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THE NEW MILITARY APPLICATIONS OF PRECISION AIRDROP SYSTEMS

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The US Army Natick Soldier Center (NSC) is teamed with the Joint Forces Command (JFCOM), US Air Force Air Mobility Command (USAF AMC), the US Army Project Manager Force Sustainment Systems (PM-FSS), and under the oversight of the Office of the Secretary of Defense (OSD) Advanced Systems and Concepts (AS&C) office, along with numerous other government agencies and contractors to plan and execute the Joint Precision Airdrop System (JPADS) Advanced Concept Technology Demonstration (ACTD).

The purpose of the JPADS ACTD is to meet the Combatant Commanders (COCOM) requirement of sustaining combat power using high altitude, precision airdrop as a direct and theater delivery method, into a dynamic, dispersed, and unsecured battle space. This must be done with speed and flexibility to provide a capability previously unavailable to the COCOM, and to enable decisive operational superiority.

The JPADS ACTD is integrating a USAF-developed laptop computer-based precision airdrop planning system known as the Precision Airdrop System (PADS) with the USA Joint Precision Airdrop System (JPADS) in the "light" weight category (2201-10000lbs rigged weights). The JPADS-MP is also being integrated with the leading "extra light" (500 – 2000lbs rigged weight) systems (Screamer, Sherpa, AGAS). The program objectives include the ability to airdrop JPADS systems of up to 10,000lbs rigged weight, from altitudes of up to 25,000ft mean sea level (MSL), with up to 30km horizontal offset, and land precisely within 100 meters of a preplanned ground impact point. An additional key metric is to have the final system work with the Enhanced Container Delivery System (ECDS) pallet under a gravity drop (ECDS is not extracted), the type V platform, or a 463L pallet (when the payload can be item-suspended). The cost goal for the entire decelerator/platform system is under $60K (in FY04 $s and in quantities of 100). This paper will provide an overview of the JPADS program goals and the status of the effort with flight test results to date. It will also highlight the research, technology and integration challenges associated with precision airdrop systems, and how the JPADS team is overcoming these challenges. This paper will also provide an overview of precision airdrop activities within a recently-established NATO Joint Precision Airdrop Capabilities Working Group (JPACWG).

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Nomenclature

AAA	Anti-Aircraft Artillery
ACTD	Advanced Concept Technology Demonstration
AFOTEC	Air Force Operational Test and Evaluation Center
AFWA	Air Force Weather Agency
AGAS	Affordable Guided Airdrop System
AGL	Above Ground Level
AGU	Airborne Guidance Unit
ALOC	Air Line of Communication
AMC	Air Mobility Command
AOR	Area of Operations
CARP	Computed Aerial Release Point
CDD	Capabilities Development Document (aka ORD)
CENTCOM	Central Command
CEP	Circular Error Probable
COCOM	Combatant Commander
COI	Critical Operational Issue
CONOPS	Concept of Operations
CTII	Combat Track II
DOTMLPF	Doctrine, Organization, Training, Material, Leadership, People, Facilities
EUE	Extended User Evaluation
FRW	Full Rigged Weight
DZ	Drop Zone
EUT	Early User Training
GLOC	Ground Line of Communication
GN&C	Guidance, Navigation and Control
GPS	Global Communication System
GUI	Graphical User Interface
HAHO	High Altitude High Opening
HALO	High Altitude Low Opening
ICD	Initial Capabilities Document (aka Mission Needs Statement)
IED	Improvised Explosive Device
JAAWIN	Joint Air Force Army Weather Information Network
JDAM	Joint Direct Attack Munition
JFCOM	Joint Forces Command
JMUA	Joint Military Utility Assessment
JPADS	Joint Precision Airdrop System
JPADS-L	JPADS Light
JPADS-MP	JPADS Mission Planner
JPADS-XL	JPADS Extra Light
JPACWG	Joint Precision Airdrop Capabilities Working Group
JROC	Joint Requirements Oversight Council
JTF	Joint Task Force
KIAS	Knots Indicated Airspeed
KPP	Key Performance Parameter
LIDAR	Light Detection and Ranging
LOC	Line of Communication
MANPADS	Man-Portable Air Defense System
MC	Mission Computer
MP	Mission Planner
MSL	Mean Sea Level
NATO	North Atlantic Treaty Organization
NSC	Natick Soldier Center
O&M	Operations and Maintenance
ORD	Operational Requirements Document (aka CDD)

OSD	Office of the Secretary of Defense
OUE	Operational Utility Evaluation
PADS	Precision Airdrop System
PATCAD	Precision Airdrop Technology Conference and Demonstration
PFPS	Portable Flight Planning System
PIP	PADS Interface Processor
PM-FSS	Program Manager Force Sustainment Systems
RAD	Ram-Air Drogue
RPG	Rocket-Propelled Grenade
RTK	GPS Re-transmit Kit
SATCOM	Satellite Communications
SLOC	Sea Line of Communication
SODAR	Sound Detection and Ranging
TOT	Time Over Target
UHF	Ultra-High Frequency
UJTL	Universal Joint Task List
USA	US Army
USAF	US Air Force
VDC	Volts Direct Current
YPG	US Army Yuma Proving Ground

I. Introduction

The purpose of the JPADS ACTD is to meet the Combatant Commander (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. This must be done with speed and flexibility to provide an optional capability previously unavailable to the COCOM, and to enable decisive operational superiority. The need for JPADS within the Department of Defense (DoD) is clear from its ranking within the ACTD reviews. JPADS was ranked within the top 5 ACTD FY04 new starts by all COCOMs, and the Joint Requirements Oversight Council (JROC) for FY04 new start ACTDs ranked it the number 2 priority. An image of the JPADS Concept of Operation (CONOPS) is shown in figure 1.

This JPADS ACTD is integrating the USAF Joint Precision Airdrop System Mission Planning (JPADS-MP) hardware/software with the US Army Joint Precision Airdrop System-Light (JPADS-L) airdrop systems (10Klb rigged weight capability). The JPADS-MP provides a mission-planning tool with wireless connectivity to the Army JPADS-L airdrop system(s) on-board the aircraft. This integrated technology allows for rapid pre-flight JPADS programming and in-flight mission, threat, and terrain/environment changes, allowing for immediate reaction by the user to real world variations from plan. It is the intent of the JPADS ACTD to demonstrate and assess systems and technologies that can provide a global delivery system capable of 24-hour fort (CONUS) to fighter (unit/teams) distribution. The JPADS-MP system resides in the cockpit via a high altitude compatible laptop computer that is also loaded with Combat Track II (CTII) secure satellite communication software and connected to the CTII hardware.

This paper provides the status of the JPADS ACTD program since its 1QFY04start, with a focus on the technical aspects of JPADS, an introduction to the CONOPs, and the general research, technology and integration challenges associated with precision airdrop. It also briefly outlines the process for accomplishing the ACTD objectives, transitioning residuals for long-term service Operations and Maintenance (O&M) support, and insertion into the formal acquisition process. It should be noted that both the JPADS-MP (USAF) and JPADS (USA) efforts are based on prior NSC work sponsored by numerous USAF and US Army sources. During the first 18 months of the ACTD, there were two systems competing in the 10,000 lb category, the Dragonfly and the Screamer. In July, 2005, a user prioritization process selected Screamer to continue as the system of choice for the ACTD.

II. The Advanced Concept Technology Demonstration (ACTD) Program

In 1994, the Department of Defense (DoD) initiated the ACTD program to adapt the acquisition process to changing economic and threat environments. An ACTD program emphasizes the assessment and integration of maturing commercial or government technology that addresses critical military needs to expedite transition of those technologies to the warfighters. ACTDs must be Joint and are considered to be the highest priority OSD-sponsored science and technology programs within the DoD. The overarching objectives of an ACTD are to conduct meaningful demonstrations of a capability, develop and test concepts of operation to optimize military effectiveness, and if warranted, prepare to transition the capability into acquisition without loss of momentum. There are three definitive outcomes of an ACTD all of which are considered a success in the true meaning of the concept and process of an ACTD:

The first is that the war fighter in the final Joint Military Utility Assessment recommends the system or system of systems for acquisition because of proven joint military utility. This decision also allows the residual capability to be fielded by the services to 1) a deployed unit providing an interim but limited operational capability or 2) to a unit that along with the ACTD team can continue to further operational and technical developments in an Extended User Evaluation (EUE). With either decision the funding support for the residuals systems will be provided by the ACTD. This decision also allows the program to enter a Milestone "B" acquisition phase with the Program Manager either sole sourcing the award to the original contractor or establishing an RFP to compete.

The second possible outcome is that if the system shows potential military utility the war fighter can recommend further technical development to meet requirements so that a definitive answer can be gained for a final decision to recommend or not recommend acquisition. This decision can be made during either the development or assessment phase of the ACTD.

The third and last outcome of an ACTD is that the war fighter clearly sees no military utility and recommends that 1) the ACTD be terminated; 2) any acquisition plans be stopped; and 3) that the lead service or government proponent of the ACTD return to the technical base to find a solution to meet the requirement. This decision can also be made during either the development or assessment phase of the ACTD.

Instead of testing to requirements as in an operational or developmental test, a Joint Military Utility Assessment (JMUA) is utilized, which identifies “value added” as the primary assessment metric to determine if the capability (technology and/or procedures) warrants further development or acquisition. In attempting to identify value added, a JMUA must cope successfully with two major challenges: 1) Incorporate the technology into realistic operational scenarios with real users and a realistic range of conditions; and 2) Collect data to measure the impact of the technology on warfighter missions and operations. The ACTD program is managed by the Deputy Under Secretary for Defense, Advanced Systems and Concepts (DUSD, AS&C).

III. JPADS Definitions and CONOPS

This section outlines the JPADS components and a potential Concept of Operations. It sets the context for the CONOPS by outlining the fundamentals of precision airdrop operations. With this background, it becomes clearer not only how to use JPADS, but also when, where, and why JPADS variants should be used and the resources required to integrate the system into a concept of operations and support.

A. Background

Within the US DoD, JPADS is defined as a family of systems with various weight classes to support focused logistics. The classes are:

- JPADS Extra-Light (XL) 200-2200 lbs;
- JPADS Light (L) 2201-10,000 lbs;
- JPADS Medium (M) 10,001-30,000 lbs; and

- JPADS Heavy (H) 30,001-60,000 lbs.

Each of these weight classes may involve more than one JPADS system with a unique decelerator system, unique Airborne Guidance Unit (AGU), etc. The goal of JPADS is to provide the capability to deliver cargos of varying weight from altitudes up to 25,000 feet mean sea level (MSL) as a threshold (35,000 feet MSL objective) via autonomously guided precision airdrop from C-130, C-17 and other aircraft to multiple impact points on the ground within a landing accuracy specified for that weight class. Accuracy requirements will be less strict for the heavier weight variants.

B. Mission and Mission Need

JPADS provides global, high altitude, precision airdrop direct delivery capability for a wide range of cargo weights and cargo types. The United States has staffed an Initial Capabilities Document (ICD) (the new DoD name for a Mission Needs Statement) for the entire family of JPADS weight classes from 200 pounds up to 60,000 pounds. A joint Capabilities Development Document (CDD), which is the new name for an Operational Requirements Document, will be completed during CY05 for at least the JPADS-XL and JPADS-L increments. Therefore, the final approved Key Performance Parameters (KPPs) are not yet available.

C. General Airdrop

Sustainment operations in the Central Command (CENTCOM) Area of Operations (AOR) and potentially most future conflicts encompass expansive, non-contiguous territories that are time/distance sensitive and subject to an asymmetric threat. Employment of forces calls for significant dispersion, extending units from supply bases and extending the Ground Lines of Communication (GLOC). The likelihood that these conditions will be replicated in other AORs in which nations find themselves combating terrorism is high given the propensity of terrorist elements to disperse utilizing difficult and compartmentalized terrain to mitigate the informational and maneuver overmatches presented to them by US and Allied Nation forces. Theater re-supply operations can be greatly enhanced with the accelerated development and immediate employment of enablers such as JPADS as a component of the theater distribution system.

D. Threat

The proliferation of Man Portable Air Defense Systems (MANPADS) and other non-traditional threats presents a serious risk for airmen and soldiers conducting resupply operations. While LOC security is never guaranteed, insurgent forces are able to continually interdict supply lines and the convoys that utilize them. The result of this action is twofold. Enemy action is targeted at non-armored combat service support vehicles, often with devastating effects. Mitigation of the enemy's ability to interdict the LOC is met by application of combat power to LOC security; ensuring freedom of movement for supply operations but robbing the fighting force of operational flexibility and resources. Similarly, there are significant risks and shortfalls associated with conducting conventional airdrop operations. For example, US and Allied Nation aircraft cannot meet desired accuracy standards once drop altitudes exceed 2000 feet above ground level (AGL). While drops below this altitude are more accurate, they are subject to small arms, Anti-Aircraft Artillery (AAA) and MANPADS threats. In addition, the time associated with deploying multiple payloads out of an aircraft necessitates a drop zone of substantial length for low altitude drops.

Strategic, operational, and tactical employment of forces in the contemporary operating environment requires a change in the way US and Allied Nations sustain their forces. The time and place of the next battle is unknown. Military planners are no longer able to define the next area of operations with certainty and thus can no longer carefully prepare by strategic forward positioning of forces, equipment, and stocks. Our current adversaries have developed tactics, techniques, and procedures that result in significant disruption of operations. Helicopters are downed by rocket-propelled grenades (RPGs); vulnerable lines of communications are disrupted by improvised explosive devices (IEDs), and by direct action. These two significant changes (strategic warning and asymmetric operations) in the environment are effecting changes in the way US and Allied Nation forces must deploy and employ forces. To provide maximum global agility and flexibility in response to global contingencies, forces will increasingly deploy from a strategic base. Current and emerging US guidance tells us that forces must be able to rapidly deploy, immediately employ upon arrival in the theater and be continuously sustained throughout the operation. New technologies enable US and Allied Nations forces to maneuver against a dispersed enemy in a distributed, non-linear, and non-contiguous fashion. These forces can operate cohesively and maintain situational awareness even while separated by long distances. However, these operations outpace the ability of the logistics tail to keep up. These new methods of maneuver must be matched by new methods of agile sustainment. NATO commanders also require sustainment capabilities that can support forces that will be rapidly deployed, immediately employed upon arrival in theater, and conduct widely dispersed operations with lightning agility. The Joint Precision Airdrop System (JPADS) is just such a capability.

E. Characteristics of Precision Airdrop

1. Higher Altitudes

Precision airdrop allows aircraft to release loads at higher altitudes than non-precision airdrop. Non-precision systems are significantly affected by winds both at altitude and near the ground. The ability of precision airdrop systems to control and/or steer in flight allows them to anticipate and counteract the effects of wind on the airdrop system.

2. Decoupled Aircraft/Load Signature

When guided systems are deployed from altitudes above 20,000 feet AGL, it is difficult to hear or see the aircraft in daylight conditions. In low-visibility conditions, it is not possible to visually acquire the aircraft. Once released, guided systems quickly leave the range of visual identification and/or earshot of the aircraft. This means that even though the aircraft may be seen and/or heard, the exact position of the impact point is unknown to the observer.

3. Flexible Computed Aerial Release Point

Because it can steer to the impact point, JPADS can be released from any flight vector and within a relatively large area in the sky dependent on the known accuracy of the winds for the mission and the glide characteristics of the systems being airdropped. This also allows for controlled dispersion of loads.

4. Enroute Mission Planning and Satellite Communications

The JPADS-MP system provides the capability to continue mission planning and effect mission changes enroute to the delivery point based on information received via non-line-of-sight satellite communications. This is a capability that did not exist prior to JPADS that gives the combatant commanders added flexibility in distribution operations.

F. Uses of Precision Airdrop

Many uses of precision airdrop can be envisioned and some have already been discussed. It is difficult to describe all of the uses of precision airdrop because airdrop is such a flexible tool. It is akin to describing all of the uses of the commercial sector's Federal Express (FEDEX) system. However, the uses of precision airdrop can be conceptually arranged temporally in stages. The stages of precision airdrop are:

- Accompanying equipment and supplies are deployed with the force as equipment essential to the mission at time of arrival into the theater of operations.

- Follow-on equipment and supplies flow into the theater in accordance with a preplanned support concept.

    - Automatic delivery of equipment and supplies is based on estimates of requirements that are scheduled well ahead of the air tasking order time lines.

    - On-call delivery is the use of carefully planned prepositioned and/or pre-rigged stocks throughout the global distribution system to satisfy emergent requirements.

- Emergency airdrop occurs when the warfighter discovers a previously unforeseen requirement that cannot be fulfilled by on-call assets.

- Demand supported precision airdrop delivery occurs when theater distribution systems and connectivity are mature enough to deliver supplies through normal requisitioning and issue procedures.

G. Why JPADS?

A partial list of advantages and disadvantages of precision airdrop follows:

1. Advantages of Precision Airdrop include
- Capitalizes on the capabilities of the strategic base providing direct, global delivery within 24 hours of mission receipt.
- Supports all forces over the entire range of military operations.
- Enables immediate employment by providing a bridge over the time gap between force entry and mature distribution network capability.
- Unconstrained by theater austerity, maturity, or lack of host nation support.
- Nullifies strategic, operational, and tactical time and distance constraints.
- Provides an option to distribute equipment and supplies when other options are untenable.
- Circumvents remote and compartmentalized terrain.
- Supports multiple entry points into the theater of operations.
- Enables the sustainment of dispersed, non-contiguous, non-linear operations.
- Does not require an extensive logistics footprint in theater
- Reduces risk to aircrews by enabling higher flight altitudes and flexible approach vectors.
- Increases aircraft availability relative to airland operations by decreasing risk to aircraft and aircraft turnaround times.
- Reduces risk to Combat Service Support ground assets by reducing exposure along GLOC.
- Reduces detection of signature (high altitude and some level of standoff).
- Provides greater flexibility to the maneuver commander by allowing changes of delivery point(s) enroute.
- Reduces cross loading, repacking, and intermodal processing times.
- Provides the capability to throughput around the SLOC, ALOC, or GLOC infrastructure.

2. Disadvantages of Precision Airdrop include
- Sustained precision airdrop operations require the capability to recover and retrograde airdrop items (cost factor).
- Precision airdrop net aircraft payload is reduced (slightly) relative to airland operations because of the need for airdrop rigging equipment and the configuration constraints on the load.
- Precision airdrop requires specially trained rigging and mission planning personnel.

H. Execution of Precision Airdrop

As a rule, the execution of precision airdrop is nearly as simple as the execution of any other mode of transportation. Although specially trained personnel are required to actually rig the equipment and supplies and prepare JPADS systems for precision airdrop, the mission is essentially a delivery of supplies and/or equipment. Sources of supply receive requisitions, make shipment mode decisions, and arrange to transport shipments to air terminals. Air terminals route the cargo for loading and movement via air. Airmen prepare, plan and execute the precision airdrop mission in a manner similar to any other contingency mission. Units in the field secure the impact area (i.e., Drop Zone (DZ)) much as they would a logistics release point. The concepts for delivering equipment and supplies via precision airdrop will be familiar to distribution managers as well as tactical units.

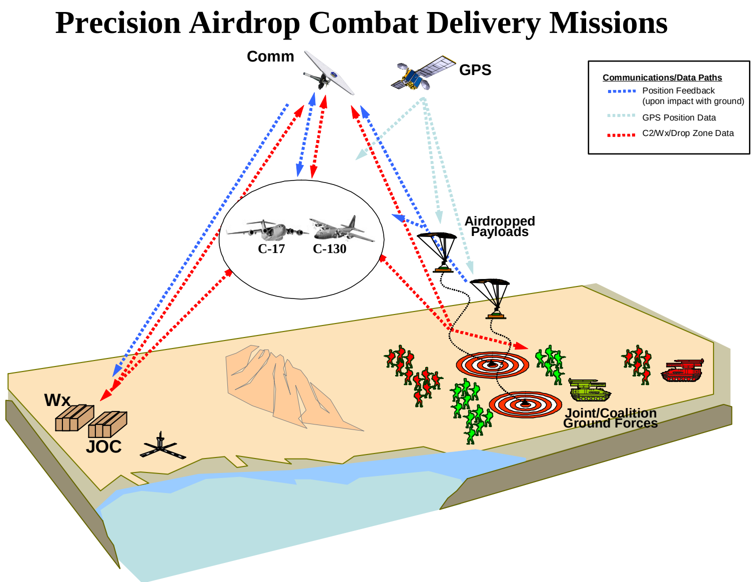

Figure 1. Notional Combat Delivery Operational View with Precision Airdrop System(s)

Figure 1 depicts a notional Combat Delivery scheme with JPADS. The delivery aircraft could be a C-130, C-17 or any aircraft capable of airdrop from high altitudes. The steps involved begin with a “call for resupply” or a planned airborne operation with personnel and equipment. The initial information required for planning such a mission includes: knowledge of what equipment/supplies are needed by the user/caller, when they are needed, and where they are needed. Ground based activities include: Determine which aircraft(s) will be used, preparation of the air droppable bundles/payloads and personnel equipment, obtain preliminary weather information and conduct mission/route planning to meet the needed timelines and to minimize detection and known threats. Weather information is provided through the Air Force Weather Agency and provides the initial information used to determine which JPADS system(s) should be used and preliminary drop location options for the planned airdrop time over target (TOT). All JPADS utilize the Global Positioning System (GPS) as the primary navigation sensor and benefit from a GPS re-transmission kit (RTK) mounted inside the aircraft to allow the systems to know where they are just prior to the leaving the carrier aircraft. Updated weather or target information can be provided to the aircraft/aircrew while in route via satellite communications (verbal or text).

A method of updating precision airdrop system mission plans on-route is also important to provide the most updated weather estimates and impact coordinates. Enroute weather updates can be provided by numerous sources (REFS 1, 2, 3) such as dropsondes, satellite winds, SATCOM’ed updates (forecasted, pilot reports, and/or ground measurements). Enroute measurements of weather are also desired to be fed back to the AFWA for improved future forecasts. The glide ratio of the precision airdrop system(s) chosen and weather conditions at the time of the mission will dictate the level of horizontal offset possible for the mission. After the optimum computed aerial release point (CARP) is chosen, the crew must execute the following: update the precision airdrop systems missions (if required), and run the check list for the airdrop ensuring that the precision airdrop system are on and ready for drop. After the loads are deployed, full visibility of the systems performance will likely be desired and this information should be available to both the aircraft and ground personnel receiving the equipment/supplies. This would likely include at a minimum: the position/location of the payload, the forces/accelerations experienced during the airdrop and upon-landing; the condition of the payload upon landing (i.e., survivability). Figure 1 shows all of these lines of communication.

Detailed Precision Airdrop CONOPS are rapidly being developed and early use of systems in real operations is helping ensure that JPADS CONOPS will be usable and take full advantage of its capabilities.

IV. Joint Precision Airdrop System – Mission Planner (JPADS-MP)

All precision airdrop systems require some type of laptop-based mission planning system and each requires somewhat different input parameters and data prior to being deployed. To avoid significant duplication and multiple laptops in the inventory/aircraft for each type of JPADS utilized, the DoD is currently investing primarily in one mission planner, the JPADS-MP. JPADS-MP is the most sophisticated mission planner for precision airdrop systems being developed at this time. JPADS-MP is under development by a large team for the USAF Air Mobility Command including: program management and execution by the US Army Natick Soldier Center, Planning Systems Inc (lead contractor for hardware, weather, and integration) with Draper Lab (mission planning), the NOAA Forecast Systems Lab (weather assimilation software), and many other supporting services. Other papers document JPADS-MP (REFS 1, 2, 3, 11)

The JPADS-MP enables aircrews to plan and initiate load release at a precise CARP (or area) through the application of accurate models of the JPADS components and enhanced wind profile/weather knowledge.

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Current enhancements include the ability to use JPADS-MP to program a wide range of high-altitude parachute systems by either plugging the JPADS-MP into each AGU respectively or wirelessly programming each system AGU individually or in combination. The JPADS is being implemented to and will be demonstrated with numerous systems at the next Precision Airdrop Technology Conference and Demonstration (PATCAD-2005, see Reference 4 for details on PATCAD-2003) and include at a minimum the following systems: Affordable Guided Airdrop System (AGAS), 2Klb and 10Klb ScreamerS, Sherpas, and Dragonfly systems. The AGAS and Sherpa systems status are described in Reference 5 and 6 respectively. Work has also begun on adapting the PADS mission planning capabilities as a test bed for heavy (30Klbs+) high altitude low opening cargo parachute systems.

V. Dragonfly

The Dragonfly is one of the two 10Klb-capable systems developed by the US Army NSC JPADS ACTD. The Dragonfly team is a collaborative effort between Para-Flite Inc., developer of the decelerator system, Wamore Inc. as the developer of the AGU, Robotek Engineering, providing the avionics suite, and Charles Stark Draper Laboratory leading the GN&C software development. The program began in fiscal year 2003 and fully integrated system flight tests commenced in the first quarter of fiscal year 2004.

The main decelerator for the Dragonfly system is a 3,470-ft^2 high performance ram air parafoil. The canopy is a true advancement in the state of the art of large parafoil system design and construction with an emphasis on low cost, ease of use and simplicity. Para-Flite has implemented advanced manufacturing techniques, such as the use of laser cutting of the rib sections, to achieve system cost goals without sacrificing performance goals. The high aspect ratio (3.2:1) semi-elliptical planform uses an advanced airfoil section and a "multi-grommeted" slider to control the deployment of the canopy. The elimination of a multi-stage pyrotechnic deployment system permits dramatic reductions in canopy design complexity, further reducing the production cost. Packing and rigging time of the system is also greatly reduced. The canopy, with a wingspan of 105-ft, can be easily repacked by two people in less than 3 hours.

Effective application of advanced wing design features such as taper, twist, and variable anhedral has resulted in a parafoil with flight performance parameters substantially in excess of what has been previous demonstrated by other large parafoil designs. Wind corrected glide ratios in excess of 3.5:1, at flight speeds better than 40 knots, have been recorded at fully rigged weights of 10Klbs. Only one-sixth of the outboard trailing edge of the canopy is deflected on each wingtip to affect directional control and braking (flare) for landing. As such, control line loads and total stroke are much lower than comparable systems and the canopy is exceptionally responsive to control input. This has permitted substantial reduction in the power requirements and total weight of the AGU used to control the parachute. (Ref. 7, 8, 13)

The AGU connects to the parafoil risers and is suspended between the parafoil and the payload. The AGU currently weights approximately 175-lb. The design has proven extremely rugged and robust through flight test. As with the parafoil design, great attention has been paid to minimization of unit cost. The AGU and its avionics suite rely heavily on the effective integration of commercial-off-the-shelf components. Primary system electromechanical subcomponents include: a pair of 1.5 hp brushed servomotors, motor controller, 68:1 gear reducers, 900Mhz RF modem (as test equipment), microprocessor, dual-channel GPS, and three 12VDC sealed lead acid batteries. Two batteries provide 24VDC to the actuators, while the third battery provides power to the avionics.

Figure 2. Dragonfly system in flight

A key element of Dragonfly is the development of Guidance, Navigation and Control (GN&C) software to autonomously fly the parafoil. This software must guide the parafoil from deployment altitudes up to 25,000 feet MSL to landings within a 100-meter CEP of the target. Other key goals include robustness to a variety of failure modes, algorithms that are sufficiently generic to facilitate adaptation to both smaller and larger decelerators, efficient enough to perform well on a very modest microprocessor, and capable of meeting system performance requirements with a navigation sensor suite limited by recurring system costs.

Dragonfly flight testing commenced in March, 2004 at Red Lake in Kingman, Arizona. Initial flights were remote controlled, executing planned maneuvers to establish the flight characteristics of the system (Reference 8). First flight of the autonomous flight software occurred in May 2004. Testing has continued since then with flights starting in October 2004 occurring at the Corral DZ at Yuma Proving Ground (YPG), Yuma, Arizona. Since then, the GN&C software was matured in parallel with evolution of the canopy, rigging, and airborne hardware, including a major upgrade to the AGU involving new actuation motors, necessitating revised flight software motor interfacing. The move to YPG was a milestone as this was the first time the system flew from a C-130 airplane, deploying at 130 Knots Indicated Air Speed (KIAS), considerably faster than the C-123 used in Kingman. Flights from military aircraft commenced in February 2005 and continued through September 2005. As the flight test program proceeded, system weights were gradually increased up to the Dragonfly maximum of 10,000 pounds (fully rigged weight), as were drop altitudes. Initial autonomous flights were deployed directly over the targeted impact point, and then gradually more offset from the target was introduced. GN&C software was initialized in early tests assuming no winds, then forecast winds were used, and then using updates of the GN&C mission file while enroute to the DZ with current winds estimates based on an assimilation of forecast and dropsonde wind data from JPADS-MP. Dragonfly’s best flight occurred in June 2005, when it landed under autonomous control 23 meters from the target.

The Dragonfly team, under various funding vehicles, has also developed a 2Klbs-capable system, called Firefly, which has had over 100 flight tests, many of them autonomous. In July, 2005, they first tested subscale version of a 30Klbs-capable parafoil (at 8Klbs), which successfully flew autonomously using the Dragonfly GN&C software. This entire family is designed for compatible AGU, avionics, canopies and flight software. Dragonfly was not selected to continue as the ACTD 10Klbs decelerator, though plans are in work to continue development.

VI. Screamer

The Screamer (References 9, 12) is the other of the two 10Klb-capable systems developed by for the JPADS ACTD. Strong Enterprises is the prime contractor, with RoboTek Engineering, Inc. providing the AGU, avionics, and GN&C software. The Screamer is a hybrid High Altitude Low Opening aerial delivery system, which autonomously navigates a 650-feet^2 ram-air drogue (RAD) parafoil flight to a programmed target point. After descending in a circular pattern above the target to a preset mission recovery altitude, two G-11 cargo parachutes are deployed to arrest forward glide and affect a standard ballistic recovery descent of 22-28 feet per second. The Screamer also includes a small platform or Recovery Mantle on which the parachutes and AGU are rigged.

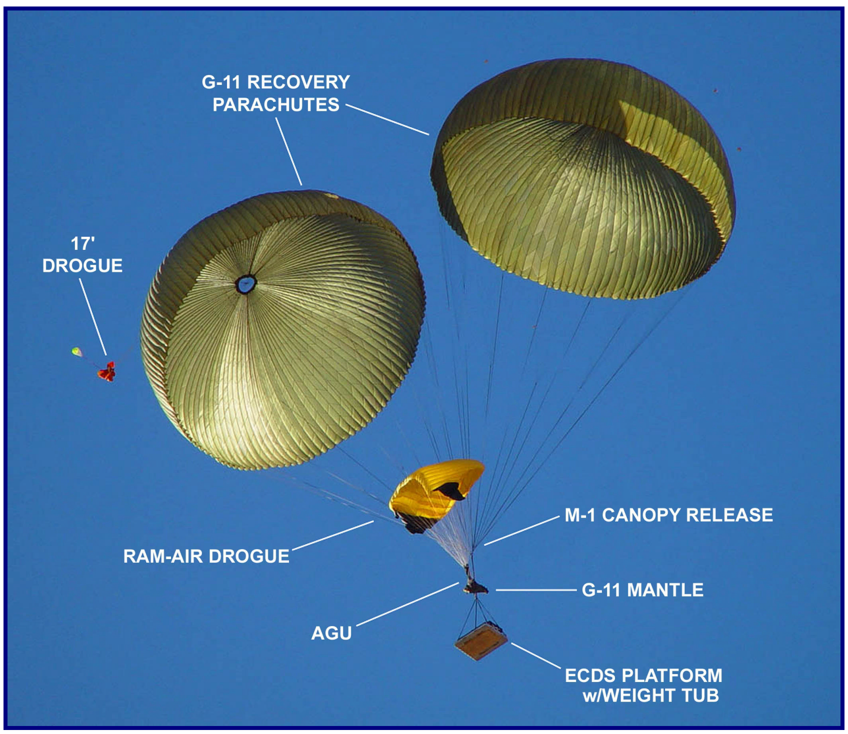

Figure 3. Screamer system near ground impact

This system is uncontrolled during the recovery phase, the last few hundred feet. The Screamer AGU has been used to fly systems from 500lbs through 10Klbs without modification beyond software changes. The 10Klb Screamer system has been flown autonomously on nearly 200 occasions and from deployment altitudes of up to 18Kft MSL and air speeds of 140KIAS from military C-130 aircraft. Landing accuracies have averaged well below 100 meters for nearly a year, and in-flight wind updates are used to modify the opening or activation of the recovery parachutes. Landings within 50 meters are common. The Screamer is shown in figure 3 under its final recovery parachutes. Screamer components are modular and man-portable. It has demonstrated capability of penetrating 60 knots winds during RAD flight.

The RAD, which deploys immediately on exit from the aircraft, applies a classic 2:1 aspect ratio parafoil planform with a cord dimension of 209 inches and a span of 423 inches. The recovery parachutes, used to affect an approximate 24 feet per second vertical recovery in the terminal flight phase, are currently deployed at approximately 900 feet above ground level.

The AGU is situated in the risers directly beneath the RAD out of the structural load path. AGU navigational and control instrumentation consists of a global positioning system (GPS) and turn-rate gyros. The AGU is 18 inches square~~d~~ by 4.5 inches and weighs 45 pounds. Two 1200 pound Spectra steering control lines cascade to the three outer trailing edge suspension lines on each side of the parafoil.

The recovery mantle is a tubular steel frame that is located directly in the load path below the main canopy riser extension and above the payload swivel, which serves as the load sling confluence point. The RM also serves as a location for the transfer link (RAD flight-to-recovery phase), which is integral with the platform and the payload swivel.

In July, 2005, Screamer was selected to continue as the 10Klbs decelerator system for the JPADS ACTD. Following Early User Training (EUT) in September, 2005, it will undergo a series of Joint Military User Assessments as described below. Military users have already purchased over a dozen Screamer 2Klbs systems, which should see operational use by the end of CY05.

VII. JMUA Objectives

The current sustainment distribution system is incapable of responding globally or within theater to a dynamic tactical environment from operational and strategic distances. Supplies and equipment generally reach users in days or weeks rather than in hours. It is the intent of the JPADS ACTD to demonstrate and assess the systems described above that can provide a global and in theatre delivery capability within 24 hours of request the warfighter (unit/teams) worldwide. The JMUA itself does not focus on the "24 hour" timeline, but rather the capability and military utility of JPADS to deliver supplies to the warfighter in field conditions. To assess the JMUA objectives and report on the JPADS military utility, the assessment team developed three critical operational issues (COI, see Table 1) and many supporting objectives. In addition to the formal assessment, significant data on the decelerator systems was collected through technical testing with US Army-developed instrumentation packages. This data collection will continue with the Screamer throughout the JMUAs.

Table 1. Three Critical Operational Issues support the JPADS JMUAs

COIs/Objectives
COI 1. Does the JPADS system-of-systems successfully support payload delivery at the target weights and standoff distances in its intended operational environment?
COI 2. Does the JPADS system-of-systems provide the Joint Task Force Commander with an enhanced operational capability?
COI 3. Is the JPADS system-of-systems suitable for employment in its intended environments?

To formulate these COIs and objectives, the assessment team combined the operational capabilities required by users with ACTD objectives and information gathered during integration process, team meetings, and technology demonstrations. Test measures supporting the COIs and objectives were developed with the extraction of tasks from the Universal Joint Task List and Service task lists from the participating military services. The UJTL serves as a common language and reference system for joint commanders, combat support agencies, operational planners, combat developers, and trainers to communicate mission requirements. It is the basic language for development of a joint mission essential task list that identifies required capabilities for mission success. The three levels of war organize the UJTL: strategic, operational, and tactical—the JMUA execution is at the tactical level of war.

Doctrine, Organization, Training, Material, Leadership, People, facilities (DOTMLPF)

The JMUA will address DOTMLPF impacts, which will be a critical piece of the methodology. The JMUA IPT will be cognizant of this throughout assessment (e.g., via observation, warfighter interviews, etc.). Reporting DOTMLPF findings will be within appropriate the JMUA objectives. DOTMLPF specific issues include:

- Doctrine: Will introduction of the technology necessitate changes to current doctrine (e.g., new procedures or changes to concepts of operation and tactics, techniques, and procedures)?
- Organization: Will the technology enhance mission responsiveness?
- Training: Will fielding of the technology require additional training? What type, how much, when? Will periodic refresher courses be required?
- Materiel: What additional equipment will be required to support use of the technology?
- Leadership: How will introduction of the technology affect leadership? How will it combat the "fog of war?"
- People: Will warfighters with a specific skill set be required to operate the technology?
- Facilities: Will fielding of the technology require certain facilities for storage or setup?

VIII. International Activities

NATO has prioritized numerous capabilities needed for Defense Against Terrorism (DAT) at the Conference of National Armaments Directors (CNAD) level within NATO. Precision Airdrop for Special Operations Forces (SOF) has been prioritized as the 5th highest short term DAT prioritization. In addition, precision airdrop is listed as a Long Term Capability Requirement within NATO. The CNAD tasked the ATO Air Force Armaments Group (NAFAG) to lead precision airdrop activities. The NAFAG tasked Capability Group 5 (known also as Air Group 5) to lead precision airdrop activities within NATO. In September 2004 the Group established an ad hoc Joint Precision Airdrop Capabilities Working Group (JPACWG) as the lead NATO body for Precision Airdrop. The JPACWG is chaired by the US Army Natick Soldier Center and has a two year Plan of Work which includes the development of precision airdrop technology roadmaps, an early look at interoperability and other activities. Of particular note, the JPACWG was tasked by the NAFAG to investigate, plan, and execute an international precision airdrop demonstration by the end of October 2005. This demonstration has been planned to take place 17-21October at the US Army Yuma proving Ground as part of the Precision Airdrop Technology Conference and Demonstration.

This PATCAD will be the third of what has developed into be an every other year event due to the increased level of interest in precision airdrop activities from around the world and the advances being made in precision airdrop technology. PATCADs are facilitated and primarily sponsored by the US Army Natick Soldier Center with PATCAD-2001 held in September 2001 and PATCAD-2003 held in November 2003. The PATCAD-2005 will be partially sponsored by NATO to showcase numerous non-US precision airdrop systems with some early interoperability precision airdrops during the event. The event is also a reality check in that it shows what a system/technology is claimed to do, versus what it actually does, in front of a large audience. An enormous amount of technical data is collected at PATCADs and the results will be used by the JPACWG to help with their activities.

In addition to sponsoring part of the PATCAD, NATO approved and is sponsoring a NATO Industrial Advisory Group (NIAG) study on precision airdrop activities. This involves numerous subject matter experts from over nine NATO nations involved in precision airdrop activities and the NIAG kick off meeting has just taken place (1-2Sept05). The priority areas to be addressed in the study are:

“Technology roadmaps and cost reduction recommendations”,
“Weather information gathering and interfacing”, and
“Life Cycle Definition and needed volume”.

A fourth topic “Testing and Training Facilities” will be addressed with support from the JPACWG which will provide information on government-owned test and training facilities.

NATO has also sponsored an effort to define the details of the NATO requirements and CONOPS for precision airdrop for special operations forces with a focus on supporting the NATO Response Force (NRF) activities. All of these activities are being executed with the JPACWG and are allowing for excellent sharing of precision airdrop information within NATO to help ensure that all nations’ systems are available to support the NRF and other NATO activities in the short term (DAT priority) and advancing and fully interoperable to support future NATO activities (i.e., LTCRs).

IX. Advanced Sensors and New Applications

NSC is conducting research on two key advanced sensor systems to improve the landing accuracy of precision airdrop: height sensing and remote wind sensing. Since most precision-guided airdrop systems use GPS signals as their primary navigation sensor, ground height is only known to around 60 feet. High-glide airdrop systems like Dragonfly need to precisely time the braking maneuver to achieve landing precision. Hybrid airdrop systems like Screamer could benefit from precise height knowledge for accurate timing of recovery parachute release. The precision height sensor, under development by Creare, Inc. of Hanover, NH, utilizes Sound Detection and Ranging (SODAR) and will provide <1 foot height--ground accuracy during the last 500+ feet of flight. SODAR was selected because of its ability to penetrate ground foliage, making the sensor useful over a broader range of terrain. This compact sensor unit will weigh less than 10 pounds and occupy less than 75 cubic inches. The unit cost will be less than $ 500. Several flight tests of this system have been conducted to date, and flight tests of the unit integrated with autonomous GN&C flight software should take place during FY06.

Another sensor technology of great interest to precision airdrop is remote wind sensing. The approach currently most favored uses light detection and ranging (LIDAR). With this technology, laser light is projected into the atmosphere and the returns from aerosols or molecules are detected and analyzed, primarily using Doppler techniques. Many government agencies are working in this area, including on-going efforts at NSC, SOCOM, Army Research Laboratory, Army Research Office, and NASA. Coordination of efforts among these activities has been going on since June 2005.

Two LIDAR strategies are being explored that are particularly useful for airdrop. The first would put a lidar wind sensor in the airdrop carrier aircraft, to measure the winds below and in the direction of the target point prior to the drop mission. This wind data would be assimilated into the airdrop mission planning process in a similar fashion as drop sonde data, described above. Sensors for this approach need to have ranges between six and ten kilometers. The approach would provide timelier and more accurate wind knowledge, improving landing accuracy for both ballistic and guided systems. A second strategy is to put a smaller, lower range lidar wind sensor on a guided airdrop system, to feed real-time “look-ahead” wind data to the autonomous flight software, again for the purpose of improving landing accuracy. Both strategies have been supported by Small Business Innovative Research (SBIR) contracts, and the results of the various efforts shared among all the agencies noted above.

In addition to cargo airdrop, the JPADS-MP has been extended for use by parachute jumpers. The Military Free Fall community has been developing (both through organic and contracted research projects) navigation aids for jumpers, that include a heads-up display of GPS position with steering queues based on wind prediction. Based on a new Unfunded Requirement (UFR) funded in late August 2005, a program has begun to provide PADS winds and full JPADS-MP planning to this display wirelessly, thus giving the jumpers greatly improved steering queues based on better winds data and improved system modeling.

All of the systems described here will result in less risk, more safety and improved mission success for our troops in the field.

X. Conclusions

Planned airdrops for the JPADS ACTD continue with the JPADS-MP linked to both of the 10Klb JPADS-L decelerator systems with emphasis on locking down on configurations, increasing reliability, and pushing for higher altitudes (up to 25KftMSL). An Early User Training (EUT) for the JPADS ACTD systems was conducted in September 2005. Three JMUAs are planned starting in December 2005 and concluding during the summer of CY06. The JPADS-L technologies are then expected to transition to PM-FSS under a formal program of record at the Milestone B level. A two year residual phase with remaining JPADS ACTD assets will be executed with support from DUSD AS&C during FY07 and FY08. Low Rate Initial Production will start in FY10 if the Systems Design and Development program is successful and meets all Key Performance Parameters during Operational Testing.

In July, 2005, the two 10Klb JPADS-L decelerator systems being developed were assessed in a "user prioritization" meeting, leading to the decision that Screamer will continue throughout the JPADS ACTD program. Thus, the September 2005 EUT was conducted with Screamer.

JPADS-MP is being matured and linked to many JPADS-XL systems and other airdrop applications concurrently. This paper provided a short overview of what an ACTD is and how they are assessed. It also provided the reader a draft CONOPS outlining the need and anticipated use of JPADS. In addition, the paper briefly reviewed on-going technology initiatives to improve landing accuracy of all airdrop systems.

The JPADS ACTD is the largest and highest priority US airdrop program supported by the Department of Defense to date. Airdrop investments are rapidly increasing within the US and Allied Nations. Various JPADS systems are in the process of being fielded under Urgent Operational Need Statements or UFRs for current operations. Concurrently, the JPADS-XL program prepares to become a formal program of record the early 2006.

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