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# QUALIFICATION OF THE GUIDED PARAFOIL AIR DELIVERY SYSTEM – LIGHT (GPADS-Light)

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## ABSTRACT

The Guided Parafoil Air Delivery System - Light (GPADS-Light) is a fully autonomous parafoil guidance system utilizing the military Global Positioning System (GPS) and a high performance 750 $ft^2$ parafoil for precise delivery of payloads to a predetermined target. GPADS-Light is the first Advanced Precision Air Delivery System (APADS) to be fielded to the U.S. Department of Defense. These systems were purchased by the U.S. Soldier Systems Command, Natick Research, Development and Engineering Center (Natick) from SSE Incorporated as part of the Warfighting Rapid Acquisition Program. This paper presents the results of the recent formal qualification by Natick of GPADS-Light, and describes Pioneer Aerospace Corporation's GS-750 parafoil, which employs a high-performance NASA LS(1)-0417 airfoil.

This parafoil generates total system glide ratios in excess of 4:1 in straight flight with 'real' payloads, providing total mission offset:altitude ratios of 3:1. GPADS-Light has a qualified delivery accuracy of 100 m circular error probable (CEP). GPADS-Light, and its commercial GPS equivalent, ORION™, have logged over 500 flights. The military system is qualified to deliver payloads in the range 700 to 1,100 lb, and has further demonstrated the ability to successfully deliver payloads up to 1,500 lb.

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## GPADS OVERVIEW

The Guided Parafoil Air Delivery System (GPADS) is the Natick's designation for a precision guided delivery system consisting of an autonomous Airborne Guidance Unit (AGU) and a family of high-glide ram-air parafoils. The AGU includes the Flight Management System (FMS). An on-board computer processes data received from a military GPS receiver as well as other sensors, and inputs the merged data to a guidance algorithm that generates commands to control the parafoil. The FMS flies the parafoil system to a soft, upwind landing at a pre-selected site.

GPADS-Light is the smallest of the three weight classes of GPADS. GPADS-Medium and GPADS-Heavy have been designed by Pioneer and SSE to deliver payloads over the range of 7,000 to 40,000 lb, on parafoils with wing areas of 3,600 to 7,350 $ft^2$. Payload weights ranging from 7,200 to 36,750 lb have been successfully demonstrated over the last three years. GPADS-Heavy is currently being adapted by NASA as the recovery system for the International Space Station X-38 Experimental Crew Return Vehicle.

## GPADS-LIGHT RAPID ACQUISITION

The U.S. Army Battle Labs have long been major proponents of the Advanced Precision Airborne Delivery Systems (APADS) concept. GPADS-Light is the first of these systems to be fielded to the U.S. Department of Defense (DoD). Natick's Mission Need Statement calls for GPADS-Light to rapidly and safely deliver warfighting essentials to support forced entry in order to sustain operations in non-permissive environments. GPADS-Light supports the need to precisely deliver critical items to combat forces on time and to multiple targets simultaneously, while avoiding the need for the delivery aircraft to approach the target. The system has been qualified to carry loads of 700 to 1,100 lb of usable payload from altitudes up to 25,000 ft above mean sea level (MSL) and from offset distances in excess of 20 km (12.4 mi) with an accuracy of 100 m (328 ft) CEP.

### GPADS-Light Applications

Natick and the U.S. Army Battle Labs expect GPADS-Light to fill a major role in precision airdrop, with missions including troop resupply, delivery of support bundles alongside airborne troops, cachet pre-positioning, weapons delivery (single weapons, palletized systems and dispensers), delivery of humanitarian relief supplies, and leafleting. The primary users of GPADS-Light consist of small, five-to-ten-man expeditionary units of Special Forces or Marines. GPADS-Light suits their operational needs from a number of strategic and tactical standpoints: reduced aircraft vulnerability due to standoff delivery, the ability to target multiple drop zone (DZ) delivery points from a single release point, smaller DZ requirements due to precision guidance capability, reduced load dispersion and reduced DZ assembly time, just-in-time resupply of rapidly moving combat forces, day/night operational capability, and extremely low RADAR signature.

### U.S. Army Acquisition Strategy

The GPADS-Light program is one of only two Warfighting Rapid Acquisition Programs (WRAPs) within the Department of the Army. WRAPs employ all the current DoD acquisition reforms in an effort to field new technology in under two years, instead of the four or more years that is typical of conventional acquisitions. Natick conducted a market survey to determine the level of APADS technology available from industry. Natick awarded a GPADS-Light contract on the basis of product viability and best value to the government. SSE had already developed the ORION Precision Guided Delivery System and had sold this commercially available system to the Australian government. Natick's market survey concluded that the ORION system, when integrated with the Precision Lightweight GPS Receiver (PLGR), would meet its mission needs. In October 1995, a contract for a WRAP was awarded to SSE for 10 GPADS-Light systems with options for an additional 95 systems.

## SYSTEM DESCRIPTION

GPADS-Light is comprised of an AGU, mission planning and simulation software, parachute system, payload, and associated payload rigging.

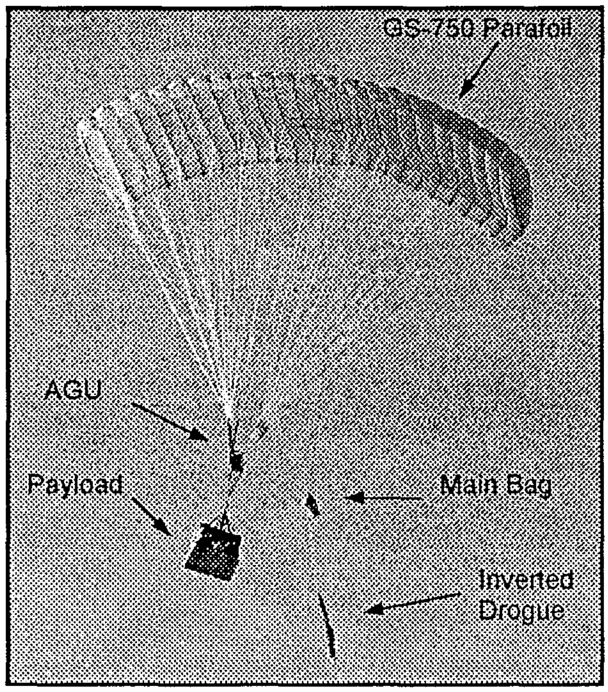


**Figure 1 GPADS-Light System in flight**

As shown in Figure 1, the four parafoil risers are attached to the top corners of the AGU and the payload is suspended from the AGU using a swivel harness assembly. This canopy/AGU/payload rigging scheme was developed by SSE to allow the system to interface with existing Army and Air Force payload hardware. The GPADS-Medium and -Heavy parafoils, on the other hand, are rigged directly to the payload with the AGU mounted on the aft deck of the coupled payload pallet. The GPADS-Light load is typically rigged as a stack, as shown in Figure 2, with the drogue parachute positioned atop or aside the main parafoil pack which sits on the AGU.

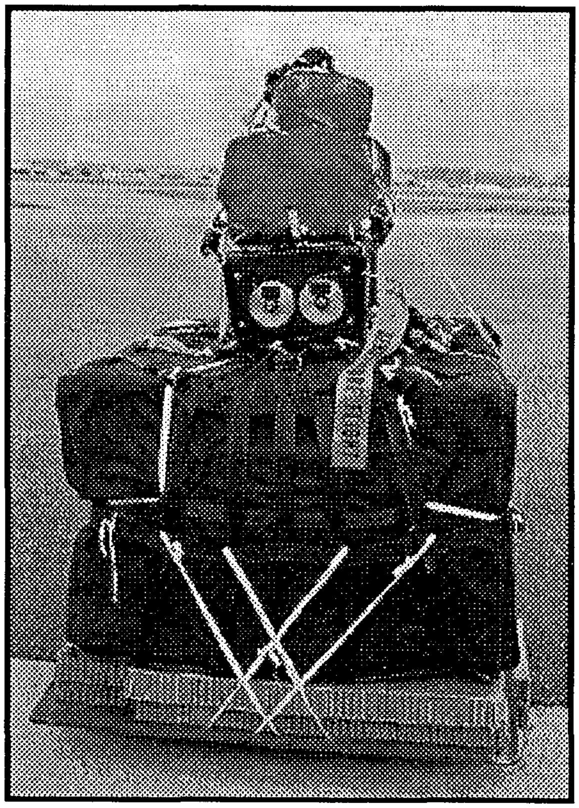

**Figure 2 Fully Rigged GPADS-Light and Payload**

The parafoil pack and AGU are tied down to the top of the payload. GPADS-Light is typically static line deployed as a ramp bundle. The system is compatible with a wide range of fixed and rotary wing aircraft and has been dropped by the military from CH-46, CH-47, CH-53, UH-1, and C-130 aircraft.

**AGU and Mission Planner**

A detailed description of the design of the original ORION AGU and the Mission Planner has previously been published by Allen[1]. The only practical difference between an ORION and GPADS-Light AGU is that GPADS-Light utilizes the military, P-code GPS system, whereas ORION was developed using commercial GPS. Other than a few enhancements, functionality is the same for both systems.

**Mission Planner**

The GPADS-Light Mission Planner allows the user to setup and simulate missions in order to produce a final, 'rugged' mission plan. Given target, payload, and predicted wind conditions, the Mission Planner will provide an optimum release point for maximum standoff at a user-defined release altitude (Figure 3).

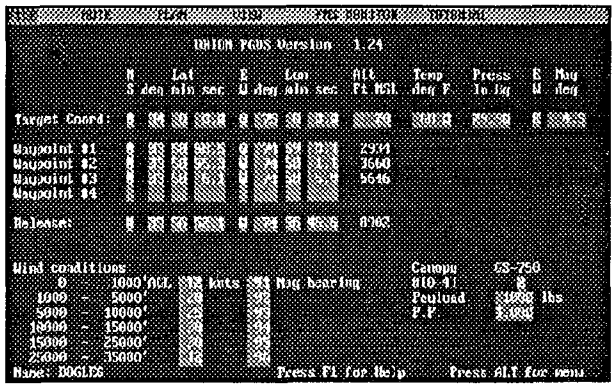

**Figure 3 Mission Planner Main Input Screen**

The simulator allows the user to investigate the effects of changing wind conditions and release point error on the success of the mission (Figure 4).

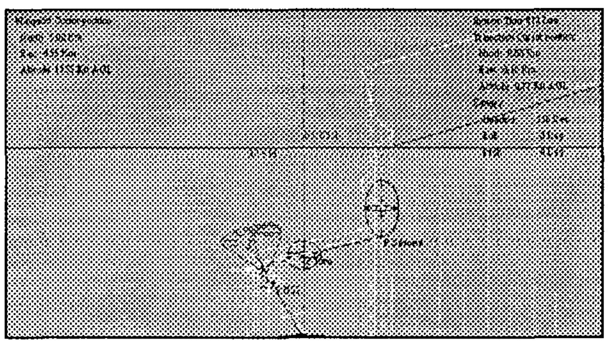

**Figure 4 Simulation Result Screen**

In this way, the user can determine a release point that will provide GPADS-Light with the maximum probability of mission success, given worst case conditions and restrictions.

**Airborne Guidance Unit**

The basic components of the GPADS-Light AGU are as follows:

- 80286 single board computer
- 80287 math co-processor
- PLGR military GPS receiver
- Barometric pressure sensor
- Fluxgate compass
- Servo actuators

The AGU computer components and flight control software comprise the Flight Management System (FMS). The AGU components are mounted in a waterproof, glass reinforced resin housing.

When powered up by removal of the "Hot Launch" pin, the FMS automatically conducts built-in-test (BIT), and signals a pass or fail condition by means of an LED. BIT includes verification that the PLGR has the correct 'key' and 'almanac' information to facilitate operation as a P-code (military) receiver.

After BIT, the FMS enters GPS acquisition mode. If the delivery aircraft is equipped with a GPS repeater, then the AGU will be able to be fully locked on prior to deployment. Anytime prior to deployment that the AGU is tracking GPS, the AGU indicates by LED whether the system is currently in or out of range of the target. When a GPS repeater is not present, the AGU is only able to acquire satellites after deployment from the aircraft.

When deployed from the aircraft, extraction of a deployment pin from the AGU by the main canopy bag signals the FMS to switch to tactical mode. The AGU controls the flight of the parafoil in the conventional manner, using the servo actuators to produce a mixture of differential and simultaneous deflection of the left and right trailing edges.

A GPS repeater was not used throughout the testing for qualification of GPADS-Light. Typical times to GPS tracking following deployment ranged from 30 to 250 seconds. During times when GPS tracking is not available, the AGU will 'dead reckon' the navigation of the mission based on compass and barometric pressure sensor data alone. The system assumes that the release point was correct, and that the wind profile is the same as that programmed into the AGU as part of the mission plan.

Once GPS tracking is established, the FMS accurately navigates the system through any programmed waypoints to the programmed target area, while determining and compensating for actual wind conditions in real-time. Upon reaching the target area, GPADS-Light maneuvers to lose excess altitude before the FMS controls the system through a final approach and soft, into-wind landing at the target coordinates.

**Parachute System**

The parachute system consists of a 13.13-ft nominal diameter radial cruciform drogue parachute and a 750 $ft^2$, 23-cell parafoil. The drogue pack is static-line rigged to the delivery aircraft (Figure 5).

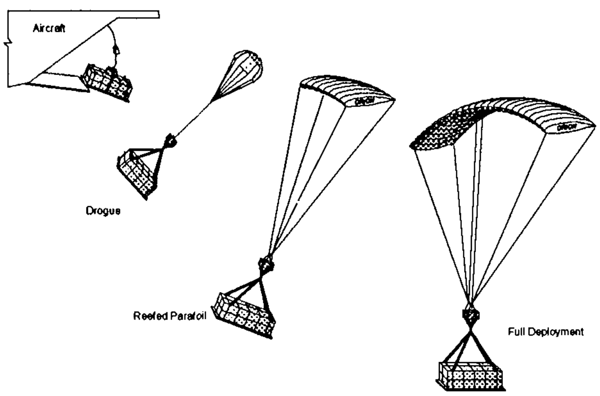


**Figure 5 Deployment Sequence**

The drogue riser assembly performs several deployment functions. First, as the load separates from the aircraft, a cut-knife attached by lanyard to the drogue riser cuts the webbing which holds the parafoil/AGU assembly down to the payload. This allows the swivel harness assembly, which attaches the payload to the AGU, to extend during drogue parachute deployment, rather than main canopy deployment. In this way, the peak snatch load on the system at swivel harness full-stretch is minimized. The drogue is then extracted and inflates.

The drogue riser attaches to a cut loop which ties the parafoil pack to the AGU. The cut loop is severed by a time-delay pyrotechnic cutter which is armed on release. Load is then transferred from the tie-down assembly to the parafoil deployment bag. The drogue then extracts the parafoil.

As the parafoil is stripped from its deployment bag, time-delay reefing cutters are armed. Once the parafoil canopy clears the bag, the bag and drogue riser are drawn over a drogue canopy pull-down line attached to a bridle on the upper surface of the parafoil and running through a channel in the drogue riser. The deployment bag, drogue riser and inverted drogue then remain attached to the system for the entire flight.

The parafoil is deployed in four stages, employing Pioneer's patented spanwise de-reefing technique[2] (Figure 6). In the first stage, the outermost cells of the canopy inflate while most of the parafoil's cells are closed by a series of lacing loops affixed to two of the parafoil keels. At a preset time, a cutter severs a locking knot, allowing the second stage of cells to deploy and inflate, revealing a smaller number of center cells still closed off.

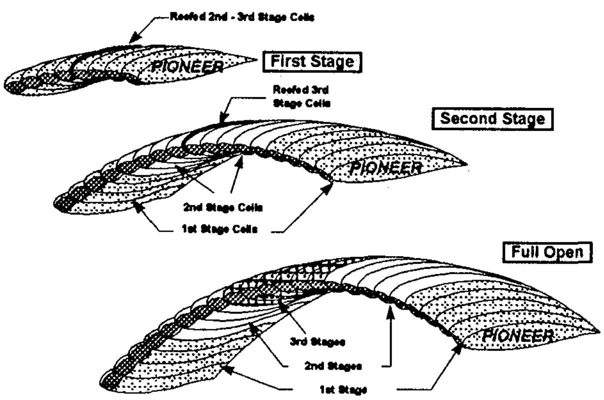


**Figure 6 Patented Parafoil De-Reefing Sequence**

Finally, a second cutter functions, allowing the center cells to deploy and inflate. A short time later, the FMS commands both control lines to retract, releasing pre-set trailing edge brakes. The parafoil is now fully inflated and flying.

The GS-750 flies operationally at wing loadings ranging from 1.16 to 2.23 lb/ft$^2$. At these wing loadings, GPADS-Light has a wind penetration of 22 to 30 knots.

**Payload**

The primary Army payload for GPADS-Light is a standard Container Delivery System (CDS) bundle. The CDS bundle is a 4 ft × 4 ft container incorporating a skidboard for interface to the aircraft, crushable honeycomb for impact attenuation, and an A-22 cargo sling for cargo containment and load suspension.

**GS-750 Parafoil**

The GPADS-Light main parachute is a 750 ft$^2$ parafoil designated the GS-750 by Pioneer. The GS-750 is unlike any other cargo parafoil in that it takes advantage of a thick supercritical airfoil section to achieve superior lift-to-drag performance. Theoretical and empirical studies by McGhee and Beasley[3] in the early 1970's showed that the subcritical characteristics of supercritical airfoil sections indicated performance increases over conventional airfoil sections. With an interest in developing high-performance wings for propeller-driven aircraft, they designed an airfoil shape which was 17 percent thick and had a blunt nose and a cusped lower surface. This airfoil, which they designated the GA(W)-1 for General Aviation (Whitcomb), had several key features including a large upper surface leading edge radius to attenuate peak negative pressure coefficients and delay stall onset at high angle-of-attack, and a contoured profile to provide approximate uniform chordwise load distribution.

The investigators' work continued throughout the '70's, and resulted in a family of low- and medium-speed airfoils based on the GA(W)-1[4]. In the process, they modified the 17-percent low-speed airfoil to reduce the pitching moment coefficient. This section is shown in Figure 7. By the end of the '70's the now-designated LS(1)-0417 airfoil was in use with the Beech Model 77 and Piper PA-38 Tomahawk aircraft.

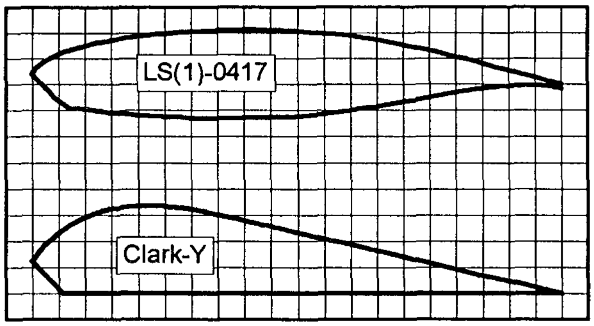


**Figure 7 LS(1) and Clark-Y Airfoils**

In 1990, Pioneer undertook the investigation of a parafoil constructed with the NASA LS(1)-0417 airfoil. ("LS(1)" indicates "low speed (first series)" while "0417" indicates an airfoil with a thickness of 17 percent chord and a design lift coefficient of 0.4.) As part of the Advanced Recovery Systems for Advanced Launch Vehicles program (NASA contract NAS8-36631, Phase 2), Pioneer tested two 1,200 $ft^2$ parafoils in the NASA Ames Research Center 80 ft × 120 ft test section of the National Full-scale Aerodynamic Complex[5]. The two models were identical in every respect except the airfoil. One model had a 17-percent thickness Clark-Y section and the other had the NASA LS(1)-0417 section (Figure 7). Both models had an aspect ratio of 3.0:1 and were constructed of zero-porosity coated Nylon. The two models were rigged with quadrifurcated Kevlar suspension lines. The ratio of line length to span was 1.0:1 for both models.

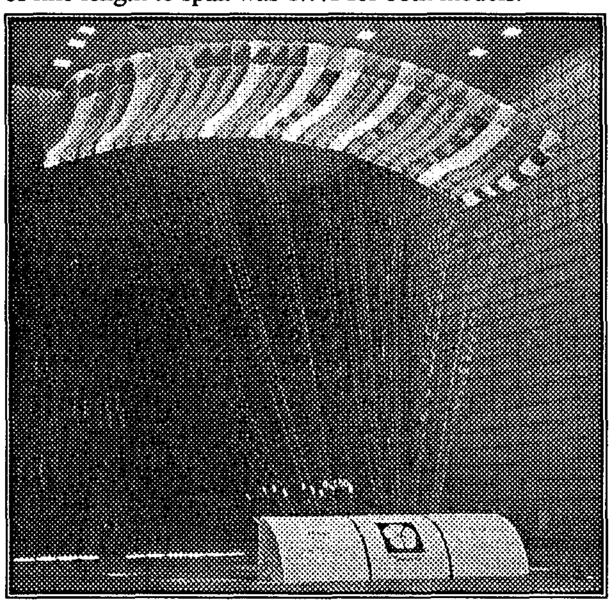

**Figure 8 Wind Tunnel Testing of LS(1) Parafoil**

The LS(1) model is shown flying in the wind tunnel in Figure 8. Six components of force were measured. Load cells were used to measure chordwise and spanwise loading as well as lateral forces.

Results of these tests indicated that at low-lift conditions, the LS(1) wing had approximately 7% higher lift-to-drag (L/D) than the Clark-Y wing. Maximum lift for the LS(1) was reduced, however, owing to the lack of forward camber. Still, results were encouraging and NASA Ames Research Center and Natick pursued experimental and theoretical evaluation of an LS(1) wing with a much reduced inlet.

NASA Ames and Natick tested a 45%-scale version of the Pioneer wing, also in the NASA Ames 80 ft × 120 ft wind tunnel[6]. Results of these tests show that a wing with a 4% inlet produces a 25% increase in maximum L/D over the 8.4%-inlet LS(1) wing tested by Pioneer. NASA Ames/Natick results for the LS(1) wing are shown alongside Pioneer's Clark-Y data in Figure 9. The LS(1) canopy maximum L/D of 5.1:1 is 16% higher than the maximum L/D of the Clark-Y. Based on these results, Pioneer set out to develop a functional LS(1) parafoil.

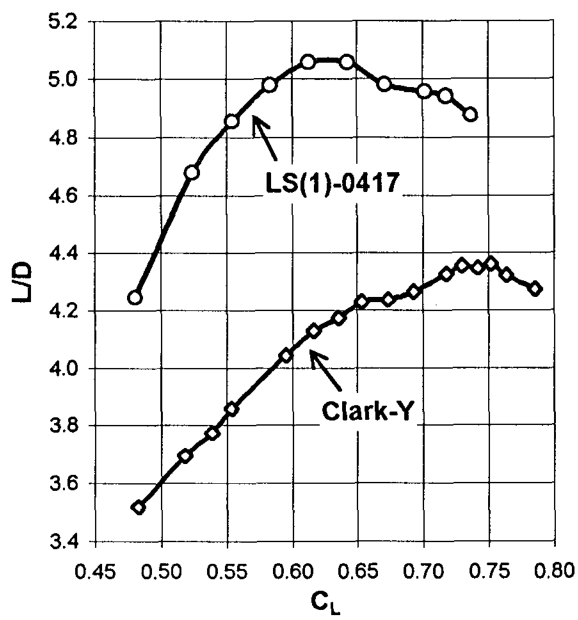


**Figure 9 L/D Performance of LS(1) vs Clarke-Y**

In setting design details, including aspect ratio, inlet design, rigging angle, number of cells, materials, cross-port venting, line length ratio, number of reefing stages, deployment brake setting and deployment staging timeline, Pioneer employed the standard design practices as ultimately published by Lingard[7] in 1995. In fact, features of the GS-750 were specifically included in the case study presented by Lingard in the section of the referenced design monograph entitled "Detail Design."

The final, qualified GPADS-Light parafoil is a 23-cell LS(1)-0417 canopy with a zero-porosity Nylon upper surface and low porosity (0-5 $ft^3/ft^2/min$ @ ½" water head) lower surface. The canopy has an aspect ratio of 3.0:1. Suspension lines are constructed of Spectra™ and have a line length-to-span ratio of 1.0:1.

Considerable attention was paid to other design details, notably tip droop and rigging angle. Proper tip droop is essential to ensure adequate inflation and control characteristics, especially given the lateral stability characteristics of this supercritical airfoil.

## SYSTEM PERFORMANCE

The first ORION Precision Guided Delivery System, flown in 1992, utilized a 375 $ft^2$ parafoil (modified forerunner of the MC-4 personnel canopy which is currently in use by the U.S. Army). In 1993, SSE transitioned to flight tests utilizing Pioneer's prototype GS-750 LS(1) parafoil to investigate the benefits of the high performance wing.

In the spring and summer of 1994, a U.S. Army Battlelab conducted a series of Battlelab Warfighting Experiments (BWEs) at Fort Bragg, NC, to determine the viability of ORION for the GPADS-Light mission. These tests allowed the government to provide feedback to SSE and Pioneer, resulting in product improvements based on user input.

The government was also able to test the ORION system in a more operationally representative scenario, providing the developers with useful experience. The contractor-funded development, along with the government funded evaluation of the commercially available ORION system, led to the 1995 award of the WRAP to SSE for the procurement of the first ten of up to 105 GPADS-Light systems.

### Pre-qualification

In September 1996, Natick conducted a series of ten pre-qualification flight tests. The tests were designed to validate the performance of the PLGR in the GPADS-Light application, and to confirm the deployment and flight characteristics of the upgraded GS-750 parafoil system. Minor modifications had been made to the parafoil brake release configuration since delivery of ORION systems to the Australian Army in October 1995.

Tests were conducted at the U.S. Army Yuma Proving Grounds (YPG), AZ. GPADS-Lights, rigged to standard CDS bundles weighing between 700 and 1,100 lb, were delivered singly from a C-130 Hercules flying at 130 KIAS at altitudes of 10,000 to 18,000 ft MSL from standoffs of 4 to 6 km. The tests confirmed the validity of the current design configuration and demonstrated a system accuracy of 90 m CEP. Seven of the ten units landed within 100 m of the target, while three of the units landed within 30 m (Table I).

Tests 1A through 5A were conducted in conditions where the actual winds were significantly different from the winds planned into the missions earlier in the day. Air space and safety-footprint considerations resulted in the release point being moved. The miss distances on Tests 2A and 5A were ascribed to the long lock-on times of the GPS receiver (253 and 162 seconds respectively) resulting in the systems dead reckoning from an assumed, but then obsolete release point. The extended lock-on times in both cases caused the systems to be unable to reach the target even after establishing full GPS guidance. The systems in Tests 1A, 3A, and 4A achieved GPS tracking fast enough to allow the systems to compensate sufficiently for the changed winds and release point.

The miss in Test 9A was attributed to an error in the rigging of the right winch control line which caused a severe built in right-hand turn for which the system could not fully compensate.

**Technical Type Qualification**

On the basis of pre-qualification test results, Natick elected to count these tests as part of the formal system evaluation, and to proceed directly to technical type qualification testing of GPADS-Light. Technical type qualification testing is the first of two steps leading to GPADS-Light Type Classification and issuance of a National Stock Number. The second step in the process is operator qualification in which the representative "user groups" demonstrate the ability to properly program, rig, deploy and maintain the system in an operationally representative setting, using real payloads.

Technical type qualification testing was conducted at YPG over a four-day period in October 1996. The U.S. Army conducted 28 tests in four separate missions. Payload weights ranged from 700 to 1,495 lb. Again, units were deployed from a C-130 Hercules flying at 130 KIAS. Release altitudes ranged from 18,000 to 25,000 ft MSL at standoffs from 7 to 21 km. Units were either deployed separately, or two at a time on a ten-second spacing.

Due to weather and air-space limitations, many of the releases were forced to be downwind and crosswind from the target. These tests clearly demonstrated the benefits of GPADS-Light over conventional, round parachute air delivery systems, showing that the user is not limited by the restriction of only releasing directly upwind of the intended target.

The results of these tests are summarized in Table I. Combined with the ten pre-qualification tests, 17 of 38 units landed within 100 m. Fifty percent of the units landed within 103 m. Skewing the results were four tests which flew improperly.

Analysis after Test 4 revealed a problem with that AGU's internal CPU clock. This caused an incorrect initialization of the GPS receiver, and thus prevented the PLGR from acquiring a fix. The system dead reckoned for the entire duration of the flight. The clock was reset, and appeared to then function correctly. Following a repeat of the problem with the same AGU on Test 16, it was confirmed that the clock failed to function reliably. The CPU was replaced, and the system was used on subsequent flights with no problems.

Two other units, Test 11 and Test 22, were viewed to spiral to the ground immediately after apparently good parafoil deployments. Close examination of the canopy brake release mechanism revealed an isolated problem.

A vinyl-coated steel cable affixed at one end to the parafoil aft riser assembly is used to secure the folded riser and set the brakes. During canopy rigging, this cable is inserted through an eyelet in the parafoil control winch line. On AGU-commanded brake release, the left and right control winch lines are hauled in simultaneously. Ordinarily, the winch lines pull the brake release cables out from their respective Nylon set loops, thereby releasing the brakes.

However, in tests 11 and 12, the highly loaded Nylon loop pinched the vinyl coating on the steel cable to such an extent that the cable could not be extracted by the winch line. Only one side of the canopy brakes was released, causing the parafoil to fly in a permanent tight spiral. Following technical type qualification testing, the flexible plastic-coated brake cable was replaced with a solid stainless steel pin. This design modification was subsequently demonstrated in operational flight tests with the U.S. Marine Corps. Partial brake release has never been observed since the introduction of this new brake release pin.

Based on these findings, at the time of the writing of this paper, the Army's Type Qualification Review Board is considering the exclusion of these four anomalous tests from the data base for the purpose of evaluating GPADS Light performance. Meanwhile, in November 1996, Natick publicly released the following qualification test results: "GPADS-Light has satisfactorily demonstrated the ability to deliver payloads weighing from 700 to 1,100 lb at release altitudes ranging from 10,000 to 25,000 ft MSL at offsets up to 21 km. GPADS-Light lands within 260 m of the target 94% of the time, within 150 m 71% of the time, within 100 m 50 % of the time, and within 55 m 21 % of the time."

**GPADS-Light System Accuracy**

Of the 38 drop tests conducted during technical qualification of GPADS-L, six were affected by circumstances, as described above, that were beyond the control of the FMS. The remaining 32 tests were considered to be those that represent the capable accuracy performance of GPADS-Light (Figure 10).

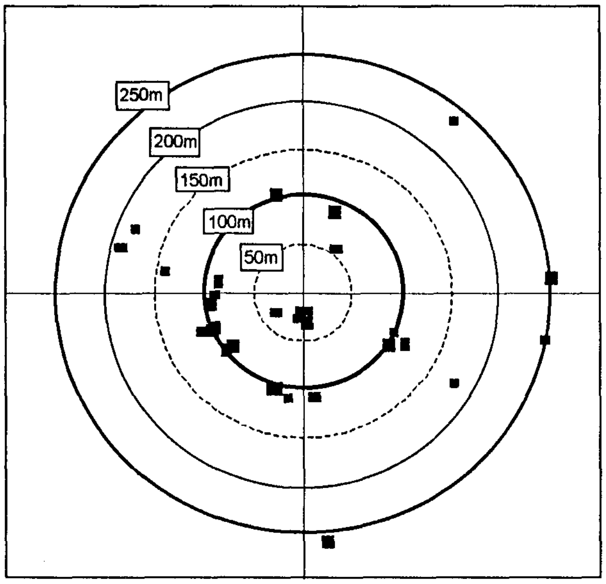


**Figure 10 Accuracy Results of GPADS-Light**

These results demonstrate the inherent accuracy performance of the GPADS-Light system. The distribution of these data is as shown in Table II.

| Distance from Target | Percent of Systems |
|---|---|
| 50m | 19% |
| 100m | 50% |
| 200m | 88% |
| 250m | 98% |

**Table II Landing Accuracy Distribution**

## OPERATOR QUALIFICATION

In December 1996, GPADS-Light contractors conducted a one-week formal rigging and mission planning training course for personnel from all four service branches. In January 1997, the U.S. Army Operational Test and Evaluation Command (OPTEC) commenced an independent series of operationally representative trials designed to demonstrate the ability of military personnel to adequately plan a mission, program the AGU, rig and deploy the unit, and recover, maintain and recycle the system. As of the end of January 1997, OPTEC had successfully conducted the first five trials. Natick anticipates completion of Operator Qualification testing in March or April 1997. Successful completion of operator qualification will lead to Type Classification of GPADS-Light.

## ADDITIONAL ACTIVITIES

In addition to formal qualification testing, GPADS-Light has been undergoing extensive evaluation by the U.S. Marine Corps 7th Landing Support Battalion. From October 1996 through February 1997, the Marines conducted over 30 tests of GPADS-Light. In March, they used GPADS-Light to resupply forward troops during the Hunter Warrior Advanced Warfighting Exercises at the Marine Corps Air Ground Combat Center, Twenty-Nine Palms, CA. The Marines have deployed GPADS-Light from a variety of aircraft including C-130, UH-1 Huey, CH-46 BullPhrog, CH-47 Chinook, and CH-53 Super Stallion.

## FUTURE DIRECTION

Natick and the GPADS-Light developers are evaluating expansion of the performance envelope as well as reduction in logistics burden. Activities include evaluation of the flight characteristics of a permanently reefed parafoil for lighter payloads, demonstration of flight characteristics at higher wing loading, and development of mechanical disreefing devices. Meanwhile, the government continues to pursue other system applications, including embassy compound resupply, aircraft decoys, marine mine emplacement, rocket thrust section recovery, sensor and munitions delivery, and leaflet delivery systems.

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| | | | Release Conditions | | | | Mean Wind | | Target | Accuracy | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test | Date | Payload Weight (lb) | Altitude (ft MSL) | Offset (km) | Range (deg) | Velocity (KIAS) | Magnitude (kt) | Bearing (deg) | Elevation (ft MSL) | Distance (m) | Bearing (deg) | Comment |
| 1A | 9/4/96 | 1,100 | 10,000 | 4 | 290 | 130 | 15 | 270 | 400 | 90 | 180 | |
| 2A | 9/4/96 | 1,100 | 10,000 | 4 | 290 | 130 | 15 | 270 | 400 | 580 | 300 | 250 s delay in GPS lock-on |
| 3A | 9/4/96 | 1,100 | 10,000 | 4 | 290 | 130 | 15 | 270 | 400 | 90 | 300 | |
| 4A | 9/4/96 | 700 | 10,000 | 4 | 290 | 130 | 15 | 270 | 400 | 100 | 310 | |
| 5A | 9/4/96 | 700 | 10,000 | 4 | 290 | 130 | 15 | 270 | 400 | 180 | 310 | |
| 6A | 9/6/96 | 1,087 | 18,000 | 6 | 170 | 130 | 14 | 80 | 400 | 20 | 330 | |
| 7A | 9/6/96 | 1,091 | 18,000 | 6 | 170 | 130 | 14 | 80 | 400 | 90 | 170 | |
| 8A | 9/6/96 | 1,075 | 18,000 | 6 | 170 | 130 | 14 | 80 | 400 | 30 | 160 | |
| 9A | 9/6/96 | n/a | 18,000 | 6 | 170 | 130 | 14 | 80 | 400 | 800 | 250 | Rigging error |
| 10A | 9/6/96 | 1,055 | 18,000 | 6 | 170 | 130 | 14 | 80 | 400 | 20 | 160 | |
| 1 | 10/7/96 | 1,087 | 18,000 | 8 | 290 | 130 | 12 | 80 | 1,090 | 30 | 135 | |
| 2 | 10/7/96 | 1,091 | 18,000 | 8 | 290 | 130 | 12 | 80 | 1,090 | 85 | 30 | |
| 3 | 10/7/96 | 1,075 | 18,000 | 8 | 290 | 130 | 12 | 80 | 1,090 | 35 | 180 | |
| 4 | 10/7/96 | 1,055 | 18,000 | 8 | 290 | 130 | 12 | 80 | 1,090 | 3,000 | 340 | No GPS lock-on |
| 5 | 10/7/96 | 1,060 | 25,000 | 11 | 290 | 130 | 12 | 80 | 1,090 | 28 | 85 | |
| 6 | 10/7/96 | 1,055 | 25,000 | 11 | 290 | 130 | 12 | 80 | 1,090 | 55 | 120 | |
| 7 | 10/7/96 | 1,066 | 25,000 | 11 | 290 | 130 | 12 | 80 | 1,090 | 250 | 140 | |
| 8 | 10/7/96 | 1,060 | 25,000 | 11 | 290 | 130 | 12 | 80 | 1,090 | 180 | 225 | |
| 9 | 10/7/96 | 1,097 | 25,000 | 11 | 290 | 130 | 12 | 80 | 1,090 | 260 | 135 | |
| 10 | 10/7/96 | 1,076 | 25,000 | 11 | 290 | 130 | 12 | 80 | 1,090 | 100 | 130 | |
| 11 | 10/8/96 | 1,070 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 5,000 | 200 | Incomplete brake release |
| 12 | 10/8/96 | 1,085 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 190 | 250 | |
| 13 | 10/8/96 | 1,068 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 140 | 30 | |
| 14 | 10/8/96 | 1,080 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 115 | 90 | |
| 15 | 10/8/96 | 1,081 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 108 | 135 | |
| 16 | 10/8/96 | 1,055 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 10,000 | 45 | No GPS lock-on |
| 17 | 10/8/96 | 1,100 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 95 | 130 | |
| 18 | 10/8/96 | 1,070 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 95 | 80 | |
| 19 | 10/8/96 | 1,492 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 97 | 180 | |
| 20 | 10/8/96 | 1,495 | 18,000 | 7 | 210 | 130 | 12 | 110 | 1,090 | 250 | 190 | |
| 21 | 10/10/97 | 1,110 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 235 | 340 | |
| 22 | 10/10/97 | 1,080 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 20,000 | 210 | Incomplete brake release |
| 23 | 10/10/97 | 1,120 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 100 | 335 | |
| 24 | 10/10/97 | 1,110 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 110 | 130 | |
| 25 | 10/10/97 | 1,100 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 103 | 60 | |
| 26 | 10/10/97 | 1,120 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 110 | 330 | |
| 27 | 10/10/97 | 1,150 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 102 | 305 | |
| 28 | 10/10/97 | 1,100 | 25,000 | 21 | 210 | 130 | 12 | 130 | 1,090 | 107 | 50 | |

**Table I GPADS-Light Qualification Test Results**