



**UNMANNED TACTICAL AIRLIFT
A BUSINESS CASE STUDY**

GRADUATE RESEARCH PROJECT

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AFIT/IMO/ENS/10-16

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Abstract

Much literature has been published on unmanned aircraft in general, particularly in the roles of intelligence, surveillance, and reconnaissance (ISR) as well as attack. Less has been written on the use of unmanned aircraft in mobility roles. What has been written was from a strategic airlift perspective and air refueling. Virtually nothing, however, has been published on unmanned tactical airlift. The purpose of this study is to examine unmanned tactical airlift from an Air Force perspective. This is not a quantitative analysis, but rather an examination of the merits of unmanned tactical airlift as well as a recommendation of why, what, how, and when the Air Force should pursue such technology. Due to the lack of literature, this cannot be considered a formal case study; however, a thorough examination of available literature is presented as well as research by other authors suggesting desirable characteristics for an unmanned tactical aircraft. In addition, barriers to implementation are examined and a potential way ahead for the Air Force suggested as well.

To my children...you are the joy of my heart.

To my wife, my best friend and my Sunshine here on this earth.

Most of all to my Savior, to whom I owe my all.

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Jason T. Williams

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UNMANNED TACTICAL AIRLIFT; A BUSINESS CASE STUDY

I. Introduction

Background Motivation

Imagine the year is 2018. A special platoon of Recon Marines is quietly making their way through the night towards their objective, a terrorist camp which has taken control of a dam, threatening thousands of civilians downriver. The platoon is moving independently, but is not alone. Two other platoons are also making their way to the dam; each independent, yet perfectly synchronized in mission, tactics, and maneuver. However, this will be the third target the company has attacked in the past six days. Each platoon is in need of resupply before commencing the operation the following night. Earlier in the day, the company commander had requested resupply, and now each platoon is hunkered down waiting in the dark for their much needed ammunition and food stores. All is silent, then directly overhead a slight noise catches the attention of the first platoon. Like a ghost, a small rotorcraft descends out of the night sky, not coming in sight until an impossibly short distance above the tree tops. It looks like a helicopter, yet makes nowhere near the same amount of noise. And the differences don't stop with sound. The craft has an obvious front, but there is no cockpit to be seen. Weapons are attached to hard points under stubby wings, and a cylindrical container is suspended beneath the craft's hull. As the craft touches down, two members of the team rush out carrying a third member. The two mobile troops gently set their companion down, then open the container and haul out its contents. They then carefully slide their wounded comrade into the container, which a closer inspection reveals has accommodations for a

single person. After securing the container-turned-litter, the Marines retreat from the craft hauling their supplies as the unmanned aerial vehicle (UAV) quietly returns to the night sky, disappearing from sight and sound seconds after lift-off. The process is repeated with a second UAV which touches down immediately after the first departs to take its place conducting surveillance duties around the landing zone. Moments later, the second aircraft lifts into the still night sky, and the Marines depart in the direction of the dam. The platoon is resupplied with its wounded cared for, and all members are ready for the next night's operation. Elsewhere, this scene is repeated for the other two platoons. Within a 15 minute window, the entire company is resupplied, and the enemy never even realized it was happening.

Is this a Hollywood director's runaway imagination, or a real possibility for the future of resupplying small unit operations? In fact, these are just a few of the uses of cargo UAVs being discussed by the Navy, and more recently, by the Air Force as well. Even larger cargo UAVs may be possible in the future, perhaps even replacing current manned strategic and tactical airlifters. For today and the near future, only smaller models are in existence, which would limit their conceivable use to servicing smaller operations, such as the one described above.

Problem Statement

This research examines the topic of using UAVs as intratheater cargo airlift supporting small scale operations. While other papers have been published on the use of UAVs in other airlift roles, there has been little to no published work on unmanned theater airlift, particularly at the tactical level. As such, no hard requirements or concepts of employment are yet in existence. This paper will begin by hypothesizing possible

requirements for the use of cargo UAVs. Next, it will present a bare-bones concept of employment (CONEMP). Finally those inputs will be used to hypothesize what attributes may be desirable for a tactical cargo UAV. In the process of accomplishing these tasks, the author will also report technology gaps, barriers, and make recommendations for future study.

Research Questions ***

This paper will focus on the following research questions.

1. Should the United States Air Force develop or participate in developing a tactical unmanned airlift aircraft?
2. What notional CONEMPs might apply to this system or systems?
3. What attributes should a tactical unmanned airlift aircraft have?
4. What barriers exist in using current technology to meet a notional requirement with unmanned airlift vehicles?

Methodology

The research questions are addressed by investigating through a literature review and interviews the current status and environment surrounding unmanned aerial vehicles writ large. In addition, purposed future missions for a tactical cargo UAV are examined, specifically Joint Distributed Operations (JDO). The results of a particular study on resupplying a Marine JDO platoon is presented to assist in recommending potential characteristics for a tactical cargo UAV.

Assumptions and Limitations

This study is largely theoretical. No hard requirements are in place for unmanned cargo vehicles, so each section of this paper is built on the previous section's results.

Recent efforts to develop Joint Distributed Operations as operational tactics present a viable context for the use of an unmanned tactical airlift vehicle, assuming they come to fruition in the current or future conflicts. Another assumption is the history of the military expanding the use of tactical airlift beyond the scope of its original design would also hold true for unmanned tactical airlift as well. In other words, if utility can be shown in one airlift mission, there are many others it can be applied to as well. This paper identifies technology gaps currently preventing or limiting implementation of this technology. Any recommendation to proceed with this technology assumes these barriers can be overcome economically enough to make future implementation feasible.

The quantitative research is based on two papers. The first was written by Marine Captain Matthew Bain, “Supporting a Marine Corps Distributed Operations Platoon: A Quantitative Analysis,” published in September of 2005 (Bain, 2005). The second is an U.S. Army sponsored report by General Dynamics entitled, “Future Modular Force Resupply Mission for Unmanned Aircraft Systems (UAS)” (General Dynamics, 2010). This paper assumes both works are accurate and applicable to other services’ infantry units. In the case of Captain Bain’s paper, though it is dated, it is still applicable as the nature of an infantry unit has changed little. Finally, this paper assumes future technology will continue to be based largely on research implemented today.

This paper focuses on the near term of 5 to 10 years, though future strategic decisions for what type of airlift might be in service 50 or 100 years from now will be impacted by decisions made today. However, with the limited focus of this paper, assets that are likely to be readily available in the near term are smaller scale systems. Given the economy and shrinking defense budgets, the likelihood of purchasing enough small

scale systems to replace larger manned systems in traditional mobility roles is unlikely in the near term, even assuming any limiting technical barriers existing today could be easily overcome. As a result, this research will assume the most likely initial use of tactical unmanned cargo airlift is to support small unit-sized operations, either in combat or small scale humanitarian relief.

Implications

Increasing personnel costs and risk in delivering goods the last tactical mile may make unmanned airlift an increasingly attractive option to decision makers. If so, the result could be a step away from the traditional view of manned airlift towards a future which could include skies populated by fewer and fewer mobility (and combat) aircraft with pilots physically on board. Such a thought is painful for professional aviators who have spent their lives not only honing skills which have given the United States an unparalleled air force, but rooting their very identity with that same community. However, much work is left to be done before this vision becomes reality. The literature review will reveal at least some of the salient points and issues which need to be addressed.,

The paper continues with an examination of literature which the author will use to answer the research questions. While all of the literature reviewed is relevant, particular attention should be given to the position of the Federal Aviation Administration as well as Captain Bain's (2005) research paper. The questions are summarized in a final discussion which include suggestions for future research.

II. Literature Review

Introduction

This chapter begins by examining studies which present possible characteristics of a potential unmanned tactical airlift aircraft, and the current use of unmanned aircraft by United States government agencies. Next, current and future context for possible uses of unmanned airlift are presented. Finally, studies on what level of support is anticipated for future small unit combat operations will be examined as well as potential barriers to full implementation of this system.

Unmanned Aircraft Terminology

There are a number of terms and acronyms referring to unmanned systems. While many of these terms can be used interchangeably, there are some differences. The most generic term is unmanned aircraft (UA), which refers to any pilotless vehicle. Most people in and out of the Department of Defense (DOD) would recognize the term UAV, or Unmanned Aerial Vehicle, which is interchangeable with UA. A similar term with essentially the same meaning is Remotely Piloted Aircraft (RPA). This distinction will become more significant as the Air Force continues toward the goal of increasing UA autonomy (HQ USAF, 2009). Another related term is the Unmanned Combat Air Vehicle (UCAV), which is a UAV with attack capabilities, as the name suggests. These terms should be differentiated from an Unmanned Aircraft Systems (UASs). UASs include not only the aircraft itself, but the support equipment used to control and employ the aircraft. A UAS may employ more than one UAV at one time.

United States Government and Unmanned Aerial Systems

Congressional Mandates for Unmanned Systems

In 2001, Congress issued a mandate to the Department of Defense on the procurement of unmanned vehicles. Section 220 of the Floyd D. Spence National Defense Authorization Act for FY2001 (Public Law 106-398), stated two key, overall goals for the DOD with respect to UAS and Unmanned Ground Vehicle (UGV) development. First, by 2010 one third of the aircraft in the operational deep strike force should be unmanned, and second, that by 2015, one third of the Army's Future Combat System (FCS) operational ground combat vehicles should be unmanned (United States Congress, 2000).

Congress went on in 2006 to give further guidance to the DOD for the advancement of unmanned systems. Section 141 of the John Warner National Defense Authorization Act for FY2007 (Public Law 109-364) called for DOD to establish a policy giving the Defense Department guidance on unmanned systems (United States Congress, 2006). Some key points of the law included: identifying a preference for unmanned systems in acquisitions of new systems, addressing joint development and procurement of unmanned systems and components. In addition, the law directed the transition of service-unique unmanned systems to joint systems as appropriate, the organizational structure for effective management, coordinating and budgeting for the development and procurement of unmanned systems, and developing an implementation plan to assess progress towards meeting goals established in Section 220 of the Floyd D. Spence National Defense Authorization Act for FY2001. The law also directed the Federal Aviation Administration (FAA) to submit a report back to Congress on its progress in

developing a policy for testing and a plan for achieving wider access by unmanned aerial vehicles to the National Airspace System (NAS). The FAA responded by connecting future UAV integration into the NAS to its ongoing efforts to update the NAS as a whole (Cox, 2009).

The Federal Aviation Administration and Unmanned Aerial Vehicles

The FAA has been deeply involved in leading a multi-agency program to update the NAS with an initiative it calls NextGen. NextGen is an umbrella term for the ongoing, wide-ranging transformation of the United States' national airspace system (NAS). At its most basic level, NextGen represents an evolution from a ground-based system of air traffic control to a satellite-based system of air traffic management (FAA, 2009a). However, the program includes a broad range of initiatives the FAA hopes will lead to improvements across the aviation spectrum from the NAS, to the environment, to safety and security (FAA, 2009b). NextGen is also the FAA's long term answer to Congress on how UASs will safely intermix with manned aircraft in the NAS. Since NextGen initiatives require special equipment to communicate with controllers and other aircraft, this will drive what equipment will be required on unmanned aerial systems in the future.

The first piece of new equipment being implemented is called Automatic Dependent Surveillance-Broadcast, or ADS-B. ADS-B coverage is currently spotty as it is still in initial testing phase (Figure 1). However, by 2013, the FAA intends to have coverage over most of the country to include Alaska, Hawaii, and Puerto Rico (Figure 2). Increased coverage should lead to regulations and procedures for UASs which are closer to those for manned aircraft.

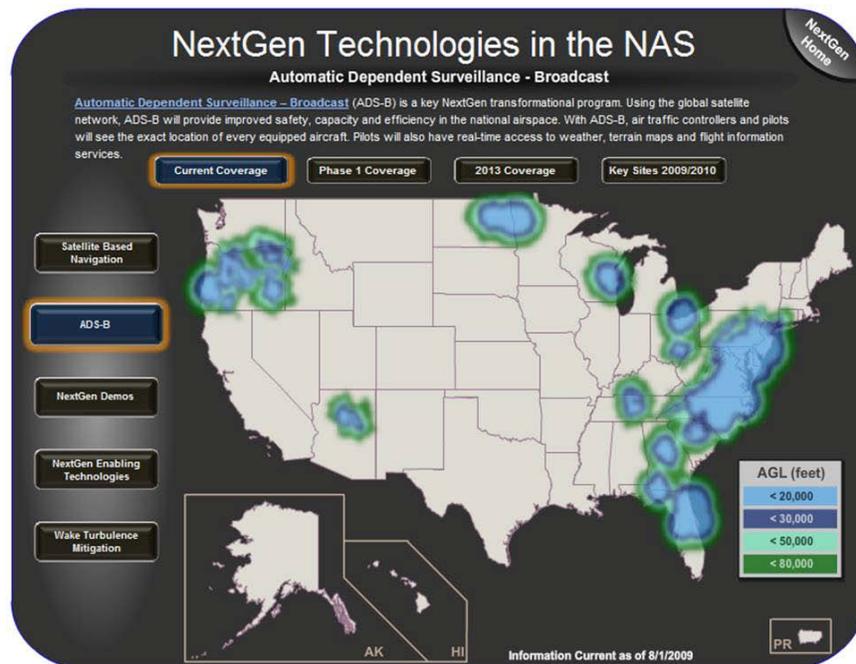


Figure 1. Current ADS-B Coverage (FAA, 2009c)

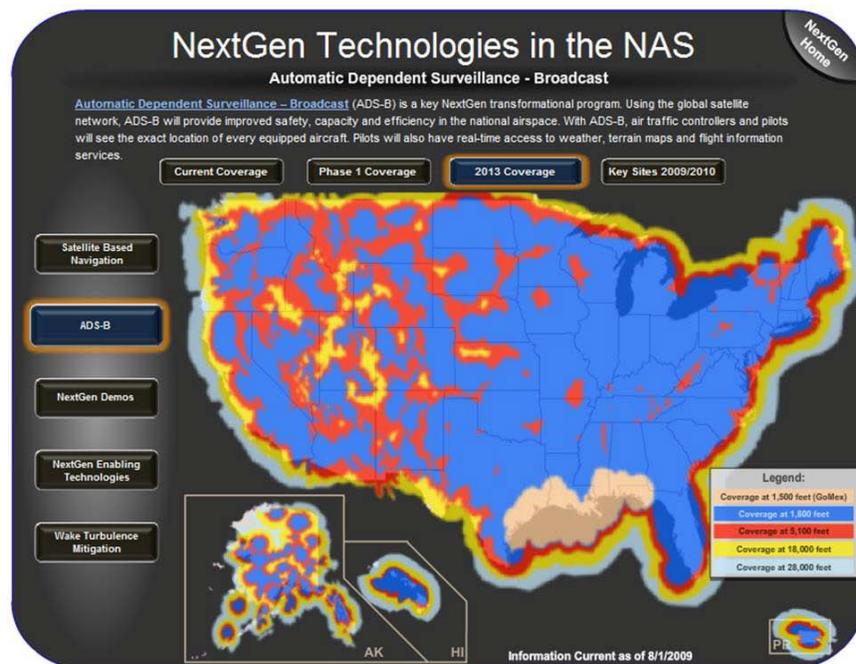


Figure 2. ADS-B Coverage in 2013 (FAA, 2009c)

While the construct of the NAS itself may be a barrier to unfettered unmanned aircraft access, UAS's have several other challenges to address before they can be treated

as a manned aircraft. The Honorable Randy Babbitt, FAA Administrator, in an interview with the author on January 7, 2010, listed his leading concerns on UASs mingling with manned aircraft. Mr. Babbitt's concerns with unmanned aircraft may be summed up in one word: safety (Babbitt, 2010). In a speech at the Aerospace Industry Association's (AIA) Board of Governors Meeting on November 18, 2009, Mr. Babbitt asserted "unmanned aircraft systems are not ready for seamless or routine use yet in civilian airspace" (Babbitt, 2009). He went on to acknowledge, however, "unmanned aircraft systems are here to stay" (Babbitt, 2009).

There are several areas Mr. Babbitt listed in the interview and speech to be addressed before the FAA would be willing to allow unmanned systems unrestrained access to the NAS. His top issue is unmanned aircraft must contain failsafes guiding their flights should the data link be lost during flight. A related concern is the integrity of the data stream linking the aircraft with its pilot and sensor operator crew. The data link needs to have reliable security protecting it from an attack or takeover of its control system. In either case, uncontrolled unmanned systems must take safe actions which are predictable by air traffic controllers and pilots alike.

In relation to other aircraft, another area Mr. Babbitt listed for improvement is the ability of the aircraft to see and be seen. His definition of this is, "the capability of an unmanned aircraft system to remain well clear from and avoid collisions with other airborne traffic and vice-versa" (Babbitt, 2009). Many UASs are equipped with cameras to aid the crew in landing as well as surveillance equipment in the case of systems intended as Intelligence, Surveillance, and Reconnaissance (ISR) aircraft. However, optics are of little use if they are pointing in the wrong direction, and even if the aircraft

is equipped with advanced cameras and sensors, they may not have the field of vision of a human pilot. The author personally has conducted several flights where a mid-air collision was only prevented by the human pilots looking outside the aircraft and spotting the unexpected conflict. Unmanned systems need similar abilities to conduct safe flight outside of protected airspace. Over the battlefield, the airspace is strictly controlled by the military, so all flights in and out are known and tracked by military controllers. This practice both enhances the safety of allied aircraft while allowing for speedy identification of enemy air forces in the area. In contrast, aircraft operating in civilian airspace are only required to file flight plans if they are under instrument flight rules. Traffic operating under Visual Flight Rules (VFR) may never even talk to a controller in some areas, and would have little chance at spotting a small UAS, especially if the pilot had no idea one was in the area.

UASs by nature are relatively small aircraft, an attribute which pays dividends on the battle field but does not lend itself well to “see and avoid” in civilian airspace. Both size and speed play a part in avoiding another aircraft. Even larger aircraft can be difficult to spot in flight, especially head on. When aircraft are head on, the closure rate is the combined speeds of the two aircraft. A pilot would have very little time to react even if they did spot a small unmanned aircraft.

Actual safety issues are not the only problem. The popular perception of the safety of UASs must also be taken into account. For the majority of the population, the only contact they have with aircraft is to ride in them as passengers or to watch them fly overhead. Even if they just watch aircraft go by, there is a legitimate concern for safety should someone be so unfortunate to be standing underneath two aircraft as they collide

overhead. Should the FAA move too quickly at certifying a new technology, such as UAVs, there is any number of organizations who would not hesitate to criticize the apparent or real lack of wisdom on the part of a government agency. The FAA is an organization under the Executive Branch of the government, and therefore must take politics into account in its policy making. Public opinion of the safety of pilotless aircraft is essential to how much leeway the FAA will afford them in the NAS.

The FAA recognizes unmanned aircraft will be an increasing reality in the skies over the United States in years to come. Currently however, the FAA treats UAVs essentially the same way as it does small toy remote controlled airplanes. Rules allowing UAVs to operate the same as manned aircraft are being considered, but as stated above, it will be a while until those rules are a reality. In the meantime, the primary way the FAA approves UAVs for flight in the NAS on a case-by-case basis. Each request is considered individually, and if approved, the FAA issues a Certificate of Authorization (COA) for the user based on the following principles (FAA, 2009d):

- The COA authorizes an operator to use defined airspace and includes special provisions unique to each operation. For instance, a COA may include a requirement to operate only under Visual Flight Rules (VFR) and during daylight hours. Most are issued for a specified time period (up to one year, in some cases)
- Most, if not all, COAs require coordination with an appropriate air traffic control facility and require the UAS to have a transponder able to operate in standard air traffic control mode with automatic altitude reporting.
- To make sure the UAS will not interfere with other aircraft, a ground observer or an accompanying “chase” aircraft must maintain visual contact with the UAS.

The FAA believes the system is working out for the moment. The FAA issued 102 COAs in CY 2006, 85 in CY 2007, 164 in CY 2008. As of October 2009, the agency has issued 89 COAs and has 188 applications pending (FAA, 2009d). However, this can only be a temporary measure. Mr. Babbit acknowledged the future of aviation will

contain unmanned systems, and the FAA's role is to pave the way for unmanned technology to succeed, while ensuring above all else safety is enforced. As the nation's acceptance of unmanned aircraft grows and as the technology matures, the scale of UASs are bound to grow, as will their numbers. Until then, the largest bottlenecks are safety technology and producing a set of rules which will both keep the skies safe while promoting the growth of this segment of the air transportation market.

There seems to be some dichotomy between the agency's primary concerns on UAV integration into the NAS, and the efforts the FAA told Congress it was taking to that end. Upgrading the NAS is an important step, and the new technology will certainly assist in the safety of all aircraft, including UAVs. However, NextGen does not directly address the three concerns mentioned by Mr. Babbitt. In fact, the NextGen system planning currently does not address UAS capabilities (HQ USAF, 2009). However, the FAA is working together with DOD, NASA, Department of Homeland Security, Department of Transportation, and Department of Commerce to ensure that UAS operations are compatible with NextGen system design.

The FAA has contended in numerous documents and statements it does not consider unmanned systems safe for the NAS, mostly because of the requirements for "see and avoid" set out in Title 14, Part 91.113, which mandates the right of way for air operations. While the agency contends this as a matter of course, it has not yet published the standards which would give unmanned systems equal access to the NAS. In fact, according to an official in the Flight Technology and Procedures Division, which is currently responsible for writing the regulations for unmanned systems, the FAA does not

expect to publish those standards for just small UAVs until 2012 or maybe even 2013. The FAA is still years away from publishing standards for larger systems.

Members of Joint Forces Command's Joint UAS Center of Excellence feel the speed at which the FAA is moving is a major bottleneck for UAS advancement. This assertion is countered by Mr. Babbit's and the FAA's clear responsibility to ensure safety. Since the current FAA UAS guidance restricts UAS operations over populated areas (FAA UAPO, 2008:11), UAS use in airlift roles or as ISR for local law enforcement cannot proceed until the FAA is assured unmanned systems can operate as safely as manned aircraft (or arguably, more safely than a manned aircraft).

The FAA has been tasked with developing a plan to integrate UAS into the NAS (HQ USAF, 2009:71). It is to be a comprehensive integration, to include flight safety cases from flight rules, aircraft systems airworthiness requirements, and operator training requirements. The FAA is developing a joint interagency activity through its Unmanned Aircraft Program Office activity to implement a phased approach of procedures, policy, and technology. The FAA is using a significant amount of resources to work collaboratively with DOD in the development of sense and avoid capability and system safety levels. It would seem, however, that the first step in developing UAS safety technology which would satisfy the requirements necessary to operate in the NAS would be to first develop and publish what specific requirements are necessary. Until those standards are published, it will be difficult for industry to know precisely which elements need to be addressed, and to what level.

Department of Defense Plan for Unmanned Systems

The Department of Defense published its vision for unmanned systems first in 2005, again in 2007, and most recently in 2009 in the Unmanned Systems Roadmap, 2009-2034. The roadmap covers the spectrum of unmanned systems throughout the DOD, to include sea and ground systems, as well as aerial vehicles. The purpose of the document is to lay out a vision and strategy for unmanned systems, link unmanned systems' capability Joint Capability Areas (JCA), and finally, to focus and synchronize the DOD and related defense agencies in unmanned systems procurement and technology advancements to meet prioritized capability needs of the warfighter (DOD, 2009:xiii).

The DOD Roadmap lists several broad areas for advancement over the next 25 years (Figure 3). The DOD vision recognizes sense (or "see") and avoids (S&A) technology is not only a capability restraint but a regulatory one as well. It defines S&A as the onboard, self-contained ability to (DOD, 2009:99):

1. Detect traffic that may be a conflict,
2. Evaluate flight paths,
3. Determine traffic right of way, and
4. Maneuver well clear according to the rules in Part 91.113.

	2009	Evolutionary Adaptation	2015	Revolutionary Adaptation	2034
Dependency	Man Dependent SA/ Off Board SA		Sense and Avoid		Fully Autonomous/ On Board SA
Speed	Subsonic		Transonic		Super/Hypersonic
Stealth	Signature High				Signature Low
Maneuverability	1 "G"		9 "G"		40 "G"
Self Protection	Threat Detection		Threat Jamming and Expendables		
Sensor Ranges	Current		25% Extended		50% Extended
Icing	Visual Meteorological Conditions - Light		Moderate		Severe
Turbulence	Light		Moderate		Severe
Precipitation	Light		Moderate		Severe

Figure 3. Air Domain Performance Envelope (DOD, 2009:30)

The DOD Roadmap also briefly discusses data link security, but expands the topic to other command, control and communications (C3) issues. Data link security refers to the degree to which the system is able to ensure only authorized users gain access to either the up or down link. A secure link will resist interference either from inadvertent interruption or hostile attack. Data link security differs from the loss of the data link in that a lost data link can occur without any human interference.

Also included under the C3 heading are redundant or independent navigation, autonomy, and the loss of data link. The navigation discussion speaks to the need for more precision in navigation which will lead to the ability to certify the aircraft for Required Navigation Performance (RNP) airspace in the future. Advances in computer and communications technology have allowed greater autonomy for UAVs. The Global Hawk is already able to identify, isolate, and compensate for a wide range of possible system or subsystem failures, and autonomously take actions to ensure system safety.

Department of the Navy and Unmanned Aerial Systems

Tactical Unmanned Cargo Aircraft Systems

Though the idea of unmanned cargo aircraft has been around for a while, the Department of the Navy was the first service to look seriously at acquiring a tactical unmanned airlift aircraft. The study was in response to the Reinforced 2015 MEB (Marine Expeditionary Brigade) Assessment (Cargo UAV Variant) Study, conducted in May 2007, and a Universal Need Statement (UNS) submitted by the Marine Corps on August 27, 2008 (Linkowitz, 2008). The Office of Naval Research (ONR) posted a request for information (RFI) in January 2009 in order to understand the available technology and configuration options to address the need for an unmanned aircraft to provide air cargo delivery in support of Marine Corps Expeditionary Warfare (ONR, 2009). The purpose of this RFI was to inform ONR of technologies and concepts relevant to this capability, so that it could advise the Marine Corps of available options, and determine what technology development investments might be appropriate.

The UNS gave some basic requirements for the Cargo UAS. The aircraft was to be able to operate 35 nautical miles (NM) off-shore and 250 NM inland. The aircraft was to be able to carry cargo internally, externally, or using modular packaging that would not require material handling equipment (MHE) at the delivery point. Cruising speed was to be 250 knots with an ability to carry or lift up to 1,600 pounds of cargo in at least four multiple payload increments for air-land delivery. Additionally, the system was to support continuous autonomous operations with the ability to redirect resupply missions enroute. The UNS authors hoped to have collision avoidance technology considered, though that wasn't listed as a hard requirement. The system was to have an auto

land/auto launch recovery and was to maintain a small footprint. The system had to also be affordable to account for combat losses.

Industry responded, and ONR conducted a fly-off between the Boeing A-160 Hummingbird and the unmanned variant of the Kaman K-Max Burro from February to March of 2010. According to both companies' websites, both aircraft performed well and met the Navy's requirements (Lockheed Martin, 2010) (Boeing, 2010).

Department of the Army and Unmanned Aerial Systems

The Army sponsored two studies on unmanned aircraft in logistics roles. One was through the Rand Corporation, which focused on logistics applications for unmanned aircraft besides resupply. The other was through General Dynamics (GD) and it focused solely on the unmanned aerial resupply mission. At the time of publishing, the Rand study was still in draft form and undergoing peer review, so it could not be included in this document.

The GD study had four objectives (General Dynamics, 2010:12):

1. Define the role, requirements and benefits of unmanned aircraft in Army resupply operations in the 2015-2024 timeframe.
2. Identify key enabling technologies for the UAS resupply mission(s) and examine the technical feasibility.
3. Provide recommendations on the unit best suited to support, manage, command and control (C2) and maintain UAS resupply assets.
4. Conduct DOTMLPF (Doctrine, Organizations, Training, Materiel, Leadership and Education, Personnel and Facilities) analysis of costs of integrating UAS in future Modular Force resupply operations.

The GD researchers surveyed Army forces and discovered five broad challenges to current resupply operations. These are (General Dynamics, 2010:21):

1. Large quantities of supplies needed across extended distances, predominantly bulk liquid;
2. Enemy action
3. Environmental challenges including inclement weather, rugged terrain, and poorly developed transportation infrastructure
4. Limited distribution asset availability (primarily aircraft) due to many competing priorities
5. Inadequate resupply responsiveness to changes in the operational environment.

The researchers felt the focus of UAS resupply operations should be platoon and company sized elements, as dispersed operations of these sizes complicate logistics. The study also recommended a 4,000 lb lift capacity at “high/hot” conditions. A lift capability of that magnitude could resupply a platoon-size element in one to two sorties and an infantry company in six to seven sorties per day based on 25,000 lbs per day requirement. The study went on to say a cargo UAS design must emphasize transportation of Class I (subsistence), IV (construction items), V (ammunition), VIII (medical supplies), IX (repair parts) and limited amounts of Class III (fuel).

It should be emphasized before continuing that the resupply information the GD report provided was qualitative, not quantitative in nature. The report authors used survey data from commanders and staff recently returned from deployment to generate their estimates of supplies consumed. As a result, the GD researches found a wide variation on responses. However, they concluded companies averaged between 20,000 and 25,000 pounds per day, which was consistent with standard Army estimates for a major combat operation (MCO). Figure 4 shows the estimated supplies required for an

Infantry Brigade Combat Team (IBCT) Soldier and an IBCT Company fighting in an MCO.

Class of Supply	1 day of supply / individual at OPLOG Planner max rate (in lbs)	Platoon (IBCT) 1 day of supply (in lbs)	Company (IBCT) 1 day of supply (in lbs)
Class I (Food)	5.5	236.5	946
Class I (Water)	87.0 (10 gal)	3741	14964
Class II	1.7	73.1	292.4
Class III (B)	59.0 (8.6 gal)	2537	10148
Class III (P)	0.6	25.8	103.2
Class IV	4.3	184.9	739.6
Class V	9.4	404.2	1616.8
Class VI	0.4	17.2	68.8
Class VII	No major end items needed	N/A	N/A
Class VIII	0.2	8.6	34.4
Class IX	1.2	51.6	206.4
Mail	1.2	51.6	206.4
Ice	3.5	150.5	602.0
Number of People	1	43	172
Total weight	174 lbs	7482 lbs	29928.2 lbs

Figure 4. Mission Projected daily consumption figures for an Infantry Brigade Combat Team (IBCT) Soldier and an IBCT Company (General Dynamics, 2010:51)

The authors of the study identified several technologies which still need additional development. Those technologies included: landing zone obstacle avoidance, in-flight sense and avoid, and a night and all-weather capability. The researchers believed, however, that these technologies are achievable within the near-term time frame if a concentrated effort to accelerate the pace of development is pursued.

The GD research team identified two basic C2 options for a cargo UAS. Option 1 was the direct support option, which would put the system at the disposal of an individual unit, such as a Brigade Support Battalion (BSB), ensuring that particular unit has dedicated resupply support. Option 2 was the general support option, which would make the assets centrally managed, and available for the greatest operational need. The GD research team felt effectiveness was more important than efficiency, and so the direct

support option was the preferred choice for the following reasons (General Dynamics, 2010:120):

1. Close proximity the point of need
2. Required cargo supplies will be on hand at the BSB Supply Support Area (SSA)
3. MHE support for cargo UAS operations is available or can easily be made available at the BSB
4. BSB support operations section planning capability complements the anticipated cargo UAS planning team function, minimizing the need for additional staff support personnel

Additionally, they contended if the system is fielded with tactical units, the more automated it should be so as to reduce the C2 infrastructure required. As a related issue, the authors also emphasized the following statement (General Dynamics, 2010:120-121):

If the UAS is multi-role, with independent mission capability such as Intelligence, Surveillance and Reconnaissance (ISR), the direct support option will not remain viable. Multi-role capability will introduce competitive demand for the UAS which will reduce the availability of the asset to conduct resupply and retrograde missions. Ultimately this will result in reduced ability to accommodate time sensitive resupply missions and will likely result in longer request-to-execution cycles as competing interests are prioritized. In addition, UAS designed for cargo resupply will be poorly suited for most other UAS missions.

The GD researchers' statement regarding the danger of using a cargo UAS in a multirole mission may be an accurate reflection of what a tactical unit commander may expect inside Army culture; however, it is not good advice. ISR UAS systems are in very high demand in theater right now, but the number of UAV ISR assets is also rising very quickly to meet that demand. Cargo UAS, even if they are equipped for ISR, should not be a commander's first choice for surveillance missions because they would not be designed for it. If a commander has a short term requirement for more ISR assets, having a multi-role UAS would be a great benefit. Force providers should be offering increased options to warfighting commanders, not limiting them. Modular systems would provide

options for commanders, while still being designed primarily for, and logically used primarily for, airlift.

Finally, the authors could not make an accurate cost analysis as they did not have enough data to fully assess this question. However, it did say costs would be a critical component to whether or not cargo UAS's would be a viable option for future Army logistics. Keeping the systems affordable will be critical to the service's ability to purchase the systems in enough quantity to make them a viable alternative to heavier manned airlift.

Department of the Air Force and Unmanned Aerial Systems

While the Air Force has been experimenting with unmanned aerial vehicles since as early as 1917 (Wikipedia, 2010), its first modern UAV was not fielded until 1995. The RQ-1/MQ-1 Predator first saw action during operations in Bosnia in 1995 (Pike, 2002). The success of the Predator in the ISR mission led the Air Force and Central Intelligence Agency (CIA) to begin efforts to arm the unmanned system. These efforts led to a series of other large scale, long endurance unmanned systems, including the MQ-9 Reaper, RQ-4 Global Hawk, and the RQ-170 Sentinel, currently under development. Other smaller systems for use by soldiers and airmen in the field have also been developed or are under development, to include the RQ-11B Raven, Scan Eagle, and Wasp III. All of these systems are used in the ISR role, and the Predator and Reaper are also used in the attack role.

Air Force UAS Flight Plan 2009-2034

The Air Force UAS Flight Plan covers a broad range of unmanned aircraft topics. Subjects span doctrine, systems, missions, challenges, and a framework of technology

advancements needed to meet a vision of future UAS roles. The document is extremely comprehensive, and frankly too broad to review completely in this venue. As such, the notable points are the few which seem to be missing from the document.

The Flight Plan touches on a broad range of mission sets, however, it focuses mostly on the ones unmanned aircraft are accomplishing today, namely ISR and attack. Mobility roles are a part of the plan, but the Flight Plan sees mobility as part of a mission set 10 to 20 years in the future. To be more precise, the vision is for a single, medium-sized, modular airframe which is capable of reconfiguring to accomplish all mission sets including Air Interdiction, ISR, close air support (CAS), electronic attack (EA), Communications Gateway and Air Mobility missions (HQ USAF, 2009:38). Clearly, the envisioned airframe is to be fixed wing. When mobility is discussed, it is in a general sense or in the context of strategic airlift or air refueling. What is ostensibly missing from the discussion is tactical airlift. Yet, it seems the first airlift platform to enter active service will likely be not only a tactical airlifter, but a vertical takeoff and landing (VTOL), rotary wing chassis. Unless the Air Force intends to completely ignore this mission set, this would seem to be a gap in the current vision.

Tactical Unmanned Cargo Aircraft Systems

On September 28, 2009, the Air Force posted a request for information on the FedBizOpps website asking industry to attend a meeting at Air Mobility Command (AMC) Headquarters to present ideas for an unmanned cargo aircraft. AMC Future Concepts division (A8X) was surprised when 40 proposals came in. They narrowed down the field to 11 presentations, and then hosted an “Unmanned Cargo Aircraft Day” on November 17, 2009. Several discussions took place between the 50 Department of

Defense attendees about the direction the Air Force program should take. No decisions were made, but in short the group felt requirements needed to be better determined and AMC should not attempt to make a unilateral attempt to develop this capability. If the Air Force wishes to be the lead service in this endeavor, more work will need to be done and resources expended to surpass the efforts of the Navy and Marine Corp.

Department of Homeland Security

Aside from the Department of Defense, the other major government user of unmanned aircraft is the Department of Homeland Security (DHS). More specifically, the UAS are operated by the U.S. Customs and Border Protection (CBP), Office of Air and Marine (OAM). OAM first employed the Predator B in support of law enforcement operations on the United States southwest border in 2005 and along the northern border in 2009 (U.S. CBP, 2009). OAM operates three Predator Bs from Libby Army Airfield in Sierra Vista, Arizona and two more from Grand Forks Air Force Base in North Dakota. Two maritime variant Predator Bs are scheduled to be operational in 2010, with further expansion of the UAS network planned through 2015.

The CBP UAS program focuses operations on the CBP priority mission of anti-terrorism by helping to identify and intercept potential terrorists and illegal cross-border activity. The system also supports disaster relief efforts of its Department of Homeland Security partners, including the Federal Emergency Management Agency and the U.S. Coast Guard. The Predator allows OAM personnel to safely conduct missions in areas that are difficult to access or otherwise too high-risk for manned aircraft or CBP ground personnel.

Local Law Enforcement

As stated previously, restrictions by the FAA preventing UAV use over populated areas are keeping law enforcement officials from fully utilizing unmanned technology. Regardless, at least one police department is investigating the use of a smaller UAV to assist in their law enforcement duties. In January, 2010, the Houston Police department attempted to conduct a secret flight of a ScanEagle UAV, only to have the sortie caught on tape by a local news station (The ITS Crew, 2010). The department quickly released a statement confirming the flight and stated the possible mission sets for the craft were yet to be determined. Obviously, a persistent ISR asset would be of great use to law enforcement agencies, not just for tactical reasons, but for search and rescue missions as well.

Potential Missions for Theater Unmanned Airlift

Unmanned aerial systems are the most requested assets by Combined Commanders (COCOMs) and by units in the field (United States Air Force, 2009:2). Their popularity with field commanders for use in ISR and small attack missions has expanded so rapidly supply has not been able to keep up with demand. Since these systems also cost less than space-based or full-sized, manned aircraft, the odds for individual commanders to gain dedicated support for their missions is far greater than when using conventional systems. It stands to reason expanding use of unmanned aerial systems into the airlift mission could reap similar results.

Small Unit Operations

Many of the basic concepts of infantry tactics have remained unchanged through the ages. Modern tacticians still study the writings of Sun Tzu, Carl von Clausewitz, and

other military theorists because the lessons they teach are still pertinent today. United States Army Field Manual (FM) 3-0 lists the nine principals of war as: Objective, Offensive, Mass, Economy of Force, Maneuver, Unity of Command, Security, Surprise, and Simplicity (HQ USA, 2008:A-1 - A-3). In a 2005 presentation on the Army's Future Force Capstone Concept 2015-2024, Army Brigadier General David Fastabend broke down winning a conflict into two of those concepts: mass and maneuver (Fastabend, 2005). Today's military applies the concept of mass by deploying and employing in large units. The Army in particular due to doctrine and training does not deploy in smaller than brigade sized units. However, operations in Afghanistan have led to smaller operations, especially in and around forward operating bases. As a future concept, General Fastabend anticipated more distributed maneuvers of smaller sized units. Smaller, independently maneuvering units means a much more agile, responsive, and wide-spread supply system is required. Even without the complications of mountainous terrain and limited road systems, such a construct would seem to point to an airlift solution. The Marines have already used expeditionary concepts to deploy their forces in smaller units, but currently face the same type of restrictions when it comes to how small a unit they can employ autonomously.

The size and makeup of the force shapes the types of mobility assets the DOD purchases to support the ground troops. Assets such as large amphibious ships for the Navy, C-5's and C-17's for the Air Force are reflections of the type of mass the United States military intends to put on target, should the need arise. These large-force concepts echo back to the Cold War when the most likely opponent also employed a large army with similar mobility needs. However, this is not the type of conflict currently facing our

military. Our opponents use the small unit strategy of guerilla warfare not only because it suits the size of their force, but because guerilla warfare has been proven over the ages to be an effective tactic when facing a larger and better equipped opponent. Mao Tse-Tung, the father of “Maoism” wrote in his definitive book on the subject, “Guerrilla warfare has qualities and objectives particular to itself. It is a weapon that a nation inferior in arms and military equipment may employ against a more powerful aggressor nation.... There can be no doubt the ultimate result of this will be victory.” (Tse-Tung, 1961:42) While revolutionary guerrilla warfare isn’t the answer for U.S. forces, there is value in the concept of small unit tactics.

This thought drove the Marines to begin developing a concept they called Distributed Operations (DO), or when done in concert with other services, Joint Distributed Operations (JDO).

Forward Operating Base Support

The GD (2010) report stated the Army has a growing requirement for resupply by airlift. Not only will small distributed units need resupply, but forward operating bases as well. Conducting operations in particular into the mountains of Afghanistan is challenging at best, and often dangerous to soldiers, aircrews, and the mission. Transporting at least some of those resupplies by tactical unmanned airlift would not only limit crews to enemy fire, but release manned airlift for other missions. By the same token, the Marine Corps UNS envisioned a cargo UAV that would resupply all types of distributed units, including Forward Area Rearming/Refueling Point (FARP) operations and Forward Operating Bases (FOBs).

Joint Distributed Operations

Definition

In a briefing to the Assistant Secretary of the Navy, the Naval Research Advisory Committee defined distributed operations as an “operational approach that enables influence over larger areas through spatially separated small units, empowered to call for and direct fires, and to receive and use real-time and direct ISR” (NRAC, 2006:4). This essentially would change the basic operating unit of the Marine Corps (or Army, should they begin to operate in this manner) from the battalion level down to the platoon or even squad level. While mass on target is still achieved, it is done by the coordinated efforts of many small units instead of fewer large units. Smaller units allow military planners to leverage BG Fastabend’s second emphasis point of maneuver to its fullest advantage. This change in concept has a number of implications and challenges associated with it, which are discussed next.

Background

The scenario described in the opening paragraphs of this paper is an example of DO. The Marines have been constructing this concept for over six years now. It is the extension of a Navy concept called Ship to Objective Maneuver (STOM). In brief, STOM are littoral operations using small units to penetrate shore defenses, which then use DO to converge on the inland target. Several papers have been written by Marines on various aspects of DO, to include logistics, command and control, and joint fires. As a service, the Army has only begun to look at the topic. However, at the joint level, Joint Forces Command (JFCOM) will begin experimenting with JDO starting in the summer of 2010 (Mattis, 2010).

Supporting a Marine Corps Distributed Operations Platoon

The suggested characteristics and capabilities are based on research done by Marine Captain Mathew D. Bain. Captain Bain's research analyzed the critical logistical requirements of a U.S. Marine Distributed Operations Platoon for the purpose of developing a sustainable support plan (Bain, 2005). His research involved using several modeling and simulation programs to examine a theoretical conflict. Captain Bain's primary measure of effectiveness for his study was the percentage of enemy killed over the course of the mission. The overall concept of the simulation model was presented as an inventory queuing model (Figure 5). In the model, servers are Marines, the warehouse is the supply chain, and the inventory is the supplies the DO squad has on hand. In a very Marine fashion, a "satisfied" customer is a dead one. The mechanics of the three sets of simulation Captain Bain used during his research are very complex and beyond the scope of this paper. However, his findings are very pertinent.

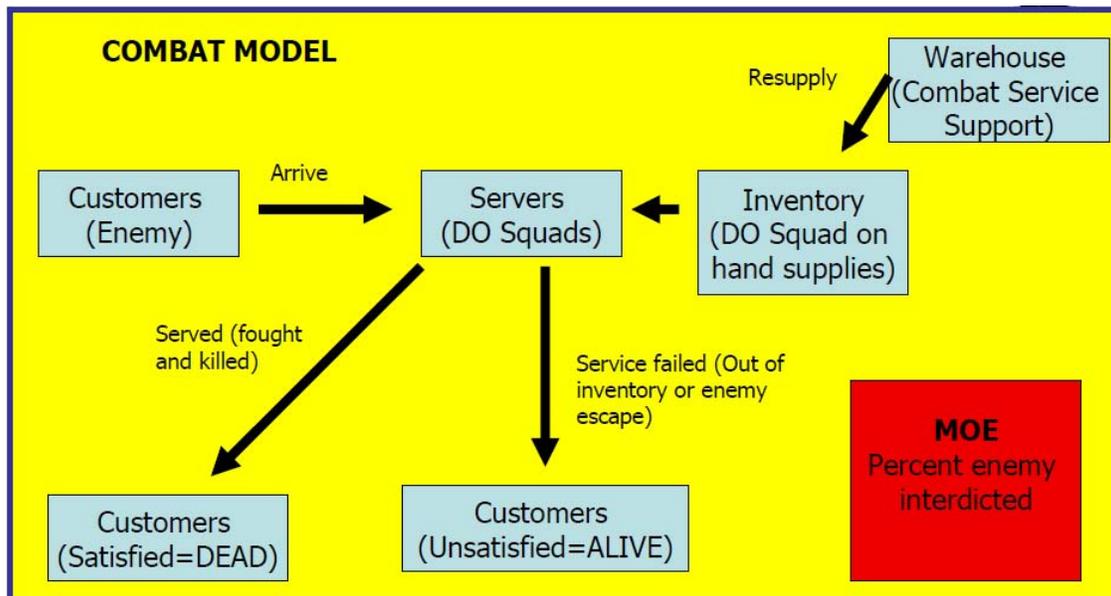


Figure 5. Captain Bain's logic flow for his research simulation (Bain, 2005:23)

Capt Bain had three research questions (Bain, 2005:xxi):

1. What are the critical logistical factors relating to mission success for the DO platoon in the missions envisioned in Marine Corps Warfighting Lab's (MCWL) Wargame Scenarios?
2. What are the critical logistical capabilities of the Marine Expeditionary Unit (MEU) that will enable it to provide continuous sustainment to a distributed force?
3. What is the supportability of a DO platoon across the range of missions?

He found the critical success factors for logistical support to be responsiveness of the supply chain, combat usage rate, and days of supply (DOS). For the second question, he found the critical logistic capabilities are as follows (Bain, 2005:xxiii):

- The DO platoon must have the capacity to carry at least three DOS.
- The combat service support (CSS) agency must have the ability to sustain scheduled resupply deliveries at least every two days.
- The CSS agency must be assigned dedicated, responsive, high speed delivery means.
- An anticipatory (or sense and respond) logistics system should launch missions 12 hours ahead of a predicted stock out or equipment failure.
- Resupply deliveries must be accomplished quickly, stealthily, or with heavy security (or a combination of all three).
- Logistical responsiveness, intelligence, aerial surveillance, and fire support are critical for unstable or extremely dangerous missions.
- The best performing logistics system (based on those modeled and analyzed) combines rapid request, fast delivery, aerial surveillance, a scheduled resupply rate, three or more DOS capacity, and a sense and respond logistics capability.

Finally, Captain Bain concluded, "A DO platoon is logistically supportable across a wide range of missions, providing the MEU is willing to commit the necessary resources, which are substantial, to support one platoon." A glance at his support strategy, which was based on the resources available to the Marine Corps when the paper was published in 2005, reveals the scope of support needed for only one Marine DO platoon (Bain, 2005:xxiii):

- The DO platoon should carry three DOS and combat ammunition load
- Two CH-46s should be assigned in direct support, transporting supplies internally
- Two AH-1Ws should be assigned for escort and landing zone security

- Two DOS resupply packages pre-staged and organized into fire team sized packages
- CSS agency should be located within 55 kilometers of the DO platoon
- Pilots, aircraft, and supply and ammunition packages should be on standby to keep response time less than four hours
- CSS agency should remain in continuous contact with DO platoon in order to track requirements and respond to demands

Bain (2005) used the following data for the purposes of his simulations. The cruising speed of the CH-46 was 145 knots. Its internal lift capacity was 3,890 pounds at 90 degrees and 4,000 feet. Two DOS without ammunition weighed 5,400 pounds; with four squad half loads of ammunition, the total weight of the resupply was 7,350 pounds. Eleven fire team sized packages weighing 500 pounds without ammunition would be needed to be positioned and waiting for the resupply efforts. Adding ammunition would increase the total weight required to an additional 1950 pounds, which could be packaged however mission dictated. Dividing between existing fire team packages would increase the weight to 677 pounds.

With regards to the airlift assets, Bain commented: “The risk of a DO platoon operation increases with the length of time it takes for supporting aircraft to reach it. This research estimates that a 15 minute or less time of flight is effective and gives an operational radius of approximately 50 kilometers using the CH-46” (Bain, 2005:xxiv). He went on to say having aerial surveillance of the DO platoon’s operating area was valuable in the simulation, and deploying a tactical UAV with the unit should be considered. The key to supporting a DO platoon in the field is maintaining a swift and agile supply chain flexible enough to respond to push or pull logistics.

Bain’s analysis of his data revealed some additional aspects of resupply. Unsurprisingly, the responsiveness of the supply chain was less important when the combat demand was low, and increased as the contact use rate increased. Setup of the

resupply event was inversely related to the speed of the event, so that a fast setup would mitigate a slow speed resupply, and a high speed resupply could mitigate a slow setup. The DOS was also less important in a responsive resupply environment.

Taken together, Bain (2005) recommended resupplying the platoon once every two days on average using pre-staged, fire team sized packages. Again, the airlift footprint for each event would be significant: two CH-46s hauling the supplies with internal transport (versus an external sling), and two AH1Ws providing suppression and landing zone (LZ) security, not to mention any UAV assets used for ISR. In order to maintain responsiveness when the platoon began combat operations requiring the supply chain to shift from a preplanned “push” system to a pull system, aircrews and aircraft would need to maintain standby status for the duration of the operation. Needless to say, this may preclude the use of those aircraft for other requirements. In addition, the DO platoon would need to remain within 55 kilometers of the supply chain origin to maintain optimum transit time of the supplies.

DOD Unmanned Systems Roadmap 2009-2034 UAS List

The DOD Unmanned Systems Roadmap 2009-2034 listed a number of unmanned systems being pursued by all the services, including UASs. While the capabilities of the systems listed focused on the ISR and attack missions, there were a few UAS system listed which are or could be capable of filling a tactical airlift role.

Boeing A160 Hummingbird

The Boeing A160 Hummingbird began as an effort by Frontier Systems, Inc., at Irvine, California. On May 4, 2004, Boeing purchased Frontier Systems and began work transitioning the concept aircraft to a production model (Boeing, 2004). The

Hummingbird is one of the finalists for ONR's UAS fly off in March 2010, and was one of the participants in AMC's cargo UAS symposium in November 2009.

The A-160 Hummingbird is a vertical take-off-and-landing UAV designed to fly up to 2,500 plus nautical miles with 30 to 40 hour endurance. Its modular payload design can carry up to 1,000 pounds, and allows for the aircraft to be used in a number of different roles. Along with precision re-supply, the UAS can provide reconnaissance, surveillance, target acquisition, communication relay, sensor delivery and eventually precision attack capabilities.

Between March 9-11, 2010, Boeing successfully demonstrated the Hummingbird to the Marine Corps at the U.S. Army's Dugway proving ground in Utah. According to the Boeing website, the A160T completed seven test flights during the demonstration, including a two-minute hover at 12,000 feet with the 1,250-pound sling load, and a nighttime delivery to a simulated forward operating base. The A160T's ability to execute accurate autonomous deliveries also was demonstrated (Boeing, 2010).

Combat Medic Unmanned Aircraft System for Resupply and Evacuation

This program is a research project purposed to investigate UAS technologies for delivering medical supplies and Life Support for Trauma and Transport (LSTAT) systems to combat medics and evacuating patients from hostile situations. While this program is focused on the medical mission, it need not be limited to patients and medical supplies, though obviously the Geneva Convention stipulations would apply to its use. However, this program is still in its infancy, and would not be a likely contender for immediate use in the tactical airlift mission.

Most of the specifications for this vehicle have not yet been determined. However, the threshold payload capacity is 500 pounds and the objective capacity is 1000 pounds. Five hundred pounds would allow for one patient and 1000 pounds could carry two.

MQ-8 Fire Scout

The Fire Scout is a Navy Acquisition Category (ACAT) IC program currently in the production phase (US Navy, 2010). The Army had selected the aircraft to be used as part of its Future Combat Systems Unmanned Aircraft Class IV system (DOD, 2009). However, the Army went on to cancel the program in January of 2010 in favor of the Shadow UAS (Havens, 2010). Also known to the Navy as the Vertical Take-Off and Landing Tactical Unmanned Aerial Vehicle (VTUAV) system, the UAS is designed to operate from air-capable ships with initial deployment on a Guided Missile Frigate (FFG), followed by final integration and test on board the Littoral Combat Ship (LCS) (US Navy, 2010). The system is primarily intended to serve in the ISR and attack roles; however, it is a potential platform for airlift as well.

The MQ-8 has a payload capacity of 600 pounds and can fly at speed up to 110 knots. It has a service ceiling of 20,000 feet and a five hour loiter time with a range of 110 nautical miles.

RQ-4 Global Hawk

The Global Hawk is a high-altitude, long endurance UAS designed to provide ISR to a broad area of up to 40,000 square nautical miles per day (DOD, 2009). While it is not designed to conduct the airlift mission, it is presented as an illustration of the type of payload possible by UAS aircraft and the foot print required for use.

The Global Hawk RQ-4B variant has a payload capacity of 3,000 pounds, and can fly at speed up to 340 knots. It has a 5,200 nautical mile radius and can loiter up to 28 hours. However, it also requires a prepared surface to operate and has a wingspan of 130 feet, only two feet less than that of the C-130 (US Air Force, 2009).

Other Cargo UAS Systems

At the time the DOD UAS Roadmap 2009 was published, the airlift mission for UASs was only a side note. At the time of publishing this report, interest in the airlift role for UASs has increased, though not to the level of ISR or attack. As such, manufacturers are bringing up their products as contenders for DOD to examine for future purchase. The following is not intended to be a comprehensive list of available systems, nor is it espousing the use of any particular system. These systems are listed to examine some capabilities available to DOD for the tactical airlift mission, and to illustrate any future program starting point.

Kaman K-MAX BURRO

The K-Max Burro and the Boeing A160 Hummingbird were the two systems selected to participate in a Marine Corps-sponsored technology demonstration in February of 2010. The A160 results were discussed previously. The Burro completed its demonstration to the Marine Corps in February of 2010. Performance attributes demonstrated included hovering at 12,000 ft. with a 1,500-pound sling load; delivering 3,000 pounds of cargo well within the six-hour required timeframe to a forward operating base (two 150 nm round-trip flights). Controllers remotely controlled the flight and a precision load delivery by a ground-based operator in both day and night conditions and uploading a new mission plan to the aircraft's mission management system during flight.

As an optional demonstration, Team K-MAX showcased the Unmanned K-MAX helicopter's four-hook carousel, which enables multi-load deliveries in a single flight. Lifting a total cargo of 3,450 pounds, the aircraft flew to three pre-programmed delivery coordinates, autonomously releasing a sling load at each location. At the customer's request, the fourth load delivery was performed under manual control by the ground operator.

III. Methodology

Research Design

There is a gap in the literature and research on the use of unmanned airlift, particularly at the theater and direct delivery level. Therefore, the research for this paper is largely in the literature surrounding possible mission areas for unmanned airlift, the current use of UASs in the United States, and an examination of existing tactical unmanned airlift systems. The next section of this paper draws conclusions from this material, present a high level concept of employment for unmanned cargo airlift, postulate some desirable characteristics and capabilities for the aircraft, and then conclude with recommendations for future actions and research.

IV. Results and Analysis

The research questions posed by this paper were designed to investigate the typical who, what, where, when, how, and why questions of a potential unmanned tactical airlift aircraft. This paper cannot cover every programmatic issue; however the more pressing issues are covered.

Research Question 1

The first research question covers the why and when questions: “Should the United States Air Force develop or participate in developing a tactical unmanned airlift aircraft?” In the opinion of the author, the short answer to this question is “yes” for a number of reasons. First, the vision at a number of layers of governmental leadership for the future of aircraft lies in unmanned systems. Second, the obstacles which exist in normalizing use of unmanned aerial systems are significant, and will require time and effort to solve. Finally, there is an emerging, and arguably even existing, set of missions for which a tactical unmanned system could be utilized in the near term with clear benefits over traditional airlift.

A Vision for Unmanned Systems

The vision of a future filled with unmanned systems to include aircraft lies at a number of layers of leadership. The Congress has clearly communicated its desire for the DOD and the FAA to take steps increasing the use of unmanned aircraft in more than one public law. The FAA is taking steps, albeit slow ones, to realize that vision. The Department of Defense in its Unmanned Systems Roadmap documents the desire not only of Congressional leaders but of combatant commanders to proliferate unmanned systems on an even wider basis to the soldiers, airmen and sailors in its employ (DOD,

2009). The Air Force and other services are clearly increasing the numbers and use of unmanned systems, particularly aircraft. The expectation of all interested parties is unmanned systems will play an important role in the future.

Timing for Developing a Tactical Unmanned Airlift Aircraft

A reasonable question to ask of this endeavor is why pursue it now? The DOD Unmanned Systems Integrated Roadmap pushes both strategic and tactical airlift out to 2028 (DOD, 2009). The Air Force does not set a specific timeline for unmanned airlift in its UAS Flight Plan, but does recognize the importance of integrating unmanned aircraft into the national airspace system (HQ USAF, 2009). The flight plan emphasizes the need to develop sense and avoid technology, which is also one of the concerns Mr. Babbit highlighted as a critical stepping stone for acceptance by the FAA.

The Flight Plan recognizes a second of the FAA's concerns, namely public acceptance of unmanned aircraft: "there needs to be a concerted coordinated public affairs communications strategy to highlight the USAF UAS accomplishments and emerging positions on UAS issues" (HQ USAF, 2009:42-43). The American public is very familiar with the idea of unmanned systems. While the public may even be enamored with the concept of UAV use overseas in support of combat operations, the idea of climbing inside an unmanned airliner is a long way from being accepted. Even the idea of ISR assets potentially watching them unseen from overhead may cause public discomfort should privacy advocates begin to lobby against widespread use over American soil. However, there are signs already of a growing acceptance of unmanned systems being used at home in support of Homeland Defense missions. Oscar Wilde once said, "Paradoxically though it may seem, it is none the less true that life imitates art

far more than art imitates life” (Wilde, 2007). The recent movie “Transformers II” showed a Predator supporting a Marine platoon and the Fox network television show “24” this season features the use of unmanned ISR assets it calls “drones” to assist in tracking down terrorists in New York City. A cynic might observe Hollywood only accurately represents real life by accident; however, growing incorporation of unmanned systems by entertainment media could be a sign of growing public acceptance.

However, making changes in the culture of a population takes time. Simply increasing the information flow about the military use of unmanned systems overseas is helpful, but the current battlefields are thankfully far from the United States shores, and therefore distant from the average American’s daily life. Supporting and sponsoring the use of unmanned aircraft at home in ways that are visible and tangible to the average American will have far greater impact on their acceptance by the general population. News stories about unmanned systems defending our borders or newspapers showing pictures of a tactical unmanned airlift aircraft supporting a humanitarian relief effort can make a difference now. If tangible efforts to increase the civilian population’s acceptance of the use of unmanned aircraft over U.S. soil, particularly airlift systems, do not begin until the planned implementation in 2028, it will take still longer to develop the public trust of those systems. During his interview, Mr. Babbitt emphasized the fact the public view of unmanned aircraft technology had as much to do with its integration into the NAS as did the existence of any enabling safety technology would by itself (Babbitt, 2010). A future unmanned airliner may have every safety technology currently in development coupled with a perfect safety record, but if the average consumer refuses to

trust it, that capability will die on the vine both for the civilian sector and the military as well.

A major benefit of pursuing this technology is not the immediate benefits, but future dividends which may not be fully recognized until much larger scale efforts are made to produce unmanned airlift in the future. However, if there are no combat benefits which can be realized in the near term, this project would likely be better left until such time as it would reap at least some benefits. Fortunately, there are opportunities which can be realized near term by using small tactical unmanned airlift to support such operation types as Joint Distributed Operations.

Missions for Tactical Unmanned Airlift Aircraft

Joint Distributed Operations seem to be an ideal candidate mission to be supported by tactical airlift UAVs. Captain Bain admitted his recommended helicopter support plan for JDO would require a significant effort. He did show his concept was a viable means of supporting a JDO platoon, however there are a number of potential shortcomings with his plan other than just the magnitude of effort.

There are a number of alternatives which theater commanders have at their disposal for resupplying forward deployed troops by air. Options include delivery by either airland or airdrop methods or a combination. Each weapon system and method of employing them have different attributes which commend them to supporting different missions of varying sizes. With regard to supporting the JDO mission, the smaller systems, such as the Sherpa, C-27J, and the future concept Light Mobility Aircraft (LIMA), would seem to be more appropriate choices given the size of lift most likely needed. However all existing means of aerial resupply have in common the visual and

noise impact they make and they are all manned by people. The very nature of JDO is it is conducted behind enemy lines which inherently put those troops at greater risk, along with the airmen who must fly past their enemies to support the Marines or soldiers on the ground.

Another key attribute of JDO is the use of multiple geographically separated units, all of whom would need to be resupplied at similar rates. The number of locations and number of times each unit would need to be resupplied would require a very large airlift effort. Either several aircraft would need to be sent to support each of the individual ground units, or one large aircraft would be needed making multiple stops. Either option would in turn extend its exposure to enemy fires as well as increase the chances of alerting the enemy to the presence and location of the ground units.

If Captain Bain's plan is followed, other impacts are evident. First, keeping four helicopters on call for each deployed JDO platoon keeps those resources from being used elsewhere. While the set of four helicopters could support more than one JDO platoon, at some number of platoons, the number of required helicopters and associated support people and equipment would increase proportionally. Large operations would require a large number of assets flying at a significant operations tempo all tied to supporting a single mission. This would represent an extraordinary effort which might be suited to accomplishing an infrequent high value mission, but may prove unsustainable for a large or protracted engagement.

Assuming a two week mission from the forward operating or staging base, six to seven resupply mission would be required. Four helicopters flying together are not subtle either due to the noise or visual impact of the formation. Even for an area in which allied

forces enjoyed air superiority, a resupply mission would be at least noticed, if not keyed on for a kinetic enemy operation. Each supply mission would expose the platoon's location, which could in turn reveal mission objectives or allow the enemy to mount an accurate counter attack. The aircrews would also experience risk as the enemy would come to expect the missions, even if they were not sure precisely where they were headed. As the enemy should be expected to take note of the pattern for each resupply mission, each sortie would operate with increased risk both to the Marines or soldiers on the ground and to the aircrews resupplying them.

Finally, conducting over 30 sorties (if ISR assets are included for the mission) for each JDO platoon may not be the most efficient use of resources. A company of JDO platoons would increase those sorties by four to five times. Given the relative skill of United States rotary wing pilots, these sorties would likely be very effective at resupplying a JDO platoon and protecting both the helicopters and operators during the resupply. However, unmanned tactical airlift aircraft represent cost-effective way to achieve the same effects. Later analysis will illustrate this point more fully.

Implications for Command and Control and the Joint Fight

Readers may note the missions mentioned in the previous section may not be Air Force missions. In fact, while delivering cargo and personnel “the last tactical mile” has received much attention over the last couple of years, the job of resupplying distributed units or FOBs are often not accomplished by the Air Force at all. The Army has made no secret of the fact they would prefer to do it themselves, in fact. The critic might then prefer this not be an Air Force acquisition at all. While this is an option for the Air

Force, this author believes there are still reasons for the Air Force to offer its mobility and UAV expertise to this effort, if not acquire its own systems.

First is the issue of command and control of these systems. Both the Departments of the Navy and the Army are actively pursuing this system for the sake of supplementing both their ground and rotary-wing mobility assets as well as decreasing risk to their aircrews and truck drivers. Their requirements have a lot of overlap, and could be met by the same cargo UAS. Even if they do not buy the same system, unmanned systems are much cheaper than manned systems, and so in the near future there could very well be lot of unmanned cargo UAVs fielded. If these systems are all or mostly employed in the direct support mission, that is a lot of individual commanders directing their personal mobility aircraft in whatever means they see fit. Unless there is both procedural and actual enroute control put in place on these systems, the skies over the theater could soon become perilous to both manned and unmanned aircraft. Having a “personal” UAV flying a preplanned route set by individual field commanders works well for individual units, but depending on the proliferation of these units, could be very problematic for joint airspace control. Joint Force Air Component Commanders (JFACCs) will need a means to both procedurally and proactively, if necessary, command and control all unmanned systems in their airspace, whether the asset is joint use or “owned” by the field commander.

This is not a suggestion that the Air Force should actively command and control all UAVs in theater whether they are joint use assets or not. However, the Air Force has the infrastructure in place to allow for beyond line of sight control of unmanned aircraft. It would be foolish to assume there would never be a need to redirect an unmanned airlift

aircraft once it started its mission, or that line of sight control or even SATCOM would be sufficient C2 to accomplish that task. Furthermore, while industry, the FAA, and the DOD are actively pursuing see and avoid technology, no specifications have yet been published or technology put into place to ensure enroute separation. Simply putting these aircraft on autopilot does not ensure enroute safety of other aircraft in the area. Enroute flight following and control would help mitigate that risk.

This author recommends first procedural controls be put into place to govern the airspace access of direct support cargo UAVs. Secondly, cargo UAVs should be capable not only of semi-autonomous flight to include auto takeoff and landing, but also of active line of sight control and active enroute control by beyond line of site means, such as the Air Force's satellite control system. Finally, as UAV proliferation continues to increase the need for reliable see and avoid technology will increase proportionally. As the Air Force tends to think more along the lines of joint use assets than its sister services, it is crucial for Air Force leadership to stay actively engaged in this program to help influence these types of decisions which affect the joint airspace.

If the Air Force chooses to participate in this acquisition program, it is likely other services would perceive that participation as a threat to their hope of acquiring a direct support asset for their own commanders' use. If this system does turn out to be affordable enough to purchase mass quantities of the system, it could be considered by field commanders to be almost an aerial Jeep. A cargo UAS would be extremely useful in this role, and recommends this view be encouraged by Air Force leadership. The command and control issues are not a means to take control of an asset but help sister services accomplish the mission for which these assets are intended. It would be counter-

productive to have a cargo UAV on autopilot plow into another aircraft enroute or inadvertently deliver supplies to the enemy who has just overrun the position of the unit the system was intended to supply simply because it could not be controlled enroute.

Research Question 1 Summary

Realizing a future wherein unmanned aircraft fly overhead of your average American accomplishing missions ranging from ISR to cargo to medevac without a second thought will be a slow process. Making large leaps in technology, laws, and public acceptance which will normalize the use of unmanned aerial systems in general, and unmanned airlift aircraft specifically, is unlikely. These types of advances happen incrementally over time. Investing in a tactical unmanned airlift aircraft now will realize some immediate benefits in mission accomplishment, but will most likely reap its greatest rewards not today or even tomorrow, but in a future with unmanned aircraft incorporated and accepted into daily life. Tactical unmanned airlift aircraft are a natural next step towards that future. Additionally, as unmanned systems will continue to quickly proliferate, it is crucial for the Air Force to stay involved in systems such as an unmanned tactical airlift UAS to ensure C2 and compatibility with and safety in joint use airspace.

Research Question 2

The second research question posed by this paper is “What notional CONEMPS might apply to this system or systems? Included in this question is the nature of the missions or effects this system is intended to achieve. Also, who should employ this system to accomplish those missions? Finally, how should the system be employed by these players to accomplish the missions with the intended effects?”

What missions should Unmanned Tactical Aircraft accomplish?

Unmanned systems are ideal for missions considered to be dull, dirty, or dangerous (General Dynamics, 2010:11). The vision for this particular system should be short-range resupply. This capability would be ideal for supplying a Joint Distributed Operations platoon, or similar operation. However, as that concept is still under development, the primary mission initially would be to resupply FOBs. Other roles are clearly possible, however, until the system gains FAA and ICAO acceptance, its use will be limited to combat zones, over water (such as resupplying off shore oil rigs), or uninhabited areas. Closely related to JDO would be Special Operations missions. On a broader scale, this system would be ideal for aerial resupply where responsive, small scale, low profile airlift is needed. This system is also suited well for short range resupply through contested airspace considered to be medium to high risk for manned airlift. Adding a modular ISR capability to this system would further reduce the footprint of support, both logistically and from a mission security point of view.

Dangerous airspace need not be the only environment this system is employed in. This system would also be useful at the tactical level for disaster relief efforts in distributing supplies from the main staging areas to outlying communities and pockets of survivors. A system which combined airlift and ISR would be useful in an attempt to both locate survivors and provide them needed supplies until help can arrive. Once again, these sorts of uses would require special coordination with the FAA or local nation. The effort required to coordinate such missions may well be worth it however, as such missions gain instant media coverage, which in turn moves the political machine closer to more global acceptance of unmanned aircraft.

Other less common resupply efforts might also be addressed, such as missile sites or Alaskan bush communities. Airlift aircraft are traditionally useful across any number of roles, as the C-130 clearly demonstrates with its wide spectrum of missions. The usefulness of this system would similarly be limited only by the creativeness of its beholder. However, for the sake of design, the greatest military utility would be supporting small combat units performing JDO or similarly distributed operations.

If this system proves to be effective at resupplying small units, its concept would be a stepping stone to larger, more capable systems. There has been a debate in mobility communities over the past few years of the best way to deliver supplies “the last tactical mile.” This catch phrase refers to the final distance supplies must travel to reach the forward most ground troop closest to the fight. The shortcomings in this department fueled the debate surrounding the acquisition of the Joint Cargo Aircraft, the C-27J (AirForce-Magazine.com, 2009). Larger systems with similar characteristics and capabilities to the UAV being proposed in this paper could bridge the gap between effectiveness and efficiency of common use airframes by providing an alternative cheaply enough to allow individual infantry and Marine commanders in the field their own “personal” airlift. Clearly before an unmanned system can be used similarly to a manned airlift platform, changes in technology and perception are needed. These barriers will be covered in the discussion for Research Question 4.

What effects should Unmanned Tactical Aircraft accomplish?

The first purpose of Captain Bain’s research was to discover which critical logistical factors of resupplying a DO platoon contributed to mission success. The data strongly suggested responsiveness was most critical, followed by combat usage rate and

DOS (Bain, 2005). The conclusion then is whatever means of transporting the supplies to the Marines or soldiers should be primarily concerned with ensuring those three factors as much as possible.

The requirement of responsiveness should play a large determining role in the method of transportation chosen for tactical resupply. However, it is a vague term which should be tied to specific qualities. Responsive supply to a Marine or soldier should be immediately available on their timeline. While scheduled resupply is certainly the most preferable and the least complicated for the unit providing the resupply, it may not be enough for a troop under enemy fire. If ammunition or food runs low, or worse, runs out, the responsiveness of the resupply could be the difference between life or death of the combat troops, which in turn determines the success or failure of the mission. If resupply is viewed in equal terms to fires, a troop does not need an artillery shell dropped on a grid coordinate sometime next week; he needs it right NOW. A platoon should not run out of critical supplies if it is planning properly and supported well, but depending on the plan going perfectly gives no credence to the fog of war. Ideally, a supply system should be as responsive as supporting fires. Tactical unmanned aircraft may for the first time provide this as a capability.

Currently, airlift planning is defined and constrained by the Airlift Tasking Order (ATO) 24-hour cycle. This system has succeeded very well at bringing order to the chaos of resupplying an area of responsibility. It meets the strategic and operational levels of war very well, as long as the requested resupply is more than 24 hours out. The system can accommodate shorter time spans, but any change once the plan has gone into execution requires a plan change which impacts the airlift plan for the next day, if not

even further into the future. Responsiveness exists in the current system, but at a cost. As previously mentioned, dedicating support to a DO platoon either ties up dedicated organic airlift or takes away common use airlift from the entire system.

Who Should Develop Unmanned Tactical Airlift Aircraft?

This system, especially if it is employed in manner similar to how Captain Bain recommended traditional rotary wing assets should resupply a JDO platoon, lends itself especially to the direct support mission. As a result, the systems should be attached to either infantry or light cavalry units and be piloted either organically or by imbedded Air Force operators. Use of these systems might be cost-effective solution to the direct support question currently being debated by Army and Air Force leaders.

During the first symposium for unmanned cargo aircraft hosted by Air Mobility Command, possible characteristics of a potential system were discussed. While no definitive answers were decided upon, the group did feel any work in this area should be a joint effort. This author full-heartedly agrees with this assessment, for reasons stated above. A more pertinent question than who else should be involved besides the Air Force, is whether or not the Air Force should be involved. This author would recommend it should be. Other services are making enormous efforts in this area for systems up to and including medium sized unmanned aerial systems, while the Air Force has lead the way for medium and large UAVs (DOD, 2009). A tactical unmanned airlift aircraft would fall somewhere in between. While the direct support mission certainly favors the other services, this system would be a direct stepping stone to larger systems, which would certainly favor Air Force patronage. In addition, while other services perform some airlift duties, and do so admirably, global mobility is one of the core

competencies of the Air Force, and as such even a short range mobility asset still falls within the circle of Air Force influence. Not to put too fine a point to it, but if the Air Force wishes to maintain its dominance and leadership in the mobility realm, it should pursue supporting even small systems such as this, even if the most immediate beneficiary would be another service.

Who should be the unmanned cargo aircraft force providers?

The primary force providers should be Army and Marine Corps infantry units, probably at the battalion level. Depending on how “affordable” these systems turn out to be, the proliferation may even be at the company level. An MQ-9 Reaper costs around \$13.375 million. Research was not able to find a definite cost for Kaman’s K-Max Burro or Boeing’s A-160 Hummingbird. However, since neither aircraft is likely to be equipped with the sensor suite a Reaper carries, it is unlikely they will cost more. Regardless, these systems will likely be affordable enough to purchase a small fleet of them.

At this point, it would probably even be best if the services pursued different contractors, as well. This should be possible with affordable unit cost even without economies of scale. This would allow for competition, and for more parties working on advancing technologies which will benefit unmanned cargo aircraft in the future.

The remaining question is whether or not the Air Force should purchase any systems. This author recommends the Air Force should buy at least some of these systems to support common users. Not only will the mission be enhanced by the Air Force’s participation, but there could be other benefits as well. First, with greater proliferation of these systems comes greater comfort and acceptance among both service

members and civilians. This plays at least some role in how quickly the FAA is willing to move to incorporate the systems into the NAS. On that note, greater participation can only help advance technologies which will help with UAV entrance in to the NAS. Finally, as previously stated, owning some systems will allow the Air Force to help continue to guide cargo UAV policy and integration into the joint arena.

How Should Unmanned Tactical Airlift Aircraft Be Employed?

Specific recommendations for specifications of the unmanned systems will be addressed by the next research question; however some characteristics will be introduced in this section.

If Captain Bain's supply plan is used, resupply missions to particular platoons should be conducted every two days on average. He also emphasized the need for the supply chain to be sensitive to both push and pull demand. This required level of responsiveness will require pre-packaged supplies to be on hand and ready for a UAV mission just as they would for a traditional manned resupply effort. Given an unmanned tactical airlift aircraft with similar speed characteristics as a CH-47 (approximately 150 knots cruising speed), forward operating bases will still need to be within 50 miles of the operating location of the JDO platoon.

An unmanned tactical airlift aircraft should be smaller and quieter than a traditional helicopter. Additionally, the flexibility of an aircraft with vertical take-off and landing (VTOL) capability would be an enormous asset to ground troops, especially if these aircraft are used for the direct support mission. Given a quieter and smaller aircraft with the capability to loiter, resupply missions could provide their users with a window of time for resupply instead of a specific time. Additionally, the risk to the user would be

reduced as unmanned tactical airlift aircraft would be far less noticeable by sound, sight or even radar. Clearly, the aircrews of the manned helicopters are also potentially safer, as they can now be used for missions which do not require repeated flights over and to the same geographic areas. They can now be used for missions that may still require manned aircraft.

How Should Unmanned Tactical Airlift Aircraft Be Controlled?

This system is ideal for the direct support mission, and could be used as a common user asset as well. Primary command and control should be at the discretion of the unit commander the system is assigned to. As mentioned in the discussion in Research Question 1, there should be some central coordination of the use of these assets. It may be necessary to include these missions on the Air Tasking Order for the sake of deconflicting the airspace, not for exposing the lift capability to the mobility system writ large. While Combined Forces Commanders (CFC) may elect to employ some number of unmanned cargo aircraft to the joint use system, command and control of direct support assets should remain with the unit commander. While a likely level of command would be the battalion level, the only limit would be the mission required and training.

Ground unit commanders must realize, however, the impact employing their “personal” cargo UAV may have on the joint airspace picture, especially if they attempt to do so without coordination. A cargo UAV flying a mission on autopilot is not the same as a manned helicopter who is not only in contact with ground or airborne C2, but can redirect either the flight path of the aircraft to avoid an airborne obstacle or redirect the mission itself as needed. In densely populated airspace, or when conducting missions which need to be reflagged, C2 may need to be relegated to an enroute UAS pilot via

satellite, then passed back to the supported field commander when the aircraft reaches its destination. In such a circumstance, for the duration of the enroute portion of the flight, tactical control (TACON) of the remote pilot would be passed to the field commander conducting the resupply mission. As sister service operation of larger ISR UAS becomes more widespread, this construct of C2 may have more relevance to all types of unmanned aircraft.

Research Question 2 Summary

Tactical cargo UAVs are ideally suited to the direct support mission, which has implications for who should primarily procure, operate, and command and control the assets. While it would be valuable for all services if the Air Force was involved in the development and procurement of this asset, it would not be necessary for the Air Force to take a lead role at this time. However, the Air Force could and should play a part in conducting missions where the enroute portion of the resupply mission goes beyond line of site of the C2 nodes of the unit conducting the mission. In those cases, the Air Force could support the mission by controlling the asset from after launch until control could be passed to the receiving party. Even if these assets are commanded and controlled solely by the users, it will be very important that their use is coordinated through the ATO process. Independent employment of unmanned tactical airlift could cause hazards to manned flight operations.

Research Question 3

The third research question addresses the physical attributes the author recommends for a tactical unmanned airlift aircraft, given the CONEMPs suggested in

the previous section. These recommendations are based primarily on Captain Bain's research and the report conducted for the Army by General Dynamics.

What cost structure should Unmanned Tactical Airlift Aircraft have?

A temptation when acquiring a new system is to buy as much capability as one can afford, if not more than one can afford. Such a decision may actually be appropriate for some systems, and it could be argued in some cases a more capable system offers the best value. This system is intended to support small combat units operating in medium to high risk environments. These environments may not be located in airspace where the United States enjoys sovereignty or even complete air superiority, particularly in the case of special operations support. Operating in such an environment would be hazardous to the pilots because of ground or airborne threats. Conventional wisdom would require either a large support package of combat aircraft to guard the airlift assets, or an attack campaign which would create a permissive airspace for mobility aircraft. However, the former might actually endanger the ground troops who were hoping to maintain a low profile and the latter may not be a viable option depending on the international relations (or the appearance of relations) the nation is wishing to maintain despite the combat operations it is conducting.

An unmanned system, however, could operate independently without risking pilots and subtly enough to avoid adding risk to the ground mission. Because such a mission does carry risk to the aircraft, attrition should be expected. As such it would be preferable to purchase an asset which accomplishes the mission but does not adversely impact the force structure if it is lost in combat. For example, purchasing an asset with expensive defensive suite could be counter-productive if it added a significant amount to

the overall cost (acquisition, operating, and maintenance). While a degree of survivability is desired, keeping costs low enough to purchase significant numbers of these systems is more important to the overall mission. The same logic applies to other advanced system additions which may not be essential to the basic mobility mission set..

There are other benefits to acquiring a simple and inexpensive system. First, the government would be able to afford more of them. This would not only reduce the risk of loss, but provide much more cargo airlift capacity to the user. Second, a simple system would be easier and cheaper to maintain and repair, particularly in deployed or field conditions. Finally, simple systems are less likely to experience difficulties related to the integration of the technology, which leads to greater availability of the asset.

What chassis style should the Unmanned Tactical Airlift Aircraft have?

The kind of responsive flexibility Captain Bain describes is best achieved by a vertical takeoff and landing (VTOL) aircraft, though airdrop was also listed as a viable resupply method. There are some tilt-rotor unmanned aircraft being explored in industry, however, these style of aircraft are far more complex, and therefore expensive, than a comparable rotary-wing aircraft. The Air Force tendency is to look first to fixed wing options due to the historical and legal separation between the Air Force and Army, and, because Air Force aircraft are primarily fixed wing. For this mission, however, a fixed wing aircraft would not be flexible or responsive enough to be able to meet the requirements of supporting a JDO or resupplying FOBs.

There are a number of reasons for this observation. Fixed wing aircraft, even those designed for short field take-off and landing (STOL) operations, require some sort of runway to operate. Even C-130 and C-27J style aircraft have limitations on what type

of surfaces they land on. Air Force regulations require some type of landing zone survey be accomplished before using a surface as a landing zone (HQ USAF/A3OS, 2007).

In other words, operating fixed wing aircraft into a location requires not only for friendly forces to control the real estate to be landed on, but worse, for the surface to be prepared. While these requirements can be waived, it is not normal procedure for the Air Force to operate in such a way. JDO requires resupply every two days per platoon. These units are actively maneuvering toward an objective, and as such may not be in even the same region from day to day. Expecting these platoons to spend time every two days to first find, then survey, and then prepare an LZ for resupply would be at best counter-productive to their mission. Even with preplanning, the landing sites would still require survey and LZ preparation, which still would take time the platoon may not have. The burden imposed by these requirements restricts any air-land resupply effort to be accomplished by a VTOL-style aircraft. These aircraft only need enough of a break in the foliage and terrain to ensure clearance to maneuver, and a flat place on the ground large enough for the aircraft itself. No other style of aircraft chassis provides enough flexibility to resupply JDO by airland.

What lift capabilities should an Unmanned Tactical Airlift Aircraft have?

Captain Bain summarized the cargo requirements for supporting a JDO platoon with two DOS as being 5,400 pounds of supplies and 148 cubic inches without ammunition. Four squad half-loads of ammunition would add approximately 2,000 pounds at 48 cubic inches. The cargo capacity of an unmanned tactical aircraft would depend on how many units decision makers would like to employ per resupply. Also,

given the differences in density between routine supplies and ammunition, the stores should be evaluated separately to determine lift characteristics.

The Marine Corps Universal Need Statement called for a slightly lower requirement. It required the ability to operate 35 nautical miles (NM) offshore to a point 250 NM inland with a payload of 1,600 pounds. The flight should be conducted at 250 knots enroute between an automated takeoff and landing. Since the aircraft would be operated from onboard ship to locations with varied terrain and vegetation, it should also have a small landing footprint, though the size of the required footprint was not specified. Affordability was also an important requirement as these aircraft would operate in combat.

Similarly, the General Dynamics report, recommended a lift capacity of 4,000 pounds in order to support a company-sized requirement of just under 7,500 pounds per day or a company sized supply of nearly 30,000 pounds per day. The numbers between the Army estimate and Marine calculations are very close, so the GD report's minimum recommendation would apply to either service. Lesser weight capability could still serve, but would ultimately lead to less capability as increased sorties would be needed to resupply a company-sized element. Based on these figures, the recommendation is either a minimum capability of 4,000 pounds or 8,000 pounds. Intermediate values would not reduce the number of sorties required, and more capacity would be unnecessary. It may be, however, that greater than 4,000 pound lift capacity would be cost preventative in the construct being recommended by this paper. As an unmanned aircraft can be operated nearly continuously, limited only by maintenance status and fuel availability, purchasing more units could give more capability than buying fewer units with greater capacity.

Insufficient data is available at this time to make any more than a guess as to what actual advantages may be, but as data becomes available, future studies should be done.

The GD report also recommended several other attributes of a potential unmanned cargo aircraft. It recommended a range of at least 400 to 420 kilometers, and the ability to operate in varied weather conditions. The environment it described was essentially Afghanistan, which has one of the most challenging environments in the world. Wind, high density altitudes, precipitation, sand and dust, uneven terrain, and ground obstacles are all considerations for a cargo UAV. The GD research team also asked their survey respondents what degree of delivery precision they required (Figure 6.) While the most common response was within 100 meters, there were a significant number of respondents (approximately 10 percent) who gave a requirement of under two meters.

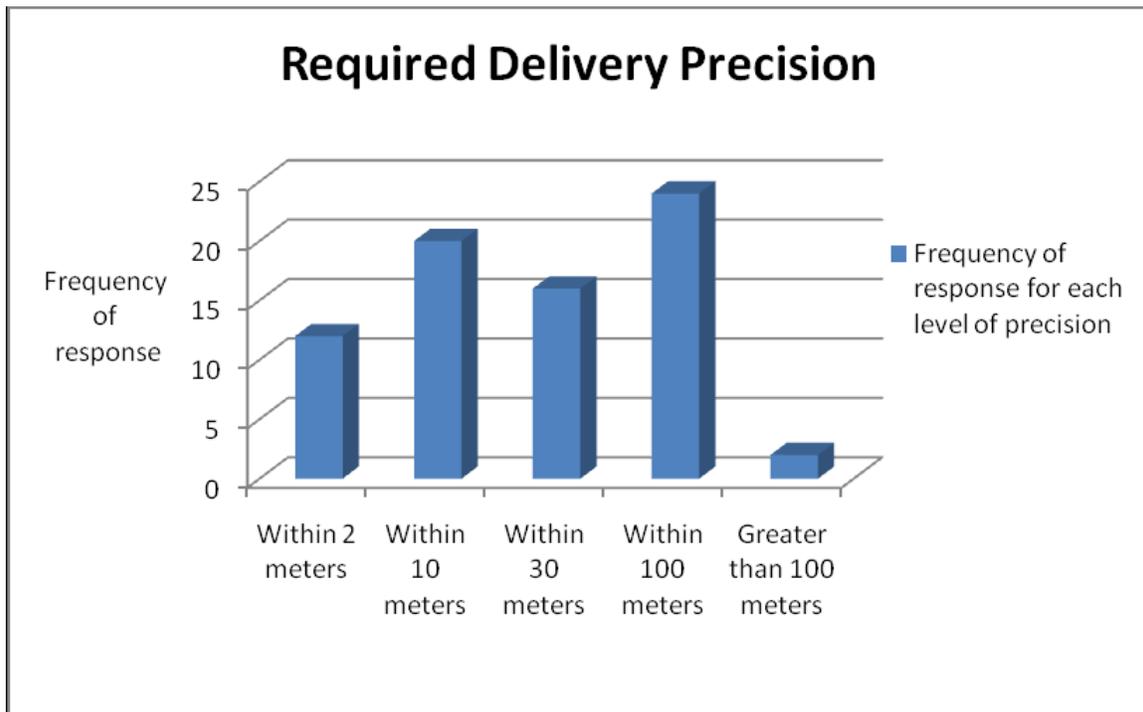


Figure 6. Resupply delivery precision survey results (General Dynamics, 2010:60)

The GD researchers also asked their participants about other attributes they found to be important for a cargo UAS. The top responses included: day/night operating capability, all-weather capability, ability to land in a confined area, speed of delivery, low maintenance needs, mission endurance, ability to carry a wounded individual, load capacity greater than 2,000 pounds, low noise signature, mission range, and autonomy (Figure 7).

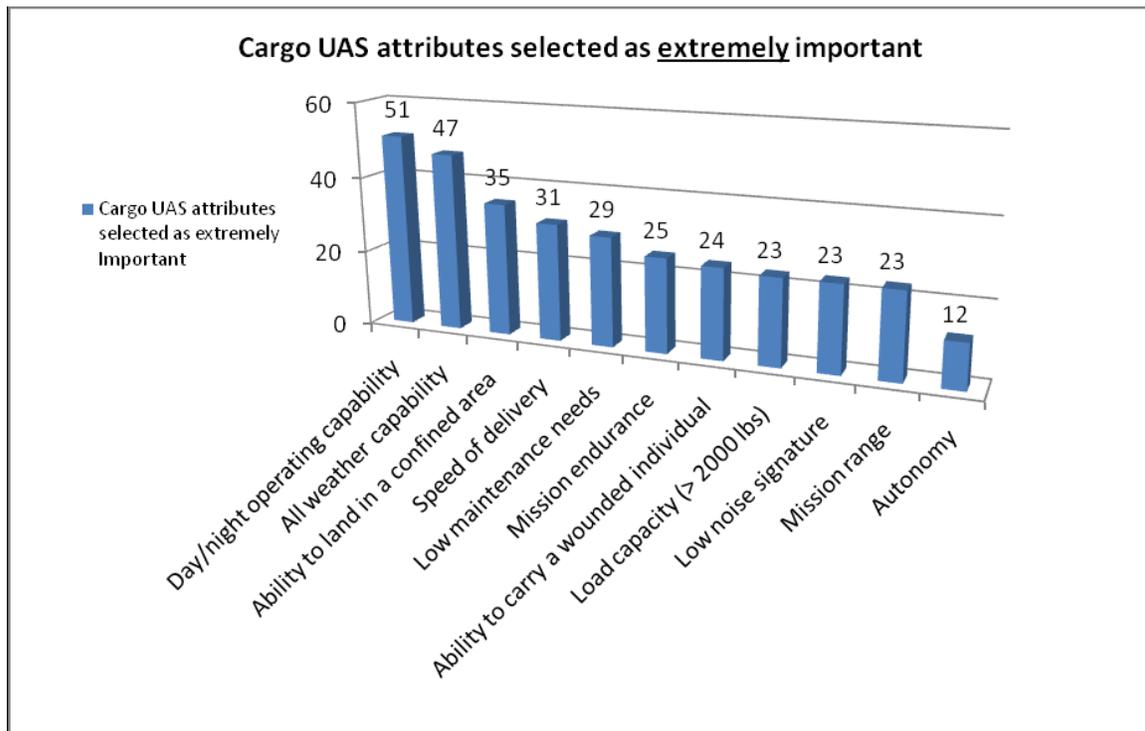


Figure 7. Rank order of important attributes for the cargo UAS (General Dynamics 2010:61)

Research Question 3 Summary

The research showed that the requirement for a tactical unmanned aircraft was not for a complex machine, but one which could operate in a complex environment, such as the environment which Afghanistan offers. The need is for a VTOL aircraft which has the ability to deliver an objective load of 4,000 pounds, though the Marine Corps threshold was less at 1,600 pounds. The precision threshold should be 100 meters with

an objective of two meters. The Army's round trip delivery distance should be in the order of 400 to 420 kilometers (216 to 226 NM), though the Marine Corps initial requirement was to be able to operate for at least 285 NM. Assuming they intended this to be a round trip, this is a requirement for 570 NM, which is as much as 354 nautical miles further than the Army requirement. The differences in the services' requirements support the pursuit of different contractors and models, unless an affordable craft can be purchased which meets the objective numbers for each services' requirements.

Research Question 4

The final research question asks what barriers exist in using current technology to meet a notional requirement for unmanned airlift vehicles.

The technology exists today to conduct this mission and meet most of the requirements presented by the Marine Corps and Army. Both the Boeing A-160 Hummingbird and Kaman K-Max Burro met the requirements of the Navy UNS at the fly off earlier this year. The Army requirements are very similar, though it remains to be seen if either of the above systems or another similar one would be considered to be affordable. These systems could be used tomorrow in the combat zone, if decision makers so desired.

Unmanned Aircraft and the National Airspace System

The biggest long term technological limitation for all unmanned aircraft is the ability to fly in a national airspace system, be it the United States or elsewhere. The two top concerns are "see and avoid" or "sense and avoid" capability and the loss of control, either by the loss or compromise of the data link. The first barrier that should be addressed is not the development of the technology itself, however. The first order of

business must be to publish requirements for that technology. Until the FAA or some other regulatory body of another country publishes hard technological requirements, industry will have no target to shoot for in the development of these technologies. Since this is uncharted territory for everyone, it is going to take a degree of fortitude for those policy makers to make a decision, and accept they will not have a perfect solution the first time. They cannot wait until technology is in place to publish these policies. Nor should the FAA continue to claim unmanned systems cannot “see and avoid”, cannot perform in a predictable manner upon loss of the data link, and are generally unsafe until it defines what each of those things actually mean. The proverbial chicken and egg could be applied here, but in this case, the chicken is the policy, and it must come first if real progress is to be made.

Progress in this area needs to come sooner than the 5, 10, or even 20 years being predicted by the DOD Roadmap or the USAF UAS Flight Plan. Currently, the United States enjoys control of the skies over Afghanistan and virtual control of the Iraqi NAS. However, the United States is trying actively to build the infrastructure of both countries back to the point where they are again sovereign nations by their own right. When that happens, and as those countries begin to make their own airspace control rules, it should come as no surprise that they are no longer pleased to allow unmanned systems unmitigated access to their sovereign airspace, particularly if the United States does not even allow them unrestricted access to its own airspace. Solving the issues preventing UAS access to our nation’s NAS should be a top priority.

Of close secondary importance to written guidance from the FAA is for all interested parties to jointly develop a list of requirements. Even if this system is to be

purchased unilaterally by one service, it will be operated in a joint environment, coordinated and controlled by a Joint Forces Air Component Commander, with all of the restrictions and complications of joint operations bring. As with UAS entry into the NAS, publishing which goals the program is trying to achieve will have a unifying effect on the efforts to advance the technology.

Affordability

Another issue is that of affordability. This system must be affordable enough to purchase quantities which would allow it to be the aerial equivalent of a High Mobility Multipurpose Wheeled Vehicle (HMMWV). This system could at least partly solve many of the tactical airlift and manning issues plaguing both the Army and the Air Force, but it must be affordable to do so. Achieving a cost effective and mission effective system will involve a full-spectrum approach to the acquisition program. This is not only a technological issue, but a contracting, system design, economical, manufacturing, and political issue as well.

Command and Control

Command and control is also a barrier, though not for strictly technological reasons. Currently, the Air Force does not have a homogenous C2 system even between its own unmanned systems. Due to contract limitations, each UAV system continues to be proprietary and unique to the individual system. Discussion in Research Question 1 emphasized the need for a cargo UAV to be capable of remote split operations, which the Air Force is already adept at. However, this argument loses traction without a common C2 architecture between Air Force RPA systems for use by a potential cargo UAS.

Contested Space and Cyberspace Environments

Should forces be operating in an environment which is contested in space or cyberspace, use of tactical unmanned airlift, or any unmanned operations, could be problematic. Superiority in these regions will be necessary to ensure the ability of unmanned aircraft to operate. Since it may not be possible to guarantee superiority during all phases of conflict, it will be necessary for the foreseeable future to continue to maintain a manned airlift force, even as technology and policy solutions become available for the other barriers listed.

Research Question 4 Summary

There are off-the-shelf products available today which can meet the most basic requirements for all services interested in a tactical unmanned airlift aircraft. However, before any unmanned airlifter can be fully utilized, there are several barriers which will need to be faced. The largest long term barrier is entry into the United States National Airspace System. In truth, this barrier exists world-wide for anywhere but Iraq and Afghanistan, but the United States NAS should be handled first. This could provide a model for other countries acceptance of unmanned aircraft in their sovereign airspace. Overcoming this hurdle should be done first by the FAA producing a “target” list of safety requirements for unmanned aircraft so that industry and DOD can know what technology is required.

The two biggest pieces of the safety puzzle is the ability of an unmanned aircraft to see and avoid and guaranteed command and control, regardless of opposition. Solving these problems will both help NAS entry, and increase the operational usefulness of unmanned systems operated by the DOD.

V. Summary

This paper has attempted to cover the major questions about unmanned cargo aircraft from an Air Force perspective. The recommendations are those of the author, based on facts and previous research.

The Air Force should pursue not only assisting in developing, but perhaps even purchasing these systems for a number of reasons. What they amount to is unmanned systems are the future of aviation. Most predictions by the services did not anticipate unmanned airlift as becoming a factor for another decade, mostly because they realize the limitations of including these systems in the NAS. However, urgent need statements from the Marine Corps and vision statements from the Army are making the day of unmanned airlift appear to be just around the corner.

This reality has implications for the Air Force. Paths are already being set by the Navy and Army as to which systems are to be purchased and the CONOPS under which they will operate under. Most of those decisions are well thought out and meet the needs of the respective services, yet they may not be taking the joint picture completely into account. If the Air Force wishes to have a voice in a system which will be the forefather of our future mobility fleet, then it should act now to participate in this acquisition program.

The most notable changes which may need to be addressed in the Navy and Army programs are that of command and control. Both procedural and actual controls are needed to address the critical enroute phase of flight. Currently, both the A-160 Hummingbird and K-Max Burro depend on largely semi-autonomous route following

with limited beyond line of sight capability. The Air Force's remote split operations concept could help our sister services maintain enroute control of their systems, even in mountainous terrain. Procedural controls ensuring those flights appear on the ATO will help protect other pilots from the wave of unmanned airlift missions which are sure to come.

The reality that unmanned airlift is coming sooner than predicted also puts a degree of urgency on the need for see and avoid technology, as well as ensured control of the systems. However, even before the technology is fielded, requirements and expectations for the degree of capability required must be published by the FAA. Without clear goals to shoot for, industry cannot hope to hit the right target.

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14. ABSTRACT Much literature has been published on unmanned aircraft in general, particularly in the roles of intelligence, surveillance, and reconnaissance (ISR) as well as attack. Less has been written on the use of unmanned aircraft in mobility roles. What has been written was from a strategic airlift perspective and air refueling. Virtually nothing, however, has been published on unmanned tactical airlift. The purpose of this study is to examine unmanned tactical airlift from an Air Force perspective. This is not a quantitative analysis, but rather an examination of the merits of unmanned tactical airlift as well as a recommendation of why, what, how, and when the Air Force should pursue such technology. Due to the lack of literature, this cannot be considered a formal case study; however, a thorough examination of available literature is presented as well as research by other authors suggesting desirable characteristics for an unmanned tactical aircraft. In addition, barriers to implementation are examined and a potential way ahead for the Air Force suggested as well.					
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