Planning, Execution, and Results of the Precision Airdrop Technology Conference and Demonstration (2003)

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I. Introduction

During the week of 3-7 November 2003, the second Precision Airdrop Technology Conference and Demonstration (PATCAD) was executed at the US Army Yuma Proving Ground in Yuma Arizona. The PATCAD 2003 was facilitated by the US Army Natick Soldier Center (NSC) and partially sponsored by numerous other organizations to include: US Army PM-Force Sustainment Systems, US Air Force Air Mobility Command, US Special Operations Command (SOCOM), US Army Tactical UAV Office, Deputy Under Secretary for Defense for Advanced Systems and Concepts (DUSD-AS&C), Foreign Comparative Test Office, US Army Yuma Proving Ground (YPG), and ECIII.

Over 250 individuals attended the PATCAD 2003 from 10 Nations (Australia, Canada, France, Germany, Netherlands, Norway, Singapore, Sweden, United Kingdom, and the United States). During the PATCAD 2003 week, fourteen companies presented briefings on their current systems/technologies that emphasized their capabilities as well as future plans and improvements. The companies that were demonstrating during the week were able to explain what would be seen during the drops of their systems. Thirteen different precision airdrop systems were live demonstrated at or near the La Posa Drop Zone at YPG. The systems demonstrated ranged in maturity from new prototype systems, having their first autonomous drops at PATCAD 2003, to relatively mature systems which have hundreds of drops and are already in operational use in some countries. PATCAD is not to be viewed as a competition as the systems demonstrated have a wide range of Technology Readiness Levels (TRLs).

Nearly 50 total airdrops were conducted over the course of the event. The systems demonstrated included the following, listed by manufacturer/developer: MMIST: Sherpa, Snowgoose and Snowbird; Planning Systems, Inc. and Draper Labs: Precision Airdrop System (PADS); Strong Enterprises: SCREAMER, Powered Airborne ATV and 4-passenger Trailer; Para-Flite: 5Klb large parafoil (uncontrolled); Dutch Space: SPADES; Vertigo Inc.: AGAS; EADS: Para-Finder (personnel Navigation Aid); Stara Technologies: Generic Delivery System, currently know known as GNAT; Atair Aerospace: ONYX; NASA and Pioneer Aerospace: 4200 sq. ft. autonomous parafoil system.

Many people and organizations contributed funding, test assets, and test execution expertise to make PATCAD 2003 a success. Contractors and government personnel both spent countless hours during the planning and execution of the event.

PATCAD 2003 was the second formal event bearing its name. The motivation behind NSC sponsoring and facilitating PATCADs is to bring the international community together not only to witness and discuss a range of

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state-of-the-art precision airdrop systems, but to encourage continuous communication/collaboration between governments and militaries, identify common requirements, and discuss future plans, programs, and needs.

This paper will describe in detail the rationale, timing, and planning required to execute a PATCAD, provide an overview of the program and systems demonstrated and displayed, and describe the results of the event. In addition, related future events that are being planned at the time of this paper submission, specifically PATCAD 2005 and NATO related efforts, will be presented. It will also describe the safety aspects and technical considerations for executing a PATCAD and the airdrop logistics and lessons learned from this and related events.

II. Planning

When planning a PATCAD there are two main areas to address, the administrative aspects and the technical aspects. The administrative planning includes all of the logistics of registration and payments, accommodation and meals, and other areas. The technical aspects are those that involve coordinating the airdrops themselves, including rigging of the systems, scheduling of the aircrafts, safety, and other issues. More detail on the planning for each of these areas is given below.

A. Administrative

The administrative planning for a PATCAD begins at least nine months prior to the event. First, the dates must be chosen based on the historical weather for the area and aircraft availability. Rain would ruin the demonstration days of the event so it is prudent to schedule it during the most historically dry time of year. Once the dates have been established, an announcement and invitation must be sent to the airdrop community so they can mark the date and schedule their time and possible trip. A list of nearly all government personnel, both U.S. and foreign, with interest in precision airdrop is collated and an email sent. Once the announcement of the event is sent, lodging in the area must be determined. The planning team contacts local hotels to negotiate renting every room available at the government rate. A caterer or team of caterers is contacted and prices negotiated for meals for all of the conference attendees. Meals will be needed at different locations through the week, either on the drop zone, at a hotel, or at the conference location.

A communications plan is established before the event. PATCAD organizers make sure that internet access and commercial and DSN phone lines are going to be available to attendees. The conference administrators make sure that they will have radio or cell phone communication between themselves for any last minute organization or needs. An emergency plan is also established. The base and local emergency services are alerted to the large number of attendees expected in the area, and emergency numbers are kept on hand. A helicopter is put on alert or stand-by in the case that someone has to be evacuated from the remote drop zone.

Entertainment was booked for two evenings during the week. Local singers and dancers performed both at an evening reception and at the final banquet dinner.

A website was designed, built, and maintained to allow attendees easy on-line registration, access to information regarding schedule, systems being dropped, lodging information, and more. After the event, photographs and video from the week were posted, along with results from the many airdrops executed. Wind information was also provided for a Four-Powers Long Term Technology Project weather assessment being conducted by scientists from France, Germany, the U.K. and U.S.[1,2]

As with any government sponsored event involving military VIPs, proper protocol was followed. Administrators made sure that the appropriate transportation and amenities were made available to all visiting VIPs.

The local and national media were informed of the event and invited to attend a day of drops on the range. They conducted interviews with attendees and organizers, and shot video of some of the proceedings.

B. Technical

Test planning for an event such as PATCAD 2003 began as early as six months prior to the demonstration to ensure each systems individual hazards were evaluated and mitigated through the implementation of operating procedures which would ensure safe execution of the demonstration. US Army Regulation AR 385-16 requires that hazards in Army systems be identified, assessed and risks associated with these hazards properly managed while executing a test event. This step is critical to the safe execution of any test event, no matter how small, even when executed in the vast range spaces Yuma Proving Ground (YPG) offers.

System Safety engineers began by evaluating the different technologies being demonstrated during the event and addressed the specific hazards presented by each technology. In general these can be broken down to three major categories; System Specific, Ballistic Malfunction, and System Drift Hazards.

System Specific Hazards are those unique to the system under test. If the system employs methods such as; computer pre-mission planning, system initialization and verification prior to exit, pyrotechnic cutters, pneumatic actuators, or unique human factors interfaces; these items must be evaluated to determine what unique procedures will be put in place to maximize the probability of mission success. It is also essential that they are properly documented, trained, and executed prior to deploying the system on the test range. These hazards and risk mitigating procedures are developed jointly by the product developer, the manufacturer, and the test range safety personnel.

Hazards associated with the ballistic malfunction of parachute systems are various and apparent to those who have been involved with the test and evaluation of new airdrop technologies for any period of time. Many aspects of the airdrop environment simply cannot be evaluated in a lab environment or by modeling, so development engineers simply rely on the randomness of the airdrop environment from high performance aircraft to assess system performance. Unfortunately in doing so, they risk total malfunction of the recovery system, which presents hazards of a single large bundle free-falling to impact, or quite possible a total destruction of the bundle at high altitude, which results in many smaller pieces of the item being dispersed over the drop zone. In both cases, the results could be catastrophic if personnel are located in the ballistic surface danger zone. The spread of material during a catastrophic event is largely dependent on what the payload and drop altitude are, but in the case of PATCAD 2003 it could generally be characterized by Eq. (1) and is depicted in Figure 1:

$$y = \begin{cases} \sqrt{600^2 * \left(1 - \frac{(x-1000)^2}{1000^2}\right)} & 0 \le x \le 1000 \\ \pm 600 & 1000 \le x \le 2000 \end{cases} \tag{1}$$

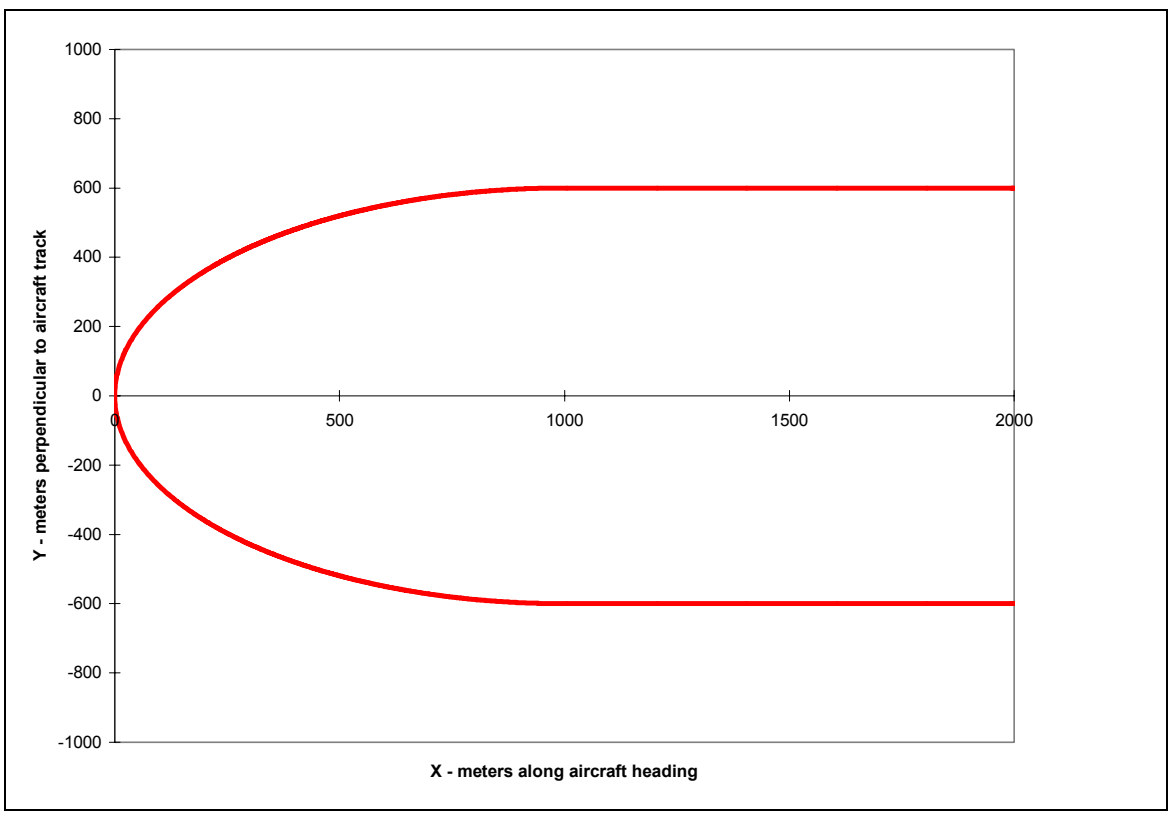

Figure 1. PATCAD Ballistic Fan

This ballistic safety fan is the union of an ellipse and a rectangle, whose major axis (x-axis) is defined as the flight path of the deployment aircraft at the time of exit, and x / y coordinates are expressed in meters. It is always critical to ensure that no personnel or critical equipment are located within the ballistic safety fan.

The third sets of hazards typically assessed are those which could occur with a system under a fully inflated recovery parachute. Personnel and equipment may be authorized into this safety fan, but only if they maintain positive communications with the primary range safety officer during the event. Range safety engineers identify the risks presented by a myriad of system configurations which may include: high-glide systems, low-glide systems, guided-systems, systems which may or may not include a certified Flight Termination System (FTS), etc. All of the various system configurations present unique safety concerns. In the general case of a gliding parachute, the surface danger fan can be generalized by an ellipse whose major axis (x-axis) is defined along the mean effective wind from the drop altitude. Eq. 2 generalizes the equation for the Surface Danger Fan while under a recovery parachute, for most conditions.

$$y = \sqrt{b^2\left[1 - \frac{x^2}{a^2}\right]} \quad -a \le x \le a \tag{2}$$

$$a = \frac{5}{4}(G_r * H_{rp} + T * \overline{W})$$

$$b = \frac{5}{4} G_r * H_{rp}$$

Where:

$$G_r = Glide_Ratio$$

$$H_{rp}(m) = \mathrm{Re}lease_Altitude$$

$$\overline{W}(m/s) = Mean_Effective_Winds$$

$$T = Time_of_Flight = \frac{H_{rp}}{V_z}$$

Where V_z is defined as the steady state vertical velocity of the system. The release point for the drop is offset up-wind by a distance h, where $h = T * \overline{W}$. For evaluation purposes, let's consider a high-glide parafoil with autonomous guidance onboard. For a general case where winds are from a heading of 270°, the surface danger zone is depicted in Figure 2.

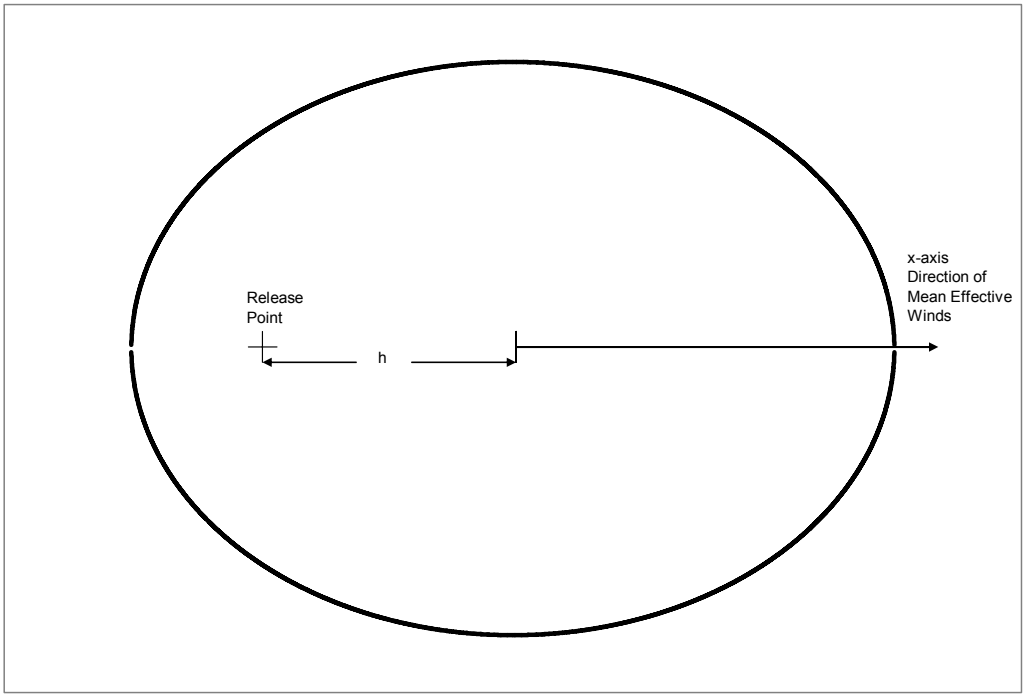

Figure 2. Surface Danger Fan

The primary goal of the range safety engineers is to ensure the general public is not exposed to hazards which could injure them or damage any equipment. In the test case considered, the maximum glide of the parafoil must be considered under the winds it will experience during the drop, and the release point offset such that if it were to be deployed and the guidance system immediately failed, it would remain on the test range. In the case of PATCAD 2003, La Posa DZ at YPG was utilized. Its eastern most edge was only 1,000 meters from the boundary of the test range, but 3,000 meters from Arizona Highway 95. For this reason, airdrop altitudes were limited for some high-glide systems. Winds were measured at 2 hour increments throughout the PATCAD event to continually monitor the risks due to changing weather conditions. Additionally, the high-glide systems were rigged with a single control input to ensure the system would enter a spiral should the guidance unit fail, minimizing the ground track of the system. Most autonomous systems tested during PATCAD 2003 employed a ground based steering override capability which further enhanced the safety of the event. A sample ballistic safety fan and surface danger zone are depicted in Figure 3 for a high-glide parachute which was released from a heading of 045° true, in which the mean effective winds were from 270° true.

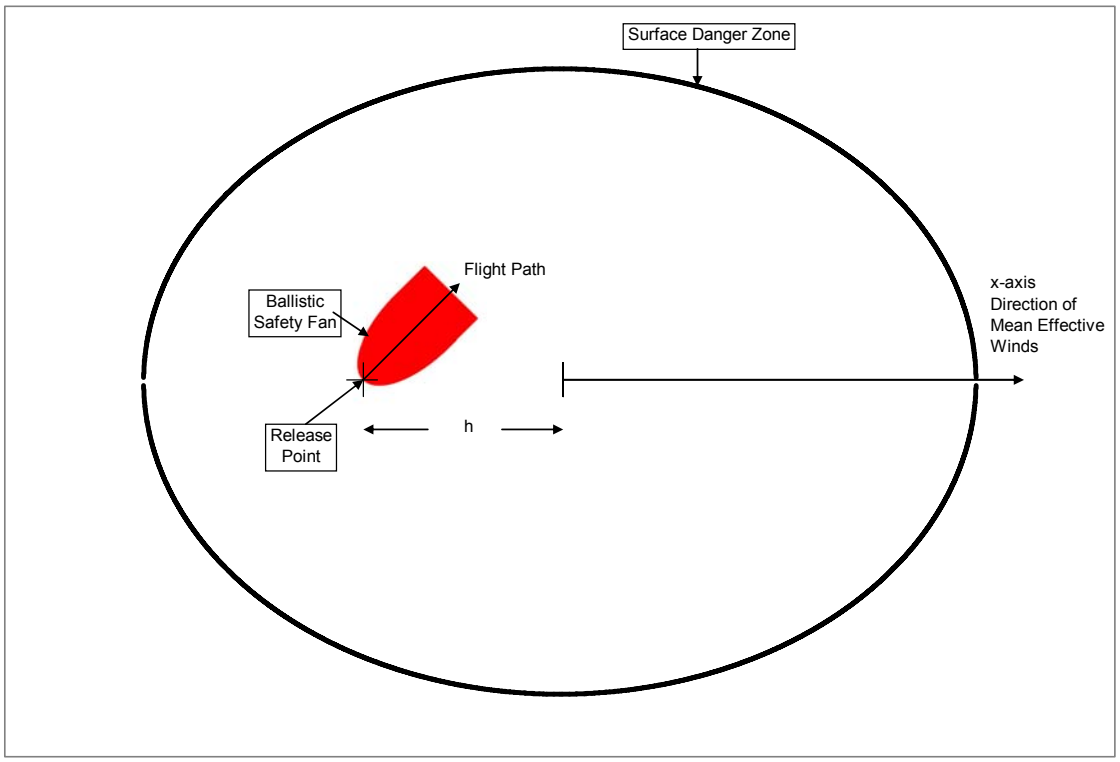

Figure 3. Sample PATCAD Fan

This safety fan was overlaid on range maps to ensure the intended release point did not place any of the visitors in harms way. If it did, the intended release point and subsequent impact point were modified to keep the personnel on the DZ in a safe area.

It is important for all who consider executing any test event, no matter how small, to analyze the inherent risks associated with the individual systems under test. While all risks can never be eliminated, they can typically be mitigated to the point where the residual risk is acceptable to the approving authority as defined by AR 385-16. Test ranges are accustomed to assessing system hazards and can help provide safety oversight, but as in an event as complex as PATCAD 2003, time is critical and pre-planning is required. Assessing safety as an after-thought is not the way to ensure public safety.

Another important technical consideration is the deconfliction of frequencies. Each guided system that was demonstrated operated on a system-specific frequency. When planning the order in which the systems would be dropped, each system's frequency had to be taken into account. Some systems operated on the same, or close to the same frequencies of other systems. These systems were separated with at least one drop in between them, to allow time for the system to land and stop transmitting before another was deployed. Other programs being tested in the area must also be queried to ensure that they are not using any test equipment on a frequency that would interfere.

III. Schedule

The availability of the conference center and the limitations on air crew and aircraft flight time were the two most significant factors when preparing the schedule for the weeks events. The Sunday evening before the week began was dedicated to registration and check in. Participants registered and paid via the website before arriving in Yuma and checked in to receive a badge and other conference materials.

Monday was dedicated to government and contractor briefings. Government briefings were on the overall status of precision airdrop, including a brief history, our current capabilities, and the road ahead. They also offered information on the Yuma Test Center's capabilities for hosting and executing airdrop tests. Contractor briefings gave the audience an overview of what specific technology they were working on, its capabilities and utility. This

gave attendees an idea of what was new in precision airdrop, as well as a preview of what they would be seeing during the live demonstrations later in the week.

Tuesday included morning live demonstrations on the test range, and an afternoon of additional contractor briefings. The live demonstrations included a ground launch of a powered parafoil UAV, and airdrops of numerous guided systems from an altitude of 10,000 ft. Briefings held in the afternoon were from those contractors who hadn't yet briefed nor demonstrated.

Wednesday included a morning of live demonstrations back at the range and an afternoon of contractor static displays. Contractors were given space in a hanger to display their systems and related printed material. They were given the opportunity to speak one on one with all of the attendees and to discuss other programs that their company may have been working on. Some of the contractors at PATCAD were working on other airdrop technologies from those which they were invited to demonstrate. This forum allowed them to showcase some of their other work and to entertain questions.

Thursday was designated as VIP day. Every system invited to PATCAD was live demonstrated on the range. All attendees spent the day on the range and a separate area was set up for the VIPs. They were given the opportunity to ask questions of any government or contractor personnel. The day was designed to allow VIPs with busy schedules to attend the PATCAD for one day and get maximum exposure to all of the systems and players.

Friday was reserved as a back-up day in case bad weather caused a delay or cancellation of any of the other days. We did not have any weather related delays during PATCAD 2003, so the back-up day was not needed. A static line jump opportunity was offered to all military and civilians attendees on active jump status.

IV. Systems and Results

Overall, thirteen different precision airdrop systems were live demonstrated at PATCAD. Below is a short description of each of the systems and the results of their drops from the week. A results table is shown to summarize all of the drops performed during the week. This information was relevant at the time of the PATCAD 2003. Many of the contractors have updated/improved their systems since the time of the event and many of the systems' performance and accuracies have improved.

A. MMIST Snowgoose

The MMIST Snowgoose[3] is an Unmanned Aerial Vehicle that uses a 115 HP Rotax-914 engine and a 500 sq. ft. canopy (725 sq.ft canopy for air launch) for powered flight. The system can be airdropped from a cargo plane or ground-launched off the back of a High Mobility Multi-Wheeled Vehicle (HMMWV). The Snowgoose features six cargo bays that can be used to carry various combinations of modular fuel bins and custom payloads with a total cargo weight of 600 lbs. Each cargo bay can be individually opened at specified points during flight to release the payloads. The maximum flight altitude is 18,000 ft. MSL. The snowgoose can be programmed pre-flight to provide fully autonomous waypoint-to-waypoint flight control, payload release, and autonomous landing. Ground control can override an autonomous flight via RF modem or also via Satellite modem (Iridium). Some applications of the system are precision cargo delivery, communications and remote sensing, and leaflet disbursement. Custom payloads for the Snowgoose include a Meteorological Sensor suite, Drop-sonde Dispenser Payload, a Comm-Relay package, an optical payload, a sensor monitoring, control, and logging module, and wireless Ethernet.

The participants at PATCAD witnessed two ground launches of the Snowgoose from the back of a HMMWV. The launches and post-mission landings were executed at the C-17 strip next to the La Posa DZ. During the two missions, the snowgoose demonstrated its ability to collect wind data, dispense leaflets, and drop cargo. The system was launched and climbed to altitude and dispensed an A-sonde and two TDrop-sondes, which transmitted weather data to a PADS ground station, to a nearby airborne aircraft, and back to the Snowgoose itself. PADS was able to use this wind data to assist in the mission planning of other drops later in the day. The A-sonde release was executed through the Iridium Satellite Modem link. A-sondes and TDrops are both used for wind sensing; TDrops have Meteorological (PTH) sensors and A-sondes are the wind collection devices currently used by PADS.

Two leaflet drops were executed during the week. About 30 lbs of leaflets were dropped each time from an altitude of 1000ft AGL. The target areas were both one sq. kilometer in area.

Two re-supply cargo bundles were dropped from the snowgoose during the week. One re-supply drop was unsuccessful due to a bin jam. The door of the bin did not open correctly and the cargo could not drop out. The second re-supply drop was executed from 1000ft AGL and was 400m off target. After completing the missions, the snowgoose flew back to the C-17 strip where its landings were under radio control.

B. Precision Airdrop System (PADS)

The precision aerial delivery system (PADS)[4,5] is a ground mission planning and airborne mission execution support system for high-altitude airdrops from U.S. Air Force C-130 and C-17 aircraft. PADS assimilates high-resolution four-dimensional (4D) forecast weather fields from the Air Force Weather Agency (AFWA), high-resolution topographic data from the National Imagery and Mapping Agency (NIMA), and wind data measured in near-real-time with an A-sonde to produce a three-dimensional (3D) wind, pressure and density field for a given DZ at the planned drop time. Ballistic payload release and descent trajectory models use the 3D field to determine the Computed Air Release Point (CARP). The CARP is the optimal time and space range in which to release a load with the highest probability that it will land at its intended impact point. This computation takes into account the planned aircraft airspeed, course, and altitude at release for the payload to reach its intended impact point. The entire process is accomplished prior to flight on the ground and is then updated in the aircraft using a laptop computer that has been ruggedized for low-pressure operations at altitude.

During PATCAD, ballistic High Velocity Container Delivery Systems (HVCDS) bundles were programmed before take off, using downloaded wind forecast models posted by the Air Force Weather Agency (AFWA). During the mission, the aircraft made a pass over the DZ and two A-sondes were released out the side door, one transmitted wind data to the airborne PADS system and the second sent data to the ground PADS in the visitor area. The airborne PADS successfully received the wind data, assimilated it with the AFWA forecast winds, and recalculated a CARP for the ballistic loads. The aircraft circled and flew to the CARP and the bundles were released. It is theorized the aircraft was about 340 meters east of the intended CARP at payload release during the 04Nov drops resulting in the large miss of the target.

C. Sherpa

The Sherpa[6] is a Commercial Off the Shelf (COTS) cargo delivery system manufactured by MMIST of Canada. The system consists of a ram-air canopy, a parachute control unit, and a remote control. It is currently capable of delivering between 250 and 1200 lbs of payload. Modifications are currently underway to increase the payload capacity to 2,000 lbs. The mission is planned before flight by entering the coordinates of the intended impact point, current available wind data, and payload characteristics. The system software uses the data to generate a mission file and calculate a Computed Aerial Release Point (CARP). Upon release from the aircraft the Sherpa flies autonomously toward the intended impact point.

During PATCAD processed wind data was transmitted to the four individual Sherpas using an PADS wireless Guided System Interface Unit (GSIU) attached to each Sherpa. On the ground before take-off, all four Sherpas were programmed to land at the same impact point by using the PADS wireless interface.

While the aircraft was inbound an officer in the spectator area selected new impact points for the four Sherpa payloads, simulating a changed ground combat environment as if the supplies were needed in a different location. The officer made the decision to change the impact points of two of the systems (#1 and #3). This change was sent to the PADS operator on board the aircraft via CTII text message. The changed impact points were uploaded to the AGUs of Sherpas #1 and #3 and all four Sherpas received an updated wind profile from PADS. The four Sherpas were dropped together at the calculated CARP. To ensure the systems did not collide during flight, the drogue times of the four systems were varied. Two of the systems did collide on exit during the first drop. The drogues of two systems entangled. This event helped highlight the need for a better deployment method of guided systems, which is currently underway.

D. Strong SCREAMER

The 10,000 lbs SCREAMER design is based on the 2,000 lbs SCREAMER concept developed by Strong Enterprises in 1999. The SCREAMER system utilizes a ram-air parachute as the drogue with typical wing loading in excess of 10:1 and flies at speeds capable of penetrating most upper level wind conditions. The SCREAMER Ram-air Drogue (RAD) is controlled either remotely from the ground or autonomously during the initial phase of flight by an onboard Airborne Guidance Control Unit (AGCU). It is guided to a point above the intended landing location at which time a pair of round cargo recovery parachutes is deployed. Forward speed is arrested and the payload is set down at 18-26 fps.

All 7 SCREAMER drops conducted at PATCAD had successful recoveries. The two outliers, the 10K the first 2K on 05Nov had rigging errors resulting in asymmetrical flight that could not be compensated for by the AGCU. The problem has since been addressed and corrected.

The SCREAMER 10K system is being further developed under the Joint Precision Airdrop System Advanced Concept Technology Development (JPADS ACTD) program.[7]

E. ParaFlite 5K Parafoil

The Para-Flite 5K Parafoil is an intermediate proof-of-concept prototype funded by the U.S. Army Natick Soldier Center in pursuit of the development of a 10,000 lb capable parafoil system. The program focused on the evaluation of low cost manufacturing techniques and slider-controlled deployment of a large parafoil. The system has been demonstrated, under remote control, at the objective payload weight of 5,000-lbs.

Due to range safety concerns at PATCAD the system was dropped uncontrolled from 6000ft MSL with a rigged weight of 5,000 lbs. The system was dropped twice during the week and for both tests a single U.S. Army standard 28 ft extraction parachute was used as a drogue to stabilize the system prior to main canopy deployment. Following the slider controlled deployment of the parafoil, the left deployment brake was released to put the system into a slow right hand turn. During both drops, the parafoil opened and flew successfully without damaging either the payload or the parachute.

Guidance, Navigation, and Control[8] have been added to this parafoil to create the Dragonfly system[9], which is being developed under the JPADS ACTD program.

F. Dutch Space SPADeS

Dutch Space of the Netherlands, in partnership with the National Aerospace Laboratory and parachute supplier, Aerazur of France, is developing a cargo delivery system utilizing a ram air parachute and Global Positioning System (GPS) to autonomously fly a payload of 50-500 lbs to an impact point. A prototype version of the Small Parafoil Autonomous Delivery System (SPADeS)[10] has already shown the delivery of payloads to pre-programmed locations with an accuracy of within 100 m.

The design of the prototype system is based on an existing Aerazur G9 parafoil in use for manned flight and commercial-off-the-shelf equipment. In a step-by-step flight test program, the procedure of parafoil deployment, the in-flight system characteristics, the remote control of the system via a radio link, and the performance of the auto pilot have all been tested and verified successfully. The Royal Netherlands Army supports the development of this system.

On the first day of drops (Drop #1 & #2) the wrong impact coordinates were provided to Dutch Space and programmed into the systems. The altitude of the target point was off by more than 45 meters, which led the system to believe it still had more time and altitude to get to the target. In addition, the second drop also had a problem with the safety pin. The safety pin on the SPADeS systems must be removed in order for the actuators to be activated. During this drop the pin was not removed effectively and the system went into "safety mode" and spiraled directly to the ground. Although there were some problems with the drops on the first day, the next four drops were very successful, and represent some of the most accurate data points collected for a precision system during the week.

G. Vertigo AGAS

The Vertigo Affordable Guided Airdrop System (AGAS)[11] uses electro-mechanical actuator systems that are positioned in-line between the parachute and the payload, and manipulate parachute riser quadrants to steer a payload. The four riser quadrants can be manipulated individually or in pairs, providing eight directions of control. The system requires an accurate profile of winds over the drop zone, which are loaded into the flight-control computer onboard the actuator system before the drop. Vertigo has developed a "WindPack" which is an under 10 lb ballistic load that transmits wind data via position to a ground station. The system steers to the wind profile, and through a combination of steering drive and prevailing winds, reaches the target coordinates.

Each day of PATCAD, windpacks were deployed over the center of the drop zone shortly before the AGAS drops. Upon deployment, the windpack began transmitting data to the mission computer, which was set up on the ground in the PATCAD spectator viewing area. The mission computer received and recorded latitude, longitude, and altitude information. Using this data, a unique wind profile was generated for each of the payloads to be deployed. Two payloads were dropped simultaneously on each pass. One had a 1600lb rigged weight and the other a 2100lb rigged weight.

H. MMIST Snowbird

The MMIST SnowBird is a dual purpose guided parachute delivery system capable of delivering 160 lbs. The SnowBird, based on the technology of the Sherpa, is designed to deliver either cargo or personnel from high altitudes and substantial lateral distances to a predetermined impact point on a drop zone. The system consists of a 150 ft^2 ram-air canopy, a parachute control unit, and a remote control. The parachute control unit incorporates impact point coordinates, payload, and wind data to formulate a flight path. The software used to formulate the flight path also calculates the Computed Aerial Release Point (CARP). Using the computer generated flight path, the system will fly to the intended impact point (IP) on the drop zone.

PATCAD was the first time that the Snowbird was dropped from military aircraft. Prior to the week, the system had only been dropped twice at low altitude and speed. Snowbird was successfully dropped three times during the week.

I. EADS Navigation Aid

EADS has changed the name of their navigation aid from the MuN-Sys to the ParaFinder. The ParaFinder is intended to provide an improved horizontal and vertical standoff capability for the high altitude Military Freefall paratrooper to reach a primary or alternate target in any environmental condition. The jumper wears the GPS with a Central Processing Unit (CPU) in a pocket of the parachute container, which is attached to a Heads Up Display (HUD). The HUD displays the paratrooper's current heading and the desired track, which is based on the mission plan, current altitude, and position. The HUD also shows recommended steering cues indicating which control line to pull in order to hit the intended impact point. The system is designed for use in situations where the paratrooper may have difficulty acquiring a visual sighting of the target. The restricted visibility may be due to inclement weather, thick ground cover, or night drops.

A paratrooper equipped with the EADS ParaFinder exited twice from a C-123 aircraft from 10,000 ft during the week. The jumper left the aircraft within the recommended release point area, and landed a few feet from the impact point by following the cues he was given on the display in his helmet.

J. Stara Technologies Generic Delivery System (GDS)

STARA's Generic Delivery System (GDS), currently known as the "gnat", an internally funded effort, utilized miniature guided parafoils from previous programs. The units presented at PATCAD were "simulated" GDS units similar in size and composed of electronic components borrowed from other previously made guidance units. Stara came to PATCAD to demonstrate the concept, not a particular system. The demonstrated unit was an integration of other projects and components put together in a short time and with no external funding. The GDS is designed for UAV deployment at moderately low speeds, not at the high speeds of AF aircraft.

The GDS Stara is currently working on is designed to be "generic" since they are frequently requested to develop guidance systems unique to specific sensors. The system currently in development will be capable of delivering payloads weighing between 2 and 20 pounds and above.

The first GDS unit deployed semi-properly and had minor damage, but still managed to land within 126 feet of the target. During descent of the first drop, the system passed through the center of the target circle several times, sometimes within a few feet. The other three GDS systems dropped were unable to get to the target because of damage suffered to the parachutes at deployment. Opening shock caused misalignment of the rigging resulting in erratic behavior of the system.

K. Atair Onyx

The ONYX-Light guided parachute system is designed to drop 75 lbs of payload or less. The development of the system was funded through a 2002 SBIR sponsored by Natick Soldier Center. It divides guidance and soft landing between two parachutes – a ram air for guidance and dumb round that is popped above the impact point for soft landing. Prior to PATCAD, the system had been dropped under remote control six times and autonomously twice at altitudes ranging from 2,000 to 12,000ft.

During the first drop, the turning rate was set at 7 degrees per second, which was much too slow and caused the system to lose accuracy in relation to the impact point. During the second drop the system experienced a line over malfunction that caused it to go into a spiral to the ground. Although the first drop experienced an error, the system

did function consistently with the guidance algorithm even though the turning rate was too low. The second system proved the capability of the emergency backup plan, which is to deploy the reserve.

L. NASA 4200 Sq Ft Parafoil[12]

The drop test objective was to demonstrate an autonomous flight using a guided parafoil system to deliver 10,000 lbs of useable payload.

The test article weight was 15,750 lb at extraction. The drop test payload consisted of a standard 20-foot Type V airdrop platform, a standard 12-foot weight tub, recovery parachutes, an instrumentation system, and a Guidance, Navigation, and Control (GN&C) system.

The recovery parachutes consist of a 60 ft ring-slot drogue parachute and a 4200 sq ft parafoil built by Pioneer Aerospace. The drogue has two stages of reefing (14 % and 42%). The drogue is cut away using standard strap cutters and deploys the parafoil. The 4200 sq ft parafoil has a 105.6 ft span, a 40.0 ft chord, and 27 cells, and is based upon the 7500 sq ft parafoil developed for NASA's X-38 program. The parafoil's Lift to Drag ratio (L/D) is about 3.5.

The NASA GN&C system was developed during NASA's X-38 program. Southwest Research Institute developed the avionics for the GN&C system, which consists of a flight computer, modems for uplink commands and downlink data, compass, winches, and laser altimeter. The winches are used to steer the parafoil and to perform the dynamic flare maneuver for a soft landing. The laser is used to initiate the flare. The GN&C software was originally provided by the European Space Agency and NASA modified the software as the result of the X-38 flight testing.

Mission planning to select the CARP coordinates was done using the GN&C mission planner and a footprint tool. These tools use winds aloft data obtained from balloons released at the drop site to select a release point that not only ensures that the load can reach the designated target point but also ensures that the released parachutes remain on the range. The target point, the winds aloft data and other mission characteristics data (such as flare time and flare stroke) are loaded into the flight computer prior to the aircraft's takeoff.

The system was dropped from a C-130 at 16,000 ft and landed approximately 206 feet from the target. As part of the demonstration, the parafoil was recovered without the assistance of a crane.

M. Strong AATV & Trailer

Strong Enterprises performed a demonstration at PATCAD of a manned Airborne All Terrain Vehicle (AATV)[13] designed to achieve sustained flight and a manned Airborne Trailer (ATR) capable of transporting up to four people. Strong Enterprises modified the AATV by incorporating a ROTAX 53 hp engine and propeller. The AATV was dropped from 10,000 ft AGL and descended at 70 mph under drogue until 6,000ft AGL, where the main parachute was activated. After a visual check of the fully deployed main parachute the pilot raised the retractable engine/propeller system into position and started the engine. When the engine is wide open, level flight is achieved. The engine was shut off for final descent and the AATV engine was started. Upon landing, the pilot released the main parachute, shifted into gear and drove away, within 2 seconds of touchdown. The total descent from 10,000 feet lasted over 15 minutes.

The ATR was dropped on the second pass of the C-123, with a pilot and two passengers. After normal drogue-fall the 1200 sq ft canopy opened and flew smoothly. Designed for precision aerial delivery missions of up to four personnel, or a combination of personnel and equipment, into a specific target area, the ATR is also used as a training vehicle. After flying to the target site and landing, the AATV and ATR pilots jettisoned the parachutes, the AATV was driven to the ATR and the ATR was hitched to the AATV and became a completely mobile, tactical transport unit, and ready for immediate action.

N. Overall Results

Below are three tables, each representing one day of drops during the week of PATCAD 2003. The system name and weight are given, as well as the weight of the bundle dropped. Which aircraft the system was dropped from is shown, as well as what altitude it was dropped from. The "Target IP" column represents which impact point on the drop zone that the system was programmed to land on. The "Impact Grid" is the latitude and longitude of the point where the bundle landed. "Distance to Target" shows how far the bundle landed (in meters) from the point it was programmed to land. Please note that the Paraflite 5K parafoil was not programmed to land at a particular point. The drop was intended to demonstrate the capabilities of the canopy and not guidance characteristics. Also of note is that the Snowgoose is not shown on the drop list since it was ground launched for demonstration purposes.

Drop Time (Zulu)	System	Weight (lbs)	A/C	Drop Altitude (ft MSL)	Target IP	Impact Grid WGS84 LAT/LONG hddd mm ss.s	Distance to Target (m)
16:08:56	ASONDE #1	1.6	C130	10000	Primary	N033 22 00.6 W114 16 42.8	417
	ASONDE #2					N033 22 09.7 W114 16 42.6	306
16:28:03	PADS 26' RS #1	1600	C130	10000	Primary	N033 22 05.6 W114 16 21.4	271
	PADS 26' RS #2	1600				N033 22 10.4 W114 16 18.3	323
16:45:38	Sherpa #1	900	C130	10000	PI #4	N033 22 09.7 W144 16 24.1	120
	Sherpa #2	900			Primary	N033 22 36.0 W114 16 06.8	291
	Sherpa #3	900			PI #4	N033 22 00.1 W114 16 26.6	796
	Sherpa #4	900			Primary	N033 22 09.7 W114 16 30.2	99
17:05:46	SPADES #1	320	C130	10000	Primary	N033 22 00.0 W114 16 20.9	393
17:16:13	Vertigo Windpack	10	C130	10000	Primary	N033 22 23.0 W114 16 46.5	579
17:37:51	SPADES #2	320	C130	10000	Primary	N033 23 54.8 W114 18 21.2	4323
18:07:10	SnowBird	160	C130	6000	Secondary	-	-
18:55:52	2K Screamer	2000	C123	10000	Primary	N033 21 44.7 W114 16 45.4	856
19:06:28	2K Screamer	2000	C123	10000	Primary	N033 22 10.7 W114 16 23.9	181
19:18:54	5k Paraflite	5000	C123	6000	Secondary	N033 21 57.3 W114 15 49.8	N/A
19:39:23	Vertigo Windpack	10	C130	10000	Primary	N033 22 25.3 W114 16 35.1	499
19:50:46	AGAS #1	1300	C130	10000	Primary	N033 22 10.0 W114 16 31.4	20
	AGAS #2	1900				N033 22 09.2 W114 16 30.7	12

Table 1 – Results from 4 November Airdrops

Drop Time (Zulu)	System	Weight (lbs)	A/C	Drop Altitude (ft MSL)	Target IP	Impact Grid WGS84 LAT/LONG hddd mm ss.s	Distance to Target (m)
15:00:55	EADS MuN-Sys	-	C123	10000	Personnel	N033 21 42.9 W114 16 30.2	0
15:21:46	6K Screamer	6000	C123	10000	Secondary	N033 23 52.9 W114 16 24.6	2280
15:42:48	2K Screamer	2000	C123	10000	Secondary	N033 23 41.6 W114 16 25.5	1930
15:54:07	2K Screamer	2000	C123	10000	Secondary	N033 22 41.5 W114 16 35.3	304
16:04:34	Stara GDS #1	4	C123	10000	Primary	N033 22 08.1 W114 16 31.3	49
	Stara GDS #2					N033 22 05.6 W114 16 05.0	678
16:27:10	Vertigo Windpack	8	C17	10000	Primary	-	-
16:36:42	Atair ONYX	75	C17	10000	Primary	N033 22 49.1 W114 16 56.7	1393
16:48:50	AGAS #1	1300	C17	10000	Primary	N033 22 10.0 W114 16 31.4	20
	AGAS #2	1900				N033 22 07.8 W114 16 31.6	60
17:00:54	SPADES #1	400	C17	10000	Primary	N033 22 09.4 W114 16 30.2	16
17:19:34	SPADES #2	400	C17	10000	Primary	N033 22 09.4 W114 16 29.6	31
17:36:51	SnowBird	160	C17	6000	Secondary	N033 22 39.6 W114 16 23.9	16

Table 2 – Results from 5 November Airdrops

Drop Time (Zulu)	System	Weight (lbs)	A/C	Drop Altitude (ft MSL)	Target IP	Impact Grid WGS84 LAT/LONG hddd mm ss.s	Distance to Target (m)
15:30:56	Strong AATV	-	C123	10000	ATV-IP	N033 22 04.3 W114 16 31.8	215
	Strong ATR					N033 21 59.3 W114 16 34.0	118
15:47:33	EADS MuN-Sys	-	C123	10000	Personnel	N033 21 42.9 W114 16 30.2	0
16:03:29	Stara GDS #1	4	C123	10000	Primary	N033 22 17.0 W114 17 00.8	807
	Stara GDS #2					N033 22 34.8 W114 16 18.3	844
16:31:03	ASONDE #1	1.6	C130	16000	Primary	-	-
16:51:11	NASA 4200 ft^2	15700	C130	16000	NASA IP	N033 23 20.6 W114 16 29.6	319
17:09:01	ASONDE #2	1.6	C130	16000	Primary	-	-
17:27:09	Atair ONYX	75	C130	10000	Primary	N033 20 50.5 W114 17 03.9	2590
19:37:56	ASONDE #3	1.6	C17	10000	Primary	N033 22 15.1 W114 16 45.5	416
19:52:58	PADS 26' RS #1	1600	C17	10000	Primary	N033 22 10.6 W114 16 31.4	35
	PADS 26' RS #2	1600				N33 22 12.2 W114 16 29.6	86
20:04:49	Sherpa #1	900	C17	10000	Primary	N033 22 08.8 W114 16 35.1	114
	Sherpa #2	900				N033 22 14.2 W114 16 29.8	143
	Sherpa #3	900				N033 22 18.1 W114 16 33.2	271
	Sherpa #4	900				N033 22 49.1 W114 17 36.4	2089
20:36:25	5K Paraflite	5000	C123	4500	Secondary	N033 24 40.0 W114 17 51.7	N/A
20:47:47	2K Screamer	2000	C123	10000	Secondary	N033 22 19.5 W114 16 43.1	782
20:58:26	2K Screamer	2000	C123	10000	Secondary	N033 22 42.3 W114 16 20.9	127
21:18:42	SnowBird	160	C130	6000	Secondary	N033 22 36.0 W114 16 28.7	155
21:28:20	Vertigo Windpack	8	C130	10000	Primary	N033 22 26.7 W114 16 26.0	542
21:40:36	AGAS #1	1300	C130	10000	Primary	N033 22 10.5 W114 16 29.2	49
	AGAS #2	1900				N033 22 10.6 W114 16 28.9	57
21:50:12	SPADES #1	400	C130	10000	Primary	N033 22 11.0 W114 16 32.0	53
22:07:20	SPADES #2	400	C130	10000	Primary	N033 22 09.5 W114 16 29.8	26

Table 3 – Results from 6 November Airdrops

V. Conclusions

The organizers and planners of PATCAD 2003 consider the event a success. The majority of participant's feedback also supports this conclusion. Both the administrative and technical portions of the event were executed as planned. Participants were able to be briefed on, and witness the latest in precision airdrop technology, as well as make important contacts within the airdrop community. Interest in precision airdrop around the globe has been increasing due to recent world events. The international interest and collaboration on precision airdrop is a testament to the importance of events like PATCAD. Precision Airdrop has recently received increased attention and prioritization within NATO. NATO requires the capability to deliver military personnel, equipment, supplies and weapons in all weather conditions, from both high and low altitudes.

A Defense Against Terrorism (DAT) prioritization list was agreed to by the NATO Conference of National Armaments Directors (CNAD). The CNAD tasked the NATO Air Force Armaments Group (NAFAG) to take the lead on meeting the DAT requirements. The NAFAG assigned this work to Air Group 5 which in turn established an ad-hoc Joint Precision Airdrop Capability Working Group (JPACWG) which was created in Sept 04, is chaired by Natick Soldier Center, and has a mandate expiring in June 2007.

The JPACWG will generate a matrix of current national precision airdrop systems and the associated mission areas they support. The matrix will be developed with input from the individual nations with the support of industry. It will also develop a precision airdrop technology roadmap with the support of Research Technology Office (RTO) and industry, a NATO Concept of Operations for airdrop, and a proposed NATO Standardization Agreements (STANAG) to support Alliance interoperability.

Another objective of the JPACWG is to support demonstrations to prove precision airdrop concepts and systems. These demonstrations will serve to expose senior NATO leaders/decision makers to emerging precision airdrop capabilities, foster joint NATO development on common precision airdrop programs, and promote additional coalition partnering, to name a few.

VI. Planning for PATCAD 2005

Planning for PATCAD 2005 is underway. The event will take place at the Yuma Proving Ground from 17-22 October 2005. The schedule for the week will be very similar to the layout of PATCAD 2003. NATO will be more involved in this year's event as a co-sponsor, and the week will feature airdrops out of both Belgium and German aircraft.

For more information about PATCAD 2005 and to register for the event, please contact any of the authors of this paper. Registration is limited to government and military personnel only, as well as the contractors who are demonstrating or invited.

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References

1. Bagdonovich B., Desabrais K., Benney R., Seeger M., Fossat F., Vallance M., Carlsson P., "Overview of the Precision Airdrop Improvement 4-Powers Long Term Technology Project," AIAA paper 2003-2102 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 20-23, 2003, Monterey, California, USA.

2. M. Seeger, H. Eulenbach, P. Carlsson, Y. Bury, C. Delwarde, R. Benney, "Four-Powers Long Term Technology Projects: Airflow Influence," AIAA paper 2005-1602 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, 2005, Munich, Germany.

3. W. Ricci, R Wolfe, S. McCann, R. Herres, "Wind Supported Air Delivery System", Proceedings of the Precision Airdrop Technology Conference and Demonstration, 3-6 November, 2003, Yuma, Arizona.

4. Philip Hattis, Kai Angermueller, Thomas Fill, Robert Wright, Richard Benney, David LeMoine, Dennis King, Jr., "In-Flight Precision Airdrop Planner Follow-On Development," *AIAA* paper presented at the Aerodynamic Decelerator Systems Conference, May 19-22, 2003, Monterey, California

5. R. Wright, R. Benney, J. McHugh, "Precision Airdrop System," AIAA paper 2005-1644 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, 2005, Munich, Germany.

6. S. Kaesemeyer, "Testing of Guided Parafoil Cargo Delivery Systems," AIAA paper 2005-1668 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, 2005, Munich, Germany

7. McGrath J., Strong T., Benney R., "Status of Development of an Autonomously Guided Precision Cargo Aerial Delivery System," AIAA paper presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, 2005, Munich, Germany.

8. Carter, D., George, S., Hattis, P., Singh, L., Tavan, S., "Autonomous Guidance, Navigation, and Control of Large Parafoils" AIAA paper 2005-1643 presented at the AIAA Aerodynamic Decelerator Systems Conference, Munich, Germany, May 22-26, 2005

9. J. Berland, S. George, "Development of a Low Cost 10,000 lb capacity Ram-Air Parachute," AIAA paper 2005-1626 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 23-26, 2005, Munich, Germany.

10. J. Wegereef, H. Jentink, "Parafoil Characterisation Tests with SPADES," AIAA paper 2005-1650 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, Munich, Germany.

11. B. Gilles, M. Hickey, W. Krainski, "Flight-Testing of a Low-Cost Precision Aerial Delivery System," AIAA paper 2005-1651 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, Munich, Germany.

12. J. Stein, C. Madsen, A. Strahan, "An Overview of the Army's Guided Parafoil System Derived from X-38 Experience," AIAA paper 2005-1652 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, 2005, Munich, Germany.

13. T. Strong, "Dispelling the Myths and Fears of Manned Vehicle Airdrops," AIAA paper 2005-1653 presented at the AIAA Aerodynamic Decelerator Systems Conference, May 22-26, Munich, Germany