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Employment of emerging UAS could enhance Marine logistic capabilities by increasing throughput efficiency, minimizing operation and maintenance cost, maintaining operational tempo, and diminishing risk to troops from IEDs. This paper will examine various emerging UASs for their capability, affordability, feasibility, and their implementation in combat scenarios to support Marine logistics for future operations.

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Aerial Unmanned and Autonomous Systems: A future force multiplier in supporting dynamic and complex logistic sustainment operations for the U.S. military.

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Marine Corps logistics always seeks to support the MAGTF in any complex, dynamic environments in war or peacetime operations while remaining agile, lean, and responsive. The constant evolution of the enemy's techniques, tactics, and procedures (TTP) has significantly challenged ground logistics to support Marines, especially in Afghanistan employing IED. Nevertheless, aerial unmanned and autonomous systems (UAS) employment could disrupt the enemy's IED TTP and revolutionize future ground logistic methods for current and future battlefield operations.

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LIST OF ACRONYMS

AACUS Autonomous Aerial Cargo/Utility System

CASEVAC Casualty Evacuation

CONOPS Concept of Operations

COP Combat Outpost

COTS Commercial off the Shelf

CUAS Cargo Unmanned and Autonomous Systems

DOS Day of Supply

EAB-O Expeditionary Advance Base Operations

ERP Enterprise Resource Planning

FOB Forward Operating Base

IED Improvised Explosive Devices

JTAARS Joint Tactical Autonomous Aerial Resupply System

LZ Landing Zone

MCWL Marine Corps Warfighting Laboratory

MEDEVAC Medical Evacuation

OCS Operational Command Supervisor

ONR Office of Naval Research

TTP Tactics, Techniques & Procedures

UAS Unmanned and Autonomous Systems

UAV Unmanned Autonomous Vehicle

ULS Unmanned Logistics System

UUNS Urgent Universal Needs Statement

VTOL Vertical Take Off and Landing

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PREFACE AND ACKNOWLEDGEMENTS

As a Naval officer with a background in electrical engineering, I was very curious about how future unmanned and autonomous systems (UAS) can enhance Military logistics. In my opinion, it was a technology that has not fully exploited by the military, and its potentials for militarization were limitless. I chose this topic because technology had advanced tremendously in the last hundred years and autonomous systems could be a new revolution of their own. I started writing this thesis under the impression that UAS could enhance military logistics, but I was not aware that the technology had already progressed further than I had expected.

I want to start off by thanking my family for their love and support throughout this academic year at the Marine Corps University. Second, I would like to thank the staffs and officers in the Marine Corps Warfighting Laboratory, the Office of Naval Research, and the Marine Corps installation and logistics headquarters. Their most up-to-date information provided valuable guidance throughout my research and writing phase of my thesis. Finally, I would like to thank my MMS mentor, Dr. Paul D. Gelpi, for his patience and willingness to accept me to take on this thesis.

Executive Summary

Title: Aerial Unmanned and Autonomous Systems: A future force multiplier in supporting dynamic and complex logistic sustainment operations for the U.S. military.

Thesis: The Marine Corps had experienced unacceptable losses to its troops and equipment from the enemy's IED TTP during ground logistic support in recent campaigns, and existing logistic sustainment methods have difficulty in bridging all the gaps during denial or limitation of service in austere and contested terrain. Implementation of emerging aerial unmanned and autonomous systems (UAS) in the immediate future could be the solution for Marine logistic vulnerability and restriction by increasing logistic support availability, reducing life cycle equipment costs, and diminishing risk to Marines from the enemy's IED TTP.

Discussion: The Marine Corps has been and will always be at the forefront of any combat engagement or counterinsurgency missions around the world. As these highly maneuverable combat elements disperse over a larger area of operation than ever before, the Marine logistics support becomes more challenging to maintain responsive, flexible, and sustainable. The use of UAS has proven successful in Afghanistan in combat operations, and the Marine Corps leadership sought to exploit the benefit of UAS in logistic supports to minimize human losses and workforce limitations. Implementation of the UAS assets in the Marine Corps logistic will be paramount for future combat logistic sustainment and support.

This paper will provide a brief description of existing UAS and examine three emerging technologies/platforms for their capabilities, affordability, and their crucial role in evolving Marine combat logistics support: mainly counter IED threats. Additionally, multiple theoretical scenarios will be introduced to illustrate the concept of operations for each emerging UAS for its functionality to enhance future Marine logistic capabilities.

Conclusion: The U.S. Military must continue to exploit new technologies to remain technological advantage over its adversaries. The introduction of UAS in its advanced form for logistics distribution is comparable to methods of conducting logistic support evolving from a horse to automobiles, and, at present, from automobiles to aerial, autonomous systems. These emerging technologies will allow unmanned and autonomous aircraft to transport Class I, III, V, medical supplies, parts, medical evacuation, and casualty evacuation: their capabilities are limitless. Additionally, the implementation of such innovations can disrupt the enemy's IED TTP by minimizing convoys on the roads. Furthermore, the employment of UAS could significantly enhance the Marine Corps' capability in its concept of operation in Enhanced Company Operations (ECO) and Seabasing.

Introduction

> Interaction therefore will be most frequent between strategy and matters of supply, and nothing is more common than to find considerations of supply affecting the strategic lines of a campaign and a war.
>
> -- Carl von Clausewitz, *On War (1832)*

Sustainment is the provision of the necessary logistical services to maintain and extend operations until mission successes or redeployment of force.[1] While the aerial unmanned and autonomous system (UAS) has proven to be a tremendous success to provide real-time intelligence and weapon delivery during combat operations in Iraq and Afghanistan and counter-insurgency missions, the military could further develop its capability in logistical support. As UAS technology advances, leaders in the Marine Corps have been promoting the exploitation of different innovation in UAS platforms to integrate into all echelons and in every domain to combat dynamic challenges in the contested environment. Gen Robert B. Neller, the 37th Commandant of the Marine Corps, directed his Marine Corps to "refine the concept of manned-unmanned teaming to integrate robotic autonomous systems with manned platforms and marines" in his Marine Corps Operating Concept 'September 2016' and Sea Dragon 2025.[2] In combined efforts from the Marine Corps Warfighting Laboratory (MCWL) and the Office of Naval Research (ONR), and with the technological advances within the industry, fully autonomous aerial combat logistic support capabilities are closer than ever to conducting reliable resupplies for today and tomorrow's battlefield.

The Marine Corps had experienced unacceptable losses to its troops and equipment from the enemy's Improvised Explosive Devices (IED) Tactics, Techniques & Procedures (TTP) during ground logistic support in recent campaigns, and existing logistic sustainment methods have difficulty in bridging all the gaps during denial or limitation of service in austere and contested terrain. Implementation of emerging aerial unmanned and autonomous systems (UAS) could be the solution for Marine logistic vulnerability and restriction by increasing logistic support availability, reducing life cycle equipment costs, and diminishing risk to Marines from the enemy's IED TTP. This paper will provide a brief description of existing UAS and examine three emerging technologies/platform for their capabilities, affordability, and their crucial role in evolving future Marine combat logistics support: mainly counter IED threats. Additionally, multiple theoretical scenarios will be introduced to illustrate the concept of operations for each emerging UAS for its functionality to enhance future Marine logistic capacity and capabilities.

Demanding Solution for IED Threat

The solution to counter IED has been in development since its utilization by the enemy in Iraq, and it had become more crucial in 2009. In 2008, President Bush signed an agreement with the Iraqi government stating all U.S. troops must be out of Iraq by Dec. 31, 2010; the military focuses would shift from Iraq to Afghanistan. As the U.S. forces started to arrive in Afghanistan, the commanders realized that logistics supports to Marines distributed across the area of operation were problematic and arduous due to its undeveloped infrastructure compared to Iraq: limited asphalt road, mountainous terrain, and enemies' increasing practice of deadly roadside IED. The commanders recognized their current state of operation was constantly changing, and it was entirely different compared to the past. The adversaries' TTP continues to evolve to mitigate the United States' unmatched military strengths and its capabilities on the battlefield. As adversaries' TTP become more sophisticated and multifaceted, Marines' logistics support has become more challenging to maintain responsive, flexible, and sustainable. Additionally, widely dispersed Marines especially in Afghanistan with extended ground lines of communication creates vulnerability for the U.S forces and offered opportunities for enemies to attack. The 2d MEB soon identified the complication of the situation and released an urgent universal needs statement (UUNS) in September 2009 that challenged the Marine Corps to explore alternative means of combat resupply of remote forward operating bases (FOBs) and combat outposts (COPs) in Afghanistan.[3]

This UUNS prompted the Marine Corps to solicit industry support to provide existing or developing technology to fulfill the requirement in Afghanistan to mitigate the human losses from the IED threat. The enemy's TTP on IED utilization was responsible for the death of 1,770 U.S troops and wounded 14,055 within Iraq from 2005 to 2010.[4] As early as 2010, the U.S. military drafted the cargo UAS (CUAS) concept of operations (CONOPS) to reduce human and equipment losses due to IEDs while conducting ground logistic supports.[5] The CONOPS will focus on using the "hub and spoke" method, which facilitates resupply operations from a central operating base, as the hub, to a FOB or a remote COP, as the spoke.[6] The advantage of this method provides a centralized supplies depot within a designated location to keep cost down and shorten the distance to FOBs and COPs. Subsequently, the K-MAX, as the first unmanned platform, arrived at Afghanistan in late 2011 to support the hub and spoke method and to demonstrate the unmanned platform logistic support capability to reduce conveys on the ground.

Existing Unmanned Autonomous System

The introduction of the K-MAX was a prominent technological asset at the time, and it was important to the ground commanders trying to mitigate IED threats for ground logistic support missions. Lockheed Martin and Kaman Aerospace Corporation initially designed the K-MAX as a manned version for heavy-lifting in the corporate industry back in 1999. By 2011, after a decade of research development, testing, and technological advances, Lockheed Martin was able to deliver two K-MAX, unmanned and autonomous capable, to Helmand Providence, Afghanistan. These two K-MAXs are capable of carrying a maximum of 6,000 pounds at sea level with a top speed up to 148 kilometers per hour. Most regarded these K-MAXs as the "first unmanned helicopter delivery operation in history," as shown in Figure 1.[7] In the first unmanned delivery mission, the K-MAX moved about 3,500 pounds of food and supplies to troops at COP Payne, completed within an hour and a half.[8] From December 2011 to May 2012, K-MAXs moved a total of more than 1.35 million pounds of cargo under the hub and spoke CONOPS between the main base and forward operating bases.[9] As the K-MAXs continued to operate until July 2014, they had completed thousands of missions in a total of 4.5 million pounds of cargo supporting troops in FOBs and COPs.[10] Unfortunately, in August 2014, a K-MAX crashed when it experienced strong tailwinds and could not regain control to stabilize the helicopter by its remote operator. This accident prompted questions about the overall reliability of the aircraft in a contested environment. Thus, the Marine Corps ceased K-MAX operation and transported the two original helicopters to Marine Corps Air Station Yuma in May 2016 for further strength training, testing, and services.[11]

The Boeing A160 Hummingbird was another unmanned platform that was in development at the same time as the K-MAX, as shown in Figure 2. The U.S. Army and the U.S. Navy originally funded the Hummingbird to develop as "a greater endurance, higher altitudes, more extensive autonomy, and greater payload" platform to endure contested environments.[12] In 2009, along with the K-MAX, the A160 demonstrated its ability to deliver 6,000 pounds of cargo in less than six hours for consecutive days of operation.[13] Subsequently, the Hummingbird program received additional $29 million for two A160 in December 2010 after successful completion of re-supply demonstration in early March 2010. Unfortunately, the Hummingbird's performance was unreliable and resulted in multiple crashes during follow-on developments. Thus, the U.S. Marine Corps chose the K-MAX over the A160 as the unmanned resupply role in Afghanistan, and, as a result, the U.S. Army abandoned the program in December 2012.

Emerging Unmanned and Autonomous Systems

The search for UAS to mitigate the IED threat for the military has never ceased, and three emerging technologies/platforms are in development for future logistics support. The first one is the Autonomous Aerial Cargo/Utility System (AACUS) program developed by the ONR along with MCWL and their private sector contractor, Aurora Flight Sciences. The team conducted the final helicopter flight demonstration of the Autonomous Aerial Cargo/Utility System (AACUS) program at Marine Corps Base Quantico, Virginia on 13 December 2017. The ONR announced the success of its program after the AACUS-enabled UH-1 helicopter performed two utterly autonomous re-supply missions without any human interaction.[14] Figure 3 shows the UH-1 performed at the final AACUS demonstration. According to the ONR, an AACUS-enabled helicopter platform can provide the Marine Corps with the extra capability to rapidly resupply forces on the front lines by incorporating this cutting-edge technology. The core of this technology contains a series of sensors with a software package, once installed into manned or unmanned rotary-wing aircraft, to provide detection and avoidance of obstacles under any weather conditions to facilitate autonomous unmanned flight.[15] Additionally, AACUS offers aid to pilots while operating in GPS and communication denied areas, allowing fully autonomous flights including landing and takeoff in contested environments, keeping pilots and crews out of harm's way.[16] Furthermore, AACUS-enabled platforms also offer a simple remote control option by using an intuitive handheld tablet, and it requires fifteen minutes or less to learn.

The AACUS started under the Innovative Naval Prototype program with the intention to provide "advanced autonomous capabilities to enable rapid cargo delivery by unmanned and potentially optionally-manned Vertical Take Off and Landing (VTOL) systems."[17] The primary goal was to create a system as an open architecture framework integratable across various VTOL while providing sufficient reliability with precision cargo delivery and, eventually, human extraction from remote sites. The AACUS could be capable of enabling future autonomous capabilities for aerial cargo and utility systems to provide rapid, affordable, reliable, shipboard-compatible supply and casualty evacuation.[18] Ultimately, current VTOL platforms equipped with AACUS could conduct any operations autonomously including logistics replenishment, resupply, transport, equipment retrograde, and casualty evacuation (CASEVAC) or potentially medical evacuation (MEDEVAC) for the future.

The second emerging technology is a mid-size platform of Unmanned Logistics System (ULS) under the CONOPS of the Joint Tactical Autonomous Aerial Resupply System (JTAARS) developed by the U.S. Marine Corps and the U.S. Army.[19] UAS in the payload categories from 50 to 500 pounds in various logistics roles, primarily aerial resupply and distribution, as shown in Figure 4, are often referred to as JTAARS or ULS. [20] The primary mission is to provide infantry units and their logistics element with an organic, autonomous aerial transportation to conduct immediate responsive resupply for forwarding deployed tactical elements. Its focus will include flexibility, maneuverability, ability to lighten the load, and probability of optimizing the Op-Tempo for the troops on the battlefield.[21]

The current ULS design included two platforms, small (TRV-50) and medium (TRV-300), to operate unmanned and autonomously to increase internal distribution capability and capacity under the hub and spoke logistics support concept, and Table 1 shows the specification for both ULS. The ULS design is committed to turning MOC's vision into reality to mitigate capability gaps such as those identified in the Marine Expeditionary Rifle Squad Initial Capability Document. These smaller platforms could provide local commanders and logisticians 24/7 logistics response capabilities within the battalion and higher organizational elements. Additionally, ULSs also offer an integrated Tactical Handheld application for simple user interface to conduct autonomous flight operation through integrated sensor package for quick flight initiation.

While AACUS and ULS are capable of providing logistic supports autonomously for more than 3,000 pounds and 55 to 352 pounds per cargo, respectively; a smaller, autonomous, capable logistic delivery option is currently in development as the "Hive" UAS by the Marine Corps. The Hive is a generic term for an expeditionary service node that can be a tactically staged container, a mobile convoy of trucks with containers, a barge, or even a hybrid airship.[22] The Hive can dispatch fast, lightweight UAS, as demonstrated in figure 5, by receiving individual warfighter demands and then allocating available assets to meet and satisfy these requests.[23] These smaller UAS are inexpensive, and they can operate by using a cloud-based Enterprise Resource Planning (ERP) platform. The ERP can meet the demand while communicating its current inventory, in near-real time, across the enterprise to build a shared supply chain picture for all logisticians and customers in the field.[24]

The objective of this program is to revolutionize logistics as necessary for a decentralized battle space as defined in the joint concepts for Expeditionary Advance Base Operations (EAB-O). The goal is to have an efficient delivery system for joint logistics over the shore and ignore the vulnerable bottleneck at the ports of debarkation, tactical assembly areas, COPs, and FOBs while leveraging Commercial off the Shelf (COTS) UAS solutions that could rapidly modernized in the civilian market to deliver.[25]

These three emerging programs—Autonomous Aerial Cargo/Utility System, Joint Tactical Autonomous Aerial Resupply System, and the Hive—could potentially fulfill all capability gaps for the Marine Corps in various requirements of logistics support. The focus for future autonomous logistics delivery and support is becoming a reality sooner than most have expected. All branches of service have their version of UAS or in a combined effort to develop a system that can be a benefit for their Soldier and Marine in the field conducting combat operations. The following portion of the paper will examine these emerging technologies/platform for their capabilities, affordability, and their crucial role in evolving combat logistics support. These assessments are not limited to UAS speed and payload, distance limitation, re-supply method, and life cycle equipment costs. Additionally, multiple theoretical scenarios will be introduced to illustrate the concept of operations for its functionality to enhance future Marine logistic capabilities.

Autonomous Aerial Cargo/Utility Systems

The AACUS program started in 2012 as an Innovative Naval Prototype (INP) program under the ONR.[26] According to the ONR, "the need for AACUS stems primarily from USMC requirements for an alternate means to provide time-sensitive logistics support to greatly dispersed locations."[27] The AACUS is fundamentally a system including software and sensors, once integrated onto any VTOL platforms, to provide a self-governing function similar to autopilot in Tesla vehicles but more advanced. The AACUS-enabled VTOL platforms will be able to conduct, unmanned or optionally piloted, independent approaches and landings with advanced route planning and trajectory planning at unprepared landing sites.[28] The system offers autonomous obstacle avoidance and precision landing capabilities including contingency management before and during the actual landing. Additionally, ground operators can communicate with the AACUS platform by using a tablet-like device, which requires no special training, during independent operations including safe loading and unloading. "The AACUS is a giant leap in autonomous capabilities to enable helicopters in the various platform to leave a base with supplies, determine an optimal route to the destination, select an appropriate landing site near soldiers and proceed with a landing then makes its way back to the base" as Rear. Admiral Matthew Klunder, the Chief of ONR, stated during the annual Navy League exposition in April 2014.[29] The AACUS's technology continues the unmanned K-MAX system that won high praise from the senior Marine Officers for its ability to deliver cargo in Afghanistan while reduced the reliance on ground convoys that were vulnerable to roadside bombs and ambushes and mitigate the risk for pilots flying into contested combat areas.

The AACUS is not a platform like the K-MAX or other UAS currently in the marketplace. It is an application kit install into existing VTOL to enable true autonomous sustainment capability across current or future type/model rotary wing and UAS platforms. The flexibility of the system is fundamentally different than any existing UAS. The AACUS could increase the availability of helicopters to conduct logistic support without depending on the sleep/rest cycle of pilots. Additionally, it does not create additional organic asset requirements to accommodate new assets like the K-MAX. The AACUS can, in actuality, when fully integrated, minimize helicopter crashes due to either pilot error, severe weather, or instrument malfunction. Although the ONR did not provide the final cost of the AACUS installed in the UH-1 helicopter at the final demonstration, they confirmed the costs were much cheaper compared to K-MAX's $12 million price tag and $1,200 per operation hours.[30] Furthermore, if AACUS integrated into current Marine legacy assets, it would not increase maintenance requirement except periodically software updates on the system, which is a considerable cost-saving compared to the K-MAX. Again, as mentioned before, the AACUS-enabled helicopter can potentially accomplish current logistics missions, in contested or uncontested environments, and a CASEVAC or MEDEVAC.

The concepts of operation of the AACUS provided by the ONR are illustrated in figures 6 through 8, representing typical operations including routine and urgent logistics missions and CASEVAC missions, that the AACUS enabled platform is capable of operating autonomously. These diagrams are accompanied with color-coded boxes to illustrate the increasing potential levels of autonomy. Each box reflects the estimation of maturity for each technology needed to reach the capacity. For example, the four capabilities listed in Autonomous Flight function (#3) in Figure 6 are Planned Route, Obstacle Avoidance, Air Traffic Avoidance, and Weather Avoidance. The "Planned Route" and "Obstacle Avoidance" are coded as green since the technologies are currently available and displayed in the final flight demonstration.[31] Others are coded as yellow or red/yellow due to a lack of a mature and established technology needed for near-term implementation.[32]

The primary focus areas for the AACUS in figures 6 through 8 illustrated the autonomous functions including obstacle avoidance, landing zone identification, self-landing, no-fly zone avoidance, and redeployment to pre-planned location. The timeframe associated with the development of each associated technology/capability is based on an estimation of current technological progression. The following demonstration scenario illustrates the CONOPS for the deployment of AACUS in the future once all the technologies are available and incorporated into the system.

AACUS Implementation Scenario

The following scenario is a condensed version of the ONR's AACUS CONOPS, and cargo UAS (CUAS) will be used to represent the AACUS-enabled platform.[33] A forward deployed unit stationed at a COP located deep in Afghanistan's mountain range is under heavy enemy fire and sustains two severe casualties and is also running low on supplies. The unit contacts the FOB to request for air support and supplies, but no manned assets are available except the CUAS. The FOB air operational command supervisor (OCS) who received the logistic support request decided to utilize CUAS to support the unit's demand. The CUAS will commence the calculation of the flight plan by incorporating existing data of obstacles, danger/avoid zones, no-fly zone, and any combat operations along its path in the next forty-five minutes, to the supply depot, then to the COP, and return to its base of operation. After the OCS approves the flight plan and all initial safety pre-cautions are complete, the CUAS will take off and fly autonomously to the supply depot to load the materials, manually by the ground support element, then to the COP. During the flight, the CUAS can also detect and avoid any obstacles that were not in the database or uploaded later on after its take-off. Additionally, the CUAS will continue to scan for, detect, and autonomously avoid other aircraft or small UAVs. When the CUAS is approaching near the COP, it will detect and scan for any obstacles that may be unsafe to land in the designated landing zone. If obstacles are present, the CUAS will automatically execute a wave-off and notify the OCS to search for another suitable landing zone. After dropping off supplies, the CUAS will load the wounded personnel for evacuation. Furthermore, the OCS can redirect the CUAS to another location if necessary before or after it has started to execute its original flight plan. As the CUAS approach the Trauma Unit, it can perform an autonomous patient condition-specific onboard landing at the designated landing zone. Once it lands, the CUAS will shut off its engine to provide a safe passage for medical personnel to receive the wounded personnel.

Based on the scenario, the operator used the CUAS because no manned assets are available but, in reality, the CUAS can be a substitution for other similar logistic operations. First, utilization of CUAS can diminish the risk for pilots landing into a hostile area while under enemy fires. Second, the CUAS can reduce the need for pilots and free them to conduct other higher priority missions. Third, the CUAS can increase availability in Marines' logistic arsenal to provide 24/7 support, which in return, increase materials throughput and maintains the operational tempo in a dynamic combat environment. Last not but least, the cost-benefit without acquiring another different type of aerial platform, with additional maintenance requirement, is substantial to the Marines in the current fiscal environment.

Joint Tactical Autonomous Aerial Resupply System

The JTAAR or ULS could provide additional autonomous delivery choices besides common ground delivery by convoy or air delivery by helicopter to support greatly dispersed locations. This capability could minimize the exposure of personnel to the unacceptable level of risk during logistic supports. Although the JTAAR can only lift at a maximum of 352 pounds compared to a much higher lift capacity of MV-22 and CH-53K, it can free up platforms to conduct other more top priority missions. Additionally, the cost of a ULS is much more affordable in the range of $15,000 to $100,000 compared to $72.1 million for the MV-22 or $87.1 million for the CH-53K, as shown in Table 1. The cost for the ULS is a rough estimate based on current market value, and it could be different due to many other variables, but it is far more reasonable. Besides the initial cost, the ULS requires minimum or no maintenance at all. Even when it needs upkeep, the ULS is small in size, five feet long by three feet wide, with limited moving parts as shown in Figure 4; Marines with zero or limited mechanical skills are up to the task. Additionally, the ULS does not follow the same maintenance requirements compared to other helicopters, which involved survivability of personnel after a crash. The equipment life cycle cost of the ULS is significantly lower compared to the high operation and sustainment cost of manned aircraft which involves staff, maintenance, fuel, and etcetera. Also, the ULS requires fewer spaces to store and operate from, approximately a sixty feet by sixty feet footprint, as shown in Figure 9. Based on the ULS's affordability, commanders can undoubtedly acquire this capability shortly after it is available. Subsequently, once the technology is mature, it can be used to complement manned air assets to improve efficiencies and provide operational flexibility for aerial resupply.

Employing CH-53 to conduct multiple spoke logistic support under the current logistics concept of hub and spoke method might not be the most productive method. Each CH-53 has to make a round trip from hub to spoke and repeat for other spokes. This process is time-consuming, a burden on the equipment, and it is a physical drain on the pilots. Locations that are at the last of multiple sorties may not receive much-needed supplies at the required time, or it may be too late in an actual combat environment. ULS implementation in the future can resolve these inefficiencies for these types of deliveries and free the CH-53 to conduct other higher priority missions. In actually, a group of twelve ULS assigned to a FOB can disperse logistics supplies much faster compared to a CH-53 delivering supplies to multiple COPs. Although the ULS has limited lift capacity and operational ranges, it can provide requested logistics supports down to COPs simultaneously due to its vast availability. This capability could provide commanders an organic, autonomous aerial logistic transportation to conduct immediate responsive resupply of forwarding deployed units as described in Enhanced Company Operations (ECO).

The ULS's abilities to complement manned air assets are also capable of providing logistics to ground units as their own organic, autonomous aerial transportation that enables immediate and assured resupplies. Other capabilities for ULS may ultimately include "emergency personnel extract (Air Stretcher), maintenance repairable parts deliver, engineering material movement and delivery, medical resupply, logistics reconnaissance and surveillance, logistics command and control, and postal and exchange services."[34] The Combat Development and Integration command developed the following three scenarios to further illustrate the CONOPs of the ULS in tactical combat environments.[35]

JTAAR Implementation Scenario

The first scenario, a dismounted infantry platoon is on day two of a planned three-day mission when it receives orders extending the mission by an additional twenty-four hours. The platoon requests sustainment resupply of Class I and batteries, a total weight of approximately 1,300 pounds, and requests resupply during hours of darkness. The platoon is operating about 25 km from its source of resupply. Once the resupply request is received, the unit commander can completely fulfill the requirement within one hour if using six ULS at once or approximately five hours if using just one ULS. In this scenario, the ULS allowed the commander to resupply its troop without waiting for the availability of other manned platforms and any administrative requirements for this specific mission.

In the next scenario, the ULS illustrated could outperform manned platform to deliver parts under austere conditions. For instance, a hydraulic pump on an AH-1Z failed. A MV-22 is delivering the part from a Forward Arming and Refueling Point 100 miles out. Due to lousy visibility at the location of the AH-1Z, the MV-22 is only able to land at a base about thirty miles away. The logistics element at the station can launch a ULS with the hydraulic pump and deliver it to the maintenance crews to repair the AH-1Z. In this scenario, the ULS could support maintenance efforts even during austere conditions, which prohibited the manned platform, to deliver critical parts rapidly to restore the equipment swiftly. The ULS can also provide other lower priority tasks to boost morale in the next scenario.

A platoon has been in a defensive position on a ridgeline for over two weeks and, during this time, the battalion has been unable to deliver mail to them. The platoon's mail includes care packages and other health and comfort items. The battalion commander recognizes it would significantly improve the platoon's morale if they can receive their care packages, but so far attempts to get the mail on a helicopter to that position have been unsuccessful due to higher priority tasking and the threat environment. The commander decided to load the mail and packages on the ULS and deliver to the platoon commander in the position approximately 25 km away. The platoon commander signs the mail receipt card inserts in the empty mail pouches and clears the ULS for return back to the battalion. In this scenario, ULS completed a low priority but necessary task to deliver morale-boosting items to the troops.

These three scenarios demonstrated that the ULS could conduct numerous functions of logistic support and provide flexibility and capability for the commanders. Although the distance and lift capacity is limited to 20 to 50 km and 250 pounds respectively, this limitation will be overcome by future technologic advances. If this innovation of ULS were available during the Iraq and Afghanistan campaign, human and equipment losses would reduce dramatically. Additionally, the cost of ULS is friction of manned platforms, as shown in Table 1. As the ULS technology advances and matures in the near future, leaders in the Marine Corps can benefit from this cost-saving innovation in future combat logistic support and sustainment operations.

"Hive" Unmanned and Autonomous Systems

The Hive UAS, compared to the AACUS and the ULS, could provide fast, on-demand support capability to the individual warfighter on the field while conducting tactical squad-size operations. The Hive is designed to operate using a cloud-based ERP platform to monitor and communicate an available inventory of each Hive, in near-real time, to the logistic managers and its end users. Major Chris Thobaben from Marine Corps Installation and Logistics discusses the service node for the Hive can be a mobile convoy of trucks with containers, a barge, or even a hybrid airship.[36] The system will comprise of a series of Commercial off the Shelf (COTS) capabilities to be integrated to provide autonomous support to the troops. The COTS drones for the Hive will be capable of carrying around fifteen pounds of Class I, III, and V within a 10 km radius. Additionally, these drones would offer capabilities besides just supplies delivery; it can quickly modify to provide "ISR, close air support or direct air support, communication support, munitions counter battery effects, and defensive drone fleets at the fingertips of the warfighter or austere operations experts."[37] The current innovation for such drones costs around $1,500 each, and autonomous operation software upgrade is possible once the technology is available. The Hive system, once fully established, could even be more affordable than the ULS. The lack of distance and lift capacity of the Hive system compared to the ULS and AACUS could make up its disadvantage in share number and affordability.

The main objective of the Hive is to support individual warfighters, and the concept of employment will be different compared to the ULS or AACUS. It focuses on reducing individual soldier's combat loads during any small unit missions and provide resupply on-demand instead of days. Troops conducting any mission outside of their patrol bases, COPs, and FOBs will require a two to four day of supply (DOS) in addition to their load. With the introduction of the Hive, Marines can carry minimum gears for missions outside of their nodes because they could be resupplied within a reasonable of time compared to hours or days if the location is hostile or not permissive for any conventional resupply methods. Additionally, lightening individual soldier's combat loads can increase mobility during combat operations; especially speed is essential to the success of the mission. Furthermore, the Hive can deploy to support humanitarian assistance and disaster relief for search and rescue and material delivery due to degraded or limited infrastructure after a natural disaster.

A Hive can be a box server, mobile, stationary, or as a tow attachment, and its theoretical CONOPS is shown in Figure 10. Each of these Hives can outfit with dozens of drones or unmanned autonomous vehicles (UAV) to deliver directly to the fire team or individual warfighters, which offer flexibility in maneuver and tempo while reducing the combat load. When demand for resupply is received, the Hive will dispatch the UAV to allocate the requested supplies, loaded by hand or autonomously at a predetermined location, and deliver the materials to the troops. After a successful delivery, the UAV will return to the Hive and wait for the next requests. A single Hive in a marshaling position located 10 km behind the line of engagement with 100 UAVs–each capable of carrying 15 pounds of Class I, III, and V–can provide more than 100,000 pounds within a 24 hour period.[38] As technological advances for COTS drones, the distant and lift capacity will increase and the cost will go down. The following is a theoretical scenario that illustrates the CONOPS of the Hive system once implemented into the logistic asset to support Soldiers and Marines in the frontline.

<u>"Hive" Concept of Operation</u>

A Marine on a patrol mission requires 200 rounds of linked 5.56 ball to return to one DOS. He then submits a request via a handheld device to have the ammunition to deliver to his grid coordinate. A local server received the demand and processed the request in a queue and assigning an appropriate Hive. The assigned Hive then selects a local platform and, autonomously, identifies an appropriate drone for the delivery mission. The drone that received the mission will load the 200 rounds, manually or autonomously, at a predetermined location or storage and process to deliver. Once the drone dispatched, the Hive will report its on-hand inventory, in real time, to increase supply chain visibility to all stakeholders. This information will provide predictable supply chain models for the next day or weeks of operational needs. After a successful delivery, the drone will refuel upon return and place back in the queue for the next mission. The Hive's CONOPS will significantly enhance on-demand resupply capability to the Marine on the battlefield; this function does not exist now, and it will be a life-saving benefit for the ground troops once fully implemented.

<u>Future Unmanned and Autonomous Logistic Operational Concept</u>

When these emerging unmanned and autonomous systems become a reality, they will support the Marine Corps' supply chain by providing an optimized tactical distribution to the troops. Thus, a blend of conventional and new logistics support capacity will extend the MAGTF's operational reach and allow logisticians to get the right stuff to the warfighter at the right time. In figure 11, a notional unmanned logistics CONOPS that further illustrates how these emerging unmanned and autonomous systems incorporated into current logistic assets to support future material distribution. Large ULS, AACUS, can provide logistic support as stated in the Seabasing Logistic, to provide critical capabilities and means to maximize the combat readiness of the warfighters from sea to shore. Medium ULS, JTAARS, at the logistic support area can provide 25 to 75 km radius logistics support to COPs or platoon-size elements at the frontline. Small ULS, the Hive, offer on-demand resupply capability within the 15 km radius to support squad size elements. These ULSs integrated into the Marine logistic system could provide accuracy and timeliness of logistics support to sustain the force.

This theoretical CONOPS of ULSs demonstrated the future logistic resupply method, and doing so, provides a solution for the UUNS issued in September 2009. According to Marine Corps Installation and Logistic, when innovation and technology of the ULSs matured and proved in military exercises, it could provide numerous values to the warfighters. First, it reduces risk to personnel conducting manned resupply operations in restrictive or contested terrain. Second, it adds an aerial resupply capability, medium or small ULS, organic to the brigade or company level for conducting steady state and emergency sustainment operations. Third, it unburdens Soldiers and Marines conducting dispersed operations. Fourth, it enhances operational flexibility and the presence of multiple systems to increase dilemmas for the adversaries. Fifth, it increases available landing zones to support widely dispersed forces. Sixth, it augments the capability to support HA/DR operations. Lastly, it minimizes exposure to forces operating in high threat or chemical, biological, radiological, and nuclear environments.

As these emerging ULSs are still in the testing phase of the development, the medium ULS could be more useful compared to the other two ULS for combatant commander. If it is available now, it should be integrated into all echelons as fast as possible, and the quantity will depend on operational requirements. The rapid implementation could start mitigating unnecessary risk and minimizing the workforce required in associated with ground logistics convoys. Current ground convoy operation will require security detail for safety, and it could be as little as one gun truck per convoy truck or as many as needed. The introduction of the medium ULS could immediately minimize the workforce needed to conduct logistics supply operations. The medium ULS can conduct hub and spoke logistics operations during the night, and it is capable of operating all night long with a minimum of just one operator. Thus, the Marines can focus on kicking down doors instead of conducting logistics operations. The medium ULS also has more advantage compared to the AACUS and the Hive. First, the technology is mature and ready to use in the combat zone. Second, the ULS costs are considerably cheaper than the AACUS in unit price, and the VTOL enabled platform still requires a large footprint to operate from and conduct maintenance requirements. Lastly, the Hive's technology is still in development, and it will not be fully functional as quickly as the ULS.

Conclusion

The U.S. Military must continue to exploit new technologies to remain technological advantage over its adversaries. The introduction of UAS for logistics distribution is comparable to methods of conducting logistics support evolved from a horse to automobiles, and now from automobiles to aerial, autonomous systems. These emerging technologies will allow unmanned and autonomous aircraft to transport Class I, III, V, medical supplies, parts, medical evacuation, casualty evacuation, and its capabilities are endless. While providing additional capabilities to the Marine Corps, these UAS cost substantially less per unit compared to the existing platforms of MV-22 or CH53s. Simultaneously, sustainment and maintenance costs are minimal, or no maintenance is required, and fuel consumption to deliver the same weight of support are much less. The capabilities offered by these emerging UAS and its cost-saving benefit, in combination, should be integrated into Marine Corps' logistic asset in the future.

Above all, the implementation of such innovations can mitigate the IED threat by minimizing convoys on the roads. Additionally, military service members that were wounded or killed by roadside IED could minimize while conducting logistic support operation or non-kinetic operation because of these UAS. By getting trucks off the roads and minimize the IED threat from the insurgents or adversaries will justify, again, to continue to develop these UAS and procurement for future implementation into the force. Furthermore, as UAS taking a more significant role in the future logistic distribution, it will drastically reduce human and equipment losses and it also significantly enhances the Marine Corps' capability to employ the Enhanced Company Operations and the Seabasing concept of operation.

After almost nine years after the release of the UUNS in September 2009, to explore alternative means of combat resupply of remote FOBs and COPs in Afghanistan, these three emerging UAS seem to provide the solution. The value for these systems could unintentionally initial another era of military logistic support evolution, in the air, unmanned and fully autonomous. As technology advances, greater capabilities are possible in lift capacity, speed, distance, and more autonomous. These UASs should become an integrated part of the U.S. Military in all aspects of warfighting functions: Logistics, Command and Control, Force Protection, Fires, Intelligence, and Maneuver.

As the U.S. military is preparing for the next war, military and civilian leaders need to recognize that future conflict will likely to happen in highly populated urban areas, like current Syria conflict. Current and future decision-makers have to take into account the anti-access area denial environment could continue to challenge our successes on the battlefield. Any existing roads and avenues of approach will quickly be destroyed by the enemies to restrict our maneuverability and logistics deliver capability to gain strategic advantages. As roads become impassable, logistics support has to rely more on air; but helicopter has proven to be the prime, easy target for the enemies since its inception in the Vietnam War. In order to disrupt this antiquated method of logistics support, full integration of UASs into the U.S. military has to begin as early as possible. These UASs are just a part of Commandant Neller's vision of manned-unmanned teaming to integrate autonomous robotic systems with manned platforms and Marines. No one knows what war is going to look like in the future, but the UASs should play a more prominent role to help the Marines to fight and win our Nation's battles against any adversaries.

ENDNOTES

[1] Joint Publication 4-0, 16 October 2013, I-1

[2] Headquarters United States Marine Corps, *Marine Corps Operating Concept*, (WASHINGTON, D.C. 20380-1775. September 2016), 16.

[3] Headquarters Marine Corps, *Universal Needs Statement for the Cargo Unmanned Aircraft System*, Washington, DC, 27 August 2008.

[4] Tom Vanden, "IEDs Kill 21k Iraqi civilians from 2005-2010," *Army Times*, Springfield, VA, 12 January 2011.

[5] Headquarters Marine Corps, *United States Marine Corps Cargo UAS Concept of Operations v1.1*, October 2009.

[6] Ibid.

[7] Lockheed Martin, KMAX, accessed Dec 22, 2017, https://lockheedmartin.com/us/products/kmax.html

[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] Marine news, accessed Dec 22, 2017, http://www.marines.mil/News/News-Display/Article/754286/mcas-yuma-welcomes-k-max/

[12] Andreas Parsch. Boeing (Frontier Systems) A160 Hummingbird, 01 July 2007

[13] Stephen Trimble. *US forces plot new role for unmanned cargo resupply* Archived March 11, 2010, at the Wayback Machine, *Flight International*, 12 August 2009

[14] Office of Naval Research press release, accessed Dec 14, 2017, https://www.onr.navy.mil/en/Media-Center/Press-Releases/2017/2017-AACUS

[15] Ibid.

[16] Ibid.

[17] Mary Cummings, The Office of Naval Research: *The concept of operations for Autonomous Aerial Cargo/Utility System.*

[18] Ibid.

[19] United States Marine Corps and United States Army, *Joint Tactical Autonomous Aerial Resupply System* 25 December, 2016.

[20] Ibid.

[21] Ibid.

[22] Major Chris Thobaben USMC, Marine Corps Installation and Logistics: White paper for Hive final mile support.

[23] Ibid.

[24] Ibid.

[25] Ibid.

[26] Mary Cummings, The Office of Naval Research: *The concept of operations for Autonomous Aerial Cargo/Utility System*

[27] Ibid.

[28] Ibid.

[29] Helicopter News, Potomac Vol. 39, Issue. 32, 15 April, 2014

[30] Lockheed Martin, KMAX, accessed Dec 22, 2017, https://lockheedmartin.com/us/products/kmax.html

[31] Mary Cummings, The Office of Naval Research: *The concept of operations for Autonomous Aerial Cargo/Utility System*

[32] Ibid.

[33] Ibid.

[34] United States Marine Corps and United States Army, *Joint Tactical Autonomous Aerial Resupply System* 25 December, 2016.

[35] Ibid.

[36] Major Chris Thobaben USMC, Marine Corps Installation and Logistics: White paper for Hive final mile support.

[37] Ibid.

[38] Ibid.

FIGURES

Figure 1. An Unmanned, USMC K-MAX Operating in Helmand, Afghanistan. Source: www.marines.mil

Figure 2. A160 Hummingbird is an unmanned

aerial vehicle helicopter. Source: www.boeing.com

Figure 3. UH-1 "Huey" flying autonomous on multiple missions during the final demonstration. Source: www.onr.navy.mil

Figure 4. Unmanned Logistics System-Air Medium (TRV-300)

Source: Headquarters, USMC Installations and Logistics

Figure 5. Fast lightweight UAS, inexpensive, commercial off the shelf
Source: Headquarters, USMC Installations and Logistics

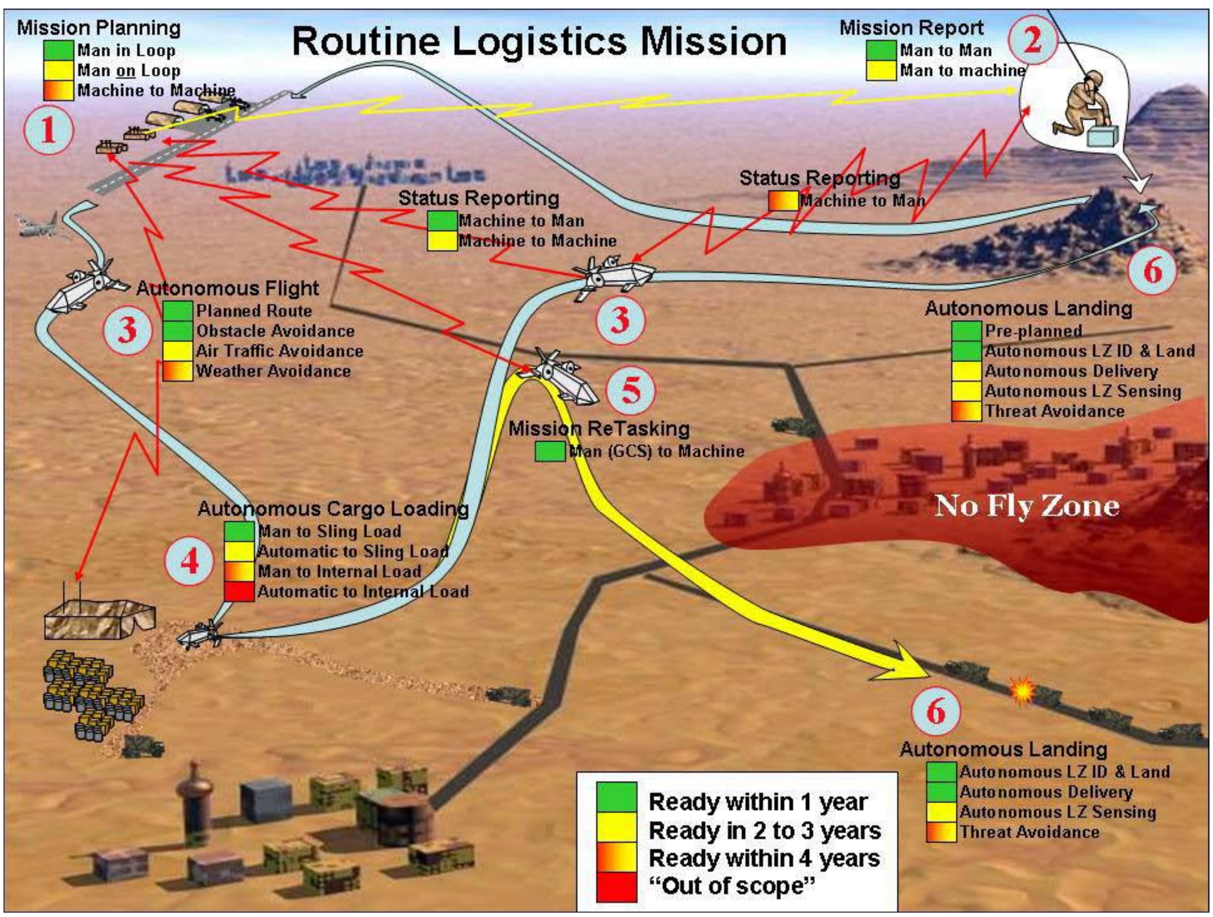

Figure 6. Routine AACUS Logistics Mission with Replanning
Source: The Office of Naval Research, AACUS CONOPS

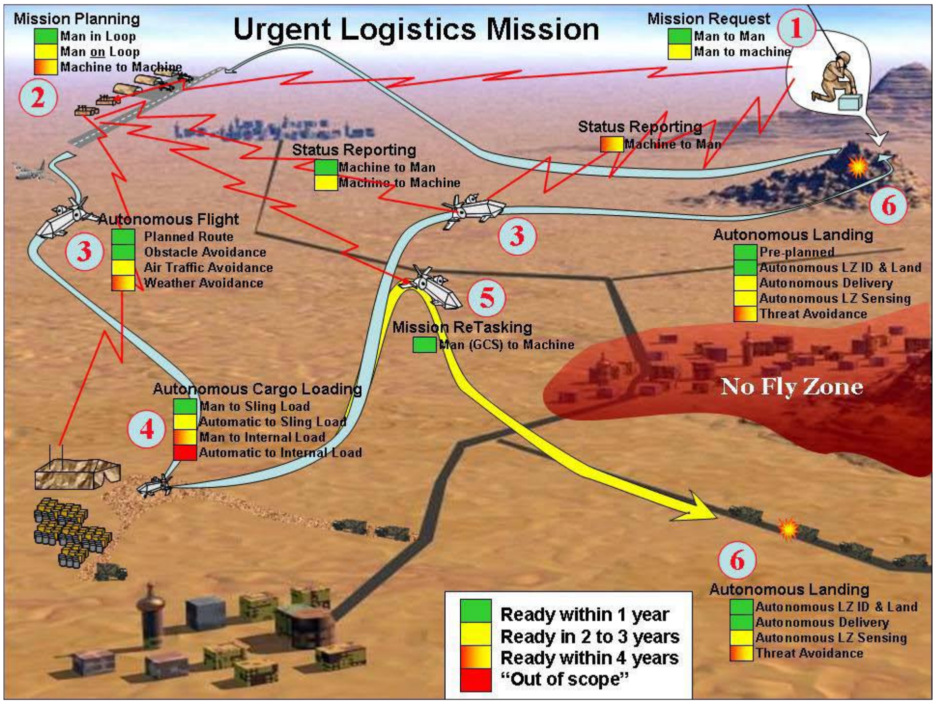

Figure 7. Urgent AACUS Logistics Mission with Replanning
Source: The Office of Naval Research, AACUS CONOPS

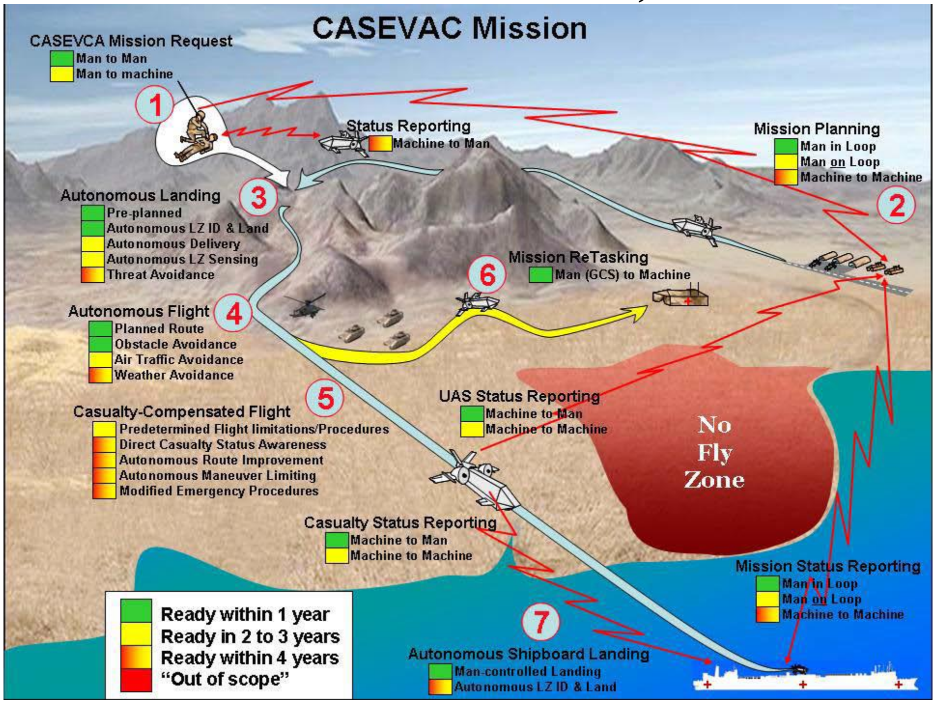

Figure 8. AACUS CASEVAC Mission with Replanning
Source: The Office of Naval Research, AACUS CONOPS

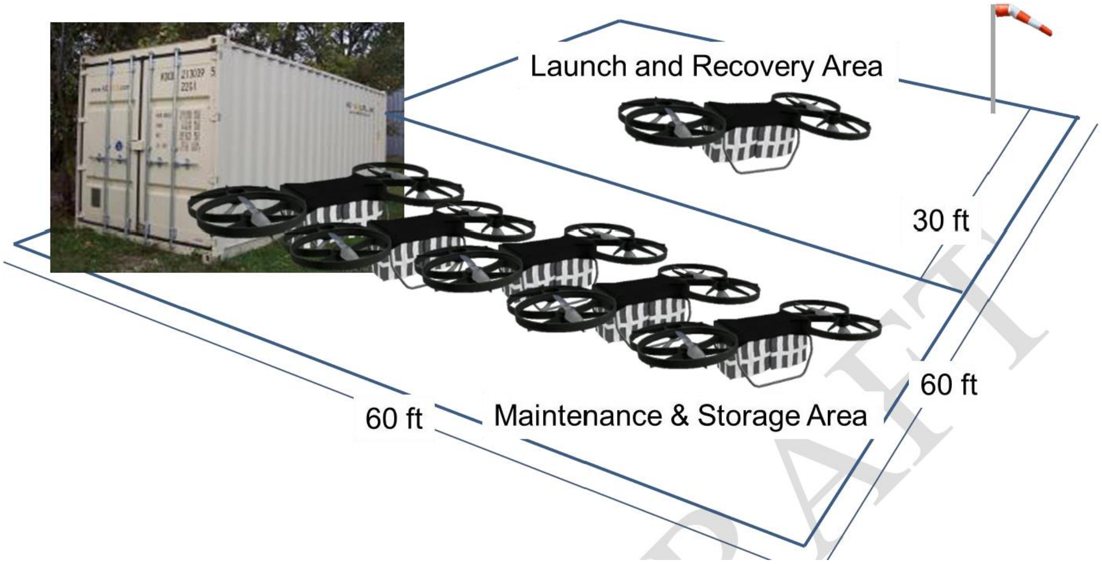

Figure 9. Notional JTAAR UAS Operational Area Laydown

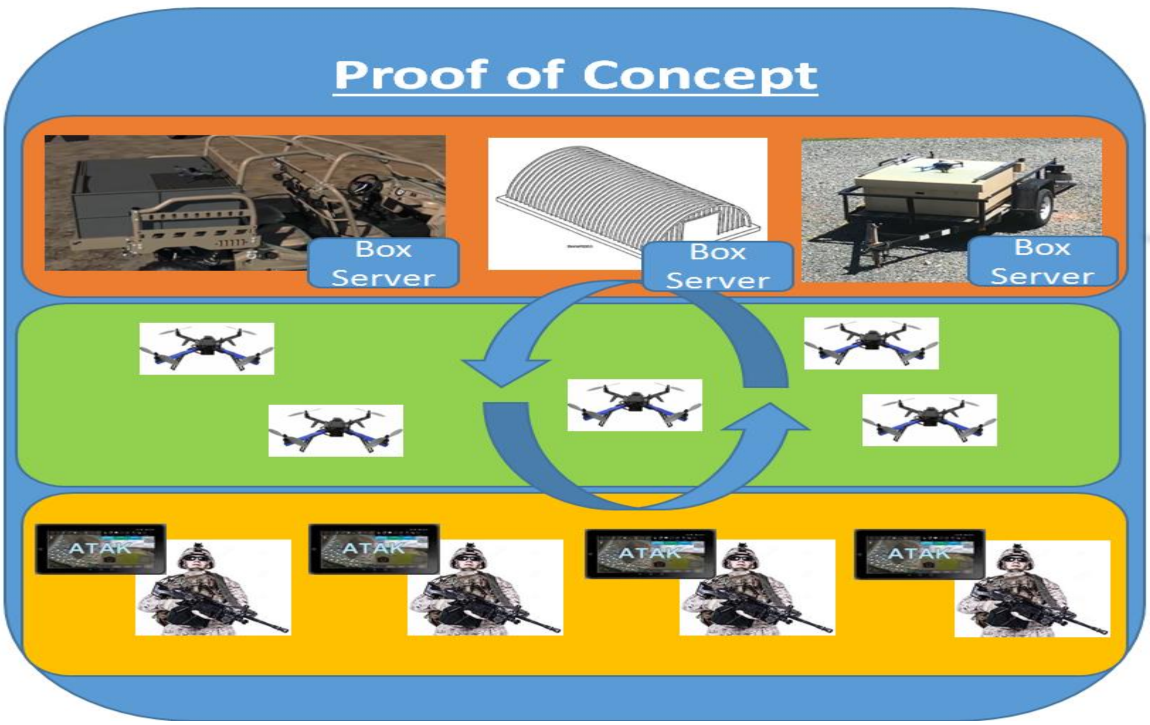

Figure 10. Hive CONOPS
Source: Hive final mile phase I matrix

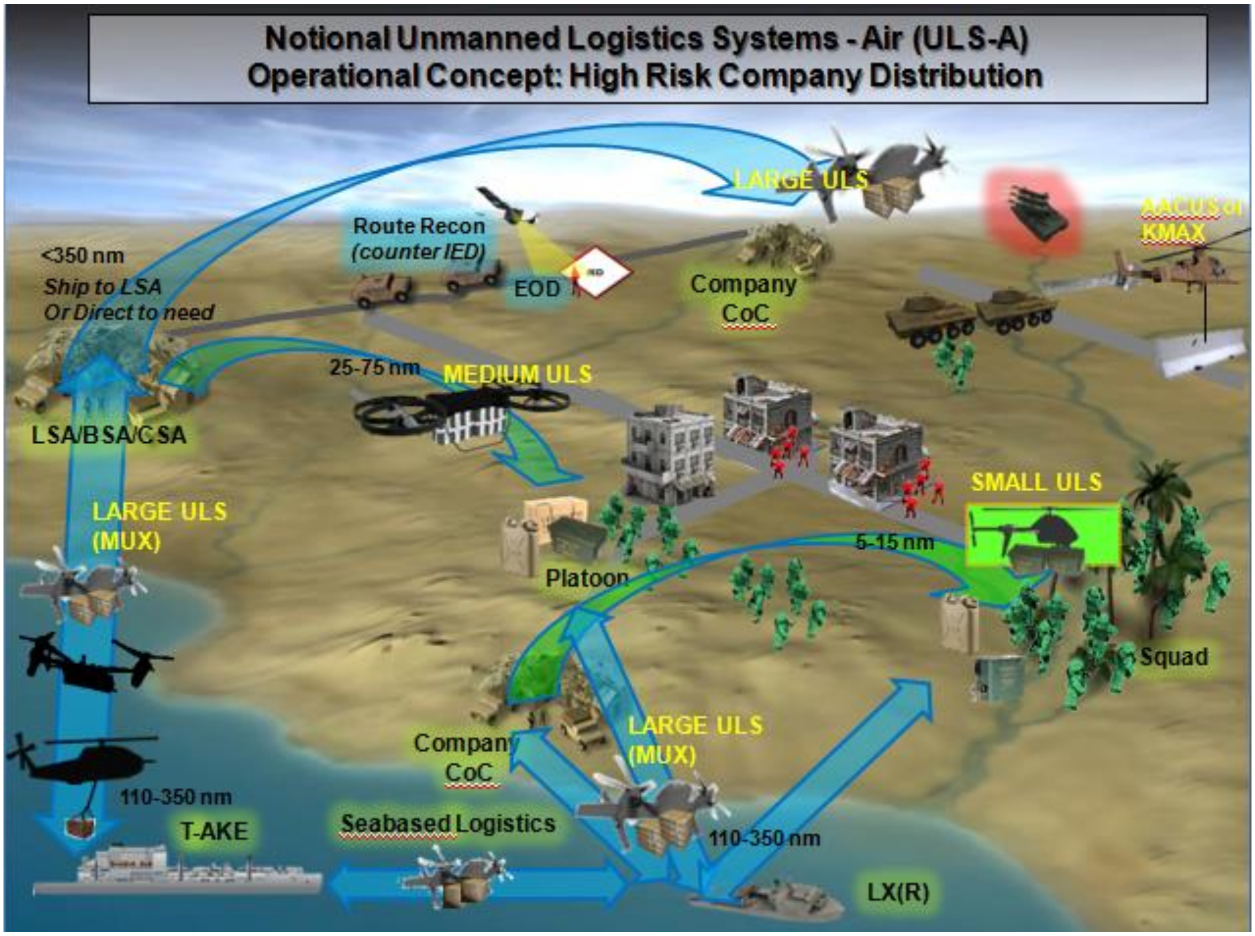

Figure 11. Notional Unmanned Logistics System CONOPS
Source: Capabilities Development Directorate.

Table 1. Unmanned Logistics System-Air Capabilities
Source: Headquarters, USMC Installations and Logistics, and Naval Air Systems Command

	Cost	Lift Capacity	Speed	Range
MV 22	$72.1 million	20,000 lbs	285mph/460kph	990mile/1592km
CH53K	$87.1 million	27,000 lbs	195mph/315kph	522mile/841km
TRV-300	~$30,000-$100,000	352 lbs	92mph/148kph	12-31mile/20-50 km 100-200+ km (Hybrid Gen)
TRV-50	~$15,000-$45,000	55 lbs	48mph/77kph	12-31mile 20-50 km 100-200+ km (Hybrid Gen)
Fast lightweight UAS	~$1,500-$3,500	15 lbs	15mph/24kph	6mile/10km

Bibliography

Borrelli, Camine and Heffem, *Unmanned Logistics System – Air*, October, 2017.

Chestnut, Melissa D. *Leveraging Science and Technology to Improve Logistics and Maintain Combat Effectiveness*, April, 2012.

Csaszar, Lawrence M. *The Joint Tactical Aerial Resupply Vehicle Impact on Sustainment Operations*, June, 2017.

Cummings, Mary. The Office of Naval Research: *The concept of operations for Autonomous Aerial Cargo/Utility System.*

Dana, Michael G. *Marine Corps Logistics in the 21st Century*, Marine Corps Gazette, October, 2016.

Denevan, Thomas J. *Cost-Based Analysis of Unmanned Aerial Vehicles/Unmanned Aerial Systems in Filling the Role of Logistical Support*, December, 2014.

Ekman, Elle M. *Simulating sustainment for an Unmanned Logistics System concept of operation in support of distributed operations*, June, 2017.

Hall, Andrew B. *Conceptual and Preliminary Design of a Low-Cost Precision Aerial Delivery System*, June, 2016.

Headquarters United States Marine Corps, *Marine Corps Operating Concept*, WASHINGTON, D.C. 20380-1775. September 2016

Headquarters United States Marine Corps, *United States Marine Corps Cargo UAS Concept of Operations v1.1*, October 2009.

Headquarters United States Marine Corps, *Universal Needs Statement for the Cargo Unmanned Aircraft System*, Washington, DC, 27 August 2008.

Ilachinski, Andrew. *Artificial Intelligence and Autonomy: Opportunities and Challenges*, October, 2017.

Lede, Jean-Charles. *Fast Lightweight Autonomy*, October, 2017.

Merkle, Timothy J. *Logistical Risk Planning Tool: Optimizing the Deployment of Cargo Unmanned Aerial System in Logistical Support Missions at the Tactical Level*, June, 2010.

NASA Tech Brief. *Autonomous Black Hawk Helicopter*, October, 2014.

Naval Research and Development, *A Framework for Accelerating to the Navy and Marine Corps After Next*, July, 2017.

Parsch, Andreas. *Boeing (Frontier Systems) A160 Hummingbird*. 01 July 2007.

Plinsky, Janina; Glass, Demetrius; and Yates, John, *Unmanned Systems for Logistics*, May, 2012.

Quaranta, Paolo. *Unmanned Capabilities for 2020 and Beyond*, AUVSI XPONENTIAL 2017, May, 2017.

Roth, Brian M. *Unmanned Tactical Autonomous Control and Collaboration unmanned aerial vehicle analysis of alternatives*, March, 2016.

Schrader, Thorsten. *Concept and design of a UAS-based Platform for Measurements of RF signal-in-space*, September, 2016.

Sharp, Jason A. *The Cargo UAS*, Marine Corps Gazette, January, 2012.

Tadjdeh, Yasmin. *More Sophisticated, Autonomous Unmanned Aircraft on the Horizon*, *National Defense*, August, 2015.

Trimble, Stephen. *US forces plot new role for unmanned cargo resupply*, Archived March 11, 2010, at the Wayback Machine. *Flight International*, 12 August 2009

Thobaben, Chris. Major USMC, Marine Corps Installation and Logistics: *White paper for Hive final mile support.*

UnderSecretary of Defense Acquistion. *Unmanned Systems Integrated Roadmap. FY2013-2038*, January, 2014.

United States Marine Corps: *Marine Corps Operating Concept*, September, 2016.

United States Marine Corps and United States Army, *Joint Tactical Autonomous Aerial Resupply System*, 25 December, 2016.

Vanden, Tom. *IEDs Kill 21k Iraqi civilians from 2005-2010, Army Times*, Springfield, VA, 12 January 2011.

Yigit, Ergene. *Analysis of Unmanned Systems in Military Logistics*, December, 2016.