REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
26-04-2019	Master's of Military Studies	SEP 2018 - APR 2019

4. TITLE AND SUBTITLE
Balancing Military Logistics through Airdrop: Outsourcing to Expedite Capability

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)
Bailey, Kevin, M., Major, USAF

5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USMC Command and Staff College
Marine Corps University
2076 South Street
Quantico, VA 22134-5068

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

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

10. SPONSOR/MONITOR'S ACRONYM(S)
Dr. Douglas Streusand

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
N/A

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Military logistics in a combat environment requires planners to balance speed of delivery with cost-effectiveness and security. The supply chain tends to lag behind the needs of troops in the field due to the difficulty in predicting consumption rates during military operations. This issue becomes exacerbated as units move further away from their supply bases and the logistics network is further stressed. Each delivery location requires a diverse mix of modes of transfer to remain flexible to changes in the combat environment. Strategically placing airdrop rigging facilities throughout the world can reach all potential areas of operation and provide the critical capability of airdrop much sooner than historically possible.

15. SUBJECT TERMS
Airdrop; Logistics; Distributed Operations; Outsourcing Airdrop

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			USMC Command and Staff College
					19b. TELEPHONE NUMBER *(Include area code)*
Unclass	Unclass	Unclass	UU	31	(703) 784-3330 (Admin Office)

United States Marine Corps
Command and Staff College
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, Virginia 22134-5068

MASTER OF MILITARY STUDIES

TITLE:
Balancing Military Logistics through Airdrop: Outsourcing to Expedite Capability

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

AUTHOR:
Kevin Bailey
Major, USAF

AY 2018-19

Mentor and Oral Defense Committee Member: Dr. Douglas Streusand
Approved: _____
Date: 25 April 2019

Oral Defense Committee Member: Lt Col ~~Kevin~~ DeWitt, USMC
Approved: K.B. D
Date: 25 APR 2019

Executive Summary

Title: Balancing Military Logistics through Airdrop: Outsourcing to Expedite Capability

Author: Major Kevin Bailey, United States Air Force

Thesis: Fixed wing airdrop should be a standard part of logistics planning for all military operations. Facilities for airdrop should receive priority during the establishment of supply bases. Careful planning and outsourcing some requirements will facilitate the rapid availability of airdrop resupply.

Discussion: Military logistics in a combat environment requires planners to balance speed of delivery with cost-effectiveness and security. The supply chain tends to lag behind the needs of troops in the field due to the difficulty in predicting consumption rates during military operations. This issue becomes exacerbated as units move further away from their supply bases and the logistics network is further stressed. Each delivery location requires a diverse mix of modes of transfer to remain flexible to changes in the combat environment. Ground transportation methods use the least amount of fuel, but require suitable road networks and longer delivery times. Helicopters offer decreased transit time but suffer from reduced cargo capacity, reduced availability, and limited performance at higher altitudes and temperatures. Fixed-wing airdrop can now deliver almost any type of cargo needed in the field. Unfortunately, it requires specialized equipment, personnel, and facilities to prepare the delivery. For this reason, logisticians rarely consider fixed-wing airdrop as a standard delivery method. When available, airdrop offers logisticians the ability to deliver cargo faster and avoid threats that hamper other delivery methods.

Conclusion: All transportation methods should be available as soon as possible into a military operation so logisticians can counter supply chain deficits and provide maximum flexibility to the mission. Ground resupply modes of transportation are usually the first available, followed quickly by helicopter aerial delivery, but fixed-wing airdrop can be employed quickly with careful planning and the use of outsourced rigging facilities. Strategically placing airdrop rigging facilities throughout the world can reach all potential areas of operation and provide the critical capability of airdrop much sooner than historically possible.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

Illustrations

Page

Tables

Page

Table of Contents

Page

Preface

As an Air Force pilot at Marine Corps University, I wanted to take an opportunity to provide a recommendation that could benefit each service equally. I previously obtained a Masters of Logistics Management which has changed my perception of the military supply chain. Logistics intertwines among all services and career fields in the military, but few truly understand the benefits of airdrop logistics. As a C-130J pilot with over 1,000 flight hours in Afghanistan and over 100 combat airdrops, I believe that airdrop is a unique tool that should be used more often in logistics planning. When used appropriately, airdrop provides the capability to increase delivery speed and throughput in ways that other modes cannot match. This paper builds upon my experience to suggest that airdrop can be available in almost any location at the opening stages of an operation through careful strategic planning. The intended audience for this proposal is logistics planners within the Air Force, Marine Corps, and Army.

Logistics in a combat environment is an inherently arduous task in which planners attempt to balance delivery speed with efficiency. In theory, a perfect resupply mission would result in materiel being delivered precisely as the receiving unit depletes its stock. This procedure would ensure that the unit never ran out of essential supplies but was not responsible for storing excess inventory. In order to avoid wasting capacity, delivery vehicles should always carry full loads. Unfortunately, the combat environment makes such precision and efficiency impossible. Equipment usage rates vary and vehicles cannot deliver a full load on every shipment. This unpredictability results in units on the ground alternating between an empty to an overflowing warehouse. Logisticians have various modes of transportation at their disposal in order to control the flow of materiel. Usually, ground resupply methods like truck convoys are established first, followed quickly by helicopter airlift. Although fixed-wing airdrop typically carries less overall tonnage than other logistics modes, it offers essential capabilities that other methods are unable to provide. It is critically important for all methods of resupply to be available as soon as possible in order to increase the effectiveness of the logistics system. Unfortunately, airdrop infrastructure is typically one of the last facilities established during most operations due to the high cost and time investment needed. However, careful planning combined with outsourcing can provide an airdrop capability much sooner than in the past.

Unlike its civilian counterpart, military logistics is unable to strive for maximum performance by moving the most amount of materiel as efficiently as possible. Civilian logisticians can usually afford to wait for a truck or aircraft to reach maximum capacity in order to move materiel as economically as possible. If military logisticians applied these principles in a combat environment, troops would almost surely run out of supplies. In civilian logistics companies, planners can forecast required stock levels and schedule shipments accordingly. The

rate at which combat units use supplies is not predictable, so military logisticians cannot predict future needs as reliably as their civilian counterparts. To counter this adversity, military logistics planners have more options available for transportation. Using each mode of transportation for its strength moves supplies as efficiently as possible and corresponds to increased effectiveness for the warfighter.

Military Logistics Principles

Although it is often an afterthought, logistics plays an integral part in any military operation. The further a unit moves away from its central supply hub, the more difficult it becomes to keep it adequately sustained. When considering the movement of cargo between two bases within the same area, the fundamental modes of transportation are either trucks or aircraft. The full logistics system uses many other forms of transportation, but it will inevitably fall on the proverbial shoulders of trucks and aircraft to get the cargo to its final delivery location. A seaport or railroad station can sustain military units directly, but logisticians rarely have these assets available. Additionally, a significant amount of research has recently been done on the Unmanned Aerial System (UAS) cargo delivery capabilities. Although this system certainly has the potential to supplement the supply chain, it does not have the capacity to replace current delivery methods completely. Typically, a mix of trucking and conventional aerial delivery assets will deliver most cargo in a combat environment. Each method has benefits and limitations that a logistician must consider when deciding how to deliver cargo to units.

Ground Resupply

Trucking is usually the first option considered due to higher availability and ease of loading when compared to aircraft. A baseline Marine Corps Direct Support Combat Logistics Battalion (CLB-DS) typically has 93 trucks capable of transporting a total of 1,562 tons of cargo.[1] Trucks can operate from a relatively small fixed investment at terminal facilities and are

capable of maneuvering on a variety of roadways.[2] Unfortunately, not all combat environments have a suitable road network to support cargo deliveries. Many operations require units to establish Forward Operating Bases (FOBs) in isolated locations that are inaccessible by truck or only accessible during specific seasons with favorable weather conditions. This trucking limitation was particularly the case in Operation Enduring Freedom (OEF), where FOBs were located in mountainous terrain to control enemy movement to and from their cave network. The nature of operations in Afghanistan forced the regular logistics system to support a distributed FOB network, resulting in thinly spread assets and logistical deficits.[3] To counter these deficits in the logistics network, planners developed creative techniques to deliver the cargo so that the system became more efficient overall.

Helicopter Resupply

For many of the isolated FOBs in Afghanistan, logisticians had no other option than to employ aerial delivery of cargo to increase speed and throughput. The two primary options available for aerial resupply of a FOB are helicopter airland and fixed-wing airdrop. Helicopter missions can move cargo either by loading it onto the floor of the helicopter or hoisting it through sling load operations. The size of the helicopter cargo compartment limits the amount of floor-loaded payload and requires a suitable landing zone at the FOB to offload. Floor loading is best suited for small or sensitive cargo that cannot withstand sling load operations. Outsized cargo is moved using a heavy-lift helicopter like the CH-53 with a hoist connected to its underside.[4] Depending on the size and shape of the cargo, load instability inflight may restrict airspeed and maneuvering capabilities during sling load operations.[5] Although helicopters are not limited to roads, their maneuverability is restricted in locations with high terrain and hot temperatures. As the weight of the cargo increases, the altitude that helicopters can operate decreases which essentially limits them to lower terrain corridors in places like Afghanistan.

Enemy forces can observe this limitation quickly and will use valleys to funnel helicopters into an ambush of anti-aircraft fire.

Airdrop Resupply

Fixed-wing airdrop provides the capability to load cargo at a major logistics hub and quickly deliver it to the unit via parachute. Due to the superior speed of most airdrop platforms, this method provides the quickest response time from upload to delivery. The US Marine Corps can provide airdrop organically from CH-53, MV-22, and KC-130 aircraft, but these airframes have limited capacity and restricted availability due to their primary missions. The CH-53[6] and MV-22[7] can airdrop up to seven and four Container Delivery System (CDS) bundles at a maximum weight of 15,400 and 4,950 pounds, respectively. The KC-130 offers the most airdrop cargo capacity at 16 CDS bundles and 42,000 pounds,[8] however its primary mission is aerial refueling and it is the only Marine Corps asset capable of this mission.[9] US Marine Corps helicopters have made very few airdrops since a mid-1990s incident in which the airdrop cargo struck the door of a CH-53 as it exited, causing extensive damage.[10]

The US Air Force has more assets available each day to specialize in airdrop missions. The Air Force operates the C-130 and C-17 aircraft as their primary airdrop platforms. The C-130 can airdrop up to 42,000 pounds of cargo[11] and the C-17 can manage 110,000 total pounds in the airdrop configuration.[12] Each is capable of delivering large, outsized cargo and smaller CDS bundles up to 2,200 pounds each.[13] US Air Force C-130J[14] and C-17A[15] can carry 24 and 40 CDS bundles respectively, a distinct advantage over Marine Corps assets.

Figure 1: Container Delivery System (CDS) Bundle[16]

On average, each CLB-DS truck is able to carry an average of 15.3 CDS bundles based on weight.[17] When compared to US Air Force aircraft, each C-130 can provide the equivalent cargo of 1.3 average trucks and each C-17 can provide 3.3 average trucks worth of cargo via airdrop.[18] This capacity is certainly not enough to replace all other modes of delivery, but there are many situations that warrant the use of airdrop.

Airdrop Strengths

Threat Avoidance

The first and primary use of airdrop in combat is due to tactical necessity. Once the ground unit identifies a delivery location, aircraft can modify their approach corridor to avoid enemy hot spots and inaccessible terrain. Most types of airdrop can deliver cargo within 300 yards of the FOB allowing for quick recovery efforts by the unit.[19] Since fixed-wing aircraft are capable of flying higher and faster than helicopters, they are less vulnerable to enemy anti-aircraft weapons. Depending on the type of weapon employed by the enemy, fixed-wing aircraft can either fly above the weapons engagement zone, fly low to mask their aircraft with the terrain, or reroute around the threat altogether.[20] When operating in extremely high terrain helicopters are limited to operating in valleys that can be easily defended by enemy anti-aircraft weapons.

Efficiency during Distributed Operations

Another reason to employ fixed-wing airdrop is to utilize the efficiency of delivering to smaller units. A fully-loaded C-130 can deliver up to 5,036 gallons of water, 22,032 Meals Ready to Eat (MREs), or 6,052 gallons of diesel fuel during each airdrop as shown on the following table.

Table 1: Fixed-wing Airdrop Capabilities

Aircraft	Airdrop Load Capacity	CDS Bundle Capacity	Total CDS Capacity[21]	Airdrop Water Capacity	Airdrop MRE Capacity[22]	Airdrop Fuel Capacity
C-130J[23]	42,000 lbs	24	42,000 lbs	5,036 gal	22,032 meals	6,052 gal
C-17A[24]	110,000 lbs	40	88,000 lbs	10,552 gal	46,163 meals	12,680 gal

Notes: C-130J maximum CDS load limited by aircraft maximum airdrop weight
C-17A maximum CDS load limited by maximum CDS bundle weight of 2,200 lbs each
Water and fuel calculations based on standards of 8.34 lbs/gal and 6.94 lbs/gal respectively

The provisions delivered by just one C-130 would sustain a FOB of 40 troops for 39 days, limited by the standard water consumption of 3.22 gallons per person per day.[25] Even if the FOB is accessible by truck, the threat posed to such a small logistics element (1.3 trucks per C-130) by Improvised Explosive Devices (IEDs) or a road-side ambush could outweigh the benefits of delivering cargo via the ground. The Low-Cost Low Altitude (LCLA) airdrop system allows fixed-wing aircraft to drop small cargo bundles up to 450 pounds, within 100 yards of a FOB.[26] This high level of accuracy permits the ground unit to secure a much smaller drop zone and occasionally allows for the cargo to be delivered inside the boundaries of the FOB. The LCLA airdrop system also permits rigging cargo bundles in flight and delivering them to multiple FOBs on the same sortie. In-flight rigging allows for resupply of multiple small units in a fraction of the time that it would take a truck convoy to transit between bases.

Delivery Speed

The most apparent advantage of airdrop is the delivery speed. If units consumed expendables at consistent rates, logisticians could plan resupply missions in advance and always use the most efficient and effective method of delivery. Unfortunately, this is not the case.

Aerial delivery provides the flexibility to react to unpredicted situations like this to resupply troops more expediently than ground delivery methods. One unpredictable situation that lends itself to airdrop resupply is when a unit experiences an unusually high level of ammunition use due to enemy activity in their area. Without a quick resupply, the unit would be combat ineffective and risk being over-run by enemy forces in the area. Some of the more isolated FOBs could wait days or weeks for a ground resupply, but airdrop can deliver the necessary cargo within hours.

Airdrop Weaknesses

Fuel Consumption

Despite its advantages, airdrop is not always advantageous or feasible. Trucks are significantly more fuel efficient than aircraft. In operating locations with extreme terrain and a distributed FOB network, experience has proven that the Medium Tactical Vehicle Replacement (MTVR) 7.5-ton truck is the most capable due to its superior power, cargo capacity, off-road handling, and survivability record.[27] The table below compares the MTVR 7.5-ton truck with the primary airdrop platforms in the US Air Force.

Table 2: Cargo Transportation Mode Comparison

Vehicle	Load Capacity	Fuel Consumption	Normal Speed
MTVR 7.5 Ton[28]	30,000 lbs	92 lb/hr	60 MPH
C-130J[29] [30]	42,000 lbs	4,000 lb/hr	375 MPH
C-17A[31] [32]	110,000 lbs	20,000 lb/hr	403 MPH

A comparison of each delivery vehicle in Table 2 along an average delivery distance of 200 miles illustrates the decision faced by military logisticians. In this situation, an MTVR convoy would take 3.3 hours to make the trek while the C-130 and C-17 would each complete the delivery in 30 minutes. To deliver the same amount of cargo it would take two MTVRs to replace a C-130 and four MTVRs to cover the cargo of a C-17. Despite the increased number of trucks in the convoy, the group of MTVRs would use 1,518 pounds less fuel than a C-130 and

8,695 pounds less fuel than a C-17 to deliver the same amount of cargo. In situations in which the cargo is not time-critical, and excess MTVRs are available, trucking cargo to a FOB is significantly more fuel efficient.

Weather Limitations

Multiple aspects of weather can impact the effectiveness of each airdrop. When a drop zone is overcast with clouds, it limits the altitude at which an aircraft can fly. Aircraft must maintain a safe distance above any obstruction if it is invisible due to cloud cover. Instead of dropping the cargo at the preferred height above a drop zone, aircraft must maintain at least 500 feet above any terrain or man-made obstruction within three miles of the route of flight.[33] This restriction can force aircraft to drop the cargo hundreds of feet higher than would be possible on a cloudless day. As the release altitude increases, parachutes are more susceptible to drifting off target and will generally spread out further as they fall to the ground. This dispersion requires the recovery team to secure a larger drop zone and recover supplies scattered over a greater area.

Wind affects every airdrop regardless of cloud cover. High winds on a drop zone increase the likelihood that a cargo bundle could drift off course or even get dragged along the ground after it lands. For this reason, regulations restrict each type of parachute to a certain wind speed which could prevent the aircrew from even attempting a delivery. Additionally, the permissible wind speed may be even lower for small drop zones to prevent the cargo from landing in an unrecoverable location. High wind forecasts on a drop zone canceled multiple airdrop missions in Afghanistan before the mission began.

Drop Zone Size

Airdrop deliveries are highly dependent upon the amount of room available for a drop zone. A drop zone needs to be mostly level and free of hazards like water and trees that can impede the cargo as it falls to the ground. Additionally, the area needs to be free of inhabited

buildings to prevent injuries from falling cargo. CDS bundles are used to deliver most airdrop cargo and require up to 1,200 yards of drop zone length to allow the bundles to spread out as they exit the aircraft.[34] Depending on the location of the unit, there may not be enough suitable terrain to establish a drop zone close to the FOB. As troops move away from their FOB to find a satisfactory drop zone, they increase their exposure to possible threats and limit the amount of cargo they can haul back.

Decreasing the number of bundles delivered on each pass or lowering the drop altitude can reduce the size of the drop zone needed. Each sortie can make multiple passes over the drop zone in order to deliver the same amount of cargo possible with a full aircraft load. However, multiple passes over the drop zone will increase the amount of time that a unit must secure the area, so this is usually only considered for low-threat locations. Decreasing drop altitude can only be done for certain types of delivery methods and in locations without extreme terrain. Each situation is unique and requires cooperation between FOB personnel, logistics planners, and aircrew to determine the best method of delivery and placement of a drop zone.

Backhaul Cargo

A unique limitation to fixed-wing airdrop is the inability to pick up cargo from a FOB following a delivery. This reverse flow of supplies makes up the backhaul portion of logistics. To achieve maximum efficiency in the supply chain, every vehicle should strive to deliver full loads and return with full loads. During sustainment operations, most expendable items typically flow in one direction, but there is always a need to move materiel back to the central logistics hub. This movement includes anything from reusable shipping containers to equipment in need of repair and mail.[35] These items can easily be scheduled for pick up on either a truck or helicopter after a routine resupply mission to the FOB, but not after an airdrop. Since fixed-wing aircraft never land during the airdrop, they have no way of retrieving backhaul cargo from a unit

on the ground. This facet of logistics provides an excellent example as to why a combined resupply approach is desirable in most operations. When utilizing each delivery method for its strength, the logistics system will work more efficiently overall.

Multi-modal Approach to Military Logistics

Despite these deficiencies, airdrop's unique capabilities make it a useful complement to other transportation modes. Ideally, logisticians would have access to all resupply methods as soon as possible in order to use the mode of transportation best suited for each mission. From November 2007 to February 2009, US Marine Corps Combat Logistics Battalions (CLB) in Afghanistan determined that ground resupply methods work best when supplemented, not replaced by airdrop.[36] When logisticians use airdrop to supply remote FOBs with small shipments and time-sensitive equipment, they can employ the other modes for missions they fit better. Trucks can support large units that are close to well-maintained road networks and helicopters can concentrate on personnel movements instead of cargo. The combination of modes increases efficiency and responsiveness as a whole.

The use of all transportation methods makes the logistics system more reliable and resilient. If the enemy increases its use of roadside IEDs, logisticians can use airdrop to resupply large units instead of risking a truck convoy in a high-threat environment. If a maintenance recall grounds an entire fleet of resupply helicopters, then a combination of airdrop and trucking can pick up the slack. Despite its limitations, airdrop can function as the primary mode of delivery, even for large units, when circumstances require.

Expediting Access to Airdrop Capability

Unfortunately, airdrop is typically the last logistics capability realized during an operation due to the large footprint required for support. In order to prepare cargo for airdrop, a

logistics element needs facilities to dry, repair, and pack parachutes as well as a substantial area to rig cargo to parachutes.[37] These facilities are expensive and time-consuming to build, so commanders often delay construction in the hope they will not be necessary. Additionally, airdrop requires the employment of specific Military Occupational Specialties (MOS) like riggers and joint airdrop inspectors, as well as qualified aircrew. Since these skill sets are not routinely available in most units, logisticians must plan well in advance to ensure their availability. Airlift units, for example, do not always include crews qualified for airdrop missions. In order to be able to perform airdrop missions, the Joint Forces Air Component Commander (JFACC) must specifically request airdrop-qualified aircrew. Preparation and planning must begin immediately across the entire joint force in order to establish the airdrop capability as quickly as possible.

Development of Airdrop through History

A look at the historical reasons for employing airdrop and the time it took to establish the capability proves its importance. Most operations controlled the logistical demand through ground-based methods at first and then branched out to aerial resupply as logistical lines dispersed, roads became deteriorated, or conditions (weather or threat) made roads impassable. Logistics planners in World War II employed airdrop for the first time during the winter of 1943 to resupply an isolated unit of the Fifth US Army. Supply trucks were unable to access the unit due to weather in the Italian Alps, so they loaded supplies into empty fuel tanks on A-36 Apache[1] bombers[38] and dropped the cargo to the isolated troops.[39] Since this watershed use of

[1] The A-36 Apache is a P-51 Mustang with an Allison engine and speed brakes to aid in dive bombing. The name Apache was suggested from the manufacturer, North American, but never implemented by the US Army Air Corps, which continued to refer to the A-36 as a Mustang.

cargo airdrop, the US military has developed technologies specifically to increase its effectiveness. Each use of airdrop has revealed technical shortfalls and stimulated innovation.

Korean War

The US Air Force developed the Fairchild C-119 Flying Boxcar in the 1940s in order to improve airdrop capability. It saw initial combat use during the Korean War as a matter of necessity to counter overrun surface supply lines, enable quick offensive movements, and extend logistical reach over impassable terrain. The United States initially maintained supply lines via sealift and airlift to South Korean bases, but these modes became unusable as the North Korean Army moved south.[40] The bases that were still under friendly control did not have the runway length needed to allow aircraft to land and deliver the needed cargo, so the US Air Force used the C-119 to airdrop a significant portion of cargo directly to the front lines following the landing at Inchon.[41] The US Air Force could employ airdrop immediately after the war began because the necessary facilities already existed in Japan.[42] Since this facility was close to the Korean peninsula, it gave logisticians the option to employ airdrop much earlier in the Korean War than would normally be possible.

When United Nation forces shifted to the offensive, airdrop sustained the rapid advances that outran surface supply lines.[43] This allowed ground commanders to take advantage of the momentum gained without worrying about running out of supplies. The Korean peninsula provided opportunities to integrate airdrop into the mission even further than traditional resupply. The US Air Force delivered an entire bridge in eight segments to the US Marines and Army troops operating at the Chosin Reservoir allowing them to escape across a river and stave off certain annihilation.[44] Terrain and poor road networks in the northern-most sections of North Korea made aerial resupply imperative. When stationed along the Yalu River border with China,

the Eighth Army relied primarily on airdrop cargo resupply.[45] The entire airdrop system surged from 70 tons per day to 250 tons per day for two months to keep the Eighth Army in the fight.[46]

Vietnam War

Logisticians continued to use airdrop effectively throughout the Vietnam War, but unlike Korea, they were unable to rely on a previously constructed airdrop rigging facility within the area of operations. The US Army's 109th Quartermaster Company and US Navy Seabees took over five months to reconfigure the port at Cam Ranh Bay into a basic airdrop rigging facility.[47] At initial operating capacity, this facility was only able to support the airdrop of 100 tons of fuel and 20 tons of rations in the first month.[48] Before establishing the airdrop capability, aerial resupply missions relied heavily on landing cargo at bases by either fixed-wing aircraft or helicopters. Most small bases were unable to support the runway requirements of fixed-wing aircraft so they resorted to using helicopters that were highly susceptible to enemy anti-aircraft fire and could only carry a fraction of the cargo permissible on fixed-wing aircraft.

Airdrop saw the most extensive use in Vietnam during resupply missions at two besieged locations. The first siege supported by airdrop was at Khe Sanh, which was surrounded by enemy forces for 77 days starting on January 21, 1968. During this period, over 8,000 tons of supplies were airdropped to keep the troops alive. Airdrop accounted for over 64 percent of all cargo delivered during the siege because landing on the runway at Khe Sanh was unreliable.[49] Many aircraft attempting to land at Khe Sanh were under constant fire from anti-aircraft weapons in the air and from mortars while on the ground. Only personnel and the most valuable cargo were delivered by landing on the runway since the risk was justified in order to prevent them from falling into the hands of the North Vietnamese.[50] Airdrop proved to be indispensable to the troops on the ground at Khe Sanh, and they eventually fended off the attackers from the north and reestablished a ground supply route on April 8, 1968.

Like Khe Sanh, the siege of An Loc in the spring of 1972 tested the capabilities of airdrop further than any conflict before. The North Vietnamese Army circled the base with a ring of anti-aircraft fire that was nearly impenetrable.[51] Any attempt at low-altitude aerial delivery was increasingly less successful as the siege pressed on. Helicopter pilots refused to fly into the "death trap," and three C-130's would eventually be shot down forcing the Seventh Air Force to permanently cancel low-altitude airdrop on May 4, 1972.[52] With no other method to supply the 4,000 coalition troops and 6,000 civilians trapped in An Loc, the airdrop riggers began to improvise. They quickly tested and perfected multiple methods of high-altitude airdrop that kept aircraft above the reach of enemy anti-aircraft fire while maintaining the accuracy of low-altitude delivery.[53] The ingenuity of the riggers during the siege on An Loc demonstrates the adaptability of airdrop to each situation. Developments in airdrop have continued over the years to offer a wide range of options available to present-day logisticians. Airdrop can deliver almost anything that can be delivered by truck if deemed necessary by the situation.

Operation Enduring Freedom

The recent conflict in Afghanistan provided the opportunity to display the full potential of airdrop through various methods unique to each situation. Instead of using airdrop for temporary restrictions on ground resupply routes or the obvious siege, the mission and environment in Afghanistan forced the logistics system into a far more distributed fashion than what surface resupply could support.[54] The omnipresent IED threat, coupled with a poor existing road network, forced truck convoys to drive slowly in order to sweep for threats and frequently stop to repair vehicles as they took a heavy maintenance toll from deteriorated roads.[55] These complications made ground resupply of the many outlying FOBs an arduous task. Airdrop in Afghanistan lightened the load of truck convoys with a smorgasbord of delivery techniques for logisticians to choose from in each situation. The joint airdrop team of logisticians, riggers,

aircrew, and receiving units worked together to identify suitable drop zones, appropriate aircraft, and the best method of airdrop to deliver the cargo needed by troops on the ground. OEF provided fertile testing grounds to advance airdrop technology and explore the possibility of outsourcing support requirements.

Technological Advancements

C-17s using the heavy equipment airdrop method can deliver outsized cargoes weighing up to 60,000 pounds.[56] Aircraft usually deliver large equipment like this to besieged bases or during airborne troop insertions. Operations in Afghanistan required some heavy equipment airdrops[57], but the primary need was for the resupply of class I, III, and V (rations, fuel, and ammunition) materiel that could easily fit into smaller CDS bundles.[58] C-17s can drop up to 110,000 pounds of CDS bundles,[59] but are limited to 88,000 pounds due to the maximum CDS bundle weight of 2,200 pounds and only enough room for 40 bundles.[60] Environment restrictions and operational requirements in Afghanistan led to the development of new methods of airdropping CDS bundles that reduced delivery delays and limitations. The primary method of CDS employment is using low-altitude (800-1500 feet above ground) conventional airdrop that uses parachute ballistics and wind calculations to determine the release point so the cargo will drift down precisely on target. This system is one of the oldest methods of airdrop still in use today and requires the least amount of special equipment.

One of the newest and most technologically advanced airdrop methods currently employed is the Joint Precision Airdrop System (JPADS), which uses a GPS-guided computer to steer the parachute from as high as 25,000 feet to its target using movable risers in the same way a skydiver steers a parachute.[61] This system significantly increased the accuracy of high-altitude airdrop and allowed the resupply of FOBs previously unreachable by conventional airdrop due to extreme terrain. Unfortunately, the JPADS guidance system is costly which requires personnel

to haul them out for use on future deliveries.[62] Many of the FOBs supplied by airdrop were only accessible by foot, so the task of recycling JPADS equipment literally fell on the shoulders of the troops it was supporting.

To solve the issue of airdrop parachute backhaul, the Natick Soldier Systems Center in Massachusetts developed the Low-Cost Aerial Delivery System (LCADS).[63] LCADS comprises a single-use parachute system that is capable of either high-velocity or low-velocity delivery of up to 2,200 pounds at only 20 to 45 percent the cost of a reusable parachute system.[64] LCADS are delivered fully assembled which provides the added benefit of eliminating the need for a parachute packing facility. In Afghanistan, the lower cost and greater convenience of LCADS made airdrop resupply more competitive with ground delivery, especially for small loads.

The last new airdrop method developed during OEF was Low-Cost Low-Altitude (LCLA) delivery which was briefly discussed previously in this paper. This system utilizes a single-use parachute similar to LCADS, but on a much smaller scale in order to deliver cargo loads between 80 and 450 pounds at a very low altitude.[65] The lower altitude (150 to 300 feet above the ground) increased accuracy significantly, often permitting delivery inside the walls of the FOB. This proximity not only offered a way to resupply critically needed items but allowed the troops to receive them from a position of relative safety. By eliminating the dangerous task of securing a large drop zone and increasing the types of delivery aircraft capable of dropping cargo, LCLA increased the availability of airdrop and reduced dependency on ground resupply more than ever before. This development contributed to the increase from 3.5 million pounds airdropped in 2006 to over 60.4 million pounds four years later in Afghanistan.[66]

Figure 2: Low-Cost Low-Altitude Bundle vs. Conventional CDS Bundle[67]

Outsourcing Requirements

As the demand for airdrop resupply in OEF increased, the logistics system had to react quickly in order to support the requests. The first airdrop rigging facility in Afghanistan was established initially to sustain a humanitarian airdrop mission to Afghan civilians, and it had little room to expand.[68] A Combined Joint Task Force used what little capacity that was left to sustain the increasingly dispersed operations in Afghanistan.[69] Instead of reducing the availability of airdrop to the soldiers in the field, logisticians fell back on a technique previously used during the Korean War; they outsourced excess airdrop rigging requirements to a newly established facility in Qatar. US Army quartermasters established an airdrop facility at Al Udeid Air Base in December 2008 and rigged over 4.6 million pounds of coalition and joint cargo in the first ten months of operation.[70] Logistics hubs in Afghanistan received some of this cargo for future airdrop missions, but most was airdropped directly from Al Udeid Air Base to troops on the ground needing a faster response time. Although the direct delivery method reduced the range of operations due to the increased flight time, it successfully engaged airdrop into the

thinly spread logistics system much quicker than it took to build new facilities in theater. The Al Udeid facility continued to supply airdrop loads to OEF until two new rigging facilities could be set up at Kandahar and Bastion Airfields in 2010.[71] By outsourcing the airdrop rigging in OEF, logisticians made sure that the technological advancements in airdrop would not go to waste.

Future of Airdrop

National Defense Strategy

Understanding how airdrop has supported the logistics system in the past can help predict ways in which it will support future operations. Although it is nearly impossible to predict the scope of potential military engagements, the Secretary of Defense has established a planning roadmap with the 2018 National Defense Strategy (NDS). Specifically, the NDS calls for the US military to employ forces dynamically with unpredictable operations in order to complicate the mission of adversary decision makers.[72] Keeping a multi-faceted approach to cargo resupply enables logistics planners to instill a sense of unpredictability to future resupply operations. Without the use of airdrop, the options for resupply missions are minimal and thus more predictable for enemy planners to decipher.

Furthermore, the NDS calls for forces to transition from large, centralized infrastructure systems to smaller, dispersed, more resilient, and adaptive basing.[73] This concept resembles the distributed network of FOBs employed in Afghanistan. Although the future fight will most likely not be as permissive as OEF, it is probable that airdrop will be at the forefront of resupply missions. The NDS states that logistics must be resilient and agile with prepositioned forward stocks, strategic mobility assets, and distributed logistics and maintenance to ensure sustainability.[74] Airdrop offers the quickest way to redistribute cargo across multiple forward supply depots while remaining adaptive to last-minute changes in planning. Ground supply lines

are much less flexible to changes, especially in an environment with degraded roadway systems and advanced threats.

Expeditionary Advanced Base Operations

The NDS further supports the growing concept of Expeditionary Advanced Base Operations (EABO) by the US Marine Corps. EABO is subordinate to the US Navy concept of Littoral Operations in a Contested Environment (LOCE), which calls for small-signature, maneuverable basing over a wide area in order to make it difficult for the enemy to detect or target.[75] This concept relies on consistently changing locations in order to keep an advanced adversary on the reactive. To support a decreased set-up time and to reduce infrastructure costs of an Expeditionary Advanced Base (EAB), the US Marine Corps will most likely not build runways for fixed-wing airland resupply at every location where Marines are positioned. Dependence on ground resupply would restrict the location of EABs to locations accessible by road. To displace EABs further from the roadway system and save on runway infrastructure costs, logisticians must rely on some form of aerial delivery. For EABs located on islands that require surface supply by ship, airdrop provides an opportunity to expediently deliver cargo without placing surface vessels in a high-threat environment. Helicopters can provide some assistance, but the obvious solution for maximum cargo capacity is to employ fixed-wing airdrop. Airdrop has the added benefit of remaining responsive to the changing conditions of EABO. If needed, aircraft can even change delivery locations in-flight.

Ensuring Success

Understanding that military logistics is most effective when all transportation options are available to planners, it is essential to ensure that airdrop is accessible at the outset of military operations. Analyzing the doctrine, organization, training, materiel, leadership and education,

personnel, and facilities (DOTMLPF) of military logistics is a useful way to consider all aspects of this capability solution.[76]

Doctrine

The *Joint Terminal Operations* doctrine, JP 4-01.5 briefly mentions providing an airdrop resupply capability,[77] but does not explain the requirements needed to establish a functional airdrop rigging facility. The entire section titled "Air Terminal Operations" only covers the capabilities offered through airland resupply, not airdrop.[78] JP 3-17, *Air Mobility Operations* exquisitely delineates the advantages and disadvantages of airland and airdrop that would be beneficial to the readers of JP 4-01.5.[79] The planning section (Annex C) of JP 4-01.5 should include a reference to JP 3-17 to provide this necessary clarity for logistics planners. Additionally, JP 4-01.5 should discuss the potential to outsource airdrop rigging requirements during the early stages of an operation. When logisticians understand that another logistics hub can support their airdrop rigging, they can employ the capability based on need, not availability. Changing doctrine at the highest level will ensure that all logistics officers understand the underlying planning considerations for each method of cargo delivery.

Organization

A review of airdrop facility organization reveals that strategically placed hubs can support any potential operating area within reach of mobility aircraft. With the ability to outsource the airdrop rigging process, not every operating location needs to invest in expensive airdrop infrastructure. Facilities located at the maximum range of aircraft can support areas with a low likelihood of combat operations. As the likelihood of combat operations increases, planners should consider moving support facilities closer to the area of interest. If operations move toward a distributed logistics network of FOBs similar to OEF, then it would be appropriate to place rigging facilities directly in the area of operations. This phased approach to

organizational planning would offer the best balance of airdrop capability with financial responsibility.

Training

Training for combat operations often focuses on the maneuver and fire aspects but leaves little time for logisticians to perfect their craft. With the advent of the EABO concept, logistics will play a much larger role in the future fight. Commanders should take time to focus their training on analyzing the combat environment and allowing logisticians to develop a suitable plan to ensure effective resupply in various scenarios. If the logistics planners can identify situations that are favorable for each mode of transportation, they are more likely to employ them effectively in combat. Not every mission will necessitate the use of airdrop, but a productive training environment will allow logisticians to determine the situations that do and employ it appropriately.

Materiel

The materiel needed to operate a rigging facility is the most significant barrier to using airdrop in a military operation. Any other mode of transportation can load cargo directly with very little additional equipment. The addition of a parachute and rigging materiel increases the complexity of any cargo delivery. Outsourcing this requirement to another facility is one solution to the materiel problem, but another could be to reduce or remove the need for rigging facilities completely. The development of the single-use LCADS parachutes completely removed the requirement for parachute repair and re-packing needed with conventional parachutes. Continuing to reduce the support and materiel needed for airdrop will increase its availability to the logistician in future conflicts.

Leadership and Education

Leadership and education are the areas that stand to receive the most change in order to promote airdrop resupply. Logisticians will be able to operate much more effectively when they

understand the resupply mission as a whole. The education should involve realistic scenarios in which planners identify appropriate modes of transportation for a given situation. This instruction should be incorporated at all levels so that senior leadership understands the impact of their decisions when they limit resupply options. Not all military operations can take the same approach to logistics, so understanding each method of delivery will ensure that they are available when needed. Education should also be completed laterally so that other career fields understand what logisticians can provide and the limitations to their supply methods. With the possibility of a logistics-heavy fight as mentioned in the 2018 NDS, it is essential for all personnel to understand the capabilities of their logistics elements.

Personnel

Changing personnel requirements may be necessary depending on the strategic planning done to offer airdrop to all operating areas. Ideally, specialty MOSs can be moved from one theater to another depending on the demand for airdrop in the supply chain. In order to be prepared to engage in multiple distributed operation missions simultaneously, the US Air Force may need to increase the number of qualified airdrop riggers and inspectors. This situation is unlikely, and the increase in outsourced rigging facilities could actually reduce the number of specialty MOSs needed overall. If outsourced facilities can cover multiple combat zones (like the one at Al Udeid Air Base did for Operations Enduring Freedom and Iraqi Freedom), the personnel requirement would be higher at the main facility, but lower overall since fewer locations are needed to rig airdrop equipment.

Facilities

The last area to consider for change is the logistics facilities installed at each base. Even if the potential to employ airdrop is remote, senior leadership should plan to develop at least one facility capable of transitioning into an airdrop support base for the theater. Logistics planners

can construct actual facilities later, but it is essential to set aside the area needed for expansion to prevent a situation like the one that occurred during OEF in which Bagram Airfield was unable to expand its airdrop facility due to limited real estate.[80]

Conclusion

Military logisticians are generally reactive to the needs of troops in the field. Predicting consumption rates of units is nearly impossible, and disparities between operational requirements and available supplies are frequent. In order to provide the most flexibility so that combat troops remain effective, logisticians must have all transportation methods available to deliver supplies. Each mode of transportation works best when employed as a team to enhance their strengths and reduce their weaknesses. The overall goal of the logistics planner is to move cargo as quickly and efficiently as needed while reducing exposure to threats. Ground and helicopter resupply methods are usually the first modes available due to their reduced barriers of entry. Fixed-wing airdrop currently requires a significant infrastructure investment but offers key advantages in threat avoidance, delivery speed, and efficiency in distributed operations. Careful planning and the outsourcing of some requirements mitigate the upfront cost of airdrop in order to employ it much sooner than normally possible in a military engagement.

History has proven that planners often overlook airdrop infrastructure in the early stages of an operation. The Korean War utilized airdrop facilities in neighboring Japan to harness the benefits of airdrop much earlier than any prior conflict. This example of outsourcing could be expanded to formulate a network of strategically placed airdrop hubs that provide coverage to any potential area of operations. When needed, supplies from the closest hub can be dispatched to respond to escalating conflict or humanitarian crisis quickly. This type of flexibility is

critically necessary as the United States prepares for the future fight as described in the 2018 National Defense Strategy and Expeditionary Advanced Base Operations concept.

To ensure successful employment of airdrop capabilities, changes should be made to doctrine, organization, training, materiel, leadership and education, personnel, and facilities. Joint Publication 3-17, *Air Mobility Operations* provides an increased level of clarity to airdrop, but references to this regulation are missing in logistics doctrine (Joint Publication 4-01.5, *Joint Terminal Operations*). Once the concept is understood universally, airdrop rigging facilities can be organized into an overlapping framework of hubs that can respond to situations anywhere in the world. Logisticians should train with an increased emphasis on distributed operations and the use of outsourced airdrop rigging from these hubs. Further reducing materiel requirements will increase the availability of airdrop and place less strain on the airdrop infrastructure network. Leadership must understand all capabilities provided by airdrop in order use it effectively as it becomes more prevalent. Personnel are best employed when centralizing tasks at an airdrop hub and removing duplicate work at unproductive facilities. Finally, as each logistics facility is developed, there should always be a consideration for evolving into an airdrop hub in the event of expanding future conflict.

Appendix A – Suggested Future Research

This paper provides the reasoning to implement a network of strategic airdrop hubs, but does not answer the question of how it will be done. To answer this question, planners must consider many variables including: basing availability, personnel availability, aircraft readiness, aircraft range, country threat conditions, and likely areas of natural disaster. Many of these considerations change continuously, so any suggested basing structure would only provide a snapshot in time. Additionally, the source for much of this data resides on classified networks and this paper was purposefully kept unclassified to reach the largest audience possible.

The "Future of Airdrop" section provides a cursory review of airdrop capabilities in a high-end fight with a peer adversary. A significant amount of planning on how mobility aircraft operate in this type of environment has already been done, but was not included in this paper due to classification levels. Planners should reference this work from a classified network to ensure it is incorporated into future plans surrounding distributed operations.

Endnotes

[1] MAGTF Staff Training Program, *MAGTF Planner's Reference Manual*, MSTP Pamphlet 5-0.3, November 2012, I-28 & II-6.
[2] Donald J. Bowersox, David J. Closs, and M. Bixby Cooper, *Supply Chain Logistics Management.* 3rd ed. (New York: McGraw-Hill, 2010), 205.
[3] Ben Connable et al., "Support to Logistics Decisions," *Modeling, Simulation, and Operations Analysis in Afghanistan and Iraq: Operational Vignettes, Lessons Learned, and a Survey of Selected Efforts*, RAND Corporation (2014): 59, http://www.jstor.org.lomc.idm.oclc.org/stable/10.7249/ j.ctt5vjwt0.11.
[4] US Marine Corps, *Multiservice Helicopter Sling Load: Basic Operations and Equipment*, MCRP 4-11.3E, Volume 1, April 10, 1997, 1-1.
[5] US Marine Corps, *Multiservice Helicopter Sling Load*, 1-1.
[6] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, MCRP 4-11.3C, March 2016, 2-2.
[7] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, 2-4.
[8] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, 2-3.
[9] "KC-130J Aircraft Makes First Combat Aerial Delivery," *US Fed News Service, Including US State News,* Apr 16, 2005, Proquest (472150449).
[10] Marine Corps Center for Lessons Learned, *Logistics Lessons and Observations*, December 5, 2006, 36, https://www.mccll.usmc.mil.
[11] Scott T. Sturkol, "C-130 Hercules: Air Force's 'Old Reliable' Airlifter Still on the Front Lines," *Federal Information & News Dispatch*, (2010): 2, Proquest (820877229).
[12] John V. McCoy, "Configuring Airdrop Packages for the IBCT," *Army Logistician* 33, no. 5 (September 2001): 12, Proquest (197286608).
[13] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, 1-5.
[14] Sturkol, "C-130 Hercules: Air Force's 'Old Reliable' Airlifter," 2.
[15] McCoy, "Configuring Airdrop Packages for the IBCT," 12.
[16] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, 8-9.
[17] MAGTF Staff Training Program, *MAGTF Planner's Reference Manual,* I-20.
[18] MAGTF Staff Training Program, *MAGTF Planner's Reference Manual,* I-20.
[19] US Air Force, *Drop Zone and Landing Zone Operations*, Air Force Instruction 13-217, May 10, 2007, 10.
[20] US Air Force, *Flying Operations C-130J Operations Procedures,* Air Force Instruction 11-2C-130J Volume 3, December 8, 2009, 181.
[21] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, 1-5.
[22] MAGTF Staff Training Program, *MAGTF Planner's Reference Manual*, IV-50.
[23] Sturkol, "C-130 Hercules: Air Force's 'Old Reliable' Airlifter," 2.
[24] McCoy, "Configuring Airdrop Packages for the IBCT," 12.
[25] MAGTF Staff Training Program, *MAGTF Planner's Reference Manual*, IV-58.
[26] US Air Force, *Drop Zone and Landing Zone Operations*, 13.
[27] Marine Corps Center for Lessons Learned, *Special Purpose MAGTF – Afghanistan Operations: Summary of Observations from Support of International Security Assistance Force, November 2007 through February 2009,* 19 August 2009, https://www.mccll.usmc.mil, 4.
[28] MAGTF Staff Training Program, *MAGTF Planner's Reference Manual*, II-4 & II-7.
[29] US Air Force, *Flying Operations C-130J Operations Procedures*, 173.
[30] *Jane's All the World's Aircraft*, "Lockheed Martin 382U/V Super Hercules," January 3, 2018, Jane's Information Group.
[31] Sandy Angers, "Fueling Efficiency: Boeing Test Pilots Find New Ways to Save Fuel – and Cut Costs," *Boeing Frontiers*, November 2010, 33.
[32] *Jane's Aircraft Upgrades,* "Boeing C-17A Globemaster III," June 22, 2018, Jane's Information Group.
[33] US Air Force, *Flying Operations C-130J Operations Procedures*, 180.
[34] US Air Force, *Drop Zone and Landing Zone Operations*, 9.
[35] Bowersox, Closs, and Cooper, *Supply Chain Logistics Management*, 221.
[36] Marine Corps Center for Lessons Learned, *Special Purpose MAGTF – Afghanistan Operations*, 3.
[37] Jimmy Taylor, "Expanding Aerial Delivery Capability in Afghanistan," *Army Sustainment* 42 no. 1 (2010): 27, EBSCOhost (48870783).
[38] Stephan Wilkinson, "Mustang by Another Name," *Aviation History* 01 (2013): 17, Proquest (1447235559).

[39] Mitchell H. Stevenson, "Aerial Resupply on the Forefront in Afghanistan," *Army* 60 no. 6 (2010): 23, Proquest (367203638).
[40] Daniel L. Haulman, "Salvation from the Sky: Airlift in the Korean War, 1950," *Air Power History* (Summer 2001): 19, Proquest (219752459).
[41] Haulman, "Salvation from the Sky: Airlift in the Korean War, 1950," 20.
[42] Haulman, "Salvation from the Sky: Airlift in the Korean War, 1950," 19.
[43] Haulman, "Salvation from the Sky: Airlift in the Korean War, 1950," 21.
[44] Haulman, "Salvation from the Sky: Airlift in the Korean War, 1950," 22-23.
[45] Haulman, "Salvation from the Sky: Airlift in the Korean War, 1950," 21.
[46] "Combat Cargo," *Air Power History* (Summer 2000): 30, Proquest (219757805).
[47] Peter Brush, "Aerial Lifeline to Khe Sanh," *Vietnam* 12 (1999): 32, Proquest (195761818).
[48] Brush, "Aerial Lifeline to Khe Sanh," 32.
[49] Brush, "Aerial Lifeline to Khe Sanh," 36.
[50] Brush, "Aerial Lifeline to Khe Sanh," 35.
[51] John A. Tokar, "Supply by Sky: An Loc Airlift," *Vietnam* 12 (2000): 37, Proquest (195763398).
[52] Tokar, "Supply by Sky: An Loc Airlift," 37 & 39.
[53] Tokar, "Supply by Sky: An Loc Airlift," 41.
[54] Connable et al., "Support to Logistics Decisions," 59.
[55] Marine Corps Center for Lessons Learned, *Special Purpose MAGTF – Afghanistan Operations*, 18-19.
[56] McCoy, "Configuring Airdrop Packages for the IBCT," 12.
[57] David Salanitri, "Air Force Airdrops Forklift at Remote Base," *AMC.af.mil*, November 30, 2011, https://www.amc.af.mil/News/Article-Display/Article/145241/air-force-airdrops-forklift-at-remote-base.
[58] Marine Corps Center for Lessons Learned, *Special Purpose MAGTF – Afghanistan Operations*, 20.
[59] McCoy, "Configuring Airdrop Packages for the IBCT," 12.
[60] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, 1-5.
[61] Stevenson, "Aerial Resupply on the Forefront in Afghanistan," 24.
[62] Stevenson, "Aerial Resupply on the Forefront in Afghanistan," 24.
[63] Jamie Bishop, Andrew Meloni, and Richard Benney, *Precision Airdrop Technology Conference and Demonstration 2007*, PowerPoint presentation, US Army Natick Soldier Research, Development, and Engineering Center, Natick, MA, February 10, 2008, www.dtic.mil/dtic/tr/fulltext/u2/a488396.pdf, C-9.
[64] Bishop, Meloni, and Benney, *Precision Airdrop Technology Conference and Demonstration 2007*, 27.
[65] Stevenson, "Aerial Resupply on the Forefront in Afghanistan," 26.
[66] Scott T. Sturkol, "10 Years of Enduring Freedom: Since the First Day, Airdrops in Afghanistan Have Made a Difference," *AMC.af.mil*, October 5, 2011, https://www.amc.af.mil/News/Features/Display/Article/150011/10-years-of-enduring-freedom-since-the-first-day-airdrops-in-afghanistan-have-m.
[67] US Marine Corps, *Airdrop of Supplies and Equipment: Rigging Containers*, 8-15 & 14-12.
[68] Taylor, "Expanding Aerial Delivery Capability in Afghanistan," 27.
[69] Taylor, "Expanding Aerial Delivery Capability in Afghanistan," 27.
[70] Taylor, "Expanding Aerial Delivery Capability in Afghanistan," 28.
[71] Angelique N. Smythe, "Kandahar Airmen Airdrop Supplies to Troops, Prepare for Troop Increase," *AF.mil*, February 2, 2010, https://www.af.mil/News/Article-Display/Article/117752/kandahar-airmen-airdrop-supplies-to-troops-prepare-for-troop-increase.
[72] US Department of Defense, *Summary of the 2018 National Defense of the United States of America: Sharpening the American Military's Competitive Edge*, Arlington, VA, 2018, 5.
[73] US Department of Defense, *Summary of the 2018 National Defense of the United States of America*, 6.
[74] US Department of Defense, *Summary of the 2018 National Defense of the United States of America*, 7.
[75] "Navy, Marine Corps Intend to Release Expeditionary Advanced Base Ops Concept," *InsideDefense.com, SitRep*, 2017, Proquest (1952420638).
[76] Chairman of the Joint Chiefs of Staff, *Charter of the Joint Requirements Oversight Council and Implementation of the Joint Capabilities Integration and Development System*, CJCS Instruction 5123.01H, August 31, 2018, https://www.jcs.mil/Doctrine, GL-10.
[77] Joint Chiefs of Staff, *Joint Terminal Operations*, Joint Publication 4-01.5, November 2, 2015, https://www.jcs.mil/Doctrine, C-C-1.
[78] Joint Chiefs of Staff, *Joint Terminal Operations*, III-1.
[79] Joint Chiefs of Staff, *Air Mobility Operations*, Joint Publication 3-17, February 5, 2019, https://www.jcs.mil/Doctrine, V-17.

[80] Taylor, "Expanding Aerial Delivery Capability in Afghanistan," 27.

Bibliography

Angers, Sandy. “Fueling Efficiency: Boeing Test Pilots Find New Ways to Save Fuel – and Cut Costs.” *Boeing Frontiers,* November 2010.

Bishop, Jamie, Andrew Meloni, and Richard Benney. *Precision Airdrop Technology Conference and Demonstration 2007*. PowerPoint presentation. US Army Natick Soldier Research, Development, and Engineering Center, Natick, MA, February 10, 2008. www.dtic.mil/dtic/tr/fulltext/u2/a488396.pdf.

Bowersox, Donald J., David J. Closs, and M. Bixby Cooper. *Supply Chain Logistics Management.* 3rd ed. New York: McGraw-Hill, 2010.

Brush, Peter. "Aerial Lifeline to Khe Sanh." *Vietnam* 12 (1999): 30-36. Proquest (195761818).

Chairman of the Joint Chiefs of Staff. *Charter of the Joint Requirements Oversight Council and Implementation of the Joint Capabilities Integration and Development System.* CJCS Instruction 5123.01H, August 31, 2018. https://www.jcs.mil/Doctrine.

"Combat Cargo." *Air Power History* (Summer 2000): 30-33. Proquest (219757805).

Connable, Ben, Walter L. Perry, Abby Doll, Natasha Lander, and Dan Madden. "Support to Logistics Decisions." *Modeling, Simulation, and Operations Analysis in Afghanistan and Iraq: Operational Vignettes, Lessons Learned, and a Survey of Selected Efforts,* RAND Corporation (2014): 59-70. http://www.jstor.org.lomc.idm.oclc.org/stable/10.7249/j.ctt5vjwt0.11.

Haulman, Daniel L. "Salvation from the Sky: Airlift in the Korean War, 1950." *Air Power History* (Summer 2001): 16-25. Proquest (219752459).

Jane’s Aircraft Upgrades. “Boeing C-17A Globemaster III,” June 22, 2018. Jane’s Information Group.

Jane’s All the World’s Aircraft. “Lockheed Martin 382U/V Super Hercules,” January 3, 2018. Jane’s Information Group.

Joint Chiefs of Staff. *Air Mobility Operations.* Joint Publication 3-17, February 5, 2019, https://www.jcs.mil/Doctrine.

Joint Chiefs of Staff. *Joint Terminal Operations.* Joint Publication 4-01.5, November 2, 2015. https://www.jcs.mil/Doctrine.

"KC-130J Aircraft Makes First Combat Aerial Delivery." *US Fed News Service, Including US State News.* Apr 16, 2005. Proquest (472150449).

MAGTF Staff Training Program. *MAGTF Planner's Reference Manual.* MSTP Pamphlet 5-0.3, November 2012.

Marine Corps Center for Lessons Learned. *Logistics Lessons and Observations.* December 5, 2006. https://www.mccll.usmc.mil.

Marine Corps Center for Lessons Learned. *Special Purpose MAGTF – Afghanistan Operations: Summary of Observations from Support of International Security Assistance Force, November 2007 through February 2009.* 19 August 2009. https://www.mccll.usmc.mil.

McCoy, John V. "Configuring Airdrop Packages for the IBCT." *Army Logistician* 33, no. 5 (September 2001): 12-14. Proquest (197286608).

"Navy, Marine Corps Intend to Release Expeditionary Advanced Base Ops Concept." *InsideDefense.com. SitRep*, 2017. Proquest (1952420638).

Salanitri, David. "Air Force Airdrops Forklift at Remote Base." *AMC.af.mil.* November 30, 2011. https://www.amc.af.mil/News/Article-Display/Article/145241/air-force-airdrops-forklift-at-remote-base.

Smythe, Angelique N. "Kandahar Airmen Airdrop Supplies to Troops, Prepare for Troop Increase." *AF.mil.* February 2, 2010. https://www.af.mil/News/Article-Display/Article/117752/kandahar-airmen-airdrop-supplies-to-troops-prepare-for-troop-increase.

Stevenson, Mitchell H. "Aerial Resupply on the Forefront in Afghanistan." *Army* 60 no. 6 (2010): 22-24,26. Proquest (367203638).

Sturkol, Scott T. "10 Years of Enduring Freedom: Since the First Day, Airdrops in Afghanistan Have Made a Difference." *AMC.af.mil.* October 5, 2011. https://www.amc.af.mil/News/Features/Display/Article/150011/10-years-of-enduring-freedom-since-the-first-day-airdrops-in-afghanistan-have-m.

Sturkol, Scott T. "C-130 Hercules: Air Force's 'Old Reliable' Airlifter Still on the Front Lines." *Federal Information & News Dispatch*, (2010). Proquest (820877229).

Taylor, Jimmy. "Expanding Aerial Delivery Capability in Afghanistan." *Army Sustainment* 42 no. 1 (2010): 26–28. EBSCOhost (48870783).

Tokar, John A. "Supply by Sky: An Loc Airlift." *Vietnam* 12 (2000): 34-40. Proquest (195763398).

US Air Force. *Drop Zone and Landing Zone Operations.* Air Force Instruction 13-217. May 10, 2007.

US Air Force. *Flying Operations C-130J Operations Procedures.* Air Force Instruction 11-2C-130J Volume 3. December 8, 2009.

US Department of Defense. *Summary of the 2018 National Defense of the United States of America: Sharpening the American Military's Competitive Edge.* Arlington, VA, 2018.

US Marine Corps. *Airdrop of Supplies and Equipment: Rigging Containers.* MCRP 4-11.3C. March 2016.

US Marine Corps. *Multiservice Helicopter Sling Load: Basic Operations and Equipment.* MCRP 4-11.3E, Volume 1. April 10, 1997.

Wilkinson, Stephan. "Mustang by Another Name." *Aviation History* 01 (2013): 16-17. Proquest (1447235559).