USAAVLABS TECHNICAL REPORT 66-82

INVESTIGATION OF DEPLOYMENT AND LANDING LOADS WITH A LIMP PARAGLIDER

Final Report

By

John W. Sobczak

September 1966

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

Distribution of this document is unlimited

Disclaimers

Disposition Instructions

ERRATA

USAAVLABS TECHNICAL REPORT 66-82

September 1966

Page 3 - Statement in right-hand corner of wing planform should read as follows:

FABRIC ORIENTATION IS PARALLEL AND PERPENDICULAR TO BISECTOR AND TRAILING EDGE.

Page 26 - Second paragraph under GENERAL should read as follows:

The conclusions, recommendations, and chronology of tests of the USAPT Parawing Project Officer, taken from his after-action report addressed to the Commanding Officer, USAPT, are given in Appendix II.

Page 29, Figure 18 - Figure title should read as follows:

Longitudinal Instability Induced by Jumper Prior to Landing.

Page 30 - Third sentence under Configuration should read as follows:

It is doubtful whether a larger size wing would have any value for an individually manned military application.

Project 1L013001A91A, House Task 66-48
USAAVLABS Technical Report 66-82
September 1966

INVESTIGATION OF DEPLOYMENT AND LANDING LOADS WITH A LIMP PARAGLIDER

Final Report

By

John W. Sobczak

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

SUMMARY

This report covers the initial evaluation of the National Aeronautics and Space Administration's (NASA) 24-foot limp parawing for use as a manned aerial delivery system. A satisfactory application of the parawing to this use will provide the capability of offset precision aerial delivery of personnel. Aided by a navigational system, the parawing could be employed during night and during conditions of adverse visibility.

The primary objective of this evaluation was the acquisition of deployment load data on the parawing. Testing, which included dummy drop tests and live drop tests, was conducted from 16 March 1966 to 20 April 1966.

In general, the measured and observed characteristics of the parawing, coupled with the comments of the members of the U. S. Army Parachute Team (USAPT) who flew the wing, indicate that the parawing has potential and merits further investigation. Specifically, the loads were found to be within human tolerance and were no greater than those experienced in jumping conventional parachutes. The glide ratio of the parawing appears to be in excess of 2:1.

CONTENTS

ILLUSTRATIONS

TABLES

BLANK PAGE

INTRODUCTION

A house task (HT 66-48) for determining the magnitude and duration of deployment and landing loads with a limp paraglider was approved on 16 March 1966. Until that time, the NASA-developed 24-foot limp paraglider had been dropped approximately 170 times, but no load information had been accumulated. All effort had been directed toward rigging, observing flight characteristics, and demonstrating the system.

The primary objective of this house task, acquisition of deployment load data, stemmed from the interest expressed by the U. S. Army Special Forces and the U. S. Army Parachute Team in evaluating the parawing for both military and sport applications. The USAPT initiated an effort to build two parawings by using the NASA design and incorporating parachute construction and rigging techniques.

Testing under this house task was initiated on 16 March 1966 for the purpose of accumulating load data prior to the USAPT scheduled live jumps of 26, 27, and 28 March 1966 in preparation for a demonstration on 29 March 1966. Test locations included the U. S. Army Aviation Materiel Laboratories research support area, the Fort Eustis airfield, and the NASA Plum Tree Island facility. Drop tests of the instrumented dummy were terminated on 25 March 1966. Live jumps were performed by the USAPT at Fort Bragg, North Carolina, up to 11 April 1966 and were followed by tests at Yuma Proving Ground. The Yuma tests were conducted to establish performance parameters by using the Yuma tracking facilities; however, extremely high winds, both on the surface and at altitude, resulted in erroneous tracking data, and the intended results were not achieved. Testing was terminated with the completion of the Yuma jumps on 20 April 1966.

DESCRIPTION OF PARAWING

The planform of the parawing consists of two isosceles triangles of 24-foot sides with included angles of 45 degrees, joined along the 24-foot sides to form a delta wing shape. The apex of the wing is truncated by 3 feet so that the overall length is reduced to 21 feet.

Wing material is a 2.2-ounce-per-square-yard, calendered, low-porosity nylon. The fabric orientation is perpendicular and parallel to the bisector of the 45-degree angle of the triangles. All fabric seams are parallel to this bisector. All fabric seams and edges are bonded.

The suspension line attachment points of the wing keel and leading edges are loops of cord, the ends of which are untwined and laid out in a fan pattern on the wing fabric and sandwiched with adhesive to a cover fabric. There are 11 suspension line attachment points on the keel and 6 on each of the leading edges. The line locations, lengths, and tensile strength are listed in Table I. Figure 1 shows the wing layout, details of the lapping and bonding of the seams and edges, and the layout and bonding technique used for attaching the suspension line pickup points.

Similar wings, manufactured by the Pioneer Parachute Company and the Irvin Air Chute Company, have the same basic NASA wing shape as that described in Table I; however, both companies have applied parachute construction techniques of stitching and applying structural tapes to the fabric for added strength.

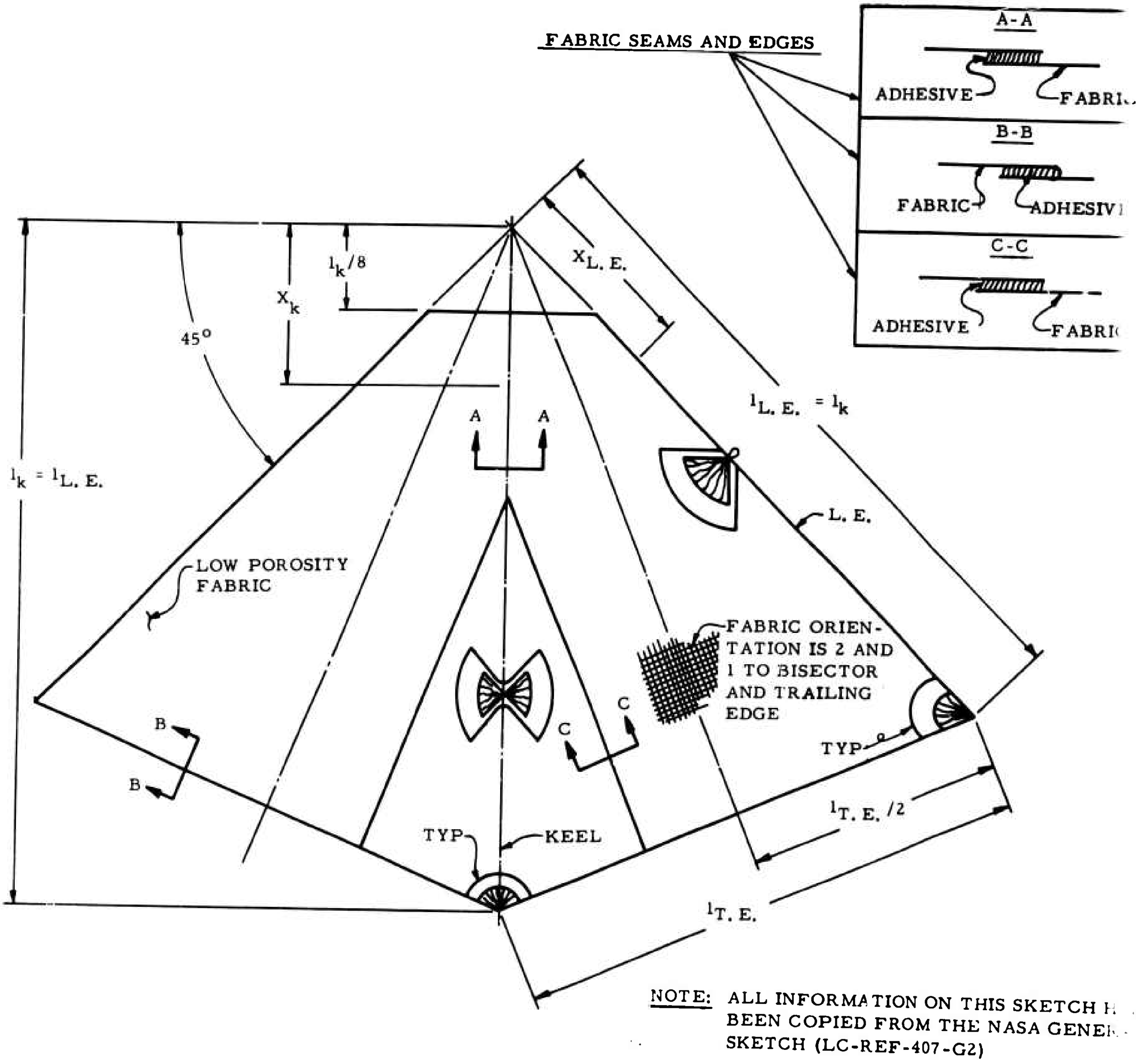
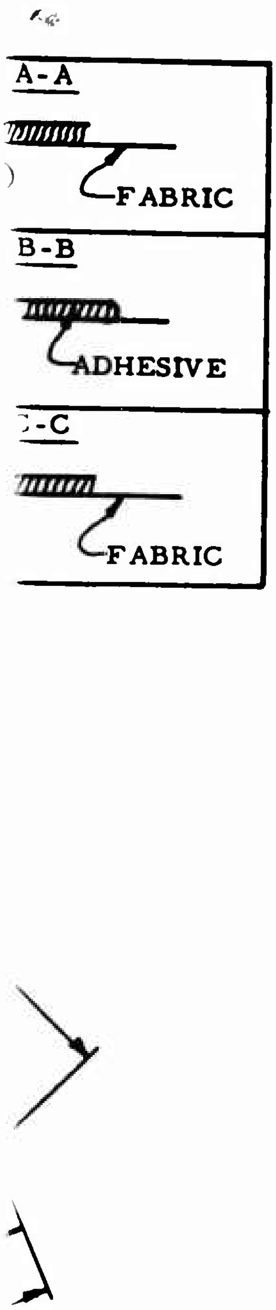


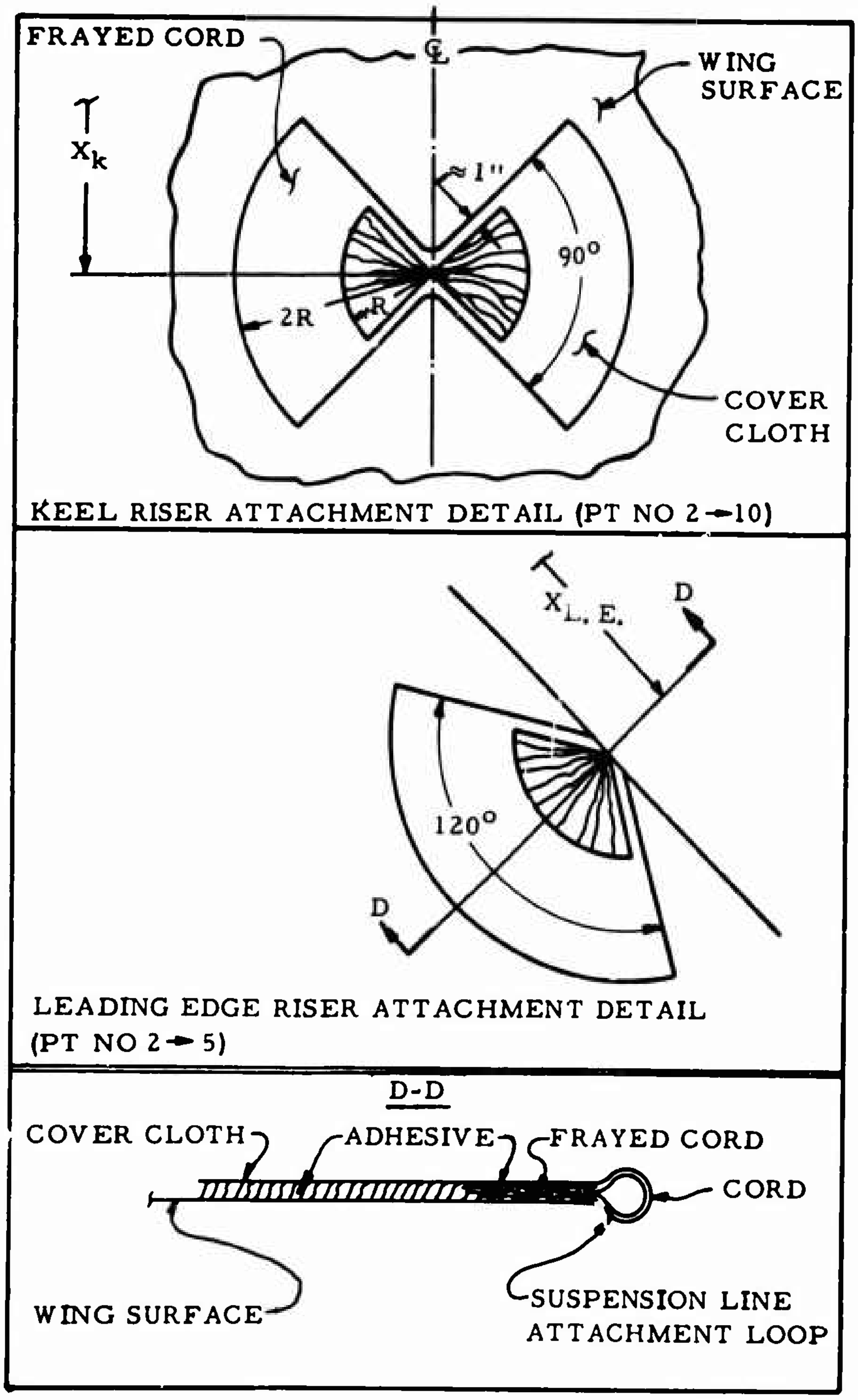
Figure 1. Limp Parawing General Layout.

A



NOTES:

1. Gusset layout angles for points on keel and leading edge not covered in details below are as follows:
   a. Leading-edge Pt No 1 - 120°
   b. Leading-edge Pt No 6 - Included angle of wing tip
   c. Keel Pt No 1 - 90°
   d. Keel Pt No 11 - Included angle of wing fabric at intersection of keel and trailing edges
2. Frayed cord of keel attachment loop spread out and cemented to both left and right panels



KEEL RISER ATTACHMENT DETAIL (PT NO 2→10)

LEADING EDGE RISER ATTACHMENT DETAIL (PT NO 2→5)

IS SKETCH HAS
NASA GENERAL

TABLE I

SUSPENSION LINE LOCATIONS, LENGTHS, AND TENSILE STRENGTH FOR THE NASA 24-FOOT PARAWING

Point No.	Leading-Edge Lines				Keel Lines			
	$\frac{x_{L.E.}}{l_{L.E.}}$	$x_{L.E.}$ (in.)	Line Length (in.)	Line Test (lb.)	$\frac{x_k}{l_k}$	x_k (in.)	Line Length (in.)	Line Test (lb.)
1	0.177	51.0	384.0	550	0.125	36	372.0	550
2	0.333	96.0	369.0	550	0.208	60	378.6	550
3	0.500	144.0	356.4	550	0.292	84	381.6	550
4	0.667	192.0	336.0	550	0.375	108	375.6	550
5	0.833	240.0	322.2	550	0.458	132	368.4	550
6	1.000	288.0	288.3	1,000	0.542	156	366.0	550
7	-	-	-	-	0.646	186	366.0	550
8	-	-	-	-	0.750	216	366.0	550
9	-	-	-	-	0.833	240	361.7	550
10	-	-	-	-	0.917	264	340.0	550
11	-	-	-	-	1.000	288	315.0	1,000

NOTES: 1. Subscript (L. E.) denotes leading edge; subscript (k) denotes keel.

2. All lines measured under 10-pound pull.

SUSPENSION SYSTEM

The suspension lines used for all points other than the No. 11 keel line and the leading-edge No. 6 lines are 550-pound test, MIL-C-5040B, Type III. The remaining lines are 1,000-pound test, MIL-C-5040B, Type V. The lines attach to conventional risers which in turn adapt by Capewell fasteners to both military and sport harnesses.

PACKING

The packing procedure used for the parawing has proven to be exceptionally reliable and has not been significantly changed since the first deployment. The procedure is as follows:

1. The wing is laid out on its side with the risers positioned in such a manner as to pull all the suspension lines to their full length (Figures 2 and 3).

2. Starting at the aft end of the wing, the fabric is pleated in approximately 1-1/2-foot sections; the lines form a bundle as each additional pleat is made. The keel lines are allowed to fall freely along the fabric and bundle as each pleat is turned; however, the left and right leading-edge lines are held together (Figure 4) and placed on the last formed pleat. The fabric and lines are kept taut throughout the folding operation to ensure that no snap load will be experienced during deployment. The pleating operation is continued until the apex of the glider falls on the last pleat, as shown in Figures 5, 6, and 7.

3. With the pleating completed, the sleeve is pulled over the wing to the start of the flap on the end of the sleeve (Figures 8 and 9).

4. The flap is folded over the end of the sleeve, and the line bundle is stowed in the rubber-band provisions attached to the sleeve (Figure 10). Figure 11 shows the parawing in the sleeve with the line stowing completed.

5. Figures 12 and 13 show the parawing packed in a standard sport pack and ready for jumping.

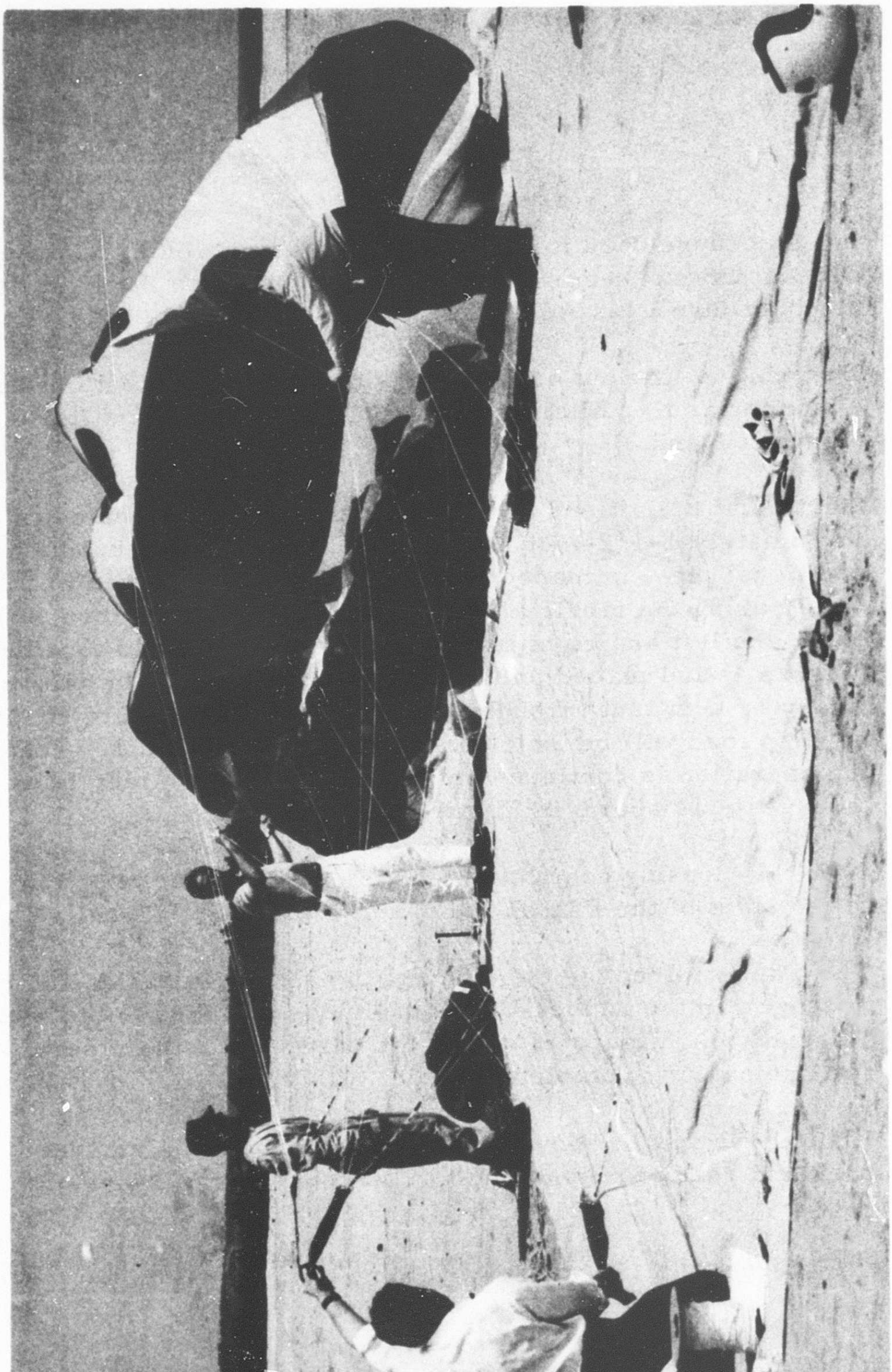


Figure 2. Untwisting Parawing Lines and Risers.

Figure 3. Wing Layout of Parawing Prior to Pleating.

Figure 4. Pleating and Line Stowage of Parawing (Start).

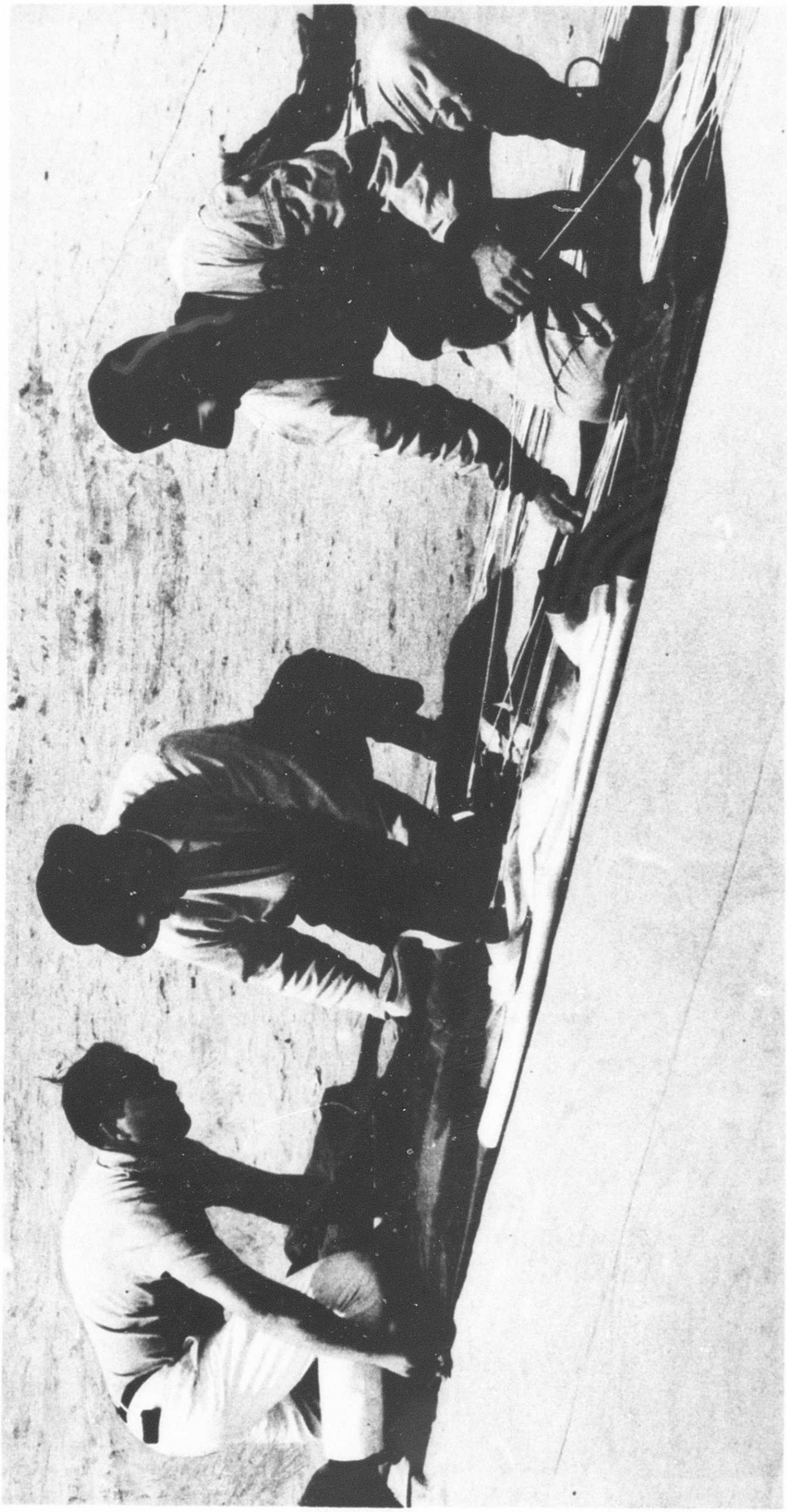


Figure 5. Pleating and Line Stowage of Parawing (Finish).

Figure 6. Line Position of Parawing With Pleating Complete.

Figure 7. End View of Pleated Parawing.

Figure 8. Stowing Parawing in Deployment Sleeve.

Figure 9. Parawing Stowed in Sleeve.

Figure 10. Line Bundle Stowage on Deployment Sleeve.

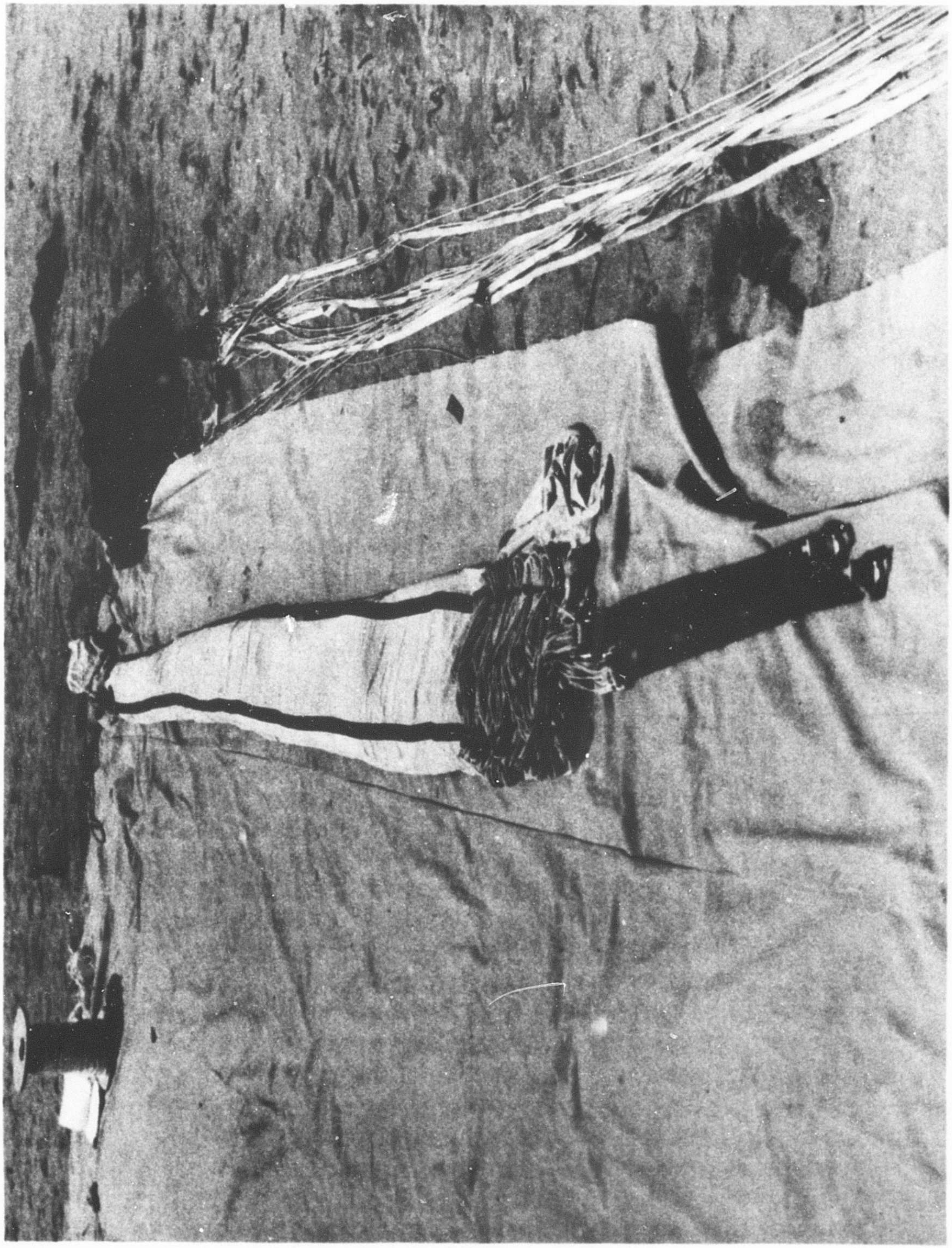


Figure 11. Parawing Ready for Insertion in Pack Tray.

Figure 12. Rear View of 24-Foot Packed Parawing.

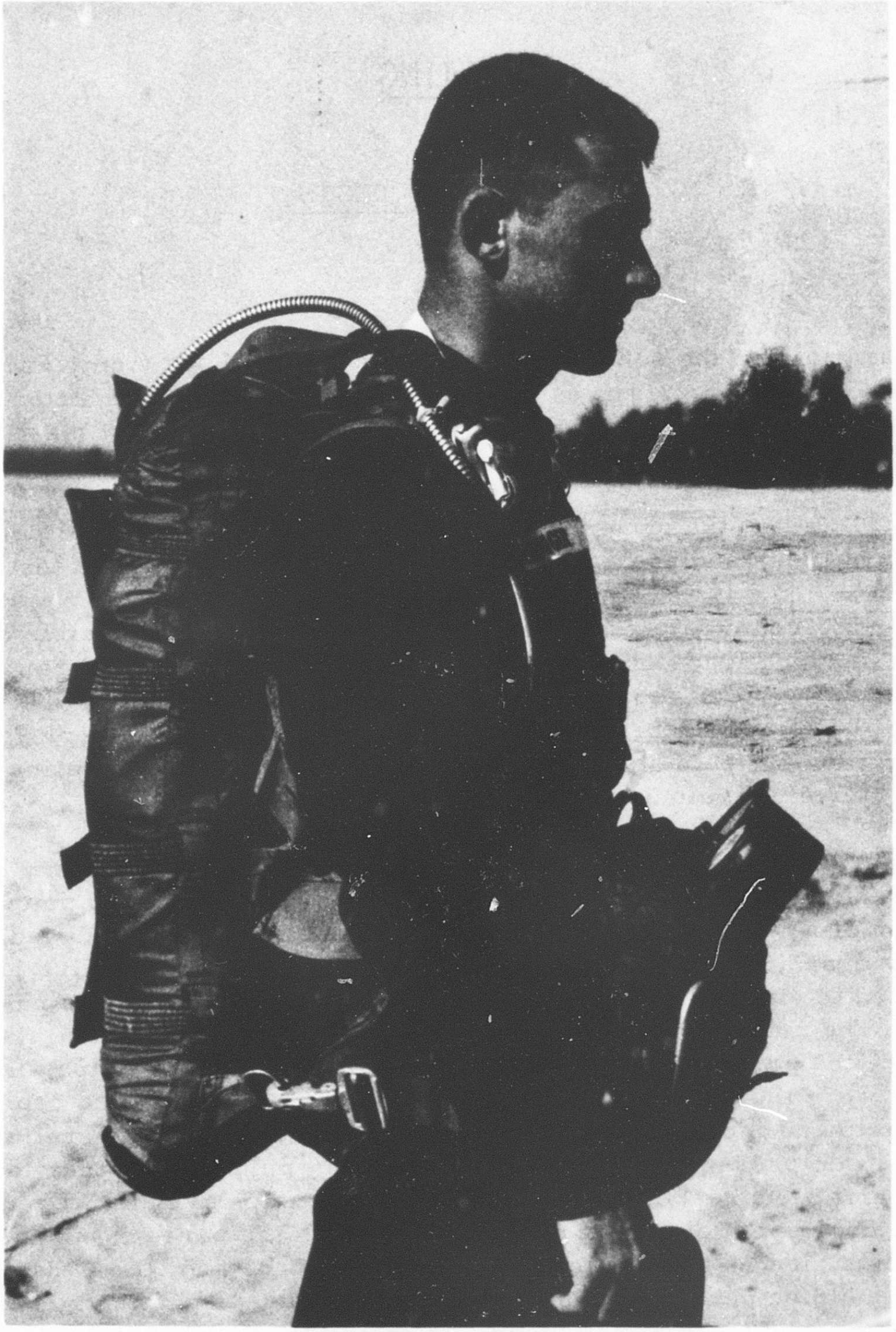


Figure 13. Side View of 24-Foot Packed Parawing.

TESTING

DUMMY DROP TESTS

GENERAL

In preparation for the scheduled live jumps by the U. S. Army Parachute Team at Fort Bragg, a series of dummy drop tests was conducted using a rope torso and an instrumented package. The purposes of these in-house tests were as follows:

1. To adapt the wing suspension system to a conventional parachute harness and pack tray and to verify the trim by flight tests.

2. To accumulate as much information and data as possible on the opening loads experienced in the deployment of the parawing.

3. To establish the structural integrity of the wing in deployments ranging from static line activation to automatic activation in terminal velocity free falls.

Because of the limited time available to perform this preliminary effort, only a portion of the desired amount of testing was completed prior to the initiation of live jumping. The results of these tests were relayed to the U. S. Army Parachute Team, with the recommendation that live jumps be limited to static line deployments or no more than clear and pull jumps. The magnitude of the shock felt on wing deployment and its duration were the primary reasons for this recommendation. Of particular concern were the loads which would be experienced in delayed deployment drops up to and including terminal velocity. The rapid deceleration at high dynamic pressures could result in serious injury to an individual and impose critical stresses on the wing and suspension system. Even with the high degree of reliability demonstrated with the parawing in past NASA tests, it was the opinion of both USAAVLABS and NASA that live jumps should be performed only after tests with rope and instrumented dummies proved to be satisfactory. It should be realized that the wing used for local tests differed structurally from the one designed and fabricated for the jumps by the U. S. Army Parachute Team. Heavier gauge fabric and standard parachute fabrication techniques were used on the

USAPT wing; therefore, it was expected to be a more structurally sound system.

TRIM DROPS

The first flight of the parawing adapted to a conventional parachute harness and rope torso dummy occurred on 7 March 1966. The wing tested was the NASA 24-foot 1.1-ounce coated parachute nylon wing designed for feasibility testing as a scale-model space recovery system. The drop was a complete success, except for a tumbling exit from the drop aircraft which caused spinning of the dummy during the first portion of the flight. Subsequent drops of both this wing and a 2.2-ounce-per-square-yard nylon wing proved that the parawing was trimmed and ready for instrumented drops.

INSTRUMENTED DROPS

The instrumented package used to measure deployment loads contained accelerometers located in the vertical, lateral, and fore and aft planes. The accelerometer outputs were recorded on a CEC 5-118 oscillograph. Figures 14 and 15 show the instrument package with the cover plate removed and the recording equipment exposed. Figure 16 shows the instrument package ready for harness and pack tray attachment.

The first two instrumented drop attempts failed when only part of the deployment sequence occurred prior to ground contact. Automatic timers were used to activate the rip cord in both of these missions. With a 2-second delay setting on the timer, the dummy would theoretically fall 64 feet prior to the start of deployment. The deployment itself, based on static line sleeve extractions, was expected to take 100 feet. The drop altitude for both missions was 400 feet. The cause of failure for the first flight was established as improper setting of the timer. A postflight duplication of the setting was timed at 4.5 seconds. This time would allow for a theoretical free-fall distance of 324 feet before rip cord extraction. This was substantiated by a film of the test which showed the pilot chute and sleeve leaving the pack as the dummy passed through the tree line. Instrumentation damage was extensive.

In the second drop attempt, an incorrect altimeter setting and subsequent drop altitude of 250 feet instead of the desired 400 feet resulted because of erroneous information received from the airfield tower. As in the previous drop, extensive damage was incurred by the instrument package.

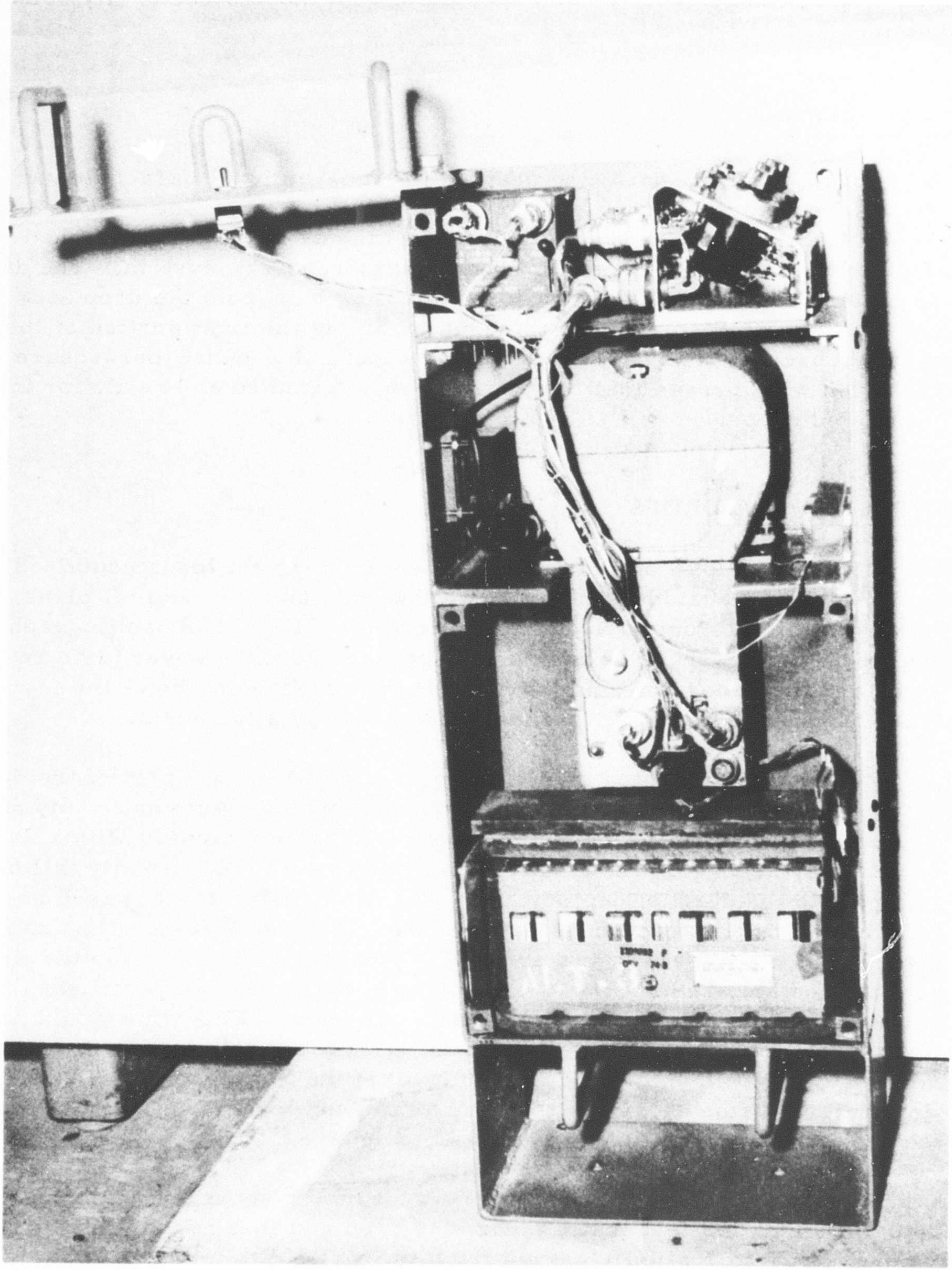


Figure 14. Instrumented Dummy With Cover Plate Removed.

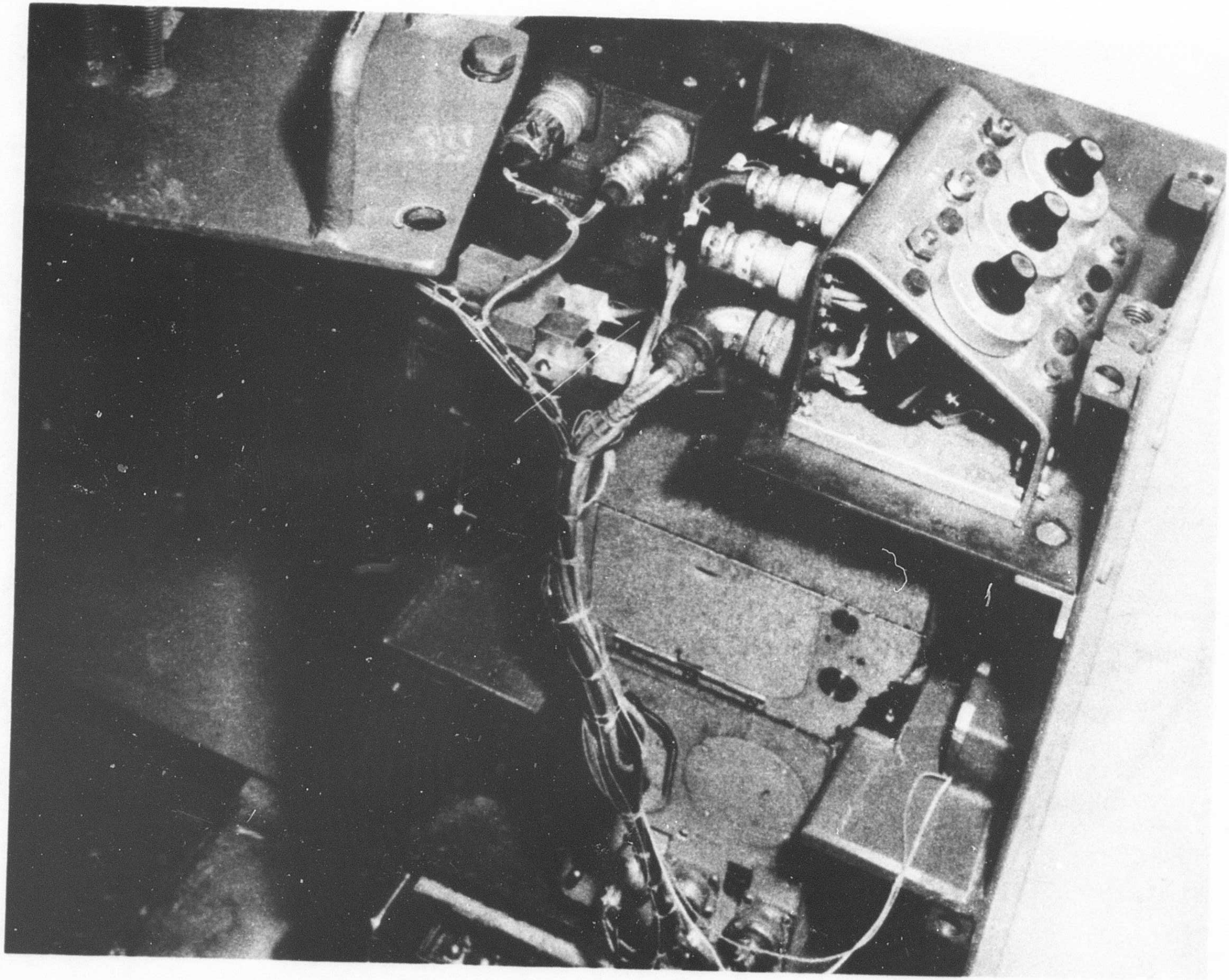


Figure 15. Close-up of Instrumented Dummy Recorder and Balance Box.

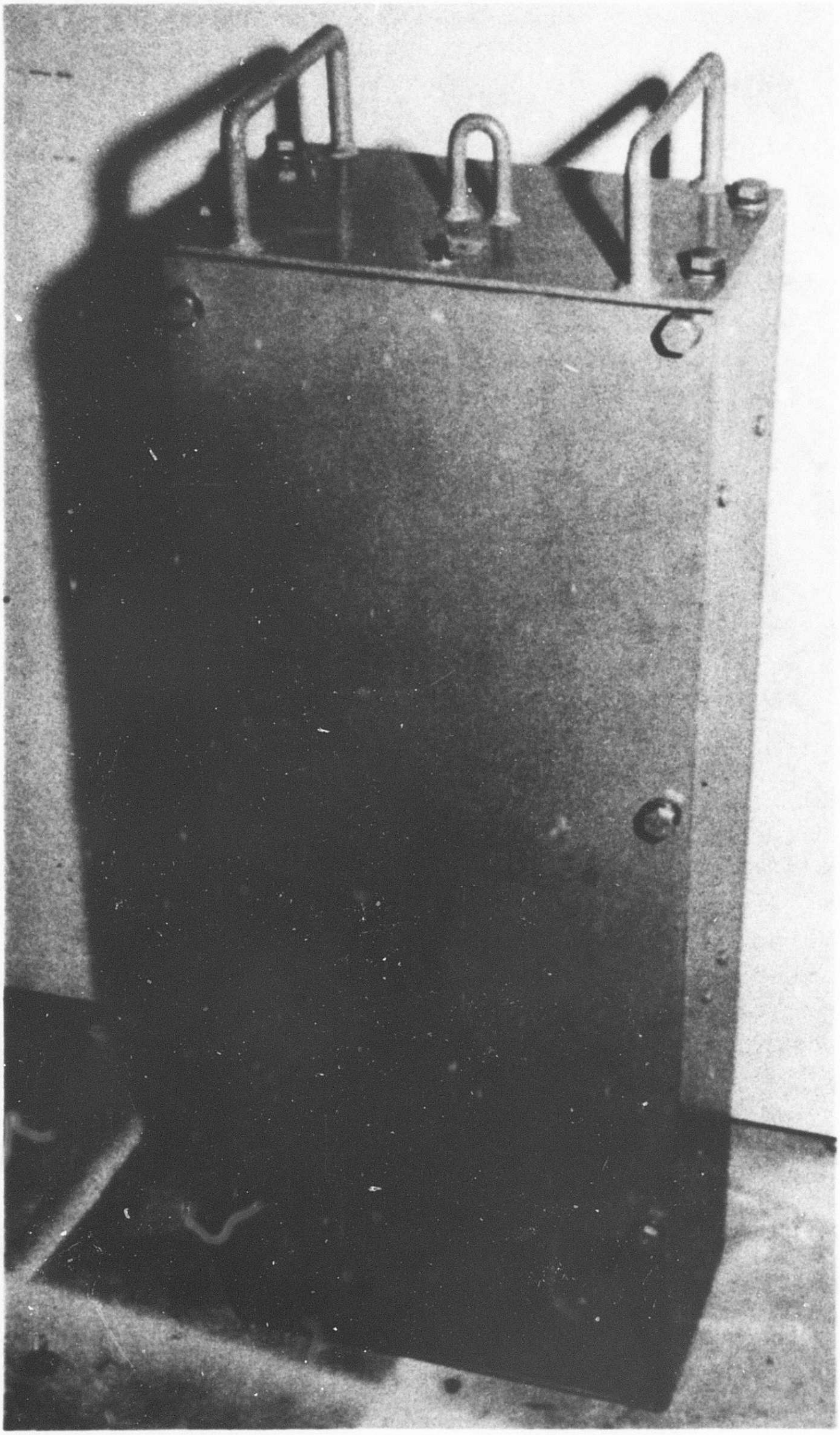


Figure 16. Instrumented Dummy With Cover Plate Installed.

In order to acquire data with minimum risk to the rebuilt instrument package, the tests were moved to Plum Tree Island, a site offering a significant increase in drop area; thereby, the local altitude restriction for uncontrolled drops was eased. The drops were static line deployments which allowed for positive sleeve extraction. An analysis of the recordings from three drops shows the maximum resultant opening load to be less than 10g. This information was recorded for a 200-pound instrument package released from the drop aircraft at an altitude of 1,000 feet and airspeeds of 20 and 40 knots.

Because of the commencement of live jumps by the U. S. Army Parachute Team on the following day at Fort Bragg, the additional tests for investigation of delayed deployment opening shocks were not conducted. A chronology of tests performed is given in Appendix I.

STRUCTURAL DROPS

A series of drops was conducted to test the structural integrity of the wings in free-fall, delayed deployments. With the exception of a few delayed deployment drops with a light (105-pound) dummy and the attempted delayed deployment instrumentation drops, all past tests of the parawing were static line deployments. These tests indicated that no major structural deficiencies were evident in the NASA parawing.

Both the 1.1- and 2.2-ounce fabric wings were dropped with 5-second delays and a suspended weight of 220 pounds. Immediate fabric rupture and seam separation occurred on deployment of the 1.1-ounce fabric wing. The 2.2-ounce fabric did not show signs of failure. A repeat flight with the 2.2-ounce fabric wing and an 8-second delay resulted in the tearing off of two line attachment gussets and the breaking of two of the nylon suspension lines. The line breakage was caused by the tightening and cutting action of the suspension line knots in absorbing the opening loads. The breaks occurred at the knots. The gusset tear was not as readily explained. Gusset loads were expected to be primarily in shear, where bonding or fabric coating failures and subsequent separation would occur. It is quite possible that the twisting and tumbling free fall of the dummy caused asymmetric loading conditions on the gussets during wing deployment. This unstable mode had occurred in past drops and could cause line wrapping on the dummy and poor load distribution among the suspension lines and gussets. Future tests may require a stabilizing device to arrest this motion and to assure a system which more closely simulates the stable free fall of a man.

LIVE DROP TESTS

GENERAL

The first live jump of the USAPT evaluation of the parawing was performed on 27 March 1966. Although the longitudinal trim was not optimum and the glider indicated a stalling tendency, the jumper performed his evaluation and landed the wing in winds which varied from 25 to 30 knots at 5,000 feet to winds gusting to 20 knots at the surface. Landing rate of descent was estimated at 10 to 11 feet per second. Subsequent jumps were performed by members of the USAPT to evaluate trim settings, maneuverability, and overall feasibility of the parawing for use in manned aerial delivery. Figure 17 shows a manned parawing in flight during the USAPT evaluation.

The activities, conclusions, and recommendations of the USAPT, along with a chronology of the test operations, are given in Appendix II.

The general reactions of the men who have jumped the parawing are favorable. The system does not offer any significant problem areas which would detract from its usefulness. The opening shock loads experienced during terminal-velocity free falls were considered to be equivalent to those felt with the present-day steerable parachute. Deployment reliability was 100 percent during the live drops, with reserve systems deployed in two cases where the wing trim was incorrect and instability occurred. Live jumps totalled 46, and 15 personnel were qualified.

AREAS REQUIRING ADDITIONAL EFFORT

A review of the results of the USAPT tests has indicated three areas which require additional reseach and engineering effort: performance, stability, and configuration (size optimization).

Performance

The gliding capability of the parawing is its greatest asset. Wind tunnel tests of this configuration have indicated that a lift-to-drag ratio of 2.5:1 is available for this system. A 2:1 lift-to-drag ratio has been fairly well substantiated by observation; however, firm flight test data must be obtained to verify it. Investigations conducted by the National Aeronautics and Space Administration on various limp paraglider configurations show lift-to-drag ratios of up to 3:1. The increase in lift to drag affords the parawing a lower glide angle and a corresponding ability to cover a

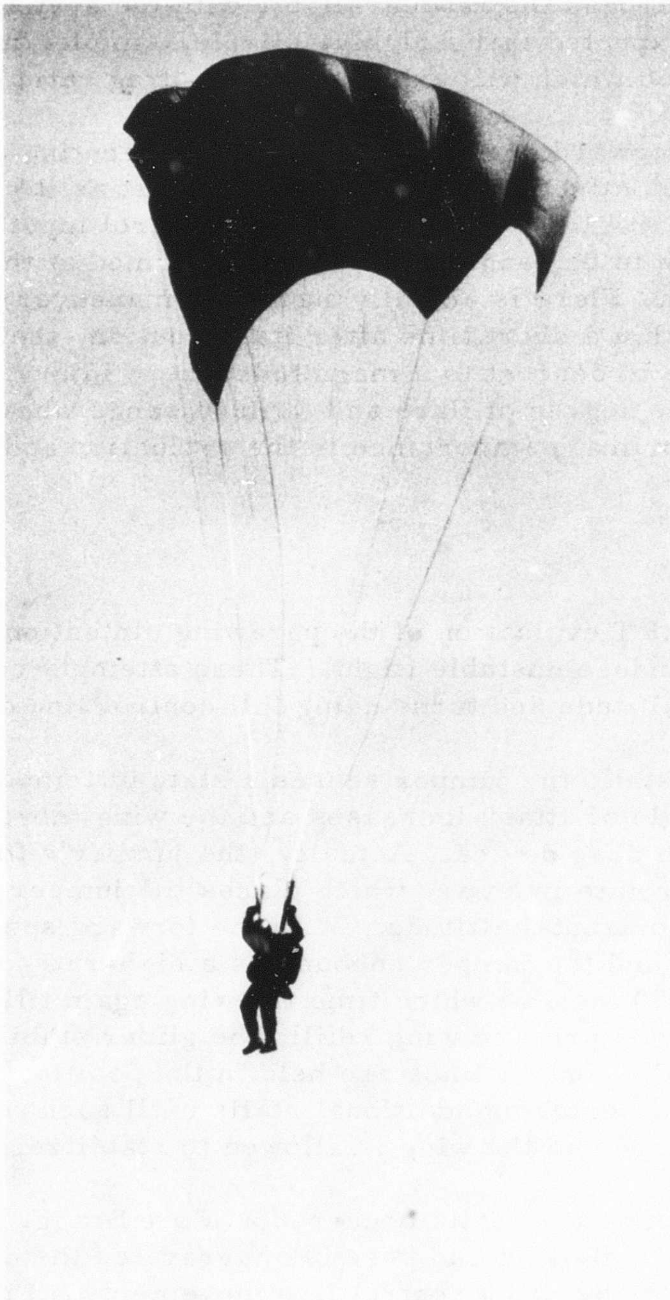


Figure 17. Manned Parawing Flight (Preparation for Landing).

greater ground distance. The desired glide ratio is dictated by the mission that the parawing is to perform, and a configuration change may be necessary to surpass the ratio available with the system described in this report. It is expected that a highly reliable, simple, manned parawing can be developed which will exhibit a lift-to-drag ratio of 2.5:1.

Retarding the forward speed of the glider by executing a flare maneuver has proven to be effective for landing a man just as it had for landing cargo in past paraglider programs. This control input becomes critical and could prove to be dangerous if it is performed at the improper time and/or altitude. Flare is actually a stalling maneuver; if ground contact is not made within a short time after its execution, the individual will increase his rate of descent to a magnitude where injury could be sustained. Establishing the degree of flare and altitude range where it is effective and safe is of primary importance in the evaluation and development of the parawing.

Stability

During the USAPT evaluation of the parawing, intentional control inputs were made to induce unstable flight. These attempts consisted of stall maneuvers at altitude and turns using full control line displacement.

Upon entering stall, the jumper senses a state of temporary suspension as the wing angle of attack increases and the wing moves behind him, acting as a high drag device. Actually, the jumper's forward inertia causes him to rotate in an arc which places the jumper and wing in what approaches a horizontal attitude. With the forward speed retarded, the wing collapses and the jumper encounters a high-rate-of-descent fall of approximately 50 feet, at which time the wing again fills. If the control lines are released prior to wing refill, the glider stabilizes. On the other hand, if the control lines are held in the position which causes the stall, the glider performs additional stalls until such time as the control lines are released and the wing is allowed to stabilize.

One case of successive stalls occurred at Fort Bragg. The jumper was not able to stop the stalls and possibly aggravated the condition by trying to trim the glider by using control line movements. Figure 18 shows the attitude of the jumper as he swings forward during the last oscillation prior to ground contact. Although the rate of descent was not extreme at this point, the jumper's body attitude caused him to land swinging backwards and striking the ground with his heels and back.

This particular wing configuration was rigged with the No. 6 leading-edge lines longer than needed for obtaining maximum lift to drag. A region of stable, optimum performance flight is bounded by stall

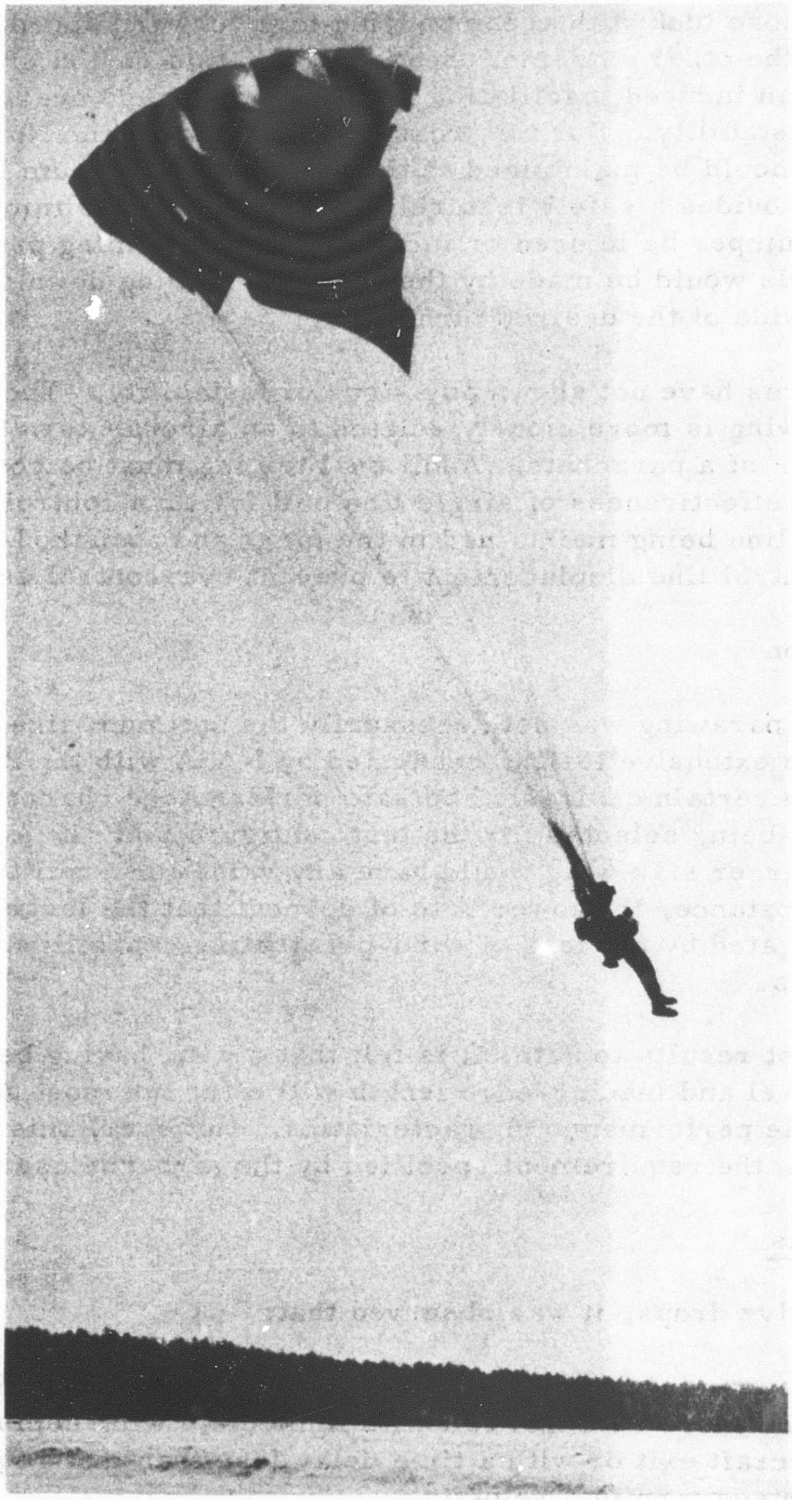


Figure 18. Longitudinal Instability Prior to Landing.

(excessive control line pull) at one extreme and low performance flight (excessive nose tuck with accompanying high forward speed and rate of descent) at the other extreme. Searching for this region of trim while undergoing an induced oscillation of stall could cause overcontrol and a divergent instability. For this reason, the length of the No. 6 leading-edge lines should be maintained at the length for maximum lift to drag. This also provides a safety feature which guarantees trimmed flight should the jumper be injured or incapable of maintaining proper trim. Turn controls would be made by the jumper's pulling down on the No. 6 line on the side of the desired turn.

To date, turns have not shown any signs of instability. The turn effected by the parawing is more closely related to an aircraft turn than to the spinning turn of a parachute. Additional testing must be conducted to determine the effectiveness of single line pull for turn control, the result of full control line being maintained in the turn, and a method of placing stops on control line displacement to prevent overcontrol and instability.

Configuration

The 24-foot parawing was not necessarily the optimum size for a manned glider. The extensive testing conducted by NASA with the 24-foot system, coupled with certain desirable and safe performance characteristics, resulted in its being selected for the test configuration. It is doubtful whether a larger size wing would have any value for a military application. For instance, the lower rate of descent that the larger size wing offers is negated by the loss of wind-penetrating capability and control effectiveness.

Based on test results to date, it is felt that a wing having between a 20- to 22-foot keel and leading-edge length will offer the most advantageous and desirable performance characteristics. However, this is completely dependent on the requirement specified by the airborne user unit.

Observations

During the live drops, it was observed that:

1. The opening shock load sensed by jumpers at terminal velocity is no more than that felt with immediate wing deployment after aircraft exit or with a time delay less than that required to achieve terminal velocity.

2. The opening shock experienced with a bag deployment is greater than that felt in sleeve deployment.

3. The parawing exhibits a glide ratio of at least 2:1.

4. Recovery from an unstable mode caused by overcontrol can be made by releasing controls and allowing the glider to trim itself.

CONCLUSIONS

It is concluded that:

1. The deployment loads are within human tolerance and have neither been measured nor observed to be greater than those experienced with existing military or sport parachutes.

2. The glider is basically a stable vehicle. Unstable modes can be achieved with improper rigging or intentional overcontrol.

RECOMMENDATIONS

It is recommended that:

1. Evaluation of the parawing be continued to define fully its application to both man and cargo delivery systems. Such an evaluation should include, but not be limited to, an investigation of technical characteristics such as performance, stability and control, and deployment loads. A concurrent investigation of safety items such as the limitations on control inputs, recovery techniques from unstable modes, and wing jettison is a necessity for a manned parawing program.

2. Test jumps of manned parawings be performed by personnel who are thoroughly qualified in test jumping and have knowledge and experience in failures and emergency procedures.

3. Future programs involving the manned parawing concept have test jump personnel assigned to the program to allow for a systematic and timely approach toward obtaining the technical data required to perform a complete and satisfactory evaluation.

In view of the limited testing which has been conducted on the parawing, no recommendations involving system redesign or change are made.

DISTRIBUTION

US Army Materiel Command	3
US Army Aviation Materiel Command	5
Chief of R&D, DA	5
US Army STRIKE Command	3
US Army Aviation Materiel Laboratories	50
US Army Test and Evaluation Command	1
US Army Combat Developments Command, Fort Belvoir	2
USACDC Armor Agency	1
US Army Combat Developments Command Aviation Agency	2
US Army Combat Developments Command Transportation Agency	2
US Army Combat Developments Command Experimentation Command	1
US Army Combat Developments Command Quartermaster Agency	1
US Army Command and General Staff College	1
US Army Transportation School	2
US Army Infantry Center	2
US Natick Laboratories	2
US Army Limited War Laboratory	3
Trans Engr Liaison Officer, US Army Airborne, Electronics and Special Warfare Board	2
USACDC Liaison Officer, Special Air Warfare Center	3
Air Force Systems Command, Wright-Patterson AFB	8
TAWC, Eglin AFB	2
Naval Air Systems Command	1
Chief of Naval Research	2
Commandant of the Marine Corps	2
Marine Corps Landing Force Development Center	2
Marine Corps Liaison Officer, US Army Transportation School	1
Manned Spacecraft Center, NASA	2
Yuma Proving Ground	2
TAC, Langley AFB	1
Secretary of Defense (ARPA)	2
Joint Parachute Test Facility	5
Office of Naval Materiel, DN	1
RTD, Bolling AFB	1
Army Research Field Office, Canal Zone	2
Army Research Field Office, New York	2
R&D Field Unit, Thailand	2
R&D Field Unit, Viet Nam	2
Defense Documentation Center	20

APPENDIX I

CHRONOLOGY OF IN-HOUSE TESTS

TABLE II

CHRONOLOGY OF IN-HOUSE TESTS

Test No.	Date	Drop Altitude (A)	Drop Speed (kias)	Test Wing	Wind Speed (kn.)	Suspended Weight (lb.)	Load	Remarks
1	7 Mar. 66	500	20	NASA 1.1 oz./sq. yd. (red)	15	220	Rope Dummy	Wing deployed approximately 100 feet below the helicopter. Lines twisted because of tumbling action of rope dummy as it was pushed from aircraft. System untwisted and glider trimmed into wind. Rate of descent estimated at 8 to 10 feet per second.
2	11 Mar. 66	1,000	40	NASA 1.1 oz./sq. yd. (red)	5	105	Rope Dummy	Light wing loading resulted in glider's flying for approximately 20 minutes and reaching an altitude of 1,500 feet during flight.
3	11 Mar. 66	500	40	NASA 1.1 oz/sq. yd. (red)	5	105	Rope Dummy	Delayed deployment drop (2 sec.). Test of wing with automatic timer used to pull rip cord. Wing deployed at an altitude estimated at 150 feet. No damage.
4	11 Mar. 66	700	40	NASA 2.2 oz./sq. yd. (red & white)	5	105	Rope Dummy	First deployment of wing from a standard parachute sleeve. Previous drops were made with deployment bags. Wing indicated need of trim to correct stall tendency.
5	11 Mar. 66	1,200	40	NASA 1.1 oz./sq. yd. (red)	5	105	Rope Dummy	Delayed deployment drop (5 sec.). Test of wing structural integrity under higher dynamic pressure openings. No wing damage.
6	11 Mar. 66	400	20	NASA 1.1 oz./sq. yd. (red)	15	200	Instrumented Dummy	Timer was set incorrectly and dummy dropped entire 400 feet without wing deployment. Instrument package and contents badly damaged.
7	11 Mar. 66	250	20	NASA 1.1 oz./sq. yd. (red)	10	200	Instrumented Dummy	Drop altitude was incorrect due to erroneous information received from tower for altimeter setting. Altitude called for was 400 feet. Instrument package badly damaged when only sleeve extraction occurred at time of impact.
8	22 Mar. 66	1,000	20	NASA 2.2 oz./sq. yd. (red & white)	Calm	220	Rope Dummy	Delayed deployment drop (5 sec.). Free fall stable with dummy face down. Full deployment occurred at approximately 250 feet above the ground. Glider settled with minimum forward speed. No structural failure.
9	22 Mar. 66	1,000	20	NASA 1.1 oz./sq. yd. (red)	Calm	220	Rope Dummy	Delayed deployment drop (5 sec.). Free fall stable with dummy face down. Deployment occurred at 150 feet, with immediate fabric rupture and separation. Failure was expected, since wing was over a year old.
10	22 Mar. 66	2,200	20	NASA 2.2 oz./sq. yd. (red & white)	Calm	220	Rope Dummy	Delayed deployment drop (8 sec.). Free fall stable with deployment occurring at approximately 500 feet. Two suspension lines broke and two line attachment gussets were torn away. Glider settled to ground in a modified wing shape. The 8-second time delay plus a 2-second sleeve extraction time gives a total time of 10 seconds. This approaches a terminal velocity free fall.

TABLE II - contd.

Test No.	Date	Drop Altitude (A)	Drop Speed (kias)	Test Wing	Wind Speed (kn.)	Suspended Weight (lb.)	Load	Remarks
11	25 Mar. 66	1,000	20	NASA 2.2 oz./sq. yd (red & white)	Calm	220	Instru- mented Dummy.	Static line deployment. Opening immediate but followed by three consecutive stalls and impact. Aft line on keel and leading edges was let out to correct this trim condition.
12	25 Mar. 66	1,000	40	NASA 2.2 oz./sq. yd. (red & white)	Calm	220	Instru- mented Dummy	Static line deployment. Opening immediate, with following flight stable and uneventful. Landing was extremely soft. The wing was identical to the one used on test 11; however, 6 inches of line was let out of the aft keel and leading edge to correct for the stalls in test 11.
13	25 Mar. 66	1,000	40	NASA 2.2 oz./sq. yd. (red & white)	Calm	220	Instru- mented Dummy	Static line deployment. Deployment satisfactory, with good trimmed flight following. Wing was the one used on test 11 with 6 inches of line let out of aft keel and leading edge suspension lines. Line length changes corrected the stalls of test 11.

APPENDIX II

CHRONOLOGY AND CONCLUSIONS AND RECOMMENDATIONS OF U. S. ARMY PARACHUTE TEAM TESTS *

TABLE III

CHRONOLOG OF U. S. ARMY PARACHUTE TEAM TESTS

Test No.	Date	Altitude (ft.)	Velocity (kias)	Weight (lb.)	Wind (kn.)	Pilot	Item	Remarks
1	28 Mar. 66	400	40	191	10-12G*	Dummy (Ft. Eustis)	24-ft. Parawing	Unstable (stalls). Added 7 inches to control lines for next flight.
2	29 Mar. 66	2,000	40	191	5-7G	Dummy (Ft. Bragg)	24-ft. Parawing (Slotted)	Unstable (stalls). Added 6 inches to control lines for next flight.
3	29 Mar. 66	2,000	40	191	5-7G	Dummy (Ft. Bragg)	24-ft. Parawing (Solid)	Stable - slight nose fold under (2-3 feet).
4	30 Mar. 66	2,000	40	191	0	Dummy (Ft. Bragg)	24-ft. Parawing (Slotted)	Aborted. Dummy came out of harness upon deployment.
5	30 Mar. 66	1,700	40	225	0	Dummy (Ft. Bragg)	24-ft. Parawing (Solid)	Out of trim - constant right turns. Nose buckle approximately 3 feet.
6	30 Mar. 66	3,800	40	210	12-15G	Live (Ft. Bragg)	24-ft. Parawing (Solid) (Jump & Pull)	First live jump of IPC parawing. No change from drop 5. Good turns, hard opening (bag). Aft lines too short, "high" loads to turn. Turn method was to pull down on one control line only. Jumper remarked that IPC wing responded better than Pioneer wing on turns and that turns were smoother. (This was jumper's third wing flight.) Note: Sleeves are used in all future deployments.
7	5 Apr. 66	3,200	60	215	12-15G	Live (Ft. Bragg)	24-ft. Parawing (Solid) (5-sec. Delay)	Shock opening about equal to that of PC. Turns felt good - response good. Aft lines lengthened 5-1/2 inches for use of proportional control.
8	5 Apr. 66	3,500	60	170	5-10G	Live (Ft. Bragg)	24-ft. Parawing (Solid) (5-7 sec. Delay)	Opening shock less than PC - turns good - control lines too high to reach - had to pull down on risers to reach toggles. Nose buckle 3-4 feet in from leading edge.
9	5 Apr. 66	3,100	60	215	12-15G	Live (Ft. Bragg)	24-ft. Parawing (Solid) (Jump & Pull)	Aft lines considered too long (no change made). Steering knobs too high.
10	5 Apr. 66	2,000	60	200	5-10G	Dummy (Ft. Bragg)	24-ft. Parawing (Slotted)	Unstable. Obvious stall attitude (nose high), but inflation of wing looked better than on previous flight. Note: This is the first terminal drop on the Rogallo wing of any type.

*Extracted from Evaluation of Parawing, Rogallo All-Flexible Deployable Glider (IDG) With Enclosures, Captain James M. Perry, United States Army Parachute Team, Fort Bragg, North Carolina, 10 May 1966.

TABLE III - contd.

Test No.	Date	Altitude (ft.)	Velocity (kias)	Weight (lb.)	Wind (kn.)	Pilot	Item	Remarks
11	5 Apr. 66	3,500	60	215	5-10G	Live (Ft. Bragg)	24-ft. Parawing (Solid) Terminal Drop (12-15 sec.)	Rear lines were shortened 5-1/2 inches (control lines only). Opening shock moderate - considered less than PC - would not respond to control - took heavy force to pull down on control lines. Left trailing edge on corner torn. Tear was approximately 18 inches long and majority of tear was due to pullout of material from tape where needle sewed tape to cloth. Upon inspection, one person who helped pack wing stated that he noticed a small tear when packing. It is considered that since this tear was not repaired, additional damage was caused. Wing was taken to USAPT loft and repaired for next flight.
12	6 Apr. 66	3,500	60	215	0	Live (Ft. Bragg)	24-ft. Parawing (Solid) (Jump & Pull)	Bad nose tuck, stall attitude, stalls worse on turns. Pilot elected to abort and cut away wing (1,500 feet deployed reserve); cut away wing but "left" Capewell hung up. Returned aft control lines to length that they were when received from IPC. Also moved control line (rings) down 6 inches on harnesses.
13	6 Apr. 66	3,600	60	215	12-15G	Live (Ft. Bragg)	24-ft. Parawing (Solid) (6-sec. Delay)	Good stable flight. Slow turns, good response - fast turns, excellent (360° in approximately 2-3 seconds).
14	6 Apr. 66	2,000	60	160	10-12G	Dummy (Ft. Bragg)	24-ft. Parawing (Slotted) (Static Line)	Wing had slip risers added to harnesses; nose was lowered and back was raised 6 inches (equally) to maintain shape of wing and to change angle of attack to counteract stalls previously experienced. Upon launch at 2,000 feet, wing deployed well, inflation was good. Wing then proceeded to weathercock into the wind and started to climb. Maximum altitude was 3,600 feet, as reported by launch aircraft (U-10). Flight time was 39 minutes; distance traveled was 16,000 meters. Flight time was confirmed by Pope AFB, which was alerted due to potential ha ard to aircraft in the area.
15	8 Apr. 66	800	70	157	0-5	Dummy (Ft. Bragg)	NASA No. 4 24 ft. (Glue & Sew)	Performance good. Angle of attack slightly high. Wing stable.
16	8 Apr. 66	3,000	70	215	0	Live (Ft. Bragg)	IPC 24 ft. (Solid)	Good deployment - slight oscillation, started to stall - leveled out - pilot made good 360° turn to right. Pilot attempted to make left turn and wing stalled out at approximately 1,500 feet. Pilot attempted corrective action, but wing would not stabilize. Stall condition prevailed, and fore and aft oscillations continued until impact. Maximum angle of oscillation appeared to be approximately 45°. Subject made contact with ground in a backward swinging motion, striking ground with heels, rear, and then back. Wind was knocked out of him for a few seconds. Vertical descent rate was not visually considered excessive. Pilot stated that he began buffeting and stalled as he went over runway - possible updraft caused stall, with pilot overcontrol.

TABLE III - contd.

Test No.	Date	Altitude (ft.)	Velocity (kias)	Weight (lb.)	Wind (kn.)	Pilot	Item	Remarks
17	8 Apr. 66	800	70	157	0-5	Dummy (Ft. Bragg)	NASA No. 4 24 ft. (Glue & Sew)	Good stable flight, good opening.
18	8 Apr. 66	600	70	157	5-10	Dummy (Ft. Bragg)	IPC 24 ft (Slotted)	Good stable flight, good opening.
19	11 Apr. 66	1,500	85	157	10-12	Dummy (Ft. Bragg)	NASA No. 4 24 ft. (Glue & Sew)	Good opening, good stable flight, 75 seconds down time.
20	11 Apr. 66	3,200	45	185	5-10	Live (Ft. Bragg)	NASA No. 4 24 ft. (Glue & Sew)	Good opening on clear and pull. Flight duration 5 minutes 45 seconds. Intentional stall at 2,500 feet with recovery by pulling down on front risers - good recovery noted. Good stable flight.
21	11 Apr. 66	4,000	65	185	10-12	Live (Ft. Bragg)	24-ft. Parawing (Solid)	Pilot jumped at 4,000 feet and opened at 2,500 feet (terminal). Flight duration 2 minutes 48 seconds. Intentional stall made with recovery by front riser pull down, wing stabilized in approximately 50 feet with positive control by pilot.
22	11 Apr. 66	3,200	65	185	10-12	Live (Ft. Bragg)	24-ft. Parawing (Solid)	Good opening, good stable flight. Pilot attempted to stall wing by pulling down on rear risers while flying downwind. Wing would not stall. Pilot used rear risers for flare action just prior to touchdown. This maneuver worked well, allowing a final descent rate of approximately 0-5 feet per second. Flight time 3 minutes 30 seconds.
23	16 Apr. 66	2,0[illegible]		210	0-5	Dummy (Yuma)	IPC 24 ft. (Solid)	Flight duration 1 minute 53 seconds. Good opening, stable flight with slight left turns from deployment to impact.
24	16 Apr. 66	4,000	45	210	0-5	Dummy (Yuma)	IPC 28 ft. (Solid)	Flight duration 5 minutes 2 seconds. Good opening, good stable flight, trim excellent.
25	17 Apr. 66	4,000	45	175	0-5	Live (Yuma)	24-ft. Parawing (Solid)	Good opening, stable flight, good control in turns.
26	17 Apr. 66	3,000	45	173	0-5	Dummy (Yuma)	IPC 28 ft. (Solid)	Flight duration 4 minutes 15 seconds. Good opening, but started oscillating and then stabilized. Vehicle flew approximately 4,000 meters from drop point, or about 2.5 miles.
27	19 Apr. 66	2,000	50	173	15S** 26 @ 2,000 ft	Dummy (Yuma)	IPC 24 ft. (Slotted)	Good positive opening, good stable flight. Flight duration 2 minutes 45 seconds.
28	19 Apr. 66	4,000	50	175	15S 26 @ 2,000 ft.	Live (Yuma)	IPC 28 ft. (Solid)	Good opening, low opening shock reported by pilot. Seemed somewhat "sluggish" on turns. Flight duration 6 minutes 25 seconds.
29	19 Apr. 66	3,000	50	210	10-12G 26 @ 2,000 ft.	Live (Yuma)	24 ft. (Solid)	Terminal opening at 2,000 feet. Good opening, good stable flight, excellent control, landed in front of spectators (Army, Navy, and Air Force Tri-Service Committee). Flight duration 1 minute 45 seconds.
30	19 Apr. 66	3,000	50	175	10-12G 26 @ 2,000 ft.	Live (Yuma)	24 ft. (Solid)	Terminal opening at 2,000 feet. Good opening, good stable flight, good control in turns, flare-out on landing (1 foot). Landed in front of spectators (same as flight 29). Flight duration 1 minute 51 seconds.
31	20 Apr. 66	3,300	70	173	10-12G 26 @ 2,000 ft.	Dummy (Yuma)	IPC 24 ft. (Slotted)	Good opening, stable flight, except for continuous left turns from deployment to impact.

TABLE III - contd.

Test No.	Date	Altitude (ft.)	Velocity (kias)	Weight (lb.)	Wind (kn.)	Pilot	Item	Remarks
32	20 Apr. 66	3,500	70	210	10-12G 26 @ 2,000 ft.	Live (Yuma)	24 ft. (Solid)	Good opening at clear and pull. Made 360° right turn, then 360° left turn, stall and recover, then flew approximately 6,000 meters, quartering into wind. Flare-out on landing at approximately 5 feet per second (cine-theodolite coverage) (approximately 12-minute flight).
33	20 Apr. 66	3,500	70	175	10-12G 26 @ 2,000 ft.	Live (Yuma)	IPC 28 ft.	Good opening with low opening shock reported by pilot. Made 360° right turn, 360° left turn, then held into wind for about 7 minutes, then flew downwind for approximately 3 minutes to flare-out and about 5 feet per second touchdown (cine-theodolite coverage). Flew approximately 4,600 meters. Note: To this date (20 Apr. 66), 46 live jumps have been made on the parawing.

*G indicates gusting of winds.
**S indicates surface winds.

CONCLUSIONS

The Rogallo parawing is a feasible and utilitarian personnel carrier. The 24-foot glider has demonstrated its ability to deploy properly, to fly in a fairly stable attitude, and to land loads of up to 250 pounds accurately and easily. It has vast potential in both military and sport parachuting.

Allied to a final guidance system, this particular vehicle presents a new and radical method of infiltration by utilizing high-altitude drift-in techniques.

From a sport parachuting aspect, the parawing may provide the "missing link" for which sport parachutists have been looking for the past few years. Until now, the average sport parachutist has been able to enjoy only those all-too-few seconds of free fall and the short ride to the ground following deployment of his main parachute. It may now be possible to combine the free fall with the challenge of gliding and to provide the jumper with the additional thrill of several minutes of "flying".

RECOMMENDATIONS

It is recommended that:

1. The Commanding Officer, United States Army Parachute Team, encourage and support the exploitation and development of an operational individual drop glider (IDG) as a feasible military personnel carrier. This can be accomplished through continued cooperation with project personnel of USAAVLABS, Fort Eustis, Virginia.

2. The United States Army Parachute Team acquire the necessary number of parawings to demonstrate their function during parachute demonstrations in both the military and civilian domains.

3. The United States Army Parachute Team continue to evaluate and gain experience on the parawings now in its possession whenever periods of practice are available.

4. The Commanding Officer, United States Army Parachute Team, consider the awarding of a suitable citation to those personnel participating in the evaluation program.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Aviation Materiel Laboratories Fort Eustis, Virginia	2a. REPORT SECURITY CLASSIFICATION 2b. GROUP

3. REPORT TITLE

Investigation of Deployment and Landing Loads With a Limp Paraglider

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report

5. AUTHOR(S) (Last name, first name, initial)

Sobczak, John W.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
September 1966	48	

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 1L013001A91A c. House Task 66-48 d.	9a. ORIGINATOR'S REPORT NUMBER(S) USAAVLABS Technical Report 66-82 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	US Army Aviation Materiel Laboratories Fort Eustis, Virginia

13. ABSTRACT

This report covers the initial evaluation of the National Aeronautics and Space Administration's (NASA) 24-foot limp parawing for use as a manned aerial delivery system. A satisfactory application of the parawing to this use will provide the capability of offset precision aerial delivery of personnel. Aided by a navigational system, the parawing could be employed during night and during conditions of adverse visibility.

The primary objective of this evaluation was the acquisition of deployment load data on the parawing. Testing, which included dummy drop tests and live drop tests, was conducted from 16 March 1966 to 20 April 1966.

In general, the measured and observed characteristics of the parawing, coupled with the comments of the members of the U. S. Army Parachute Team (USAPT) who flew the wing, indicate that the parawing has potential and merits further investigation. Specifically, the loads were found to be within human tolerance and were no greater than those experienced in jumping conventional parachutes. The glide ratio of the parawing appears to be in excess of 2:1.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Parawing						
Deployable Wing						
Gliding Parachute						
Parachute						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.