THE RIGHT PLACE AT THE RIGHT TIME- An Analysis of High Altitude Airdrop and the Joint Precision Airdrop System

GRADUATE RESEARCH PROJECT

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Presented to the Faculty

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Pete L. Carrabba

Major, USAF

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Pete L. Carrabba

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Abbreviations

AAA	Anti Aircraft Artillery
ACTD	Advanced Concept Technology Demonstration
ADS	Air Drop System
AFARN	Air Force Air Request Net
AFI	Air Force Instruction
AFWA	Air Force Weather Agency
AGAS	Affordable Guided Airdrop System
AGL	Above Ground Level
AGU	Airborne Guidance Unit
AMC	Air Mobility Command
AMD	Air Mobility Division
AMP	Avionics Modernization Program
AOC	Air Operations Center
APOD	Aerial Port of Debarkation
AS	Airlift Squadron
ATO	Air Tasking Order
AWADS	Adverse Weather Aerial Delivery System
BLOS	Beyond Line of Sight
CADS	Combat Aerial Delivery School
CAOC	Combined Air Operations Center
CAPS	Combat Airdrop Planning Software
CARP	Computed Air Release Point
CAS	Close Air Support
CDD	Capabilities Development Document
CDI	Course Direction Indicator
CDS	Container Delivery System
CEA	Circular Error Average
CEP	Circular Error Probability
CFPS	Computer Flight Planning System

CINC	Commander in Chief
CMDS	Counter Measure Dispensing System
COCOM	Combatant Command
CONOPS	Concept of Operations
CTII	Combat Track II
CTS	Combat Training Squadron
DTED	Digital Terrain Elevation Data
DZ	Drop Zone
DZCO	Drop Zone Control Officer
EFTC	Extraction Force Transfer Coupling
FCT	Foreign Comparative Test
FDMS	Flight Director Mode Selector
FNMOC	Fleet Numerical Meteorological and Oceanographic Center
FOM	Figure of Merit
FSL	Forecast Systems Laboratory
FTT	Forward travel time
FTU	Formal Training Unit
GCAS	Ground alert Close Air Support
GLOC	Ground Line of Communication
GMAS	Ground alert Mobility Air Support
GMI	Graphical Map Interface
GPS	Global Positioning System
GRADS	Ground Radar Air Drop System
GUI	Graphical User Interface
HALO	High Altitude, Low Opening
HDR	Humanitarian Daily Rations
HVCDS	High Velocity Container Delivery System
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
JFCOM	Joint Forces Command
JMC	Joint Movement Center
JPADS	Joint Precision Airdrop System

JROC	Joint Requirements Oversight Council
JRTC	Joint Readiness Training Center
KIAS	Knots Indicated Airspeed
LAPS	Local Analysis and Prediction System
LIDAR	Light detection and ranging
MAC	Military Airlift Command
MANPAD	Man Portable Air Defense Missile
MOA	Military Operations Area
MRE	Meals Ready to Eat
MSL	Mean Sea Level
MWS	Mobility Weapons School
NCEP	National Centers for Environmental Prediction
NM	Nautical mile
NOAA	National Oceanographic and Atmospheric Administration
OA	Objective Area
OEF	Operation ENDURING FREEDOM
OIF	Operation IRAQI FREEDOM
OPSEC	Operational Security
ORD	Operational Requirements Document
OUE	Operational Utility Evaluation
OS	Operating System
OSD	Office of the Secretary of Defense
PADS	Precision Airdrop System
PAPS	Precision Airdrop Planning System
PATCAD	Precision Airdrop Technology Conference and Demonstration
P-Codes	Precision Codes
PDA	Personal Digital Assistant
PI	Point of Impact
PFPS	Portable Flight Planning Software
PSI	Planning Systems Incorporated
RADAR	Radio Detection and Ranging
RAM	Raised Angle Marker
RAIM	Receiver Autonomous Integrity Monitoring

RF	Radio Frequency
SAB	Scientific Advisory Board
SAM	Surface to air missile
SATB	Standard Airdrop Training Bundle
SATCOM	Satellite Communications
SBIR	Small Business Innovative Research
SCNS	Self Contained Navigation System
SEAD	Suppression of Enemy Air Defenses
SIPRNET	Secret Internet Protocol Router Network
SKE	Station Keeping Equipment
SOCOM	Special Operations Command
SPO	Systems Program Office
SPOD	Sea Port of Debarkation
TAC	Tactical Airlift Command
TACP	Tactical Air Control Party
TAS	True Airspeed
TCTO	Time Compliance Technical Order
TDrop	Tactical Dropsonde
TFC	Time of fall constant
TO	Technical Order
TOF	Time of Fall
TOT	Time Over Target
TP	Turn Point
TRIADS	Triwall Aerial Delivery System
TTF	Total Time of Fall
TTP	Tactics, Techniques, and Procedures
UAV	Unmanned Aerial Vehicle
UMAV	Unmanned Mobility Aerial Vehicle
USJFCOM	United States Joint Forces Command
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WIC	Weapons Instructor Course
WINDPADS	Wind Precision Airdrop System

WGS-84	World Geodetic System 84
WOC	Wing Operations Center
XCAS	Emergency Close Air Support
XMAS	Emergency Mobility Air Support
YPG	Yuma Proving Ground

Abstract

High altitude airdrop increases survivability of the aircrew from surface threats such as small arms fire, light anti-aircraft artillery (AAA), and man portable air defense systems (MANPADS). Flying at high altitude helps mitigate the threat by operating outside the edges of the threat envelope. The drawback is reduced airdrop accuracy when dropping at high altitude. Because the airdrop load is not guided once it is released, its impact point is variable. Airlift aircraft have demonstrated the ability to deliver supplies from high altitude, but they have not yet been married up with current technology in order to meet the stated need for precision.

The purposes of this case study was to understand the high altitude airdrop problem, describe the CONOPS, and develop recommendations for the OSD, Joint Staff, and Headquarters staff. This study attempted to contribute to the knowledge base by examining the high altitude airdrop accuracy problem and determining possible solutions. This study also sought to determine if mobility aircraft can effectively use the Joint Precision Airdrop System (JPADS). The study examined the JPADS Advanced Concept Technology Demonstration (ACTD) whose purpose is to demonstrate and assess systems and technologies that can provide a global delivery system capable of fort (CONUS) to fighter distribution.

THE RIGHT PLACE AT THE RIGHT TIME- An Analysis of High Altitude Airdrop and the Joint Precision Airdrop System

I. INTRODUCTION

Background

> *"The United States Army is developing new concepts of operation for brigade combat teams. They plan for them to be deep in enemy territory and scattered around. And with that we need the technology to keep corridors open so we can resupply these teams. I think we are going to have to be able to airdrop with the same precision that we deliver GPS guided bombs."*
>
> *AF Chief of Staff General John P. Jumper, 31 Oct 2003*

Airdrop is necessary in areas of the world where there are no provisions to land an aircraft or where ground convoy resupply is not possible or safe. Airdrop is also used to quickly deliver humanitarian and combat forces to the battlefield. The US military can deliver combat capable forces via airdrop anywhere in the world on short notice. Historically, this method of delivery was used extensively in both world wars, Korea, Vietnam, Grenada, Panama, Afghanistan, Iraq, and numerous humanitarian and contingency operations.

There are several USAF aircraft capable of airdropping personnel, equipment, and supplies. Crews are required to use methods such as sight angle, visual reference, and onboard computers to navigate to the desired release point (AFI 11-231, 1998, pp. 24-33). All of these methods are based upon a Computed Air Release Point (CARP). The

CARP takes into account many factors such as the exit time of a particular load, the time it takes for the load to decelerate after it leaves the aircraft, the time of fall of the load, and the effects of wind on the load. After all the calculations are complete, an estimated release point location is determined in reference to the desired Point of Impact (PI).

Another type of airdrop is release from high altitude. High altitude airdrop provides an increase in survivability of the aircrew from surface threats such as small arms fire, light anti-aircraft artillery (AAA), and man portable air defense systems (MANPADS). Flying and dropping at high altitude helps mitigate the threat by operating outside or near the edges of the threat envelope. The drawback is reduced airdrop accuracy when dropping at high altitude. Because the airdrop load is not guided once it is released, its impact point is very variable from high altitude because of the uncertainty of the winds expected over a greater vertical distance.

Drop accuracies were reportedly up to 3 miles off target during Operation PROVIDE PROMISE in Bosnia. The Bosnia airdrops were predominately humanitarian in nature, and although they were very important, they were not critical when it came to US soldiers' lives. The US Army requires a significant improvement in high altitude airdrop accuracy. Current initiatives have a stated minimum requirement of accuracy within 100 meters and a desired accuracy of 50 meters from drop altitudes of 25,000 feet (JPADS CDD, CASCOM, 12 Jan 04). Current airlift aircraft have demonstrated the ability to deliver supplies from high altitude, but they have not yet been married up with current technology in order to meet the stated need for precision.

Statement of the Problem

Current sustainment distribution systems are challenged to respond globally in a timely fashion to a dynamic tactical environment. The Office of the Secretary of Defense (OSD) and Joint Staff have determined that there needs to be an objective evaluation and trade-off study of the possible solutions proposed in response to the requirements of the JPADS Concept of Operations (CONOPS). Several CONOPS are in draft form and will be evaluated to find out which one is best for OSD, Air Mobility Command and the Joint users. The current logistical supply system is slow, indirect, and complex; it is tied to known choke points: Aerial Ports of Debarkation (APODs), Sea Ports of Debarkation (SPODs), large Drop Zones (DZs) and vulnerable Ground Lines of Communication (GLOCs). Supplies and equipment generally reach users in days or weeks rather than in hours. Lighter and smaller combat units deploy rapidly and are sometimes far away from a main supply route.

Studies and Deficiencies

Various approaches have been used to examine the airdrop accuracy problem. These approaches included determining and correcting the error sources in the airdrop equation; modeling the error components to predict accuracy, determining an accurate wind profile, and developing steerable technologies to overcome unexpected wind errors. The studies are available to a researcher using standard research sources such as the Internet, published reports, and correspondence with hardware and software developers. Of the studies on the subject, only a handful of them have examined the JPADS CONOPS. What remains to be explored is how to employ this emerging capability.

Significance

A study of the JPADS is important for several reasons. First, recent conflicts have highlighted a need to improve accuracy of high altitude airdrop and provide a means of delivering supplies outside or on the edges of the threat envelope. With current and future technology and a new training program, the Air Force can have the ability to airdrop with increased precision from standoff distances with all of its airlift aircraft. The USAF can improve airdrop accuracy and increase survivability using JPADS technologies. Therefore, the capability exists to improve the accuracy of current airdrop methods.

Statement of the Purpose

The purposes of this case study was to understand the high altitude airdrop problem, describe the CONOPS, and develop recommendations for the OSD, Joint Staff, and Headquarters' staff. This study attempts to contribute to the knowledge base by examining the high altitude airdrop accuracy problem and determining possible solutions. This study also sought to determine if mobility aircraft can effectively use and should be allowed to airdrop using JPADS. This study also serves as the basis to show a need to change current directives that give guidance on how to conduct airdrops using JPADS equipped aircraft. The study examined the JPADS Advanced Concept Technology Demonstration (ACTD) whose purpose is to demonstrate and assess systems and technologies that can provide a global delivery system capable of rapid and accurate fort (CONUS) to fighter distribution.

II. LITERATURE REVIEW

Overview

There are many aspects of airdrop that relate to this study. To give the reader a starting point, the author has given a brief history of airdrop followed by reasons for high altitude employment. A review of current USAF procedures followed by an explanation of the CARP, airdrop types, and the effects of winds provides the reader an idea of all the variables that go into getting the load on target. The role of the Global Positioning System (GPS) and Combat Track II system is reviewed. This study then examines the possible CONOPS of the employment of JPADS.

History of Airdrop

A brief background of the history of airdrop accuracy and the enemy threat is important to give the reader of this study an idea of the developments that have been made to bring us to where we are today. Key events are followed by the significant use of airdrop by the military.

The idea of airdrop is not new. One of the earliest parachute designs recorded was by Leonardo da Vinci in 1495 (Parfit, 1990). The Montgolfier brothers, famous for their balloon designs, developed several parachutes. Their first experiment involved airdropping a sheep from a tower (Parfit, 1990). The first successful manned parachute descent was demonstrated in Paris France on October 22, 1797 by physicist Andre-Jacques Garnerin (Siegel, 1998).

Airdrop matured as a decisive tool on the battlefield in WWII. The German Luftwaffe dropped paratroopers on the island of Crete early in the war. The German paratroopers descended on the airfield at Maleme and the town of Canea on the island of Crete on 20 May 1941 (Klumpp, 1996). Despite the high casualties involved, the German invasion of Crete was a significant victory for airpower and the use of airdrop.

On D-Day in June 1944, over 900 aircraft and 400 gliders delivered more than 13,000 paratroopers and supplies to six drop zones near the coast of Normandy, France (MAC, Office of History, 1991). Only ten percent of the airborne forces landed on their intended drop zone on D-Day because of poor weather and lack of Instrument Meteorological Conditions (IMC) navigation capability (MAC, Office of History, 1991). The remaining 90 percent of the troops that landed were scattered around the countryside and the fighting power of the airborne troops was dissipated.

During WWII, improved navigation aids were made available. Aircraft used radio stations to navigate to and from airfields and drop zones in the China, Burma, and India Theaters. Pathfinder aircraft were used to lead other aircraft to the objective area. Radar was used on some aircraft to identify drop zones in IMC, a method we still use today (Callander, 1998).

During the Vietnam conflict, Operation JUNCTION CITY featured the war's only battalion-sized airdrop. On 22 February, 1967, 13 C-130s airdropped the 173rd brigade over Katum near the border of Cambodia (MAC, Office of History, 1991). In January of 1968, USAF C-130s airdropped supplies to 6,000 Marines at Khe Sanh who were surrounded by over 15,000 Communist troops (MAC, Office of History, 1991). At Khe Sanh, deadly groundfire and mortar attacks required the C-130s to airdrop instead of airland supplies. Poor weather at Khe Sanh would have made airdrop inaccurate if it were not for the use of an airdrop ground radar system (GRADS) to guide the aircraft to the CARP.

In April 1972, North Vietnamese Army troops poured into South Vietnam from Cambodia in what was known as the Easter Offensive. They drove south towards Saigon, which is now known as Ho Chi Minh City. At An Loc, a town 50 miles northwest of Saigon, the South Vietnamese and American forces made their stand. Under the pressure of delivering the supplies to friendly forces under siege, the C-119, C-123 and C-130 crews faced the heavy barrage of anti-aircraft fire and SA-7 missiles (McGowan, 2000). Creating new tactics to deal with the threat, the solution was high altitude container delivery system (CDS) using GRADS for positioning. An Loc was the birthplace of our current high altitude airdrop problem. After two months of continuous efforts by TAC airlifters, the siege was finally broken.

On 20 December 1989, C-130s and C-141s performed the largest night combat assault since D-Day. Operation JUST CAUSE was the invasion of Panama to oust military dictator General Manuel Noriega and secure the safety of the Panama Canal and the 51,000 Americans living there. The two-pronged assault included a 15-ship C-130 formation dropping 837 Rangers on Rio Hato airfield while a four-ship of C-130s and a 12-ship of C-141s dropped on Torrijos and Tocumen airfield (Lear, 1997). This assault package was followed by 51 C-141s dropping a full brigade on Torrijos and Tocumen (Lear, 1997). Despite over half of the aircraft in the initial assault receiving small arms and AAA damage, the mission was a success.

The Balkan Peninsula has been a hot spot for hostilities for many centuries. One of the more recent conflicts began in June 1991 when Croatia and Slovenia declared their independence from Yugoslavia (Chroman, 1993). In early 1993, Serbian forces cut off all supply lines for Bosnian Muslims in an attempt to starve them for the purpose of ethnic cleansing. The US quickly responded by pledging to resupply the starving Muslims with airdrop of food and medicine. To protect the aircrews and aircraft, the airdrops were at night and at high altitude, which provided some protection from ground fire.

The first airdrop was March 1, 1993 when C-130s dropped 30 CDS bundles of food and medicine to Cerska, Bosnia (Chroman, 1993). Initially seen as a short term mission, the size of the operation quickly escalated with nearly 150 CDS bundles being dropped nightly. By September 1993, more then 14,000 CDS bundles had been dropped with a total weight of over 10,000 tons by US, German, and French C-130s and C-160s (Williams, Studer, Studer, 1993). By the end of the operation in late 1995, over 30,000 CDS bundles were dropped (Davis, et al., 1997).

The accuracy of the airdrops varied from very good to unrecoverable. Sometimes if they were a little off target, the CDS bundles would land on the side of a mountain where they could not be reached. The drops were consuming more than 150 parachutes per night, none of which were recovered because of the dangerous locations of the drop zones. The US quickly depleted its reserve parachute stock at a cost of over $30 million and had to seek alternate means of delivering the supplies (Davis, et al., 1997). The solution was Triwall Aerial Delivery System (TRIADS). TRIADS is a system used to airdrop Meals Ready to Eat (MRE) or Humanitarian Daily Rations (HDR) by loading them in cardboard boxes which are opened up by static line after being airdropped without a parachute. The MREs and HDRs then flutter to the ground where they can be recovered and consumed.

In September 2001, Operation ENDURING FREEDOM (OEF) began fighting Al Qaeda in Afghanistan. As part of the strategy, the US airdropped food the same night air strikes against military targets began. This was an effort to show the world that the US fight was not against the Afghani people but instead against the Taliban, Al Qaeda and terrorism. C-17 cargo planes flying from Ramstein AB, Germany flew 175 sorties dropping over 2.4 million HDRs between 7 October and 21 December 2001 (Harmon, Point Paper, 2002). Arguably a political gesture, the goal of feeding the Afghan people by this method largely failed. Many of the HDR packets ruptured upon impact causing the contents to spoil. The airdrops were conducted from high altitude, above 25,000 feet using the TRIADS. Another unintended consequence was that the yellow package of the HDR resembled the yellow color of BLU-92 cluster bombs and several people trying to get to the food were killed (Neuffer, Boston Globe, 2002).

C-17 aircraft also performed nearly 70 high altitude CDS airdrops during OEF (AMC/DOK, PADS Brief, 2003). Of those drops, feedback was only obtained for four of them. Two were called accurate and successful, one load was never found, and one load landed on a house killing an Afghan citizen (AMC/DOK, PADS Brief, 2003). It was expected that the accuracy would not be very good on those CDS drops. The worst case conditions for accuracy existed as the drops were performed from extreme high altitude in mountainous terrain with limited wind information. The CARPs were calculated with a single forecast ballistic wind as opposed to a 3 dimensional wind field representing winds over rugged terrain. Parachute ballistic data was estimated because they had not tested parachutes from those altitudes before. From personal experience, parachutes designed for low altitude employment did not fare well in those conditions as the higher true airspeed and low density air mass create a much larger opening shock to the parachute which may destroy it upon opening.

In March 2003, Operation IRAQI FREEDOM began in an effort to remove Saddam Hussein from power and find weapons of mass destruction. US forces converged on Baghdad with lightning speed. Part of the strategy called for opening a northern front and the allied forces achieved this by conducting the first C-17 combat personnel airdrop of the 173rd Airborne Brigade on 26 March 2003. The 15-ship formation flew a 4-hour mission from Aviano airbase, Italy to Bashur, Iraq and dropped 990 paratroopers and equipment (DIRMOBFOR Brief, 1 Dec 03)

A recent buzz phrase in military transformation is “Factory to Foxhole” or “Fort to Foxhole”. The factory to foxhole concept is in fact not a new idea. The US Army conducted Operation DRAGON TAIL in 1990 which demonstrated this direct delivery concept (Wholesale Resupply by Sky, 1990). During this exercise, an Army depot pulled nearly 400 items including parts and supplies and rigged them for airdrop at their destination. These supply pallets were picked up at the depot and airdropped from a C-130 to troops in the field proving that a supply wholesaler could in fact re-supply a front line unit.

Why High altitude?

During the Cold War, some of the US tactics for penetrating the wall of Soviet air defenses was to fly in at low level below the coverage of the radars or below the missile engagement envelope. Flying at low altitude also provided better survivability against

Soviet aircraft which had limited autonomy and limited look down-shoot down capability. This tactic was long thought to be the best way to get to the target. During the opening days of the first Gulf war, Desert Storm, allied forces went in at low level and took significant losses. After disabling most of the high altitude surface to air missiles (SAMs), the tactics changed to fly at high altitude to get above the envelope for the shorter range SAMs and AAA. The US tactics have evolved from this to go in at high altitude from the beginning, using stealth and cruise missiles to disable the long range SAMs and stay above the shorter range threats.

During Desert Storm, airlift planners considered high altitude airdrop to deliver supplies to Allied ground forces. The reason they did not do high altitude resupply was because very few aircrews were trained to do it and the delivery accuracy was uncertain. There were a handful of Guard and Reserve personnel who had the experience from Vietnam but there was no training program in place. The leadership urged that C-130 aircrew members get trained on high altitude airdrop for future contingencies (Leland, 1997).

The biggest threat to airlift aircraft is MANPADs and AAA. MANPADs and AAA are a larger threat to airlift aircraft than airborne interceptors and radar guided missiles because of the operating environment. Doctrinally, airlifters will not operate in areas where we do not have air supremacy, although there have been exceptions. MANPADs are portable, inexpensive, shoulder-fired weapons with a small warhead but very high velocity and are widely proliferated throughout the world. The worldwide inventory of MANPADS is estimated to be between 500,000 and 700,000 systems and available for as little as $5,000 on the black market (Erwin, 2003:28). A single

MANPAD hit has a good chance of taking down an airlift aircraft. A MANPAD has an operating envelope of .5 to 3 miles in range and surface to 22,000 feet in altitude. Perching a MANPAD on top of a mountain will increase the operating threat envelope for the shooter.

AAA comes in many forms and sizes and is especially lethal at short range and low altitude. AAA guns can fire over 2000 rounds per minute and it only takes a few to hit an aircraft and take it down. Radar-guided AAA is very accurate but for the most part AAA is unguided and can be avoided by over-flying it.

The threat of MANPADS and AAA has forced us to look at high altitude employment for airdrop. Because most airdrop loads are unguided, dropping from high altitude is currently very inaccurate compared to low altitude drops. Once the load leaves the aircraft, it is at the mercy of unexpected errors in the winds and other atmospheric factors such as density which effects rate of fall.

Current Procedures

The capability exists to improve the accuracy of current airdrop methods. Crews are required to use methods such as sight angle, visual reference, and onboard computers to navigate to the desired release point (AFI 11-231, 1998, pp. 24-33). All of these methods use a CARP which incorporates the exit time, the deceleration time, the time of fall, and the effects of wind on the load (See Figure 1). After all the calculations are complete, an estimated release point location is determined in reference to the desired Point of Impact (PI).

CARP Diagram

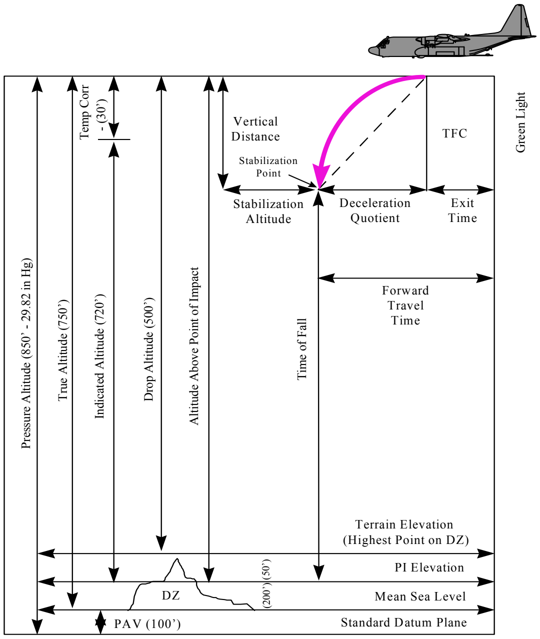


Figure 1. CARP Diagram. NOTE. From C-130 Weapons Instructor Course Handout, Little Rock AFB, Arkansas, 2003. Reprinted with permission.

High Altitude Airdrop

High altitude airdrop procedures are different than low altitude procedures. The differences include aircraft performance, load time of fall, oxygen considerations, airspeed, and regulatory guidance.

Aircraft performance is different at higher altitudes. The thinner, less dense air makes the aircraft feel heavy with sluggish performance, requiring more power to maintain airspeed and altitude. Because of the thinner air, the aircraft has a higher true airspeed to maintain a flying indicated or calibrated airspeed. The higher true airspeed translates to a high groundspeed so the aircraft is traveling a greater distance which will amplify exit time errors. At sea level, the aircraft is traveling 75-85 meters per second.

At high altitude, the aircraft is traveling 100-140 meters per second. A 1 or 2 second delay in release time can have a large impact on release point accuracy.

The total time of fall (TTF) of the airdrop load is the time of fall constant (TFC) plus the time of fall (TOF) of the load. The TTF changes greatly as altitude increases. For example, a 1500 lb High Velocity Container Delivery System (HVCDS) bundle dropped from 800 feet Above Ground Level (AGL) has a TTF of 10.1 seconds (CAPS analysis, Dec 03). That same bundle dropped from 25,000 feet AGL has a TTF of 290 seconds, or nearly 5 minutes (CAPS analysis, Dec 03). The longer the TTF is, the more opportunity for wind to affect its drift. Another operational consequence of the TTF from high altitude is the desired time over target (TOT). In general airdrop procedures, the TOT is the time when the aircrew calls "Green Light". In low altitude drops, this is acceptable as the users on the ground see the aircraft overhead and dropping at the time they wanted it. If these same procedures are used in high altitude airdrops and the user wants the load at a certain time, they will be waiting for 5 minutes to get it. This time delay will cause confusion and could hamper the objectives of the mission. It is important to identify when the user wants his supplies to land, and the aircrew can adjust accordingly.

Unlike an attack or bomber aircraft with a separate bomb bay or the munitions stored under the wings, airlift aircraft hold their airdrop loads inside the fuselage of the aircraft. In order to drop, the aircraft must first depressurize and open the cargo ramp and door. All humans will experience symptoms of hypoxia when exposed to low pressure environments without supplemental oxygen. The higher you go in altitude un-pressurized, the less pressure and subsequently, less ability to absorb oxygen. The higher you go unpressurized, the quicker the onset of hypoxia symptoms such as dizziness, tingling, shortness of breath, unconsciousness, and death.

Air Force regulations require aircrew members to use supplemental oxygen when operating at cabin altitudes above 10,000 feet. Airlift aircraft are capable of operating and airdropping above 30,000 feet Mean Sea Level (MSL). Operating at that altitude is very demanding on the human body and requires pre-breathing of pure oxygen to reduce nitrogen buildup and the chance of the bends. Any aircraft flying unpressurized above 25,000 feet requires a waiver from HQ USAF. AFI 11-2C-130V3, AFI 11-2C-17V3, AFI 11-409, and AFI 11-203V3 provide guidance on oxygen requirements and pre-breathing times for given altitudes. Even with supplemental oxygen, operating at cabin altitudes above 25,000 feet is restricted to 30 minutes, including depressurization and repressurization time

Airspeed is a key component in the airdrop equation. The aircrew flies a given indicated airspeed as required by the performance manuals. True Airspeed (TAS) is close to the same as indicated airspeed at sea level. As the aircraft gets higher in altitude and the air is less dense, the true airspeed increases for a given indicated airspeed. In simple terms, true airspeed increases about 3 knots for every thousand foot increase in altitude. So at 10,000 feet MSL, 150 Knots Indicated Airspeed (KIAS) is about 180 TAS. At 20,000 feet MSL, 150 KIAS is about 210 TAS. At 30,000 feet MSL, 150 KIAS is about 240 TAS. This is important in airdrop because even though the aircraft "feels" like it is going 150 KIAS, the true airspeed is much higher and the aircraft is moving a lot faster. As the TAS increases, the opening shock becomes greater. This concept is demonstrated to aircrew during parachute training. Air Force parachutes are designed with an altitude delay so the parachute will not open above a certain altitude, usually around 13,000 MSL, because the opening shock would be too great on the aircrew member and the parachute may fail. CDS dropped from high altitudes such as 30,000 feet MSL undergo enormous opening shock stresses and may cause the parachute system to fail.

Forward travel time (FTT) is the time from when the crew turns on the green light until the load exits the aircraft. This time is between 4.1 and 7.9 seconds for CDS drops from C-130s and C-17s (AFI 11-231, Ch 8 and 9). During this time, the aircraft is still traveling across the ground between 80-120 meters per second in a no wind situation. At higher true airspeeds, this distance is increased and contributes to additional accuracy errors, especially in a tailwind situation.

Training

Aircrews are taught airdrop theory and perform airdrops in the simulator. This training is followed by more in-depth training at the Formal Training Unit (FTU). The C-130 mission qualification course lasts seven weeks and includes in-depth academics followed by a seven-sortie syllabus. The academic portion of the training includes in-depth theory and exercises calculating a pre-flight CARP, plotting the CARP on a mosaic, and different techniques to navigate to the CARP. After the students complete ground training, they go on to the flight training phase. The C-17 mission qualification course lasts 20 training days and includes academics followed by a six sortie syllabus (C17 ACAD, 2003, pp.1-2).

After the student graduates from the FTU, he/she is assigned to an operational squadron. At the operational squadron, the now fully qualified mission crew continues training to remain proficient in airdrop. Performing high altitude airdrop is one of the most challenging and demanding missions an aircrew may be called upon to perform. Despite the challenge of this mission, no formal training requirement exists for aircrew to learn or maintain proficiency in this mission (AFI11-2C130 Vol. 1, 1998). In fact, this mission is only taught in three squadrons in the USAF.

The C-130 Weapons Instructor Course (WIC) at Little Rock AFB, Arkansas is responsible for training C-130 Weapons Officers. There are two classes for C-130 Weapons officers each year ranging in size from three to nine students. Since the schools inception in 1996, over 100 Weapons Officers have been trained. As part of the syllabus, C-130 Weapons Officers are trained to perform and instruct high altitude airdrop of CDS as a result of lessons learned in Vietnam, Bosnia, Kosovo, and Afghanistan.

The second squadron that teaches high altitude airdrop is the C-17 Weapons Instructor Course at McGuire AFB, New Jersey. There are two classes for C-17 Weapons Officers each year ranging in size from 4 to 6 students. Since the schools inception in 2003, 4 Weapons Officers have been trained. The third squadron is the 34th Combat Training Squadron (CTS) at Little Rock AFB, Arkansas where it conducts the Joint Readiness Training Center (JRTC) exercise. The 34th CTS trains up to 70 aircrews each year on high altitude airdrop, although not in as great detail as the C-130 and C-17 WICs.

Joint Readiness Training Center

The Air Mobility Warfare Center 34th CTS conducts training of high altitude airdrops to C-130 and C-17 Aircrews for US and International units. The 34th conducts training in conjunction with the US Army Joint Readiness Training Center in Ft. Polk, Louisiana eight times a year. Each JRTC rotation is two weeks long and consists of approximately 6,000 US Army personnel and 350 US Air Force personnel. The JRTC exercise simulates a low to mid intensity combat environment for the aircrews. One of the objectives of the 34th CTS is to give the player Air Force unit the opportunity to perform unusual missions for training but ones which they may be called upon to perform in combat or a contingency. One of the unique missions an aircrew has the opportunity to perform is the challenging high altitude airdrop.

A high altitude airdrop is defined as an airdrop above 3,000 feet MSL (AFI 11-2C130 Volume 3, 2000). At JRTC, the aircrew drops a 2,000 lb. CDS bundle from between 10,000 to 17,000 feet MSL. The drop altitude is restricted to below 18,000 feet MSL due to range and airspace safety considerations. The crew departs with the load on a heavyweight aircraft and flies one hour to the objective area in central Louisiana. The scenario is to resupply troops under siege at an airfield and fly at high altitude to avoid enemy light AAA and first generation SAMs. Several steps have been taken by the 34th CTS to minimize the risks associated with performing this challenging mission.

Calculating a Computed Air Release Point

To calculate a CARP, the crew obtains the ballistics from AFI 11-231 and calculates using an AF Form 4018, a Whiz Wheel, and a calculator. An alternate and preferred method is to compute a CARP using the Combat Airdrop Planning System (CAPS) program on the Portable Flight Planning System (PFPS), an AF approved flight planning software program for PCs. The crew then plots the location of the CARP on a photo or mosaic of the drop zone. Now, all the crew has to do is navigate to that exact point and call “Green Light”. Navigating to the “exact point” sounds simple; however, it requires considerable skill and training to be successful.

From the time the crew completes the planning until the time the aircraft is actually over the CARP is several hours. A lot can and does change in that time. In fact, the CARP is continually changing when variables such as temperature, pressure altitude, airspeed, and, most influential, the winds change. The crews take their experience and knowledge and update to the best of their ability the new release point. With the continually changing factors it is more likely that if a crew hits the target, it was offsetting errors as opposed to doing everything right. A Circular Error Average (CEA) of less then 225 yards is considered acceptable (AFI 11-231, 1998, p. 8). Using a forecast ballistic wind, the onboard computer can continually compute and update the CARP faster then any human can.

Effect of Winds on the CARP

The most significant variable as you drop from higher altitudes is the effect of wind on a suspended airdrop load. In 1992, The Scientific Advisory Board (SAB) determined that the “…single largest error producer in the airdrop process was the lack of accurate, real time, wind profile data over the target.” (Impact Brief, July 03). Current procedures are for the crew to plan a preflight CARP based upon forecast winds from the weather shop. These forecast winds are obtained several hours prior to drop. The aircrew attempts to obtain more current winds using readouts from the onboard computer as they climb to drop altitude near the drop zone. The crew then inputs an average ballistic wind in the computer and plots the intended CARP on a mosaic.

Although thorough planning and calculations take place to compute the CARP, a lot can happen after the load exits the aircraft. The USAF has not yet operationally fielded steerable parachutes for high altitude CDS loads, so the standard load is at the mercy of wind errors after it leaves the aircraft. The factors involved in computing a CARP, the uncertainty of the weather, and the velocity of the load contribute to the increased risk of a bundle missing the target and possibly damaging something or someone.

The effect of winds on the CARP is further complicated when dropping over mountainous regions, as was the case for the1993-1995 relief operations in Yugoslavia, and for OEF where some high-altitude airdrops were conducted over the rugged Hindu Kush mountains. Depending on a number of factors such as wind speed and vertical stability of the atmosphere, mountains can influence the winds up to a considerable altitude above the ground and cause the winds to vary significantly over relatively short horizontal distances. This aspect of meteorology has been studied by research scientists for many years and continues to be the focus of meteorological research.

A summary of fundamental and complicated physics and dynamics of atmospheric flow over mountains is contained in a Meteorological Monograph published by the American Meteorological Society (Blumen, June 1990). Rugged mountains require that winds be modeled in 3D and the ballistic payload trajectory be modeled through the 3D wind field. The JPADS program addresses both aspects for high-altitude airdrop over rugged terrain.

The accuracy of the winds used to determine the CARP is absolutely fundamental to the accuracy of high-altitude airdrop. Observed winds are more accurate than forecast winds. In fact, observed winds are used to validate and verify the accuracy of wind forecasts. The accuracy of the CARP, and the resulting ground impact point accuracy, can be improved if winds can be measured near the DZ within minutes of the drop, and those measurements used to determine the CARP.

Dropsondes have been used to measure atmospheric data for some time now. They are used by Hurricane Hunter C-130s and P-3s to determine the 3D atmospheric characteristics of tropical storms and hurricanes. They are dropped from the aircraft and transmit data back to the aircraft as they descend to the ocean. They are capable of being launched from modified WC-130 aircraft. The GPS windsonde descends by a small parachute, determines its position from GPS signals, and transmits the data back to the aircraft via UHF data communications.

A hand-launched GPS wind dropsonde called the A-Sonde was developed as part of the PADS program. Its initial purpose was to test and demonstrate PADS wind processing and airdrop accuracy improvement. The A-Sonde test article can also be used for PADS operator training and real-world contingencies. The A-Sonde data is then received by the Wind-profile Modeling System (WINDPADS) software where it is assimilated with a preflight wind model and outputs the wind field to the Precision Airdrop Planning System (PAPS).

A new type of dropsonde was developed for the US Navy. The Tactical Dropsonde (TDrop) fits the form factor of a navy chaff or flare canister and can be launched from the aircraft self defense system. The TDrop has been launched from Unmanned Aerial Vehicles (UAV) as part of an ACTD program and can be launched from a tactical aircraft's Counter Measure Dispensing System (CMDS) (Department of the Air Force, UAV Weather Initiative, October 2002). Either hand-launched or tactically deployed dropsondes can be used to measure winds over the DZ for high-altitude airdrop operations.

RADAR wind sensing is available through X-Band Doppler processing of the return of atmospheric particulates. The AN/APN-241 is a low power color Doppler radar with a wind sheer detection mode. The wind sheer mode determines shear by measuring shifts in the motion of suspended particulates such as rain and dust within 10 nautical miles of the aircraft. It may be possible to use this same technology to determine winds from the aircraft to the surface far enough ahead to process them into a ballistic wind for use by JPADS. The technical drawbacks of using radar is if there is too much particulate matter such as heavy rain, the radar will not be able to penetrate to measure particulates all the way to the surface. The same is true if there is not enough particulate matter in the air to be detected. The benefits of such a system would be that the crew can determine winds without over flying the objective area (OA) or having another aircraft over fly the OA. This capability has been theoretically analyzed and is feasible without hardware modification to the aircraft (Northrop Grumman, December 1999).

LIDAR is similar to radar, but uses a laser for measuring particulate movement to analyze wind data. The SAB recommended LIDAR as one solution to obtaining accurate near-real time winds. A major benefit of LIDAR is that the returned signals are received nearly instantaneously compared to the dropsonde or a balloon radiosonde. The LIDAR system, like the radar, cannot measure through moderate clouds due to the short wavelength of the transmitted energy. This aspect is undesirable as there can be clouds present somewhere between the surface and drop altitude. LIDAR is not eye-safe so it must be used in an unpopulated area. This is unpractical operationally in training or combat as airdrops will be made somewhere near our own troops. The LIDAR technology is improving and may be a possible solution in the future once it overcomes these shortcomings.

Global Positioning System (GPS) Dependability

How reliable is the GPS signal? The 1996 Federal Navigation Plan indicates that the availability of the signal can be offered to the military user at least 99.85 percent of the time and the reliability of the signal is accurate 99.97 percent of the time (Federal Radio navigation Plan, 1996, p.137). GPS-aided navigation solutions possess very little potential for operator error. If the GPS receiver loses lock on the signal the computer drift is minimal. The C-130 Self Contained Navigation System (SCNS) have a maximum drift of 77 meters if the GPS signal is lost for ten minutes (Czelusta, 1999: 6). The drift is based upon having a GPS with a Figure of Merit (FOM) of 1 and a completed SCNS enhanced alignment at the time of signal loss. The reduced drift rate is another reason to always obtain an enhanced alignment and load the P-codes. Once the signal is lost, the SCNS reverts to its INS-Doppler integrated solution until re-acquisition of the signal which occurs automatically without user input.

GPS Jamming

Like any other radio frequency (RF) signal, GPS is susceptible to intentional and unintentional jamming. Cases of jamming have been documented from different sources including arc welders, ignition systems, and compact disk players (Johannessen, 1997, p. 1). Limited protection is provided from jamming to military users with the P-Codes loaded in the GPS. In fact, the GPS can continue to receive the Precision Positioning signal until it is within 15 nautical miles of a 100-watt military jammer (Czelusta, 1999, p. 9). Therefore, there is protection for the aircrew if the GPS is not available while on the run-in to the drop zone. This protection makes the GPS a valuable tool to use for airdrop and should be incorporated into positioning the aircraft for the drop.

The aircrew must know if a satellite is giving them unreliable information. There are several notification methods; one of which is the Receiver Autonomous Integrity Monitoring (RAIM) where the receiver identifies any errors, advises the user, and switches to another navigation system (Langley, 1999: 1). The aircrew also uses situational awareness to determine reliability by comparing the GPS outputs to other navigational sources.

COMBAT TRACK II

Combat Track II (CTII) is a communications system capable of relaying digital data to aircraft over secure, satellite communications links. CTII is an aircraft snap-on/snap-off secure digital UHF satellite communications (SATCOM) system that enables en route aircraft tracking and data-burst communications via Secret Internet Protocol Router Network (SIPRNET) clients (PSI, June 2003). CTII provides beyond line-of-sight (BLOS) secure file transfer capability via military controlled relay satellites. The CTII radio connects to the host aircraft's satellite communications antenna and GPS antenna.

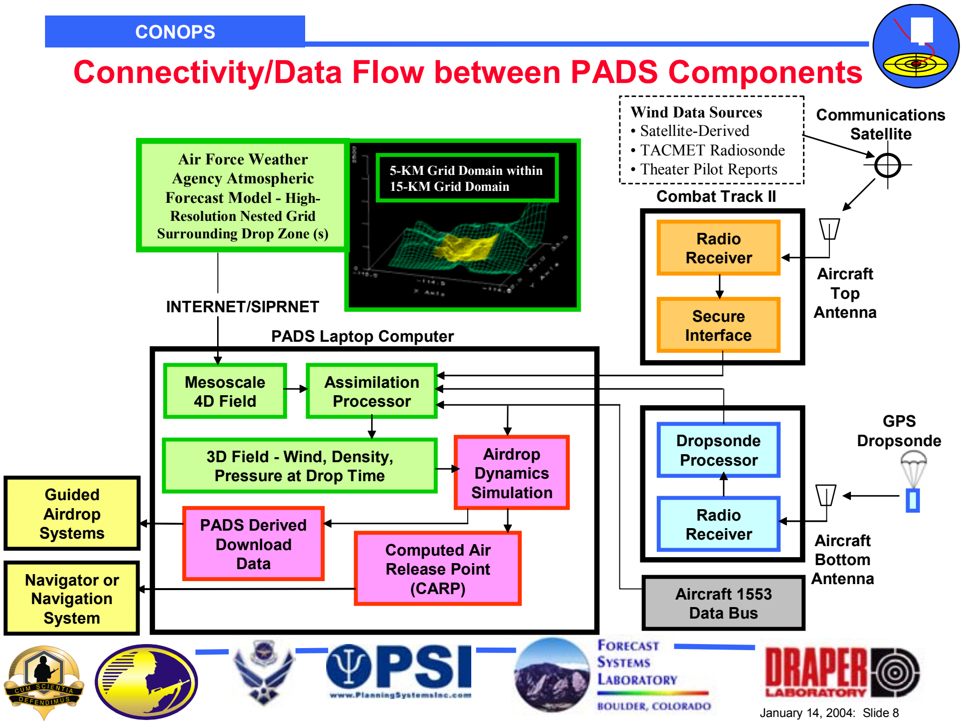
CTII can be installed on any Air Mobility Command (AMC) aircraft equipped with SATCOM and GPS antennae. The system includes a Windows-compatible laptop computer with communications and Graphical User Interface (GUI) software (PSI, June 2003). Ground units with SIPRNET access on Personal Computers can send messages and small files to equipped aircraft. CTII has been implemented operationally by AMC for ground and airborne use by aircraft for global updates in support of contingency operations. CTII has also been integrated into PADS and used to transmit ground radiosonde and mission planning data to the aircraft in order to update the CARP.

Joint Precision Airdrop System

JPADS offers a modern solution to an old challenging problem of precision delivery of supplies on the battlefield. The JPADS has been in development and evolved from a 1996 report from the USAF's Scientific Advisory Board (SAB) titled *New World Vistas- Air and Space Power for the 21st Century* (Sweetman, p1, Jun 01). In the 2000 page study, the SAB envisioned that cargo would be routinely dropped from 20,000 feet with 10-20 meter accuracy. The users of this system would apply "just-in-time" concepts to enable fort to foxhole or factory to foxhole logistics.

JPADS light has recently been highlighted by the Joint Requirements Oversight Council (JROC) as the number two ACTD priority for FY04 (Joint Staff, JROC Memorandum 154-03, 1 Aug 2003). JPADS is sponsored by the United States Joint Forces Command (USJFCOM) as a joint effort between the US Army and the US Air Force. JPADS is the integration of the USAF PADS with a US Army family of smart, self steering autonomous high altitude deceleration systems. The JPADS weight classes include the extra light (200-2200 lbs), the light (2201-10,000 lbs), the medium (10,001-30,000 lbs), and the heavy (30,001-42,000 lbs). Other users have demonstrated needs for this technology including SOCOM, US Navy, US Marine Corps, British RAF, and other allied nations.

The JPADS program has completed prototype testing and C-17 and C-130 Operational Utility Evaluations (OUE). The JPADS is being developed by a team comprised of AMC, Natick Soldier Systems Center, National Oceanic and Atmospheric Administration (NOAA) Forecast Systems Laboratory (FSL), Air Force Weather Agency (AFWA), Draper Laboratory and Planning Systems Incorporated (PSI). Using a spiral development implementation of software and hardware updates, the system is able to be used today with improvements planned and expected. JPADS generate high fidelity 3D atmospheric data fields that are used to determine the CARP and trajectory of the airdrop load. An illustration of the JPADS interface is shown in Figure 2 below.



CONOPS

Connectivity/Data Flow between PADS Components

Wind Data Sources
- Satellite-Derived
- TACMET Radiosonde
- Theater Pilot Reports

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Figure 2 PADS Wiring Diagram, NOTE, From Precision Airdrop briefing, by Mr Bob Wright, Planning Systems Incorporated. 2004, Reston, VA. Reprinted with permission.

The basic distinction between the USAF PADS program and the Army JPADS family program is the point on an aircraft where responsibility is transferred. The USAF has responsibility for the accuracy up until the ramp hinge of the aircraft where the load exits while the Army responsibility is the steerable chute technology. Though it seems like a clear separation and handoff point, the two functions are highly dependent upon each other. The three main components of the JPADS are the 3D wind-profile modeling component (WINDPADS), the Precision Airdrop Planning System (PAPS), and the guided parachute systems that depend on the output of PADS to optimize CARP determination and increase the likelihood of reaching the PI with high precision.

WINDPADS

The all weather WINDPADS is designed to provide three dimensional, high resolution wind and weather forecasting in and around the drop zone. WINDPADS was designed by PSI under contract from Natick Soldier Systems Center. The goal is to develop near-real time wind measuring devices and processes to rapidly assimilate measured data to be used in determining the CARP and trajectory of the airdropped load. This consists of a software program capable of interpreting wind data received from a variety of sources such as a dropsonde, radiosonde, radar, lidar, weather satellite cloud track winds, pilot reports, and aircraft navigation system winds.

The WINDPADS receives data from dropsondes via the aircraft's underbelly UHF antenna. The dropsonde is currently hand launched but defensive system compatible designs are being developed. The dropsonde contains a GPS and transmits atmospheric and trajectory data to the receiver aircraft. The wind data is assimilated with pre-flight forecast wind fields downloaded from the AFWA and high resolution Digital Terrain

Elevation Data (DTED) to forecast the 3D wind and density field for the time of the airdrop. The assimilated data is then transferred to the Precision Airdrop Planning System (PAPS) for processing.

Real-time transfer of digital wind measurements to JPADS-equipped airdrop aircraft en route to the DZ to support high-altitude airdrop operations is consistent with the AMC CTII CONOPS. JPADS and CTII are physically similar. Both JPADS and CTII include laptop computers to interface with the communications hardware and connect with aircraft antennae and power sources (PSI, June 2003). Use of CTII atmospheric data messages requires a digital data interface between both laptop computers (network or digital media/floppy disk) (PSI, June 2003).

Precision Airdrop Planning System (PAPS)

The PAPS is a CARP and trajectory modeling and simulation system and is the central component of JPADS. The PAPS was developed by the Draper Laboratory under government contract from Natick Soldier Systems Center. It receives the three dimensional wind and density field data from the WINDPADS component and computes a CARP and airdrop load trajectory using a series of payload release and descent trajectory algorithms. JPADS can also transmit the descent trajectory data to a version of smart guided airdrop parachute systems while still onboard the aircraft. After release, it can make steering corrections to the predicted trajectory during descent. The current airdrop planning tool used by the USAF is the Combat Airdrop Planning Software (CAPS). The PAPS differs from CAPS in that it uses a 3 dimensional wind field and improved airdrop algorithms as opposed to a single ballistic wind to calculate the CARP.

The PAPS can compute the CARP using a series of GUIs that resemble the CAPS that all airdrop aircrew members are trained on in the FTU and in the operational unit. Once the CARP is computed, the system can run a series of Monte-Carlo modeling simulations that accurately represent the dynamics and uncertainties of each component of an airdrop load deployment from release at Green Light to touchdown. The Monte-Carlo model can change a number of variables to give the expected landing ellipse, or footprint of the airdropped load relative to the planned PI. This ellipse allows the user to make decisions based upon risk of having the load miss the target as computed by the system. If the ellipse is too large, the operator can choose to modify the profile such as changing the run-in direction, lowering the drop altitude, or even delaying or canceling the mission.

The PAPS currently has detailed models of the 26 foot ring slot and the G-12D canopies with additional models being implemented in the future (Angermueller; et al, 2003). The PAPS can also determine the impact point of a failed parachute (not deployed or detached) and the error ellipse footprint around the impact point. An illustration of a normal and failed parachute ellipse footprint is shown in Figure 3.

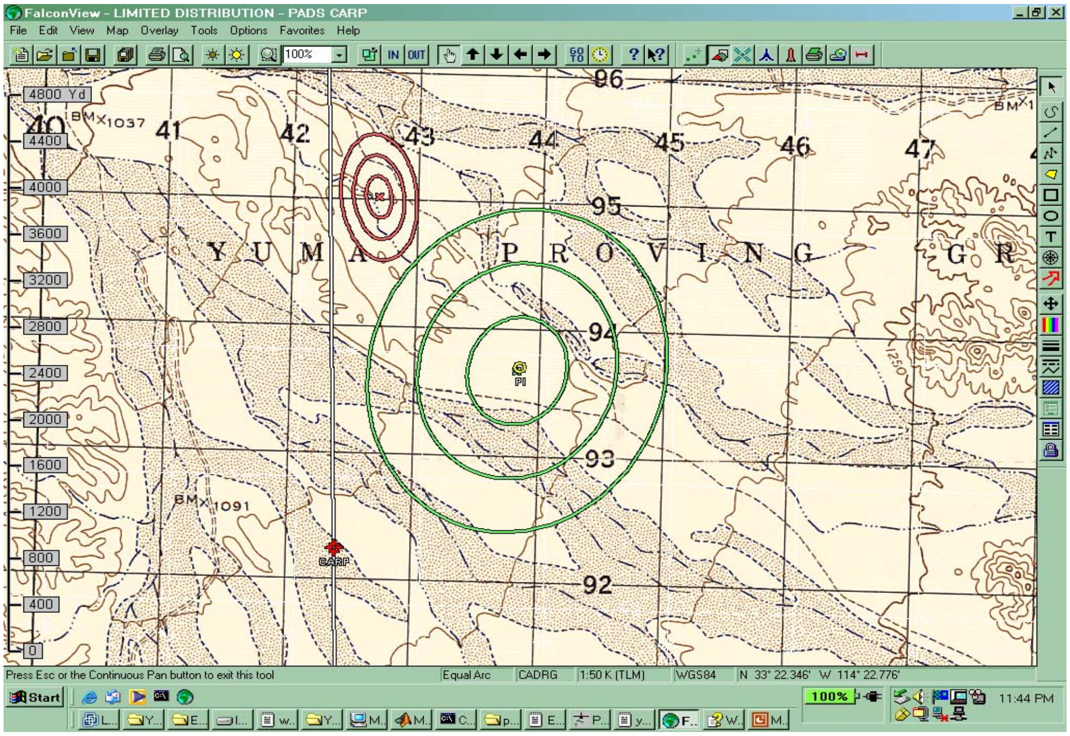


Figure 3 PAPS Monte-Carlo Ellipse footprints, Hattis, P., Draper Laboratory, 2004, Cambridge, Massachusetts. Reprinted with permission.

The possibility of a failed parachute system is a concern for the safety of those on the ground. A 2000 lb CDS bundle with a failed parachute will definitely damage whatever it hits. A normal 26 foot ring slot parachute descends between 43.0 and 82.4 feet per second (AFI 11-231, 1998, p. 138). That same bundle with a failed parachute is descending at 172 to 243 feet per second, or 101 to 144 miles per hour (PADS raw test data, interpreted 5 Jan 04). The formula for converting feet per second to nautical miles per hour is shown below:

$$\frac{\textit{Feet Per Second (FPS) / X 3600 (seconds/hour)}}{\textit{6076 (feet/NM)}}$$

= NM per hour

The PAPS will model the landing footprint of a failed parachute which will provide the user a risk assessment for continuing the drop. The actual instantaneous rate of fall is a function of atmospheric density (which is altitude and weather dependent), the payload mass, and the payload dimensions. Payload mass and dimensions are part of the failed canopy payload descent model and contribute to the payload's ballistic coefficient. The model for the failed canopy descent assumes that the parachute canopy separates from the payload upon release from the carrier aircraft. PAPS computed failed parachute footprint from 15,000 feet is shown in Figure 4. This shows the Monte Carlo generated error ellipses and corresponding circular error probable (CEP) estimates based on the same Monte Carlo data.

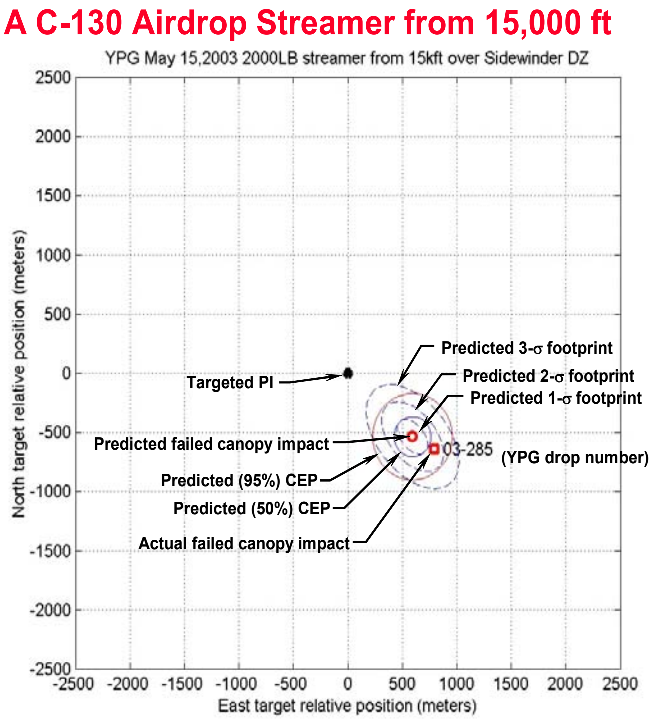


Figure 4 C-130 Airdrop Streamer From 15,000 feet, Hattis, P., Draper Laboratory, 2004, Cambridge, Massachusetts. Reprinted with permission.

The PAPS incorporates a 1553 data bus reader to capture and record airdrop information from the aircraft. This information is used to validate and update the Monte-Carlo model of airdrop error sources. An example of how this works is the capture of airspeed. If the target airspeed is 140 knots but the aircraft was traveling 142 knots at release, that info can be used for post flight processing or incorporation into the modeling deltas.

Canopy and Guidance Unit

The third portion of the JPADS is the airdrop load. There exist about a dozen steerable parachute technologies in varying stages of development. Many of these technologies were demonstrated at the 2003 Precision Airdrop Technology Conference and Demonstration (PATCAD) at Yuma Proving Grounds, Arizona and are listed in Table 1 below. Several of these technologies may be pursued by the DoD for incorporation into JPADS.

Guided Technologies Demonstrated at PATCAD 2003

Table 1. Guided Technologies Demonstrated at PATCAD 2003. NOTE. Created by Mr. Dave LeMoine, US Army Natick Soldier Systems Center, Natick, Massachusetts, 2003. Reprinted with permission.

System	Load weight (lbs)	Decelerator	Manufacturer
STARA	2-20	Ram Air Parafoil	STARA
Onyx	75	Ram Air Parafoil	Atair
Snowbird	50-500	150 Ft^2 Ram Air Parafoil	MMIST
Sherpa	250-1200	Ram Air Parafoil	MMIST
_SPADeS	50-500	Ram Air Parafoil	Dutch Space
AGAS	500-2200	G-12D	Vertigo
ALERT/Snowgoose	575	Ram Air Parafoil	MMIST
5Klb Para-Flite Parafoil	5000	Ram Air Parafoil	Para-Flite
SCREAMER	500-10000	Ram Air Parafoil/G-11	Strong Enterprises
Nasa/Pioneer Recovery System	15,700	4200 Ft^2 Ram Air	NASA/Pioneer

The PADS has been tested numerous times using the Affordable Guided Airdrop System (AGAS). The AGAS uses a standard off the shelf G12 round parachute. The parachute suspension lines are put into four groups or risers and attached to four small electric winches. The airborne guidance unit (AGU) determines which winches to rotate to pull or release individual risers to drive the parachute in the desired direction during the flight to keep the system within the calculated trajectory cone all the way to the ground. This AGU can wind and unwind one, two, or three risers at a time resulting in an associated riser pull and in effect causing the parachute to slip which gives it maneuverability. The AGU uses a GPS guidance and navigation unit following the trajectory passed to it by the PADS CARP planner via a commercially available wireless modem.

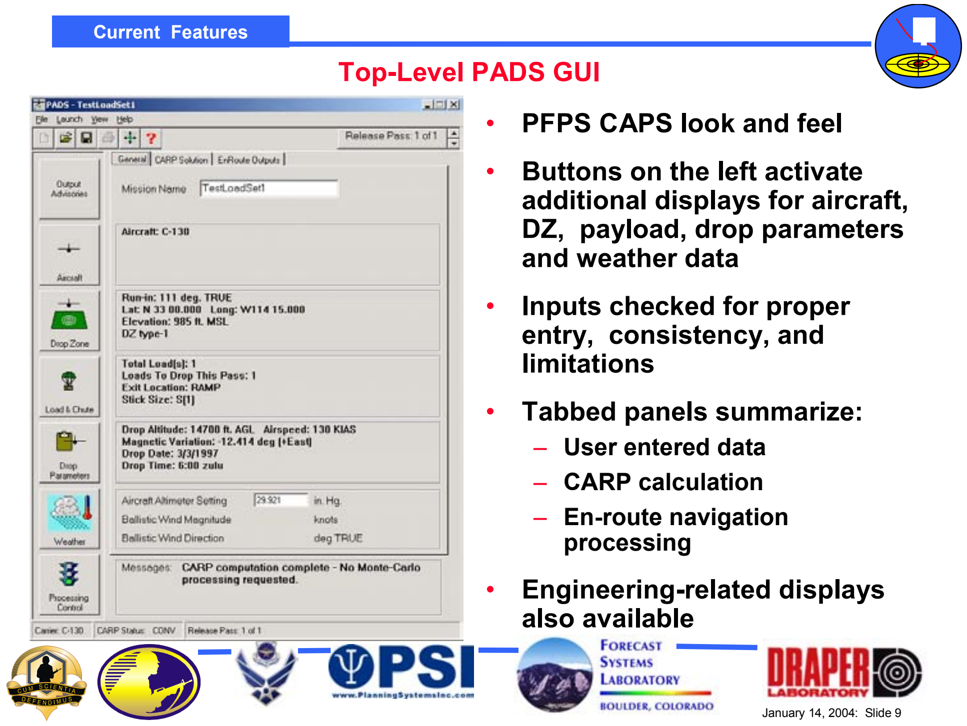
Ram air parafoils have a much greater glide ratio than round decelerators which allows them to travel greater horizontal distances and overcome greater headwinds than round decelerators. This type of parachute is square or rectangular and is usually made out of lightweight nylon. Parafoil systems are available commercially for CDS weight loads. Steerable parafoils use an AGU to pull and release control lines to steer. The PADS is used to calculate a CARP and trajectory which will make the most efficient use of the parafoil's glide ratio and speed. The release point becomes an area as opposed to a single point in space providing more options to the aircrew in avoiding threats and airspace restrictions.

Steerable ram air parafoils for CDS weights have been successfully demonstrated both operationally and during testing. Large and very large steerable ram air parafoils have been demonstrated for weights of up to almost 40,000 pounds. The canceled NASA X-38 crew return vehicle used a >7500 Ft^2 ram-air parafoil for precision landing (Dryden press release 00-16, 2000). The ram-air parafoil was the largest in history and provided NASA’s X-38 a relatively lightweight option for safely returning astronauts from the International Space Station in an emergency.

JPADS is the US Army name for the Capabilities Development Document (CDD) that outlines the requirement for steerable technologies. JPADS Light is the US Army portion of the JPADS ACTD. Other weight classes are being pursued. The JPADS-Light objectives include: deployable from up to 25,000 feet MSL with up to a 12-mile offset; a 100-Meter CEP; cost between 3 to 6 dollars per pound; and provide a soft landing (JPADS ACTD, 2003). As part of the CDD, the US Army is investing in Sherpa and Screamer systems testing this year. Smaller payload programs sponsored by the Foreign Comparative Test (FCT) office and SBIR's (Small Business Innovative Research) office are also being pursued.

Graphical User Interface (GUI)

The PADS GUI was designed to be user friendly for aircrew. The GUI was designed by a team of software developers from PSI and Draper Labs with the assistance of a USAF operational aircrew member. The PADS GUI design emulates the look and feel of current USAF mission planning software applications, although it is very different as far as the code and algorithms. An illustration of the PADS GUI is shown in Figure 5. The weather GUI page enables the operator to download forecast and observed weather data through Internet and SIPRNET connections. The weather GUI enables the operator to release, monitor, receive, and process data from dropsondes deployed from the airdrop aircraft, fighter aircraft, or UAVs (Angermueller, et al, 2003). The WINDPADS then assimilates the selected weather data to produce a high-fidelity four-dimensional windfield.



Top-Level PADS GUI

Release Pass: 1 of 1

Mission Name: TestLoadSet1

Aircraft: C-130

Run-in: 111 deg. TRUE
Lat: N 33 00.000 Long: W114 15.000
Elevation: 985 ft. MSL
DZ type-1

Total Load[s]: 1
Loads To Drop This Pass: 1
Exit Location: RAMP
Stick Size: S[1]

Drop Altitude: 14700 ft. AGL Airspeed: 130 KIAS
Magnetic Variation: -12.414 deg [+East]
Drop Date: 3/3/1997
Drop Time: 6:00 zulu

Aircraft Altimeter Setting: 29.921 in. Hg.
Ballistic Wind Magnitude: knots
Ballistic Wind Direction: deg TRUE

Messages: CARP computation complete - No Monte-Carlo processing requested.

Carrier: C-130 | CARP Status: CONV | Release Pass: 1 of 1

- PFPS CAPS look and feel
- Buttons on the left activate additional displays for aircraft, DZ, payload, drop parameters and weather data
- Inputs checked for proper entry, consistency, and limitations
- Tabbed panels summarize:
  - User entered data
  - CARP calculation
  - En-route navigation processing
- Engineering-related displays also available

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Figure 5. JPADS GUI. Wright, B., Planning Systems Incorporated, 2003, Reston, Virginia. Reprinted with permission.

In addition to determining the release point and trajectory, the PAPS determine probable landing ellipses for both normal and failed parachute systems. PAPS also utilizes a Falcon View Graphical Map Interface (GMI) which displays the ellipses to the mission planner or aircrew. From the GMI, the ellipse can be used to determine GO/NO GO for airdrop execution. The GMI can also be used to determine probable distribution pattern on sticks of CDS or TRIADS to aid in recovery.

Joint Precision Airdrop System (JPADS) Advanced Concept Technology Demonstration (ACTD)

"The purpose of the JPADS ACTD is to meet the COCOM requirement of sustaining combat power using high altitude, precision airdrop, as a direct and theater delivery method, into a dynamic, dispersed, and unsecure battlespace" (JPADS ACTD, 2003).

This must be done with speed and flexibility to provide a capability previously unavailable to the COCOM. The JPADS ACTD has five stated objectives. The first objective is a demonstration of a standardized distribution capability for providing critical supplies to users (JPADS ACTD, 2003). The second objective is the development of Joint Precision Airdrop Tactics, Techniques, and Procedures (TTP) (JPADS ACTD, 2003). The third objective is the examination of airdrop request command and control procedures (JPADS ACTD, 2003). The fourth objective is the integration of the AF PADS hardware and software with the Army JPADS-Light (10,000 lbs) airdrop system (JPADS ACTD, 2003). The fifth and final objective is to provide an immediate operational capability to US military forces (JPADS ACTD, 2003).

Summary

This chapter served as a background reference for those studying the high altitude airdrop problem. A brief history of airdrop established the foundation for the origins of the problem. The reasons for employing airdrop at high altitudes were examined along with current operational procedures and characteristics. The training that aircrews receive for airdrop was reviewed. The review identified the dramatic effect of wind on the CARP and the role of GPS for solutions. The Joint Precision Airdrop System was identified as a solution for this challenging problem and is currently the primary system being invested in by the DoD for high altitude airdrop.

III. METHODOLOGY

Population

The population of interest for this research was all possible customers and enablers of a Joint Precision Airdrop System. Due to the large number of individuals within the population of interest, the research population was restricted to all customers and enablers of a JPADS between January 1996 and May 2004. Customers and enablers in the population are familiar with current airdrop methods.

Instruments

The research instrument used for this study was printed literature, personal interviews, briefings, and personal experience. The research study is qualitative in nature; as such, the researcher examined emerging methods, observed data, document data, audiovisual data, text, and image analysis.

Research Design

This research can be categorized as a case study. A case study can be defined as an effort in which a researcher "…explores in depth a program, an event, an activity, a process, or one or more individuals" (Creswell, 2003:15). The case is bounded by time and activity. The time period of this study encompassed the beginning of the New World Vistas Report in 1996 to the time of publication of this study. Background information to frame the roots of the problem go back to 1495 and the invention of the parachute. The activity of this research is the airdrop accuracy problem and methods to solve it.

Procedures

In this qualitative study, the researcher collects open ended, emerging data with the primary intent of developing themes from the data. The thinking process is iterative, cycling back and forth between data collection and analysis to reformulate the problems and questions. Collecting, analyzing, and writing up the data occurred simultaneously. The researcher studied the setting of the participants, validated the accuracy of the findings, interpreted the data, and made recommendations for change.

Reliability

Reliability is the consistency with which a measuring instrument yields a certain result when what is being measured has not changed (Leedy, 2001, p. 31). We can measure something accurately only when we can measure it consistently. However, just because we measure something consistently does not mean it was measured accurately. The measurements on the JRTC high altitude drop scores were measured with a precision coded GPS receiver with a Figure of Merit of 3 or better. The Warrior Military Operations Area (MOA) where the JRTC high altitude airdrops occur does not have the same precision instrumentation as certified test ranges. The JRTC mission aircraft are not equipped with recording devices for the 1553 data bus, radar tracking or video playback. That data has potential reliability problems. The data from the Yuma Proving Grounds tests were measured with a GPS and radar tracking of the trajectory. In addition, the YPG tests recorded data off of the aircraft's 1553 data bus and videotaped the entire drop sequence and post flight process for anomalies. Any anomalies in the drop sequence were annotated in the test reports. Therefore, the YPG test results can be assumed to be reliable.

Validity

External criticism or establishing the authenticity of the data is not considered a problem in this study. Data are recorded by USAF officers who are considered professional aviators. Engineers and scientists on the Precision Airdrop development team are highly respected and experienced. Many studies and papers have been published by members of the team in technical journals. Several of the team participants and the program manager are governmental and non profit organizations. There are no monetary incentives to drive results. The airdrop data was recorded by calibrated test recording instruments as well as recorded data from the aircraft. Therefore, the recorded airdrop data can be considered authentic.

Internal criticism or establishing the accuracy of the data takes into account four factors. These four factors are knowledge and competence of the author, time delay, bias and motives, and consistency of data.

The first factor is the knowledge and competence of the author. In this case the author is the individual test director whose responsibility is to ensure the tests accurately reflect actual events. It can be considered that the test director is competent and understands what occurred to get a result based upon the amount of training they received prior to being assigned to a test unit. The author may also be a researcher who conducted a study related to this field of knowledge. It can be considered that the researcher and advisor or committee is competent and understands the research process.

The second factor is the time delay from when the event happened to the recording of the data. In the case of the YPG tests, the time delay was negligible. The data was recorded as events were happening. Post-test interpretations were transcribed in a time consistent with test standards. The time delay in recording the JRTC data was a matter of minutes from when the load impacted the ground to the ground party reaching the load location and recording the precise coordinates.

The third factor is bias and motives of the author. Bias is present in any research project; it is unavoidable. Due to previous experiences working closely with the PADS, the author brings certain biases to this study. Although every effort is made to ensure objectivity, these biases may shape the way the author views and understands the data collected and the way it is interpreted. The author strives to minimize and to identify any bias present in this project. A thorough examination of printed literature as well as an exhaustive consultation with experts in the field was used to obtain a complete picture of the problems and issues of JPADS. Bias clarification is a self reflection the researcher brings to the study. The author of this study states that he is a proponent of JPADS and admits he has some preconceptions on the characteristics of the CONOPS based upon his 12 years of military service and airdrop experience.

The last internal criticism was the consistency of the data. The data is considered consistent as the tests follow standard test procedures for recording and validating the results. There are some inconsistencies in the data present during the literature review which is common as new methods or ideas are developed. Terminology is one example of inconsistency as different organizations provide different names for hardware or software. It will take time for the agreed upon terminology to be worked out as the ideas get developed. In these cases, the researcher attempted to clearly convey the meaning of an idea or system despite the terminology used.

Other methods to ensure validity of this study were to incorporate research design procedures of triangulation, member checking, prolonged time in the field, and peer debriefing. Triangulation involves using multiple data sources of information and using it to build a justification for themes. Member checking is accomplished by having sources check the final report or portions of it for accuracy. The researcher has spent prolonged time in the field of high altitude airdrop. The researcher first performed high altitude airdrop in October 1993 and was a part of the PADS development team from November 1999 to May 2003. Peer debriefing involves locating a peer who reviews and asks questions about the study so the account resonates with people other then the researcher (Creswell, 2003:196).

Research Question

What is the most effective CONOPS for end-to-end (request-to-delivery) high altitude precision airdrop for OSD, Air Mobility Command and the Joint users?

Data Sources and Analysis

Investigative Question #1: What are the characteristics of a Joint Precision Airdrop System (JPADS) Concept of Operations (CONOPS)?

The first investigative question can be answered by discussing the draft CONOPS with the OPRs at AMC/DOK, Army Natick Soldier Center, and JFCOM. From the guidance received during discussion with functional experts, the author performed exhaustive research on printed literature, test reports, news articles, e-mails, and personal correspondence. The author was a member of the initial development team for PADS and attended over 30 technical meetings, conferences, and briefings. The author actively participated and instructed in nearly 100 high altitude airdrops and tests at both JRTC and Yuma Proving Ground as well as operational experience in Bosnia.

> **Investigative Question #2:** Can a Joint Precision Airdrop System CONOPS be formatted to reflect current operating methods such as those used in Close Air Support (CAS) doctrine?

This question originated from US Joint Forces Command J456 who is the lead OPR for the JPADS ACTD. The vision of members of the Joint Staff is that JPADS could be used in a manner similar to our current Tactic, Techniques, and Procedures for Close Air Support. Once the objectives have been identified, the research needs to determine if there exist functional and operational solutions to the given objective problems. The author studied Joint Publication 3-09.3, Joint Tactics, Techniques, and Procedures for Close Air Support and determined if the concepts were feasible for a JPADS CONOPS.

The author has personal experience working with Air Force A-10 and F-16 CAS as well as Marine Corps AV-8 and F/A-18 CAS during numerous exercises and training missions. CAS was often integrated into the JRTC exercise at Fort Polk, Louisiana. The scenario would sometimes call for the CAS to escort airlift aircraft to the combat area and then push ahead to soften the objective area and work fire support for the ground forces.

CAS was often integrated into the airlift package to soften the drop zone or landing zone at various Flag and Weapons School mission employment exercises.

Investigative Question #3: Is the technology currently available for meeting the precision airdrop objectives of combat sustainment?

It is important to answer this question because it sets the framework for the rest of the study. If the technology is not feasible at this time, it must be identified. If there are deficiencies in the current technology, they also must be identified. An examination of current published literature and test reports should identify the current capability and some of the known deficiencies. Correspondence with experts in the field of study should also reveal if the technology is available and what the current deficiencies are. The objectives of precision airdrop and combat sustainment must be defined. Once the objectives have been identified, the research determines if there exist functional and operational solutions to the given objective problems.

The author of this study has personal experience in the development of the hardware and software of the PADS. The writer also has participated as a primary and instructor navigator on several of the tests. The author instructed high altitude airdrop procedures at the JRTC exercise and unit level starting in September 1995. The writer estimates that he has performed or instructed nearly one hundred high altitude airdrops. This experience provides the author a starting point to focus the efforts of the research.

Investigative Question #4: Is the Precision Airdrop System best utilized as a stand alone or integrated system?

The research then identifies if the system should be stand alone as a laptop type system or integrated "behind the glass" with a software update for the C-17, C-130J and C-130 Avionics Modernization Program (AMP). An inquiry with program managers, Joint, and HQ staff is performed. The study examines the development of the stand alone, "snap-on/ snap-off" system. The study then examines the reasons to put the technology "behind the glass" which means integrated with the aircraft mission computer software. The researcher compares and contrasts the pros and cons of each method and offers recommendations on which method to pursue.

Investigative Question #5: Is it feasible and/or desirable to manage precision airdrop from a remote location?

The research identifies if it is feasible and/or desirable to compute the JPADS CARP and trajectory from a remote location such as the Air Operations Center (AOC) and transmit to the transport aircraft via secure means. The study examines any historical examples of managing airdrop from a remote location. The study reviews printed literature and test reports as well as personal correspondence with experts in the field.

Investigative Question #6: What future concepts and technologies should be pursued for a Joint Precision Airdrop System?

The study examines if other concepts for JPADS exist based upon the research and experience of the author. The study identifies if there are shortfalls in the technologies available vs. the needs of a PADS CONOPS. The study reviews printed literature and test reports as well as personal correspondence with experts in the field. The author draws upon his knowledge of airdrop and the importance of logistical re-supply to identify future technologies. The study does not limit the pursuit of future technologies based on what is currently available. The study tries to think outside the box for innovative ideas that should be examined in the near as well as distant future.

IV. RESULTS

Investigative Question #1: What are the characteristics of a Joint Precision Airdrop System (JPADS) Concept of Operations (CONOPS)?

JPADS CONOPS

It is common to have many ideas circulating on how best to perform a given task or mission. There are several CONOPS in draft and "back of napkin" format on how to perform standoff, precision, high altitude airdrop. The process starts with the anticipation or request for supplies by a unit in the field. An aircraft is tasked and loaded with the appropriate supplies. Wind data must be obtained from a variety of sources and processed to provide an accurate atmospheric field for PAPS. The PAPS then computes the CARP and trajectory. JPADS transmits the mission planning, atmospheric, and trajectory data to the guided airdrop loads. Then the guided loads exit the aircraft and steer to the designated target.

Airdrop Request

The two types of airdrop requests are pre-planned and immediate. The user on the ground passes the request up the chain from the battalion through corps to the Joint Movement Center (JMC). The JMC validates the request and passes it to the Air Mobility Division (AMD) which tasks a unit in the Air Tasking Order (ATO). The user has connectivity through the chain with the Air Force Air Request Net (AFARN). If the requirement is greater then the ATO cycle, usually 48-72 hours, it is tasked as a pre-planned request. If the time requirement is less then the ATO cycle, then it is tasked as an immediate request.

The Tactical Air Control Party (TACP) is the Air Force liaison element collocated with Army maneuver units from battalion through corps. The primary TACP mission is to advise ground commanders on the capabilities and limitations of air power. The TACP assists the land commander in planning, requesting, and coordinating air support, to include CAS, AI, Joint STARS, ISR/UAVs, theater airlift, SEAD, and CSAR. A diagram of the airlift request channels is illustrated in Figure 6.

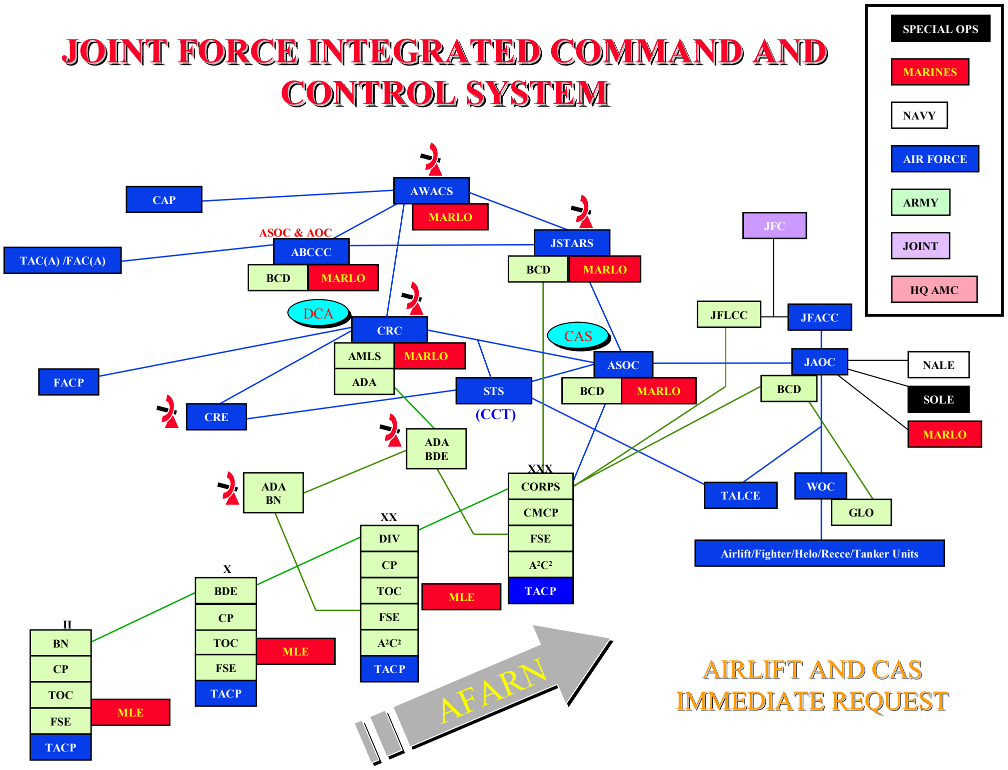

Figure 6. Airlift and CAS Immediate Request. C-130 Weapons Instructor Course courseware, 2003, Little Rock, Arkansas. Reprinted with permission.

Aircraft Tasking

The AMD receives the validated airdrop request from the JMC and tasks a specific unit and adds it in the ATO. The tasked Wing Operations Center (WOC) plans the mission, generates an aircraft, and alerts the crew. If the request is a short notice tasking, the AMD can launch an alert aircraft with the load for the mission. The AMD may also divert a current mission with a lower priority to meet the requirement.

When Army units are on the move or engaging the enemy, there are usually on-call airborne and ground alert Close Air Support aircraft available. They are scrambled to engage enemy ground targets on request. Airdrop aircraft could be loaded with anticipated critical supplies and placed on a short notice ground alert in anticipation of a ground campaign. When a user requests supplies, the response time can be a matter of an hour or two instead of 48 to 72 hours for the ATO cycle.

Time critical targeting was demonstrated in Operation IRAQI FREEDOM when an on call airborne B-1 bomber was tasked to drop precision weapons on a high priority target. The time from tasking to bombs on target was only 12 minutes (Fulghum, p.28, 14 Apr 03). Time critical targeting can also be used for JPADS. An airlift aircraft with an appropriate mix of high priority consumables such as ammunition, batteries, or water can be tasked to an on-call, airborne alert orbit near the objective but out of the threat area. The payloads can be a mix of ballistic and various guided systems depending on the accuracy required and availability of systems to support the mission. An immediate request is now only a matter of minutes instead of days or hours. In the future, small supplies could even be loaded onto UAVs. The AMD could transmit the command, CARP, and trajectory to a UAV on station over the battlefield.

Wind Data

Wind variability has been identified as the largest error component of the airdrop equation. It is therefore essential to obtain the most accurate and complete wind profile for the airdrop. There are many methods to obtain winds including forecasts, models, in-flight reports, and wind sensing devices.

Forecast winds are obtained in preflight mission planning or even in-flight on long missions by the aircrew or mission planner. These winds are obtained by the weather forecaster using a variety of sources. Meteorological forecasting stations are located throughout the world and report the local weather conditions and are frequently available on web based applications. Geostationary weather satellite imagery of cloud and water vapor are used to produce wind estimates for data sparse areas.

There are several wind models available that can predict what different conditions such as winds should be at a specified location. Weather models are run at the AFWA, the Fleet Numerical Meteorological and Oceanographic Center (FNMOC) the National Centers for Environmental Prediction (NCEP), and at the weather centers of allied nations.

One of these models is the MM5, used by the AFWA. The MM5 mesoscale weather model can compute the winds for a given location by applying algorithms to winds in 45 KM, 15 KM, 5 KM, and 1 KM grid squares (PSI, CTII, 2003). The output of the model is very user friendly and available at the AFWA website as a forecast vertical profile at a model grid point closest to the PI. Vertical wind profile data can be communicated to airdrop aircraft from a CTII ground terminal co-located at AFWA or from a CAOC with access to an INTERNET site where these data can be uploaded from AFWA. However, 4D forecast fields required by JPADS are too large (on the order of 10 MB) for CTII or other airborne communications systems, and must be downloaded during ground mission planning where high-speed communications lines are available.

In-flight weather reports can be useful to populate the wind data for WINDPADS. These reports can come from other airlift, tactical, or unmanned aircraft. In Operation PROVIDE PROMISE over Bosnia, the airlift aircraft would receive in-flight wind reports from fighter escort. About 20 minutes prior to the drop, an F-18 would descend to about 2,000 feet AGL and climb up over the DZ transmitting the winds to the airdrop formation. The navigator would then compute the vector average of the winds and use that data to compute the CARP. This technique has been used often in training and exercises but is not very practical in a hostile environment. Climbing over the DZ compromises the security of the location and exposes the aircraft to ground fire. It may be practical to send a low cost UAV to obtain winds without having to risk an aircrew if the mission dictates.

There are several wind sensing devices available which offer the best solution for obtaining near real time wind data. These devices include radiosondes, RADAR, LIDAR, and dropsondes.

Radiosondes are GPS guided atmospheric data recording devices that are attached to a helium balloon and rise to altitude. They normally transmit the data to a ground processing station, via UHF radio communications, but are capable of transmitting to an airborne aircraft via UHF communications, after some modifications are made. Radiosondes are mature and have been used for many years operationally. Users on the ground can incorporate the use of radiosondes to obtain data for the airdrop aircraft. Combat weather, combat control and other special operations personnel are familiar with there use.

RADAR and LIDAR derived winds are promising as far as obtaining winds near real time in the vicinity of the DZ. These systems will enable the aircraft to gather winds prior to the drop and be self contained on the aircraft. This technology is hypothesized to be feasible although it has not been demonstrated operationally. The technical obstacles were described in chapter 2. These technologies should continue to be pursued for the future.

The GPS hand launched A-Sonde is ready and available to be used with JPADS. The A-Sonde was developed and produced by engineers at PSI. PSI also has developed the WINDPADS which is one component of JPADS and integrated it with PAPS. Another type of dropsonde is the WC-130 hurricane hunter dropsondes. These dropsondes have been used for years to obtain atmospheric data inside active hurricanes and tropical storms. The aircraft are specially modified to drop the sondes out the belly of the aircraft and require special hardware and software to receive and process the data.

Finally, what may be the best solution is the dropsonde that can fit and be ejected by aircraft or UAVs equipped with CMDS. Almost all fighter, bomber, attack, and most airlift aircraft have a defensive system which expends chaff or flares. The obvious benefit of this system is the aircraft does not need to de-pressurize to expend the dropsonde and any aircraft or possibly a UAV can deploy it. British Aerospace has developed a tactical dropsonde called the TDrop capable of being launched from Navy CMDS dispenser systems. Modifications to the TDrop are necessary to conform to Air Force form/fit requirements (square/rectangular cross-section versus Navy round cross-section). The TDrop has been deployed from Hunter and Pioneer UAVs in several weather tests (Unmanned Aerial Vehicle Weather Initiative, Final Report, Oct 2002).

TDrops and A-Sondes were dispensed from a UAV (MMIST Snow Goose powered parafoil) as demonstrated at PATCAD, Yuma Proving Ground in November 2003 (PSI Flight Test Report, p. 5, 10 Feb 2004).

PAPS Processing

The PAPS receives the assimilated windfield data from WINDPADS and processes it using a series of airdrop equation algorithms. Both operate on the same computer. The PAPS runs a user defined number of Monte-Carlo modeling simulations and determines the expected landing footprint, or ellipse to the operator. The landing ellipse gives the operator a visual depiction in which he/she can make a risk assessment. Options may include changing the drop altitude, run-in direction, parachute type, delaying or canceling the mission altogether.

The mission planning of PADS can occur on the ground before flight using forecast winds and then updated in flight with near real time winds. Once the PADS operator has calculated the CARP and trajectory, and is satisfied with the result, he/she can pass the geographic coordinates of the release point to the aircrew to load into the aircraft’s mission computer. The PADS operator can also then transmit the calculated trajectory to guided airdrop loads via wireless data transfer.

As was demonstrated in Operation ENDURING FREEDOM, the PADS can be located at a remote location such as the JAOC or at the WOC. The operator can compute the CARP and trajectory using near-real time winds from any combination of sources that are available. Then the operator can transmit the data via CT II or other secure means to the aircraft a matter of minutes before the drop. A tactician is able to calculate the time prior to the drop the crew would need the data. They would have to take into account the time to load the data and depressurization schedule. Any significant changes to the target area, initial point, or run-in direction must be considered and coordinated in a timely manner.

Future CONOPS should include operations for the system being incorporated "behind the glass". Ideally, this would be the easiest and provide the most flexibility for the aircrew. The PADS software incorporated behind the glass relieves the need for an operator of the laptop. In addition, having the system integrated with the aircraft would provide the aircrew direct steering cues and possibly shorten the processing time. The crew would not have to scramble to load in new drop coordinates during a critical phase of flight if the system automatically updates even to the last second. The cost of incorporating this system into several avionics systems may be prohibitive and require extensive flight testing.

Airdrop Load

The author envisions that there can be multiple types of cargo loads with multiple restraint gates. This enables a PADS equipped aircraft to service multiple targets in different locations on a single mission. Typically, only a single CDS bundle or "Stick" which is a row of bundles are dropped at one time using current airdrop procedures. Multiple gates can be rigged allowing several targets. If the aircraft had four gates rigged, it could service four individual, geographically separated targets. Each of those four loads or group of loads could contain a combination of material that the user may need such as ammunition, food, batteries, water, etc. The PAPS could then transmit the desired landing coordinates and trajectory to each set of loads.

In early testing, this concept was demonstrated at YPG. Two CDS bundles with guided systems were released simultaneously from the same gate and had the same trajectory and target. It was noted that the bundles kept bumping into each other on the descent. This problem was fixed by having PAPS generate a slightly different trajectory for each load so they would not interfere with each other. At the 2003 PATCAD, four systems were reprogrammed via CTII in flight with new PI's and wind data.

High glide, ram air parafoils similar to those used by High Altitude, Low Opening (HALO) jumpers and sport parachutists are available for CDS and equipment loads. Parafoils provide a stand-off capability for the aircraft. A 3 to 1 glide ratio on a load dropped from 30,000 feet allows a standoff distance of 14.8 nautical miles (NM) under a no wind condition. A 4 to 1 glide ratio on a load dropped from 30,000 feet allows a no wind standoff distance of 19.7 nautical miles. These figures are demonstrated using the formula below.

$$\frac{30{,}000 \times 4 \text{ (glide ratio)} = 120{,}000 \text{ feet horizontal}}{6{,}076 \text{ (feet/NM)}}$$

$$= 19.749 \text{ NM}$$

This distance can be increased substantially with a tailwind. A 23 NM offset keeps the aircraft out of most IR and RADAR threat envelopes. The JPADS CONOPS from request to load impact is illustrated in Figure 7.

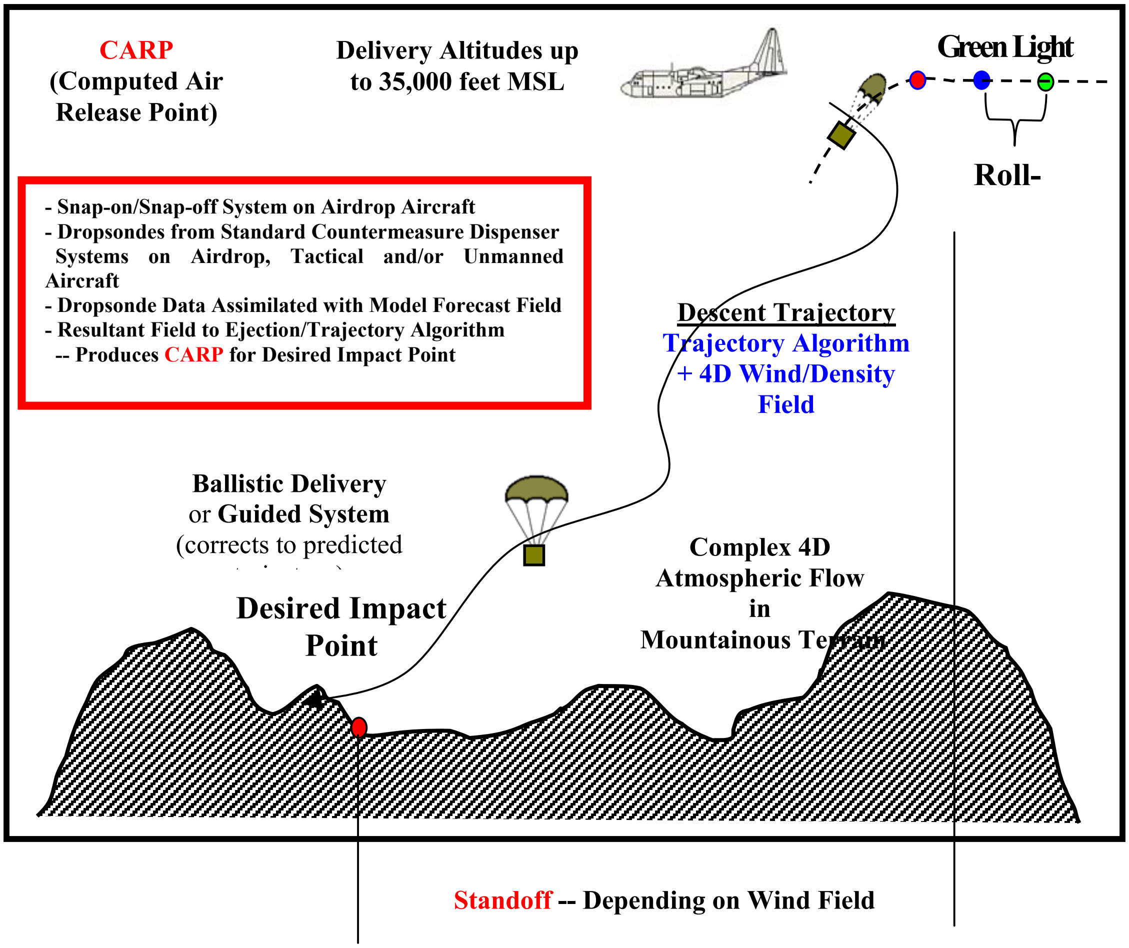

Figure 7. JPADS CONOPS. Wright, B., Planning Systems Incorporated, 2003, Reston, Virginia. Reprinted with permission.

Investigative Question #2: Can a Joint Precision Airdrop System CONOPS be formatted to reflect current operating methods such as those used in Close Air Support (CAS) doctrine?

CAS Doctrine

Instead of reinventing the wheel, the research can draw upon the doctrine of close air support which has similar characteristics to the employment of JPADS. Joint Doctrine states that the conditions for effective CAS are: “air superiority, suppression of enemy air defenses, target marking, favorable weather, prompt response, aircrew and terminal controller skill, appropriate ordnance, communications, and command and control" (JP3-09.3, ix, 1995). These same conditions are necessary for the effective employment of JPADS.

Without air superiority and SEAD, airlift aircraft are easy targets and vulnerable for loss. Target marking consists of the user providing highly accurate coordinates for the impact point. The markings do not need to be visible as the JPADS does not need to see the target like an aircrew would on a visual drop. The weather needs to be manageable for the aircrew to get through and the load to get through. Strong winds may exceed the guidance and navigation capabilities of JPADS or the aircraft. Being able to provide the critical supplies to the right unit at the right time is essential. As with any sophisticated system, it requires a degree of skill among the operators. The load must be appropriate; it does little good to get food delivered to you when you needed bullets. Secure communications are required, so as not to compromise the location of the aircraft or the intended user. Finally, command and control are important to make sure all user requests get prioritized and responded to in the most efficient manner.

Just as communications are an essential part of CAS, they will be an essential part of JPADS. Secure, reliable communications between the user on the ground and either the aircrew or CAOC is critical to pass coordinates and request supplies. Data communication is also important as the dropsonde descends and transmits wind data to the aircraft or relay platform. This data string or burst should be secure and anti-jam. One concept being reviewed is that the dropsonde descends over or near the target in a record only mode and then sends one quick, secure data burst triggered by acoustic or laser sensors just before it hits the ground. This would help ensure Operational Security

(OPSEC) by not advertising the position of the intended target. The data transfer from the JPADS to the onboard guidance and control unit on each airdrop load needs to be fast, reliable and secure.

Preplanned and immediate CAS involves both the request and the tasking. If the request is early enough to be include in the ATO, it is considered pre-planned. The CAOC can also preplan alert aircraft in the ATO to respond to immediate requests. When the battlefield is rapidly changing due to unforeseen events, immediate requests can deliver the cargo sooner then waiting for the next ATO cycle. The nature of modern warfare requires us to plan for the unforeseen, because we know its going to happen. The unknown is the location, time, and type of cargo.

Joint Doctrine states that “CAS must sometimes be provided at night, during periods of limited visibility, or under adverse weather conditions” (JP3-09.3, xi, 1995). These are challenging conditions in which to operate, but the US military has an advantage over the enemy due to its equipment and training under these conditions. The GPS and Inertial Navigation Systems (INS) allow us to operate with amazing accuracy under the harshest conditions. As mentioned earlier, optical threats such as AAA and MANPADS are dependent on visual targeting of aircraft. Night and adverse weather help to mitigate these threats.

One concept for JPADS is to follow the example used for CAS. Detailed procedures for CAS can be found in Joint Pub 3-09.3. The employment of CAS follows a process of requesting and tasking firepower to destroy a target. To draw on this concept, an airlift process can be employed that requests and tasks high altitude precision airdrop to supply troops in the field. If the requirements for CAS are foreseen early enough, they can be incorporated in the ATO as pre-planned CAS. Immediate requests are handled by alert aircraft when unforeseen events require CAS. In a joint environment, CAS requires “detailed planning, coordination, and training for effective and safe execution” (JPUB 3-09.3, 1-1, 1995). Just as maneuver force commanders request CAS to augment organic fires, these commanders can request precision airdrop to augment organic distribution channels. The speed, range, and timeliness of aircraft allow a battlefield commander to receive supplies when organic vehicles cannot make it to their distribution point.

Investigative Question #3: Is the technology currently available for meeting the precision airdrop objectives of combat sustainment?

Test Results

The use of PADS has been demonstrated in several airdrop tests in July and September 2001in which the author participated. In the July 2001 test at Yuma proving ground, Arizona, a C-130 dropped 2 CDS bundles on separate passes from 10,800 feet MSL using portions of the PADS system. A dropsonde was hand released over the drop zone, and it successfully transmitted wind field data through the aircrafts UHF antenna to the Wind Pads laptop computer. The Wind Pads computer operated by PSI assimilated the Dropsonde data with pre flight MM5 data and transmitted the wind field to the PAPS computer. The PAPS operator from Draper Labs computed the CARP and passed the release point to myself, the navigator. I programmed the onboard computer and directed the aircraft to the release point. The PAPS operator also transmitted the trajectory to the guidance and control unit on top of an A22 CDS container with an AGAS guided G12 parachute. Upon release, the CDS bundle successfully made steering corrections by a series of pneumatically actuated riser pulls to maintain the programmed trajectory. The results were promising; the first bundle landed 98 meters from the intended target and the second bundle landed 130 meters from the intended target.

The system was then demonstrated to nearly 200 participants at the Precision Airdrop Technology Conference and Demonstration (PATCAD) at the Yuma proving ground the week of September 10th, 2001. The initial demonstration was delayed 2 days due to the attacks on the World Trade Center and Pentagon. On 13 September, the system was demonstrated dropping a CDS bundle from a C-130 from 10,611 feet. The first bundle landed 87 meters from the intended target (AMC/DOK, Pads Brief, 2003). On 14 September, the system was demonstrated dropping a CDS bundle from a C-130 from 19,133 feet and landed 179 meters from the intended target (AMC/DOK, Pads Brief, 2003). The lessons learned from these tests were analyzed and incorporated into follow on versions of PADS.

Five test cycles between October 2002 and May 2003 for the PADS were performed from C-130 aircraft at YPG. A total of 47 CDS drops with weights between 500 and 2200 pounds occurred from altitudes between 10,000 and 25,000 feet (Wright, PADS Brief, 2004). Three of the drops experienced parachute canopy failures (Wright, PADS Brief, 2004).

Two test cycles in June 2003 and September 2003 for the PADS were performed from C-17 aircraft at YPG. A total of 40 CDS drops with weights between 600 and 2000 pounds occurred from altitudes of 18,000 and 25,000 feet (Wright, PADS Brief, 2004). Ten of the drops experienced parachute canopy failures (Wright, PADS Brief, 2004).

An analysis of 27 of the C-130 drops revealed a CEA of 321 meters (Wright, PADS Brief, 2004). Thirteen of the drops were at an altitude of between 9,863 and 15,315 feet (Wright, PADS Brief, 2004). Fourteen of the drops were at an altitude of between 17,427 and 24,772 feet (Wright, PADS Brief, 2004). Although the CEA did not meet the desired JPADS ACTD accuracy of 100 meters, the CEA did meet the AMC operational test objective of less than 400 meters. The tests revealed some modeling inaccuracies, and these are being improved. Green light position, payload release, and payload trajectory errors were analyzed and incorporated into the models used by PADS.

The Combat Aerial Delivery School (CADS) Joint Operations Directorate (JOD) was redesignated the 34th Combat Training Squadron (CTS) in December 2003. The JOD/ 34th has been conducting high altitude CDS airdrop training since 1999. The training consists of ground academics followed by simulated high altitude airdrop procedures in the aircraft. A few select crews are chosen to perform actual high altitude CDS drops during a JRTC rotation. Because dropsondes or other wind measuring devices are not readily available at JRTC, the crews simulate a wind finder such as a UAV or fighter aircraft to determine winds above the drop zone. The crew uses procedures such as are used in training to airdrop HALO personnel. The aircraft flies over the DZ and records winds every thousand feet up to drop altitude. Then the crew vector averages the wind azimuth and velocity using an MB-4 whiz wheel or a vector summation program as found in CFPS CAPS or a spreadsheet. Twelve high altitude CDS drops from Feb 01 to April 03 using these procedures resulted in a circular error average of 235 yards (Young, 2003). These results are shown in Figure 8.

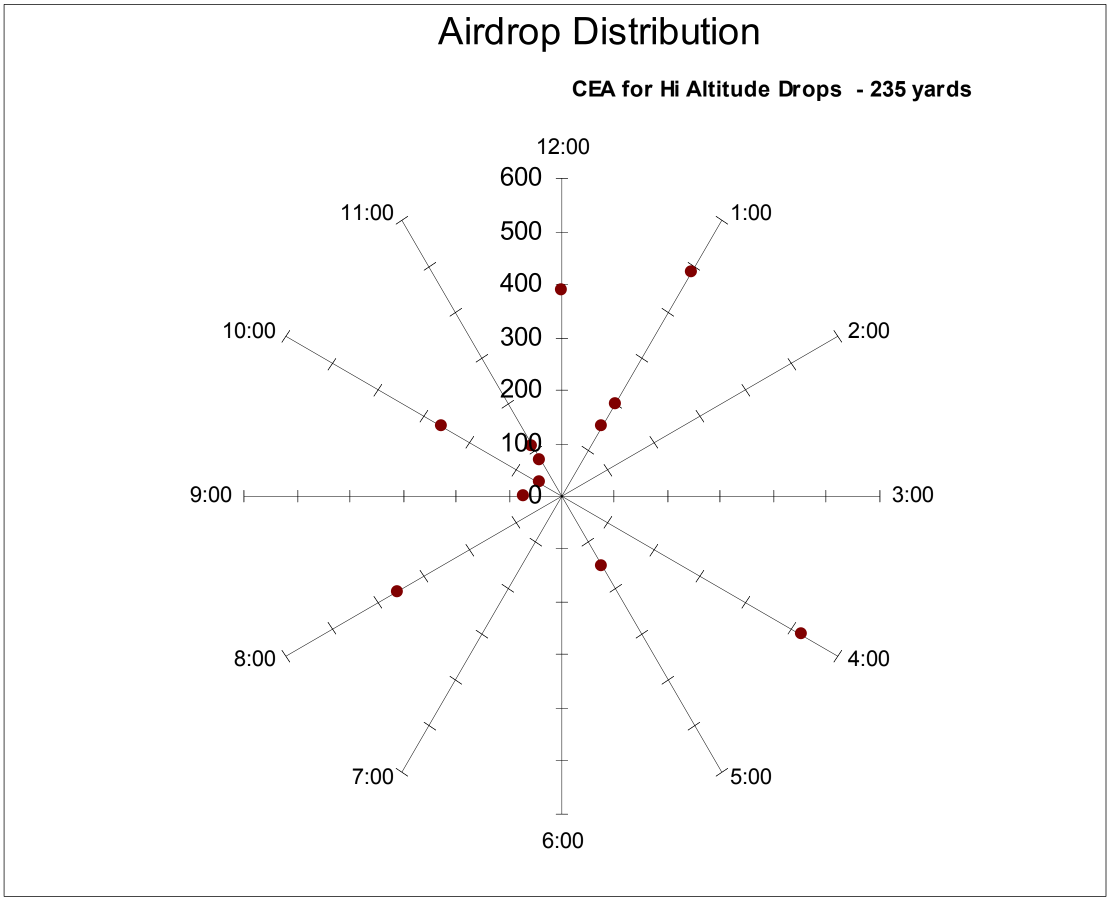

Figure 8. JRTC High Altitude CDS Circular Error Average Chart. Young, D., 34th CTS, 2003, Little Rock AFB, Arkansas. Reprinted with permission.

To bomb droppers who measure effectiveness in terms of feet from the target, the 235 yard CEA seems like a poor performance. In reality, these are unguided loads dropping for 3 to 4 minutes. Considering the average CEA for low altitude CDS during the same time period is 179 yards, the results are very impressive indeed (Young, 2004). This method is however, impractical in a combat environment. Climbing up over the drop zone from low altitude defeats the purpose of high altitude airdrop to avoid the threat. The method of averaging winds every thousand feet gets the load close in a stable air mass, but it does not work well in rough terrain or from higher altitudes. To truly get accurate results, you must be able to determine the CARP from a four dimensional wind field.

Investigative Question #4: Is the Precision Airdrop System best utilized as a stand alone or integrated system?

JPADS is a snap-on/snap-off system that is temporarily integrated with the airdrop aircraft to perform a high-altitude precision airdrop mission. JPADS components are connected to the aircraft power supply, bottom UHF antenna, 1553 data bus and the integral GPS antenna or sextant port GPS antenna. The current JPADS that is in development is a stand alone system. Stand alone means that it is laptop based. The initial prototype consisted of two separate laptops, one each for the WINDPADS and PAPS programs.

The initial prototype was demonstrated using two separate laptop computers connected by Ethernet communications for file transfer. For various reasons, each laptop computer had a different operating system. Mission planning software developed by the Draper Laboratory used PC (Windows) operating systems (OS) while the atmospheric (three-dimensional wind, pressure, density) data processing software developed by PSI used a Linux OS. Available PCMCIA 1553 data bus cards required a Windows OS. The planned atmospheric data assimilation software was the Local Analysis and Prediction System (LAPS) developed by the NOAA Forecast Systems Laboratory (FSL) (Forecast Systems Laboratory, website). The complex LAPS software was legacy code written for a Unix OS which could be run under a Linux OS.

The PADS major components, PAPS and WindPADS, in addition to the GUI for these components, were developed in parallel and integrated through designed data interfaces. This parallel development was required to meet the test and demonstration schedule for acquisition and fielding decisions by Air Mobility Command (AMC). Using a parallel development process was critical to reduce the time needed to field a system. The PADS team met frequently to discuss progress in the development of the software and frequently had teleconferences. The two computers were connected and transferred data for the first time in October, 2000 at US Army Natick Soldier Center in Massachusetts. All of the initial ground and flight testing was performed with the two laptop configuration.

In June of 2002, the two programs were merged onto a single laptop. The software was run in a dual OS environment, real PC and virtual Linux that enabled file transfer between WindPADS and PAPS to produce the Computed Air Release Point (CARP) and impact error estimates (Planning Systems Incorporated, Software Design Document, p.8, 9 October 2003). At this point, the PADS system was still considered immature but could be used in a contingency if required. AMWC CADS was able to obtain $2.1 million in USTRANSCOM CINC Initiative funds in April, 2002 to purchase ten initial systems. The ten systems consisted of a laptop with both WindPADS and PAPS installed as well as all associated wiring, cables, and antenna connectors in a hardened deployable suitcase weighing about 75 pounds (See Figure 9). In addition to the ten systems, the money also was able to purchase 70 dropsondes.

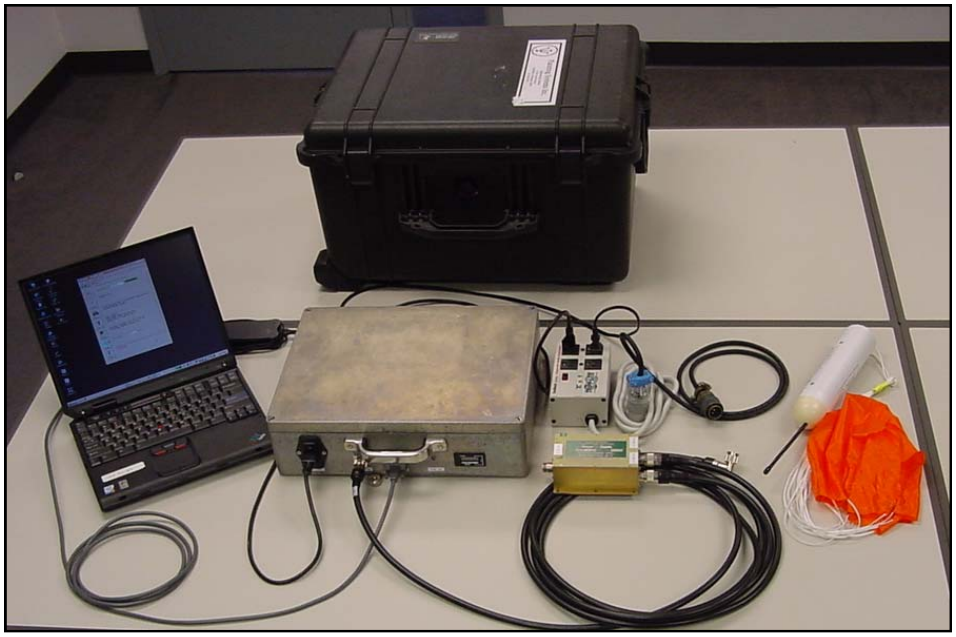

Figure 9. JPADS System with Deployable Case. Wright, B., Planning Systems Incorporated, 2003, Reston, Virginia. Reprinted with permission.

From the beginning of development, the PADS team envisioned that the system would be developed on a laptop and then eventually incorporated into onboard software for the C-17, C-130J, and C-130 AMP. Putting the software on the aircraft and having a display to the crew is what we called “behind the glass”. The demanding nature of airdrop on a crew, let alone at high altitude, night, and in a hostile environment; made the idea of putting it “behind the glass” the most practical.

Putting the software behind the glass is not a trivial matter. The developers and producers of the onboard computers for our aircraft have to agree to do it. This would cost a significant amount of money. The onboard computers are flight certified so aircraft and avionics manufacturers are hesitant to introduce software into the system that they did not produce. All of the aircraft would have to go through certification again once the software was loaded and be tested for interference and computer bugs.

Given the resources currently available for PADS, it is not feasible at this time to put the software behind the glass. The decision on whether or not to incorporate PADS "behind the glass" will be determined in the next few years. The Global Mobility Systems Program Office (SPO) is researching the possibility. Having the system laptop based does have its advantages. As a stand alone system, it can be hand carried onto an aircraft and set up in about 30 minutes. A trained PADS operator can work the system while the aircrew performs its normal duties. With minimal training, the aircrew navigator or third pilot can operate the system. Having a stand alone system eliminates the timely Time Compliance Technical Order (TCTO) upgrade to the aircraft.

Another option for a stand alone system is to shrink the hardware so the system can be run on a Personal Digital Assistant (PDA) available on the commercial market. If the leaps in computing power continue at the current rate, this should be feasible in the near future. The carry on JPADS system could be reduced from a 70 pound suitcase to a 5 or 10 pound carrying case for the cables and dropsondes.

Investigative Question #5: Is it feasible and/or desirable to manage precision airdrop from a remote location?

As discussed in Chapter 2, C-17 aircraft performed high altitude TRIADS airdrops on the first night of the war in Afghanistan. The PADS was not quite ready to be deployed to a combat environment. In fact, the system was publicly demonstrated only 3 weeks earlier at Yuma Proving Grounds the week of September 10th, 2001. This was a very new mission for the C-17. High altitude C-17 TRIADS drops were performed only twice prior to Operation ENDURING FREEDOM during the November, 2000 and

June, 2001 tests at Yuma Proving Grounds (AMC Test Report 33-16-99, Dec 2001). The flight test director developed a spreadsheet program to calculate the drift effect of HDRs from high altitude. Because the test director was the only one who knew how to use this spreadsheet, he calculated all of the release points for the C-17 TRIADS drops.

Major Rob Rhyne from the 33rd FTS deployed to Ramstein AB, Germany to plan the drops. The C-17 aircrews flew more than 6,500 miles round trip and refueled multiple times during the 22-hour mission to drop the food rations over eastern and Northern Afghanistan (Fidler, Oct 2001). Their airdrop came hours after the U.S. and allied Forces bombed terrorist targets inside the country. Weather data was not available for the drop zone and very few weather observations were available for the entire region. Using the MM5 weather model for winds, Major Rhyne calculated the drift effect and spread pattern of the HDRs and determined the release point coordinates. He then passed the coordinates via secure means to the aircrew that programmed them into the onboard computer.

The historic events of these missions are very significant. It was the first time airlift aircraft have been called to perform airdrop the same night the first bombs were dropped. It was the most hostile environment the C-17 had been exposed to until that time. It was the first operational high altitude cargo airdrop for the C-17. It was the highest altitude TRIADS had ever been dropped. It was the first use of calculating the release point for airdrop from a remote location and passing it to the crew.

The C-17 airdrop missions in OEF proved that it is feasible to manage high altitude airdrop from a remote location. The C-17 drops were using a relatively unsophisticated spreadsheet program with acceptable results. A more sophisticated

JPADS can also be used in this manner. If sufficient communications are available in a net-centric battle space, the PADS laptop computer can be operated at various ground and airborne locations, in theater or in CONUS. Regardless of location of the PADS laptop computer, PADS-updated data can be communicated to the airdrop aircraft for mission execution.

It may be desirable to manage JPADS from a remote location for several reasons. The first is flexibility. Having the JPADS terminal in the CAOC allows airlift planners to have more options on which aircraft to task. Some aircraft may not be equipped and some crews may not be trained for this specialized mission. The aircrew is very busy during the critical phase of flight on an airdrop mission. Another reason is cost control. Instead of procuring a JPADS system for each aircraft you could effectively operate with 8 or 10 systems plus some backups. The systems can be located at the AOC and the WOCs. The operators can receive the wind information and process it, then transmit the data to the airdrop aircraft. The operators at the CAOC have a more complete picture of the battle field environment than the aircrew and have connectivity to the user on the ground.

Some may argue that managing the JPADS from a remote location is a bad idea. It can be viewed as violating the tenant of centralized control and decentralized execution. The aircrew has immediate eyes on the local tactical situation and can do what aircrew do best; adapt, improvise, and execute. The author believes this argument is weak based upon the success of employing offensive weapons from UAVs in recent conflicts in Afghanistan and Iraq.

Investigative Question #6: What future concepts and technologies should be pursued for a Joint Precision Airdrop System?

There is opportunity for great logistical improvements in airdrop including using Unmanned Mobility Aerial Vehicles (UMAV), logistical airdrop orbits, and on call ground mobility logistical aircraft. Ground units could possibly be inserted to multiple objective areas intact for a direct assault precisely from a standoff distance. The technologies for some of these ideas are available now with the development of JPADS.

UAVs have proven themselves as a valuable asset in the theater warfighter's arsenal. They have provided valuable real time intelligence on the battlefield and even have been employed in a combat role. Projecting into the future, say 20 years, the next airlift aircraft developed may be unmanned as well. The military has seen the benefits of unmanned systems in terms of cost, flexibility, and lives saved. The strategists of airpower should consider the benefits of an unmanned mobility aerial vehicle. The UMAV can be employed in a high threat environment as a platform to deliver JPADS equipped loads.

In the near term, an option to explore is developing an employment method of an airborne logistical orbit. This is not a radical new idea but an evolution of existing tactics used by CAS and bombers. Just as the B-1s were used in Operation IRAQI FREEDOM in time-critical-targeting orbits, an airlift aircraft can be employed the same way. A cell of three airlift aircraft orbiting near the movement of ground forces but out of the employment envelopes of surface threats can await tasking. Each aircraft would be rigged with multiple gates for CDS. Each aircraft can have a different type of load such as ammunition, water, batteries, or other critical re-supply items. When a ground force unit requests an urgent resupply, they would communicate through normal channels or even directly to the aircraft. The aircraft can be tasked with the load to be delivered and given the coordinates for the PI. The aircraft can then immediately proceed from the orbit to the objective area and deliver the supplies. The ground forces would get there supplies in a matter of minutes instead of hours or days.

An iteration of the airborne logistical orbit is an on-call ground alert aircraft. Once again this is not a new concept but one that has effectively been employed by CAS aircraft for many years. An airlift aircraft can be loaded with expected critical supplies and a crew in the aircraft, perhaps with engines running. An urgent resupply request can trigger the launch of that aircraft. Joint campaign planners can coordinate major ground movements and offensives to determine the right number and timing of alert aircraft. Ground alert CAS is input into the ATO as GCAS or XCAS. Ground alert mobility aircraft can also be scheduled in the ATO as Ground Mobility Airlift Support (GMAS) or Emergency Mobility Airlift Support (XMAS).

Ground Units of Action can be employed as a whole by airdrop using JPADS technology. Historically, the US has employed airborne units as individual soldiers jumping from aircraft and assembling into fighting units once on the ground. The assembly process is often complicated and time consuming. The fighting units are vulnerable to enemy advantages until they get assembled for the mission. This challenge is amplified if airborne soldiers are not dropped or more importantly do not land in the exact place they were expecting.

One way to improve the effectiveness of the ground fighting unit is for them to land intact as a homogenous unit. Placing say a squad or a platoon in a container and airdropping the container can be an effective employment method. The container can incorporate JPADS technology and the unit can land precisely in the optimum location for fighting effect. This method would also provide tactical planners more options on drop locations as they are not necessarily limited to a large airfield or similar landing site. The thought of dropping a squad of 12 men in a container may make some people nervous, especially in the event of a canopy failure. The reliability of such systems must be very high to be used to drop a group of soldiers. Better materials, manufacturing techniques, and extensive testing of man-rated systems are required before pursuing such an option.

Employing a ground unit of action in a container also provides flexibility and protection to the airlift crews. Planners have more options than the standard vulnerable in-trail formation of a large airdrop. They can airdrop the containers from high altitude at standoff distances on multiple run-in axes. The containers can be equipped with defensive measures to protect against surface threats.

V. RECOMENDATIONS

Near Term

JPADS has a very useful capability for decision makers and planners. In a training environment, the impact error ellipses can be used to determine the safe conduct of high altitude airdrop missions. After the mission planner or aircrew input all of the parameters of the drop and run the Monte-Carlo simulations, they can view both the expected and failed parachute impact ellipses. The overlay of the error ellipses on Falcon View Maps and imagery provide the crew with a visual depiction of the impact point in relation to populated areas, airspace, ranges, and drop zones. Based upon this information, the crew can decide if the mission should continue as planned, revise it, or cancel it. This capability represents a dramatic improvement over the current method of estimating a failed parachute impact point.

In an operational environment, planners can use the error ellipse information to determine impact points in relation to airspace, domestic boundaries, friendly troop locations, and lines of communication. Planners can also adjust run-in directions and stand-off capability in relation to enemy surface to air threats. The airdrop aircraft can remain outside the threat engagement envelope and still drop to the user even if they are inside a threat envelope. Post drop processing data can be used to determine the expected impact location if something unusual in flight occurred such as a malfunction or evasive maneuvers.

JPADS has the capability to process wind information from a variety of sources. Accurate, timely winds near the objective area continue to be a challenge. The use of dropsondes, radar, lidar, and satellite derived forecasts are being pursued to address this problem. Another source of wind data could be the user. The Joint Staff should look into the feasibility of equipping the user on the ground with a lightweight, portable, user friendly wind balloon or LIDAR system. US Air Force Special Tactics Teams and Combat Weather Teams routinely use wind balloons to gather data. Equipping the user in the field can fill in a lot of the gaps in coverage. Joint Tactics, Techniques, and Procedures could spell out a time prior to the drop that the user deploys a balloon sonde for the aircraft or other relay platform to receive the data.

Far Term

The DoD is moving towards a network centric warfare capability. The flow of information on the battlefield is becoming nearly instantaneous. The USAF is pursuing the Combat Track II system to relay information between many nodes. A capability to explore is the use of CTII or similar data transmission source to automatically transmit selected weather information from the onboard computer to a central weather data processing facility. At any given time, there are hundreds of US and allied aircraft flying in the AOR. They can transmit winds, temperature, pressure and other information to be compiled to build a comprehensive weather forecast. The aircraft fly in different areas of the AOR at different altitudes. The system can be automated to transmit on a time schedule or other user defined parameter such as an attachment to every sent message. Modern forecasting models can assimilate the data with other sources to build an accurate forecast.

Another far term recommendation is to shrink the hardware of JPADS. The JPADS system is now a fraction of the size it was five years ago when it was initially developed. In the future as technology becomes available, the goal should be to shrink JPADS so it fits on a Personal Digital Assistant (PDA). A laptop cannot be secured easily in a cockpit and can become a hazard to the crew during abrupt evasive maneuvers.

The use of LIDAR on a JPADS system looks promising. JPADS team members should continue to pursue the use of LIDAR on future versions of JPADS. One possibility is to attach a LIDAR device to the airdrop platform, so it can continually incorporate wind information into the steering logic and guide more accurately to the ground. Another possibility is equipping ground forces with a light weight portable LIDAR system to obtain wind data from the surface on up and transmit it to the JPADS processor. To improve reliability in a jamming environment, pursue installing miniature Inertial Navigation Systems (INS) to update the Guidance and Control Unit.

Future Studies

This research project was somewhat broad in nature, covering many aspects of the JPADS and potential CONOPS. Future studies, of which there should be many as the concept and system matures, should focus on analysis of small parts of the problem. A quantitative cost-trade off analysis should be performed to determine the potential savings in cost and improved combat capability as a result of fielding JPADS. The concept has the leadership’s attention, and there are a lot of people energized to pursue this technology. The time is right to revolutionize, or at least make a significant evolutionary jump in combat logistics.

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Vita

Major Pete Carrabba is a 1991 graduate of Norwich University and earned Bachelor of Arts degrees in *Peace, War, and Diplomacy* and *Military History*. He received a regular commission as an AFROTC Distinguished Graduate. He earned a Masters of Aeronautical Science in *Aviation Management* from Embry-Riddle University in 2001.

His assignments as a C-130E/H Navigator include Pope AFB, NC; Yokota AB, Japan; and Little Rock AFB, AR. He has accumulated over 3200 flight hours. He is a 1997 graduate of C-130 Weapons Instructor Course and was an evaluator for both C-130E and C-130H3 AWADS aircraft. He instructed combat employment of the C-130 in the Combat Aerial Delivery School Joint Operations Directorate and as CADRE at the C-130 Weapons Instructor Course.

Major Carrabba was the USAF subject matter expert on high altitude airdrop and has been involved in the development of JPADS since 1999. He was recognized for his efforts on the JPADS project as the 2000 AMC Institute of Navigation Award winner and the 2002 US Army Research and Development Award. In May 2003 he entered the Advanced Studies of Air Mobility program and will receive a Masters degree in *Air Mobility* from the Air Force Institute of Technology in June 2004. Upon graduation, he will be assigned to the staff at US Joint Forces Command.