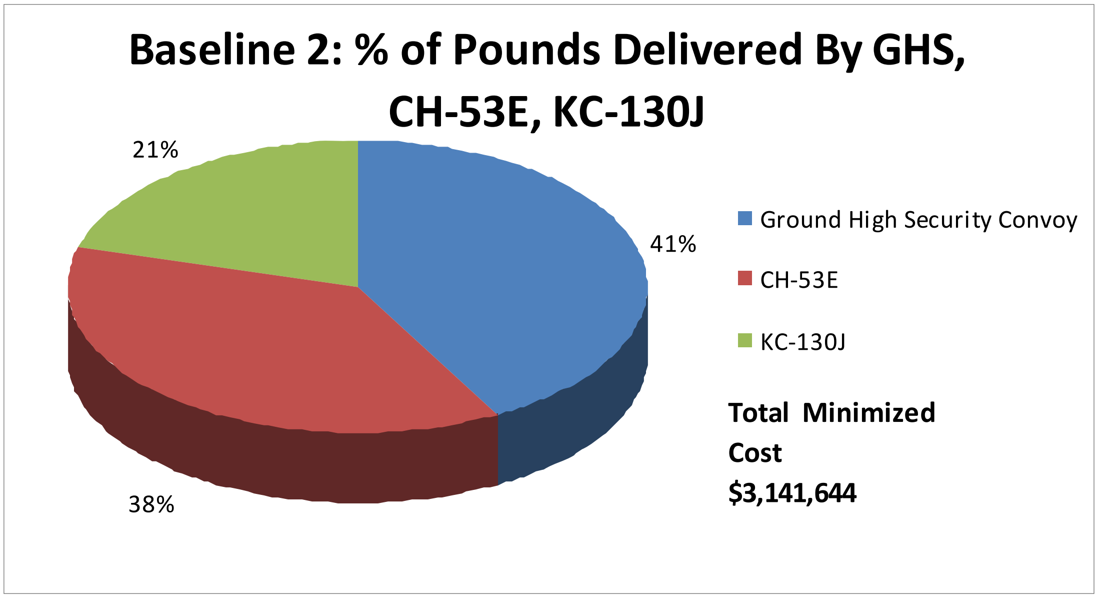

Figure 18. Baseline 2

C. Alternatives for Resupply Optimization

1. Alternative 1 (GMS, CH-53E, KC-130J, AND K-MAX UAS)

After we established baselines, we found four alternative solutions utilizing both variants of CUAS, both forms of ground convoys, and CH-53E and KC-130J. Using OptQuest, Alternative 1, depicted in Figure 19, shows that with the use of K-MAX CUAS, ground convoys can be completely eliminated with a reduced transportation cost of $743,517. This alternative illustrates the fact that an all-air method resupply has the potential to be an attractive solution, in large part due to the K-MAX's large payload capacity. A graphical depiction of Alternative 1 is displayed in Figure 19.

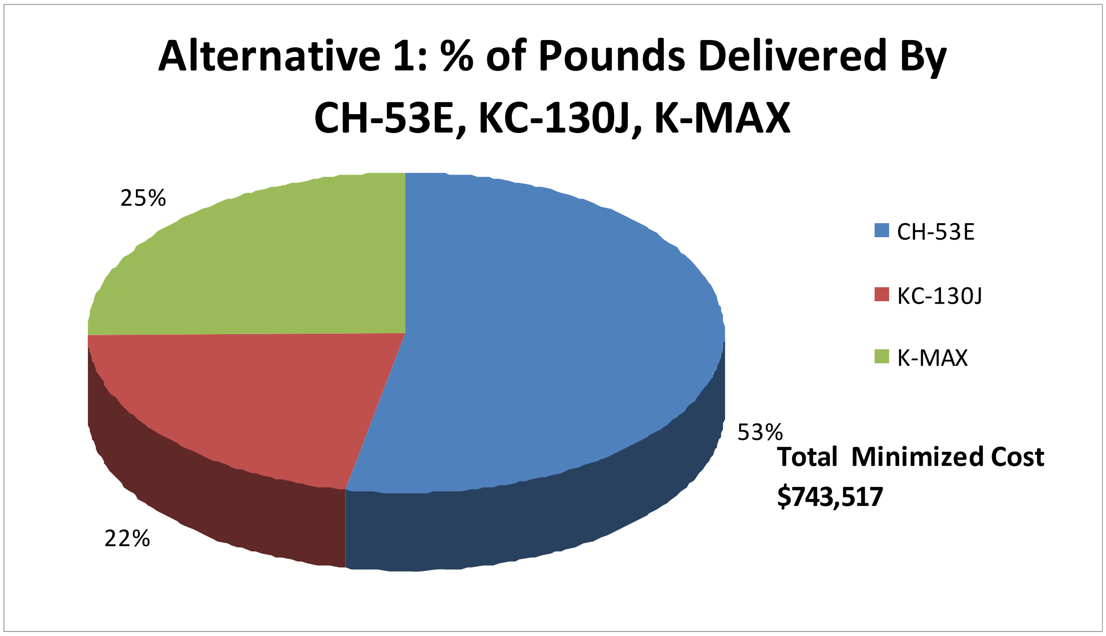

Figure 19. Alternative 1

2. Alternative 2 (GMS, CH-53E, KC-130J AND A160T UAS)

Alternative 2, depicted in Figure 20, illustrates the fact that the A160T was only used for 4% of the cargo replenishment and has a total transportation cost of $2,416,737. Of note, this alternative has a total transportation cost of over three times the cost of Alternative 1. It is appartent by analyzing this alternative that the A160T CUAS is not an attractive method of resupply because it does not take convoys out of the solution and actually increases the total cost of transportation.

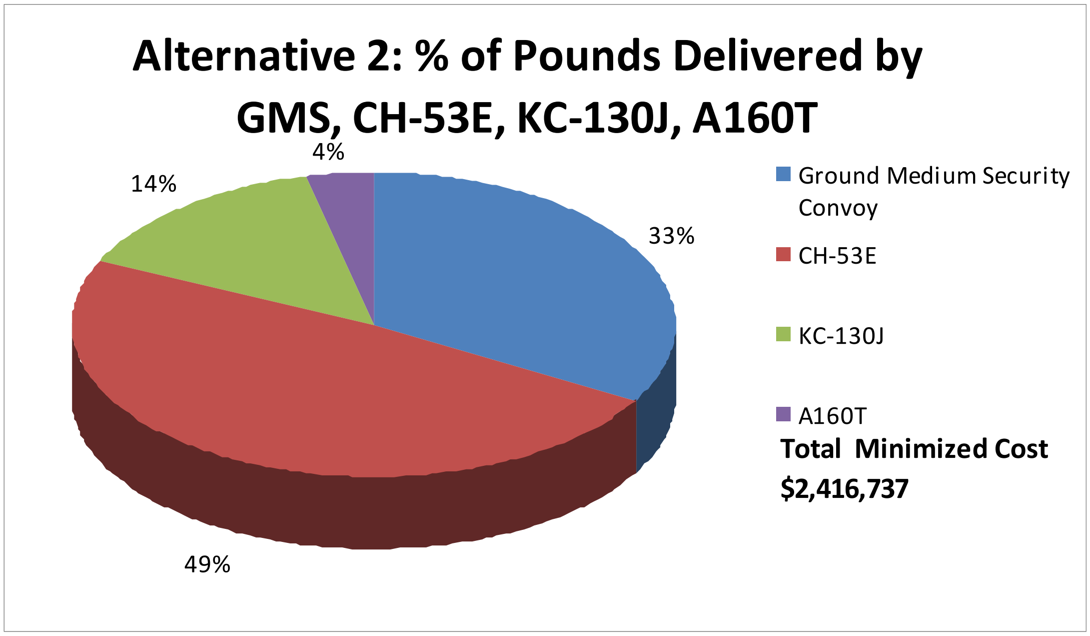

Figure 20. Alternative 2

3. Alternative 3 (GHS, CH-53E, KC-130J AND K-MAX UAS)

Although Alternative 3, depicted in Figure 21, would in theory use ground high security convoys, the solution ends the same as Alternative 1, with a total transportation cost of $743,517. This alternative illustrates the fact that with the utilization of K-MAX CUAS, ground convoys can once again be eliminated from the solution. In addition, this alternative illustrates the fact that an all-air method resupply has the potential to be an attractive solution.

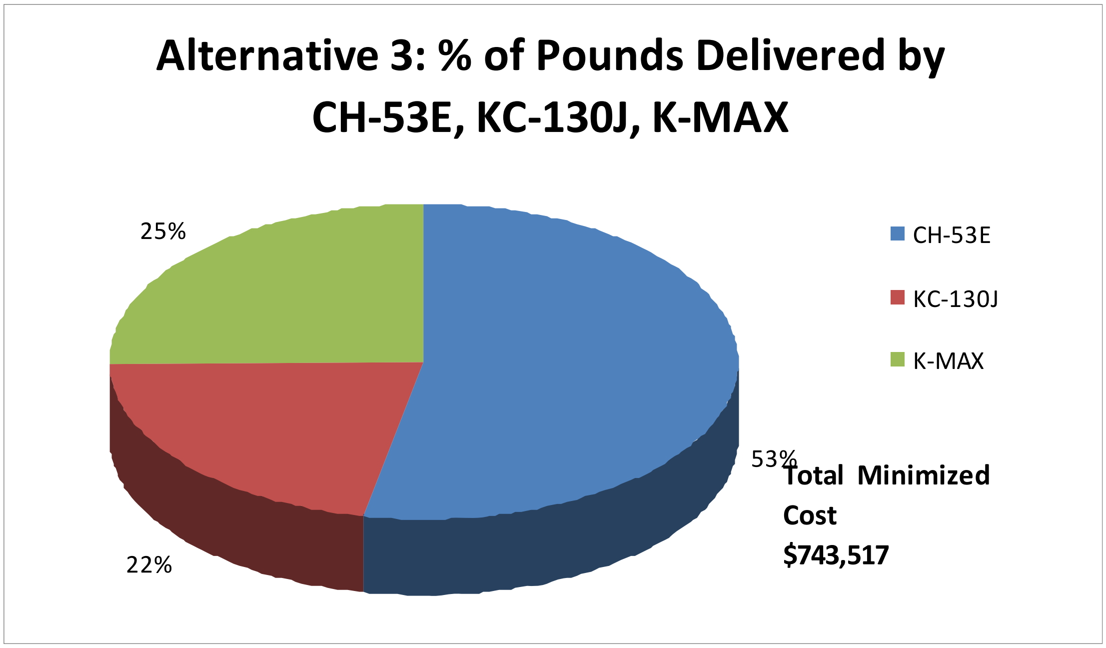

Figure 21. Alternative 3

4. Alternative 4 (GHS, CH-53E, KC-130J AND A160T UAS)

Alternative 4, depicted in Figure 22, shows that the A160T was only used for 4% of the cargo replenishment, which is similar to Alternative 2. The total transportation cost was $1,958,985, which was less than Alternative 2 due to the fact that in Alternative 4 only one high-security ground convoy was utilized as compared to Alternative 2, which utilzed two medium-security ground convoys. As discussed previously, this is due to the difference in payload capacity between the two methods of ground convoys.

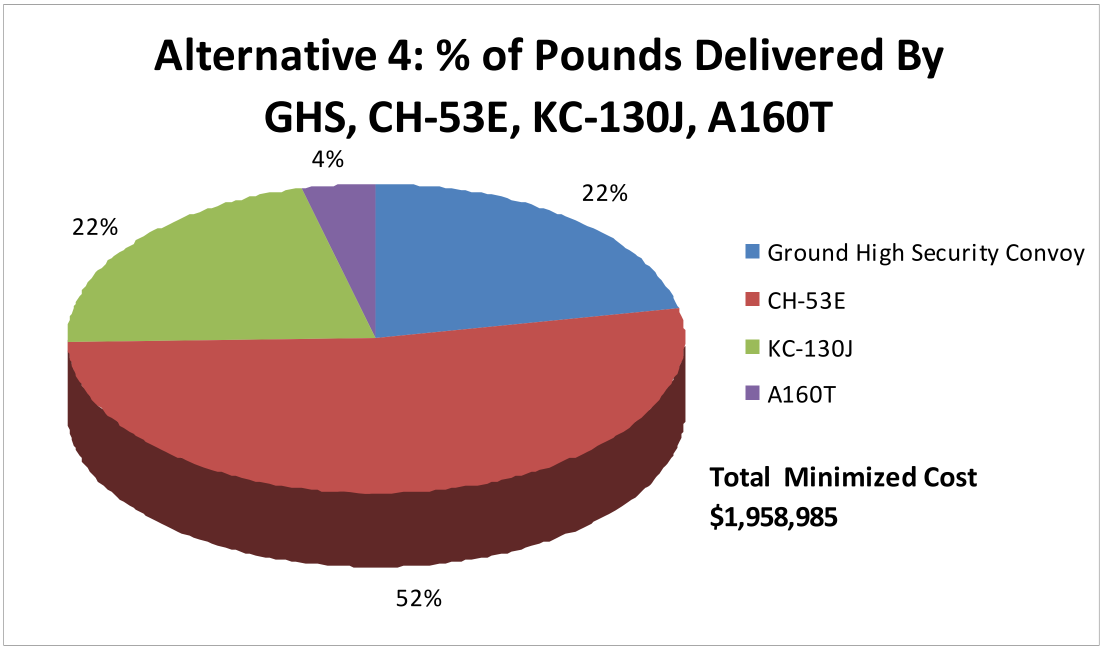

Figure 22. Alternative 4

D. Internal Rate of Return

In order to calculate the Internal Rate of Return, we utilized a 10-year planning horizon. This time frame could be viewed as a mildly unfavorable conservative assumption, but we found that the 10-year planning horizon resulted in the K-MAX recouping the initial procurement investment in the first six months of operations. We calculated the return on this investment by taking the difference between Baseline 2 and Alternative 1 and multiplying that difference by 122 annual replenishment cycles. In regard to operations and support cost computation, we were unable to find accurate data for the K-MAX due to the immaturity level of this new technology, so we utilized MQ-9 Reaper operations and support costs to approximate.

E. Sensitivity Analysis

1. Cost of Human Life

We based all baseline and alternative solutions on the value of a human life being $6 million. This number could be considered far too much or far too little, depending on different individuals' opinions. Due to the subjective nature of the value of human life, a sensitivity analysis on this value was conducted. In our analysis, we systematically lowered the cost of a human life from $6 million to $0 in $500,000 increments. Once we changed the value of a human life, we reran and re-solved the model and recorded the total transportion cost.

When analyzing the cost of human life for the K-MAX CUAS, we only utilized ground medium security, CH-53E, and KC-130J with JPADS. We did this because Alternatives 1 and 3 found that the K-MAX can completely eliminate ground convoys, so using either ground medium security or ground high security will not have an effect on the solution.

When analyzing the cost of human life for A160T CUAS we utilized both methods of ground convoys, CH-53E, and KC-130J with JPADS, due to the disparity in Alternatives 2 and 4 when we used different convoys. A graphical depiction of this analysis is shown in Figure 23.

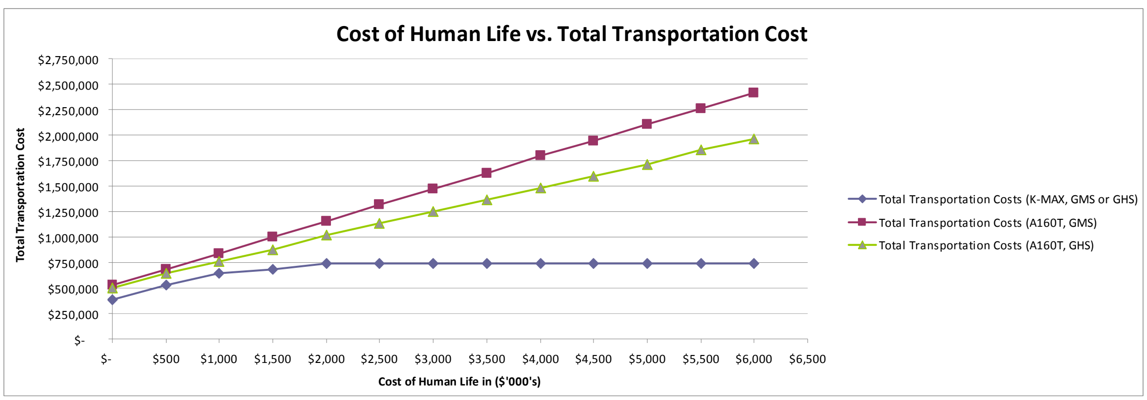

Figure 23. Cost of Human Life Graph

2. Conclusion

Based on our sensitivity analysis, we concluded that human life would need to be valued below $2 million before ground convoys would be less expensive to use than the K-MAX. By not using the K-MAX, more Marines would be exposed to risk, which would result in some loss of life based on the statistics found by JIEDDO. When human life is valued at $1.5 million, all CH-53E and KC-130J sorties and one ground convoy would need to be used to replace all but four K-MAX sorties. Based on JIEDDO, this would result in six Marines being KIA per year (General Dynamic, 2010). When human life is valued at $0, three ground convoys, seven CH-53E sorties, four KC-130J sorties, and four K-MAX sorties would need to be used. Based on JIEDDO statistics, this would result in 15 Marines KIA per year (General Dynamics, 2010). Of note, JIEDDO statistics are based solely on Iraq ground convoy operations. These KIA findings are most likely a low estimate for operations in Afghanistan. The end result of these findings is that the K-MAX is a program that the DoD should invest in and that should be considered to become a program of record.

We found that the A160T simply lacks the payload capacity to be a significant player in this scenario, and it only increases the total transportation cost quite significantly. However, the A160T may have a role in a niche replenishment scenario (special operations, immediate resupply needs, etc.).

F. Risk Analysis

There are several potential sources of cost, schedule, and performance risk for CUAS. These risks relate to technology, threats, and performance against the development plan.

1. Technological Risk

One of the primary technological areas that increases risk associated with the CUAS program is component reliability while conducting operations in an austere environment. Operating in Afghanistan will be challenging for the CUAS due to the climate, terrain, and availability of maintenance.

2. Threat Risk

Once in theater, the CUAS will most likely face real threats that were not able to be simulated during the test and evaluation (T&E) period prior to deployment. With this said, the main threat that we envision is a credible man portable air defense attack while the CUAS is making terminal deliveries to the FOBs. It may prove to be susceptible to small arms fire and rocket propelled grenade (RPG) attacks. This may result in high attrition rates, which could prove to be a major factor in the overall program cost. This will influence the number of CUAS required to complete a mission, as well as the locations where CUAS can be utilized.

3. Performance Risk

Because CUAS is a new technology, there is a risk that the CUAS will not be able to meet all specific mission requirements held by the Marines on the ground while deployed in Afghanistan. From an employment standpoint, the main potential issue is a steep learning curve between the Marines being supported and the operators of the CUAS. There will need to be clear lines of communication while the CUAS is used for logistical resupply. Requirements will need to be stated up front and operating units requiring support will need to remain flexible while CUAS technology is phased into the Concept of Operations.

V. Conclusion and Recommendations

A. Results of Analysis

1. Findings

One of the major cost drivers in our analysis is the value of human life. All baseline and alternative solutions were based on the value of a human life being $6,000,000. As stated in Chapter III, the cost of human life could be considered far too much or far too little, depending on different individuals' opinions. This figure is based on life insurance, survivor benefits, loss of earnings, lost human capital, and welfare lost to society. The DoD does not publically place a value on human life. However, other U.S. government agencies do place a value on human life. For example, the Department of Transportation and the Federal Aviation Administration use $3 million, the Environmental Protection Agency uses $6.1 million, the Food and Drug Administration uses $6.5 million and the Consumer Products Safety Commission uses $5 million (Silny, Little, & Remer, 2010). All of these values are based on year 2006 U.S. dollars and were used as a reference for the $6 million value.

Due to the subjective nature of the value of human life, a sensitivity analysis on this value was conducted. In our analysis, we systematically lowered the cost of a human life from $6,000,000 to $0 in $500,000 increments. In the course of this project, our sensitivity analysis concluded that human life would need to be valued below $2 million before ground convoys are less expensive to use than K-MAX.

As stated above, there is a disparity among the agencies regarding the values placed on human life ranging from $3 million to $6.5 million. However, all of these values are greater than the $2 million turning point found in our analysis.

2. Meaning

By not using K-MAX, more Marines will be exposed to risk, which will result in some loss of life based on the statistics found by JIEDDO. When human life is valued at $1,500,000, one ground convoy is used, replacing all but four K-MAX sorties and utilizing all CH-53E and KC-130J sorties. Based on JIEDDO statistics, this will result in six Marines being KIA per year. When human life is valued at $0, three ground convoys, seven CH-53E sorties, four KC-130J sorties, and four K-MAX sorties are used. Based on JIEDDO statistics, this will result in 15 Marines KIA per year. Of note, JIEDDO statistics were based solely on Iraq ground convoy operations. These KIA findings are most likely a low estimate for operations in Afghanistan.

3. Proposed Way Ahead

Based on our analysis, K-MAX is an attractive alternative to current methods of resupply. These findings led to our conclusion that the K-MAX is a program worthy of DoD investment and becoming a program of record.

B. Comparative Advantages of Resupply Platforms

1. Ground Convoys

Through our research we found that both medium and high ground security convoys are ideal for resupply missions (all classes of supply) that are comprised of short distances and high pound requirements for the respective FOBs. Due to their large payload capacity (64,200 pounds and 85,600 pounds, respectively), ground convoys are able to accomplish a large percentage of resupply missions, but this comes at a significant price when risk exposure and the cost of human life are factored in.

2. CH-53E

Through the course of our research, it was apparent that the CH-53E utilizing sling loads are an ideal resupply platform for Class V (ammunition). This is due to the CH-53E's extensive payload capacity (17,125 pounds), its ingress speed to the FOB, and its proven capability in austere operating environments dating back to the early 1970s.

3. KC-130J

Through our research it was evident that the KC-130J utilizing JPADS is an ideal resupply platform for Class III (fuel). This is due to the KC-130's large internal payload capacity (35,000 pounds) and the precision guided employment of JPADS. The KC-130J payload capacity would be fully utilized if it were able to land at the respective FOBs, but the scenarios we used in this project called for the KC-130J to fully utilize JPADS to conduct resupply missions, therefore the effective payload capacity was decreased to 14,000 pounds.

4. K-MAX CUAS

Our research indicated that the K-MAX CUAS is an ideal resupply platform for small or compact deliveries, most likely in the form of Class I (subsistence). As was discussed in Chapter IV, with the use of K-MAX CUAS, ground convoys can be completely eliminated and reduce transportation costs to $743,517. This alternative illustrates the fact that an all-air method resupply has the potential to be an attractive solution in large part due to the K-MAX's large payload capacity (4,915 pounds).

5. A160T Hummingbird CUAS

As stated in Chapter IV, the A160T simply lacks the payload capacity to be a significant player in our scenario (its maximum payload is 1,250 pounds), and it increases the total transportation cost quite significantly. Through our research, we did come to the conclusion that the A160T may serve a vital role in a niche replenishment scenario. Specifically, we envision the A160T as having potential to provide responsive support for special operations and time-sensitive immediate resupply requirements.

C. Source of Second Thoughts: Vulnerabilities for CUAS

If there is a significant variability in resupply operations in theater, we should expect changes in enemy tactics because the Afghanistan insurgents are opportunistic, aggressive, and constantly improving their tactics. Just as IEDs are a useful countermeasure for ground convoys, we should expect an expanded range of countermeasures against aerial resupply if that mode of resupply becomes more widely employed for Coalition logistics.

The main threat or vulnerability that we envision the CUAS encountering while making terminal deliveries to FOBs is the possibility of a credible, man-portable air defense attack. Specifically, it may prove to be susceptible to small arms fire and rocket propelled grenade (RPG) attacks. This may result in high attrition rates, which could prove to be a major factor in the overall program cost. In addition, this threat has the potential to lead to complications in employing this platform in existing CONOPS. Ultimately, this threat will influence the number of CUAS required to complete a mission, as well as the locations where CUAS can be effectively utilized.

As stated previously, the MQ-9 Reaper was used as a baseline for attrition rate computation. Due to the flexibility of our model, we were able to manipulate the baseline attrition rate to conduct an additional sensitivity analysis. However, we had to increase the attrition rate by a multiple of 38 for ground convoys to become less expensive to operate than the K-Max. Having to increase the attrition rate this drastically is unrealistic because it would result in 418 K-Max losses per year.

D. Recommendations for Follow-On Research

1. CUAS Operations and Support Costs

Throughout the course of our research, we utilized the MQ-9 Reaper to compute the CUAS operations and support costs because data was not readily available for the K-MAX and A160T CUAS. As stated previously, this void in data was due to the emerging CUAS technology. We recommend that as the CUAS becomes a more mature concept and as data is generated in Afghanistan, additional research should be conducted with respect to the true operations and support costs of CUAS.

2. CUAS Attrition Rates

As stated in Chapter III, we utilized the MQ-9 Reaper to compute the CUAS attrition rates because data was not readily available for the K-MAX and A160T CUAS. As stated earlier in our comments with respect to the operations and support cost, as data is generated in Afghanistan, additional research should be conducted in regards to the true attrition rates for CUAS.

3. Classes of Supply

Throughout the course of our research, we focused solely on the total pounds required per FOB vice breaking the requirements down by classes of supply. We feel it would be beneficial to take a closer look at the specific requirements for each FOB by classes of supply. By utilizing this methodology of explicitly focusing on the classes of supply, even more vital roles may be found in which it would be beneficial to employ the CUAS.

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List of References

Balakrishnan, N., Render, B., & Stair, R. M. (2007). *Managerial decision modeling with spreadsheets* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Conway, J. T. (2005, August). *A concept for distributed operations*. Retrieved from https://www.mccdc.usmc.mil

Conway, J. T. (2008, August). *A concept for enhanced company operations*. Retrieved from https://www.mccdc.usmc.mil

Defense Acquisition Management Information Retrieval (DAMIR). (2011 December). *MQ-9 UAS reaper* (Department of Defense selected acquisition report). Wright-Patterson AFB, OH: Author.

Defense Acquisition University (DAU). (2011, May 1). Business case analysis. Retrieved from https://acc.dau.mil/bca

Department of Defense (DoD). (2011). *United States Department of Defense fiscal year 2012 budget request*. Retrieved from http://comptroller.defense.gov/defbudget/fy2012/FY2012_Budget_Request_Overview_Book.pdf

Director, Combat Development and Integration. (2010, October). *Statement of need (SON) for immediate cargo unmanned aircraft system (UAS)*. Quantico, VA: Headquarters, United States Marine Corps.

General Dynamics. (2010, January). *Future modular force resupply mission for unmanned aircraft systems (UAS).* Fairfax, VA: Author.

Marine Forces Central Command. (2009, November). *Immediate cargo UAS JUON (ICaRUAS).* Quantico, VA: Author.

Merkle, T. J. (2010). *Logistical risk planning tool: Optimizing the deployment of cargo unmanned aerial system in logistical support mission at the tactical level* (Unpublished master's thesis). Naval Postgraduate School, Monterey, CA.

Mortimer, G. (2010, December). Navy awards Marine UAS cargo contract. *UAS News*. Retrieved from http://www.suasnews.com/2010/12/2909/navy-awards-marine-uas-cargo-contract/

Naval Air Systems Command (NAVAIR). (2009, November). *Immediate cargo unmanned aerial system (UAS) government owned/contractor operated (GOCO) services.* Patuxent River, MD: Author.

Naval Safety Center (Code 62). (2011). Statistics archive. Retrieved from http://www.safetycenter.navy.mil

Pratson, E. (2011, May). NPS students to research CUAS viability. *Cruser News*. Retrieved from http://www.nps.edu/research/cruser/Newsletters/CRUSERNews_2011_05.pdf

Robson, S. (2010, October). Pilotless helos to replace supply trucks in Afghanistan. *Stars and Stripes.* Retrieved from http://www.stripes.com/news/pilotless-helos-to-replace-supply-trucks-in-afghanistan-1.122467

Silney, J. F., Little, R. J., & Remer, D. S. (2010). Economic survey of the monetary value placed on human life by government agencies in the United States of America. *Journal of Cost Analysis and Parametrics*, *3*(1), 7.

U.S. Army Logistics Innovation Agency. (2011, March). *Logistics innovation agency cargo unmanned aerial system (CUAS) high level cost benefit analysis (CBA)*. Fort Belvoir, VA: Science Application International Corporation.

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- Contracting Government Procurement Functions
- Contractors in 21st-century Combat Zone
- Joint Contingency Contracting
- Model for Optimizing Contingency Contracting, Planning and Execution
- Navy Contract Writing Guide
- Past Performance in Source Selection
- Strategic Contingency Contracting
- Transforming DoD Contract Closeout
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- PPPs and Government Financing
- ROI of Information Warfare Systems
- Special Termination Liability in MDAPs
- Strategic Sourcing
- Transaction Cost Economics (TCE) to Improve Cost Estimates

Human Resources

- Indefinite Reenlistment
- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-term Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness

- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)
- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
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