AMRL-TR-70-104

LONG-LINE LOITER PERSONNEL RETRIEVAL SYSTEM: TRIAXIAL ACCELERATION TESTS

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13. ABSTRACT

This report describes the feasibility of using a fixed-wing aircraft, employing free-fall and circling-line techniques, to rescue personnel or retrieve equipment from the ground. The technique involves deploying a line from the aircraft while a controlled turn is maintained, causing the line to describe a diminishing spiral earthward. As a continuation of the efforts described in AMRL-TR-69-140, this report describes measurements of laundh g forces and of line tensions in recovering 185 to 231-pound dumies. For 7 launches, the mean total g was 01.7 ± .19 g/sec. Line tension at the aircraft was 360-645 pounds at launch and from 245-410 pounds when the dummy was in trail behind the aircraft. Results suggest that this method of retrieval is feasible for human subjects or equipment with regard to stability and g load at launch.

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FOREWORD

This research was initiated by the Flight Environments Branch, Human Engineering Division, Aerospace Medical Research Laboratory, under Project 7184, "Human Performance in Advanced Systems". Mr. B. C. Dixon of Lear-Siegler Systems and Services Group, designed much of the equipment (Contract F33615-69-C-1687) and served as instrumentation monitor. Mr. George Zelinskas of the Aeronautical Systems Division made required parachute modifications. Parachutes were repacked by personnel at the WPAFB Experimental Parachute Facility, and by parachute riggers at Clinton County AFB.

The following personnel of the Human Engineering Division made significant contributions as indicated: Lt Col John C. Simons (OIC and Chase Pilot); Cadet J. E. Schumick (Data Analysis); Mr. Charles W. Sears (Contracts, Field Tests); TSgt Roland Fancher, TSgt W. Owens, TSgt Richard Blue, SSgt Robert Searle (Field Tests); and SSgt Wayne Reffner (Photography).

Special appreciation is extended to Mr. E. McElyea and TSgt C. Evans, U. S. Army Contractor Pilot and Crew Chief of the U-6A aircraft, and to Air Force Reserve personnel at Clinton County Air Force Base, Wilmington, Ohio, where the tests were conducted. This report covers research performed between November 1969 and June 1970.

This technical report has been reviewed and is approved.

JULIEN M. CHRISTENSEN, PHD
Director
Human Engineering Division
Aerospace Medical Research Laboratory

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INTRODUCTION

Research by the 6570th Aerospace Medical Research Laboratory has suggested the potential practicality of using free-fall and circling-line techniques (long-line loiter) from a fixed-wing aircraft as a retrieval/rescue system. The advantages of using fixed-wing aircraft over a helicopter are speed and range.

The proposed system has been investigated, and the results and observations suggest that man-rating would be desirable. Launch g are well-within human tolerance limits and less than that of the C-130 Fulton System.

SECTION II

EQUIPMENT AND METHODS

1. Aircraft

The Army U-6A aircraft used in these tests was considered ideal. It is a high wing Dehaveland Beaver with fixed conventional landing gear, a 450-HP engine and a constant speed propeller. The aircraft was originally designed for bush flying and is very stable and highly maneuverable at low airspeeds. It is designed to carry a pilot and five passengers. The aircraft is used for personnel, cargo, and medical evacuation. It can also be used for parachute operations with a maximum of four parachutists. The aircraft is 30 feet, 6 inches long, with a wing span of 48 feet.

2. Line

The tow line used was 2000 feet of 1/2-inch woven, hollow nylon, with a rated tensile strength of 4,000 pounds. The line was deployed from a drum or faking barrel in the aircraft, through an explosive line cutter, and out through a ring attached to a hydraulic cylinder whose opposite end was attached to the left landing gear. Most of the load pull was borne by the landing gear. The hydraulic cylinder was connected to a gauge inside the aircraft which provided a line tension display in pounds. (Note that the rear cabin door was removed to facilitate operations, Figure 1.)

The aircraft was modified with fending lines which ran from the rear fuselage to the tip of the elevator, and from the elevator to in front of the vertical stabilizer (Figures 2 & 3). It was found

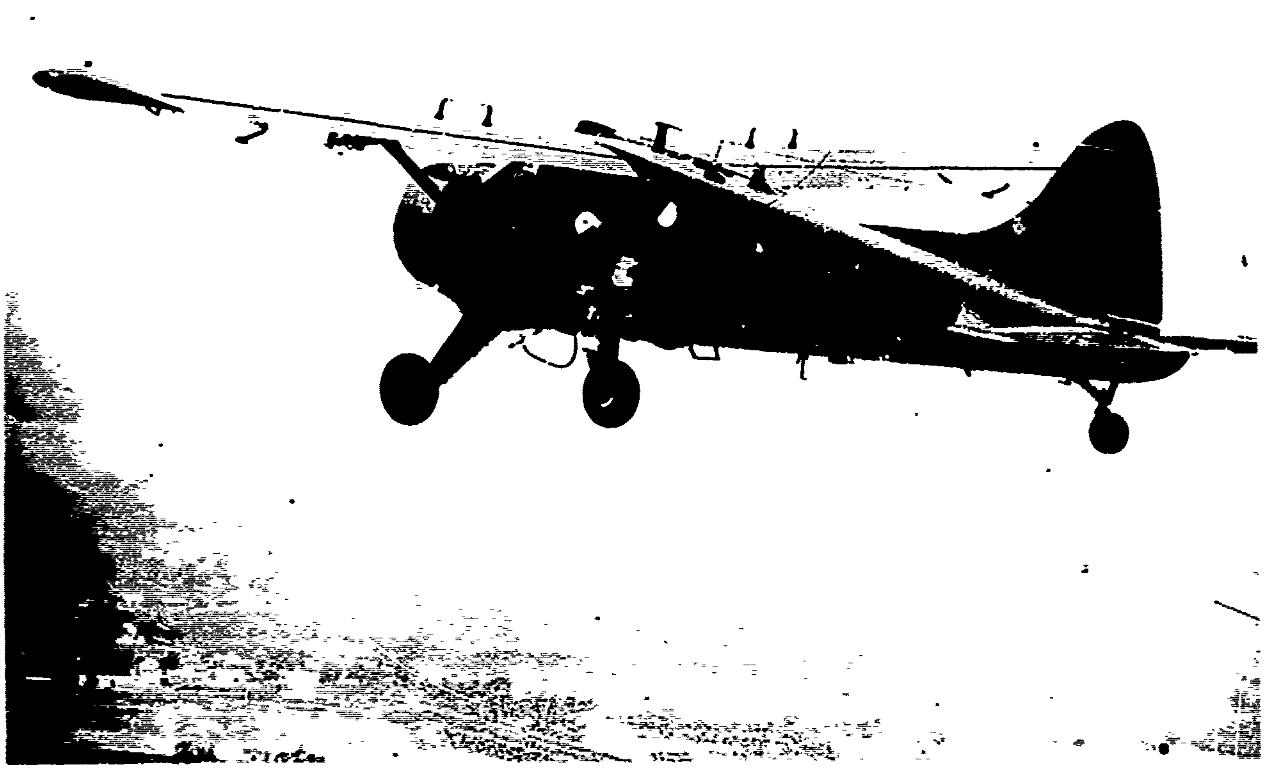

FIGURE 1 U6-A Double-line Deployment

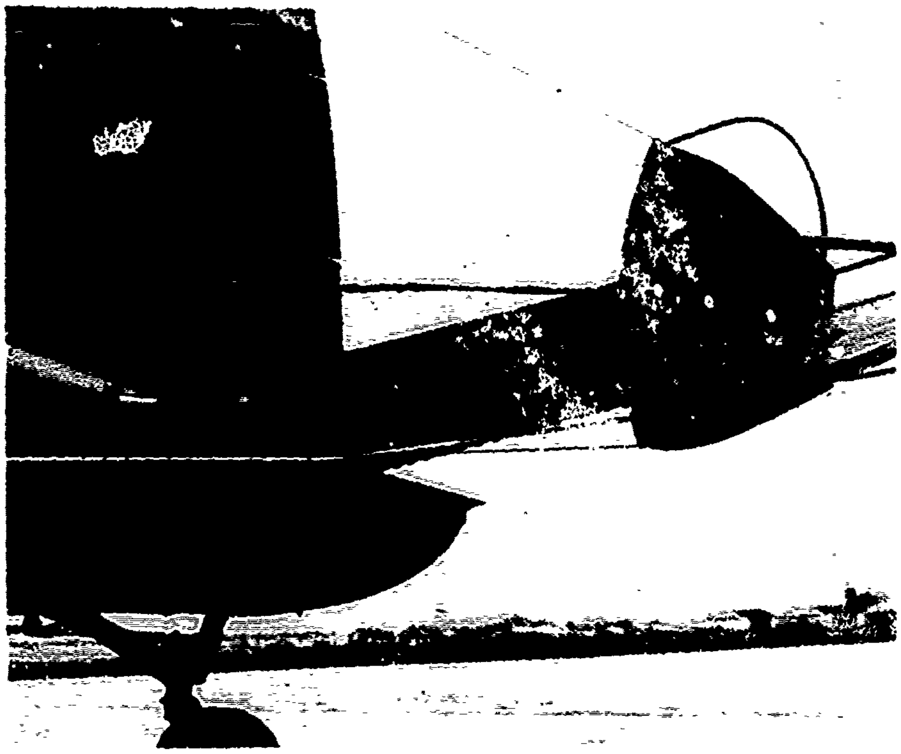

FIGURE 2 Fending Lines and Elevator Modification

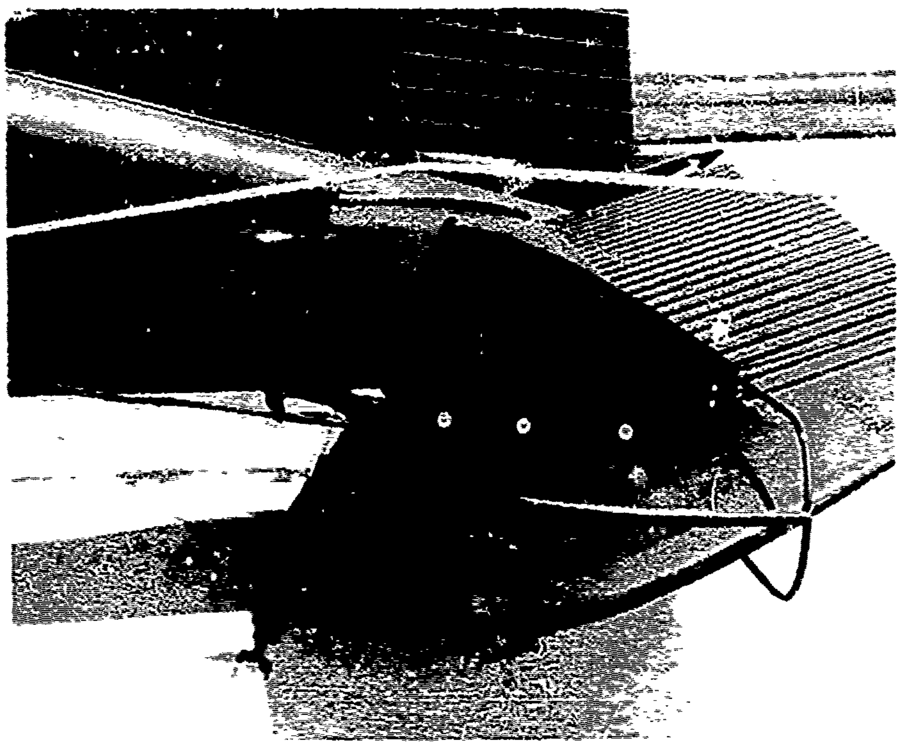

FIGURE 3 Deflection of Long-Line by Fending Line

that more than 45° of bank tended to flip the line onto the vertical fending line, although it was not difficult to disengage it by skidding the aircraft.

3. General Procedures

An aircrew of three included: pilot, co-pilot and line operator. The pilot and co-pilot performed their normal duties, and in addition, the pilot maintained communications with the control tower and the co-pilot maintained communications with the LLL ground crew. The line operator deployed the line, attached and released sliding weights, and relayed line tension data.

Immediately after takeoff, line deployment was started, using the double-line deployment method (ASD-TR-69-11).* A 20-pound cone was attached to the line so that it would slide at the end of the loop. This kept tension on the line, insuring its smooth deployment and preventing knotting.

After line deployment, the aircraft was flown into the wind, over the ground target at 1,000 feet AGL (Above Ground Level) at 75-85 knots (Figure 4). The end of the line was "bombed" to the pick-up area with a 20-pound weight (Figure 5). Immediately after dropping the line, the aircraft was banked left and orbited over the launch area so that the end of the line remained on the ground and could be retrieved by the ground crew. The bank angles required were from 30 to 40 degrees (depending on wind conditions) (Figure 6).

The aircraft speed was maintained at 70 to 75 knots at 1,000

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* Simons, J. C., B.C. Dixon, Long-Line Loiter: Improvement of Some Free-Fall and Circling Line Techniques, ASD TR 69-11, Volume I, Aeronautical Systems Division, Wright-Patterson AFB, Ohio, March 1969

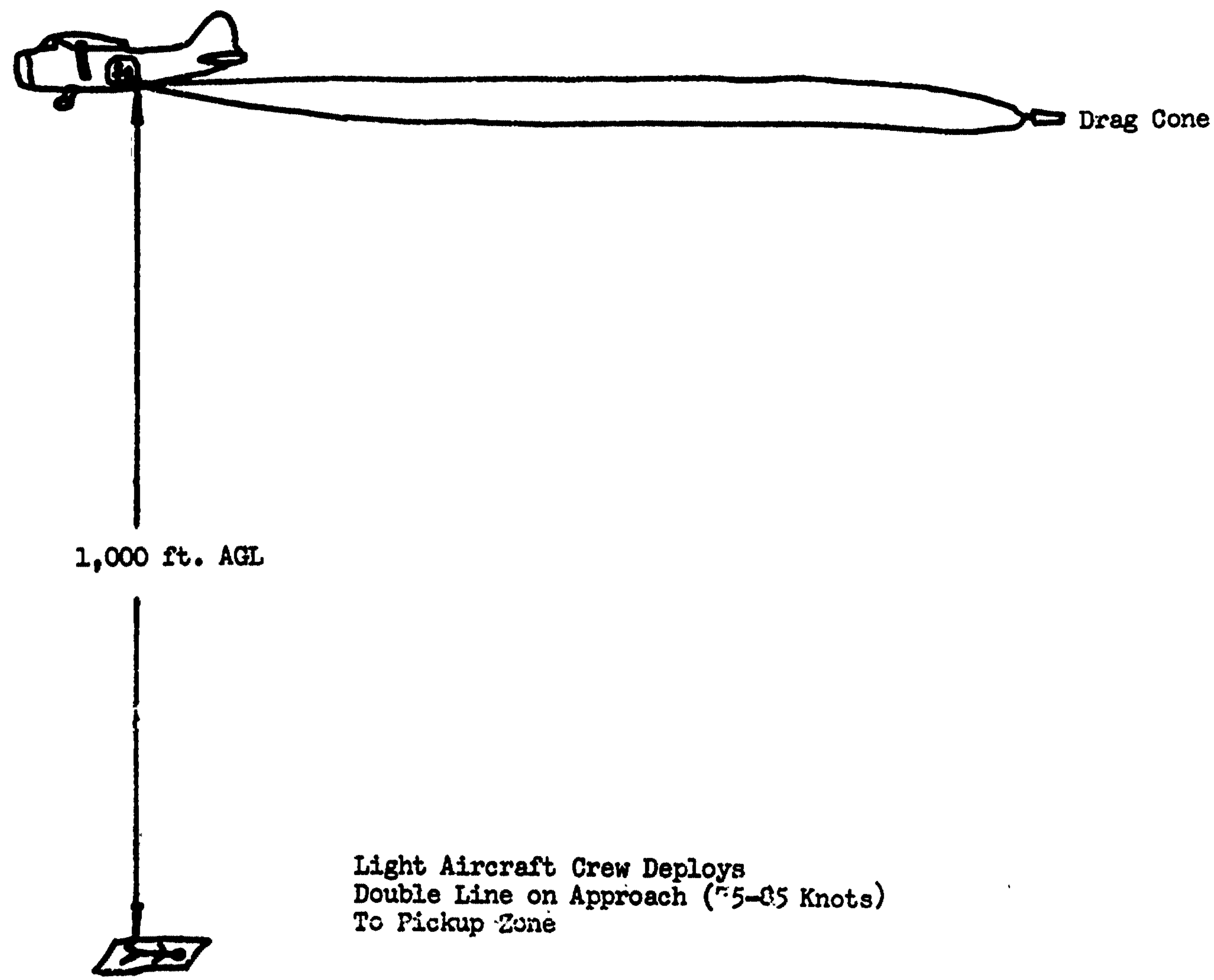

FIGURE 4 Approach to Pick-up Zone

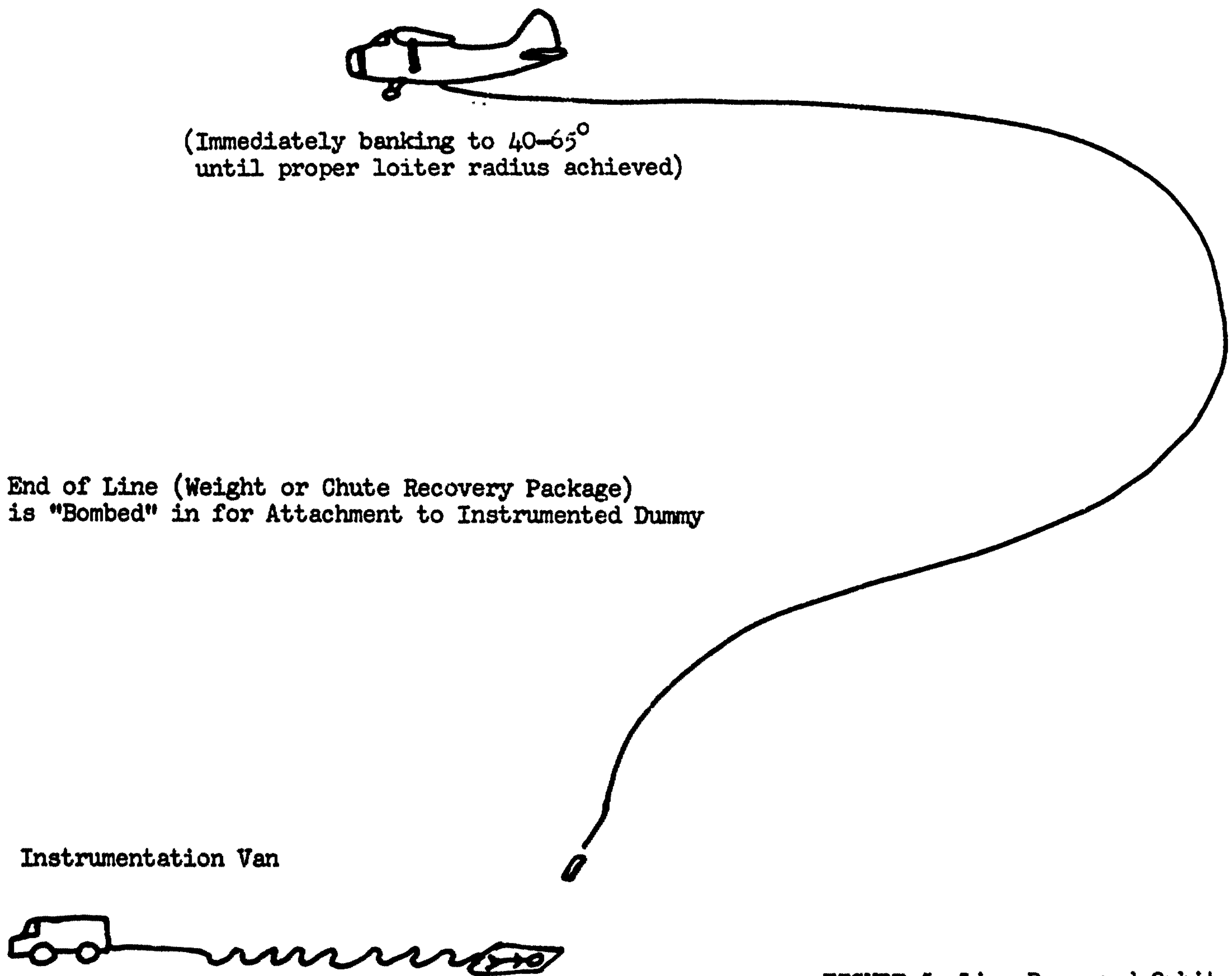

FIGURE 5 Line Drop and Orbit

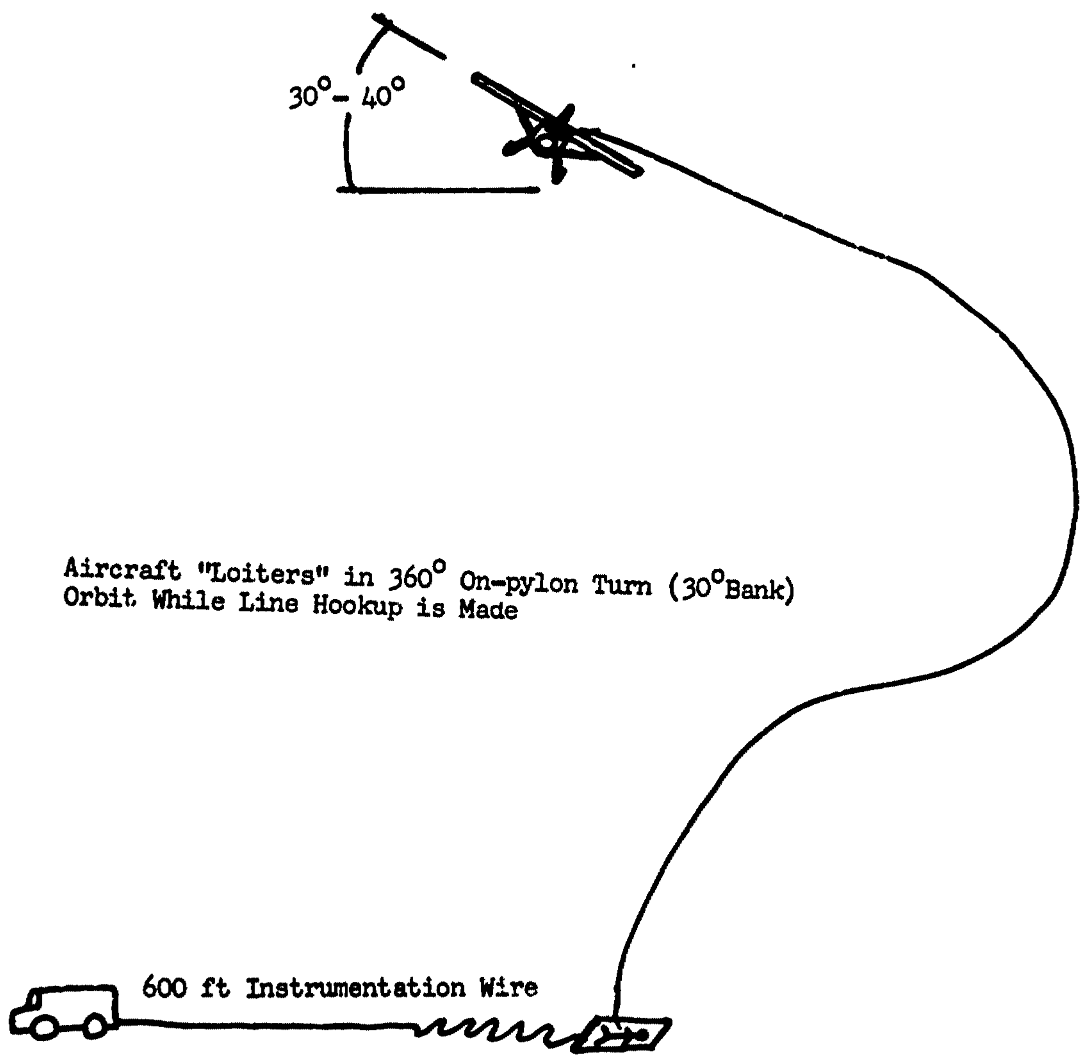

FIGURE 6 Loiter and Hook-up

feet AGL during this phase of the operation. If the winds were above 10 knots, it was sometimes necessary to fly the orbit at a lower altitude (700 to 800 ft) to reduce line tension and facilitate handling by the ground crew. Ground level winds varied between 4-15 knots, and winds aloft were from 6-30 knots during the two weeks of flying.

The orbit was maintained while the ground crew removed the cone and weights from the line and attached the line to the dummy. Just before the launch, the aircraft altitude was stabilized at 1,000 feet AGL and the airspeed was increased gradually to increase line tension slowly and minimize jolt at launch.

In order to launch, (Figures 7 and 8) the aircraft was turned to a level attitude into the wind and full climb power used to assure adequate power. The nose was raised slightly to keep the airplane at the desired launch airspeed. During the experiments, the launch airspeed was 75 or 85 knots. During the launch, the airplane slowed about 5 to 10 knots, due to drag, and level flight was maintained until speed was regained. Immediately after launch, the bank angles were kept below 15 degrees to prevent the dummy from dropping excessively before a safe altitude was reached. A climb was started and an ascent rate of about 300 to 400 FPM (Figure 7) until 2,000 feet AGL was reached. All line tension data taken at high bank angles were at 2,000 feet AGL to insure that they dummy did not drop too low.

When ready for dummy release, the aircraft was flown into the wind at 80 knots and 1500-2000 feet AGL. A release block was

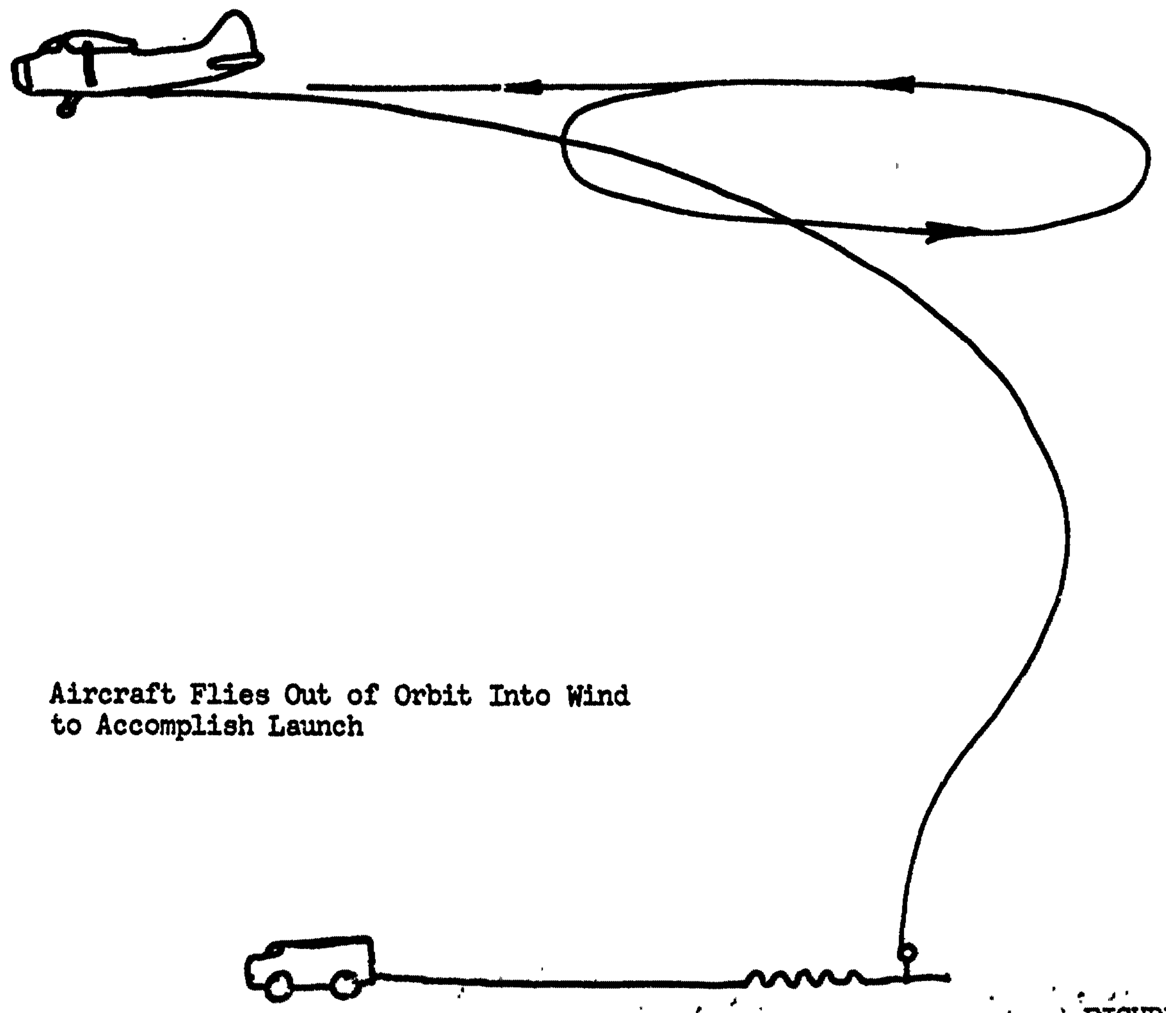

FIGURE 7. Launch

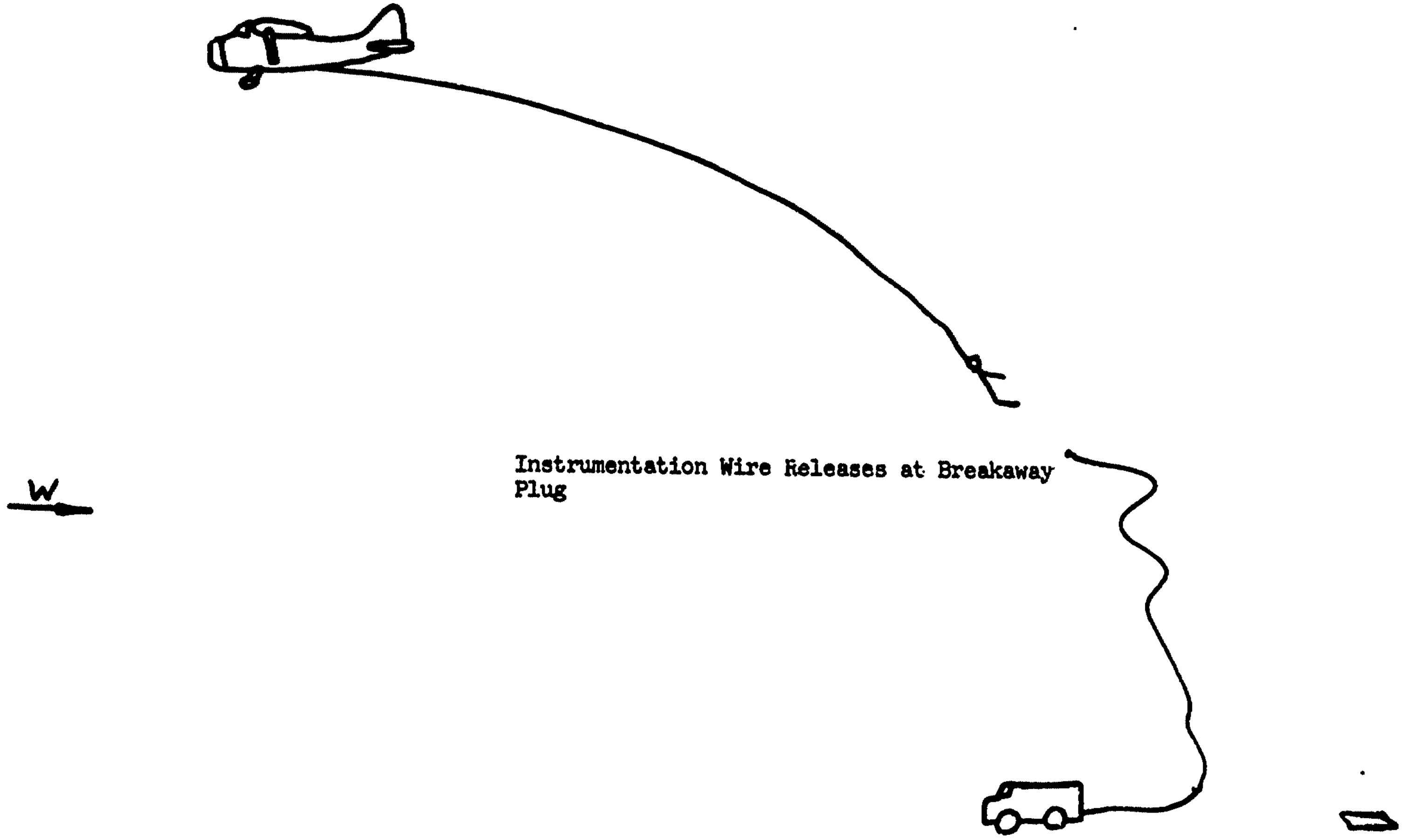

FIGURE 8 Separation from Instrumentation

deployed from the aircraft on command of the ground crew and the aircraft maintained in level flight until the dummy separated from the line (Figures 9 through 11).

After dummy release, a 20-pound weight was slid down the line to provide weight and drag for a subsequent single line delivery(AMRL-TR-69-140)*. After each dummy had reached the ground by parachute, the end of the line was delivered to the ground crew to prepare for the next launch. The single-line delivery technique was used for this purpose. The aircraft was flown to a maximum altitude of 1,000 feet AGL and a minimum of 700 feet AGL depending on wind velocity, and the orbit started around the launch area. The orbit was flown in a 30 to 40 degree left bank at approximately 70 knots airspeed. The line would then establish a loitering spiral and the end would drop to the ground for the ground crew to retrieve and prepare for the next launch.

4. Parachutes

Parachutes used in these tests were the 29-pound modified parachute assembly, personnel (Back), 50 C 7024-18, with 28-foot C-9 canopy.

The quarter-deployment bag was removed and canvas suspension line retainer strips were inserted into the inside bottom of the parachute. This insured faster chute deployment for the relatively low altitude, low airspeed conditions.

A pocket was added on the outside right flap of the parachute to house the static line. The portion of the static line going up

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* Behling, E. A., Long-Line Loiter: Personnel Retrieval System, AMRL TR 69-140, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, March 1971

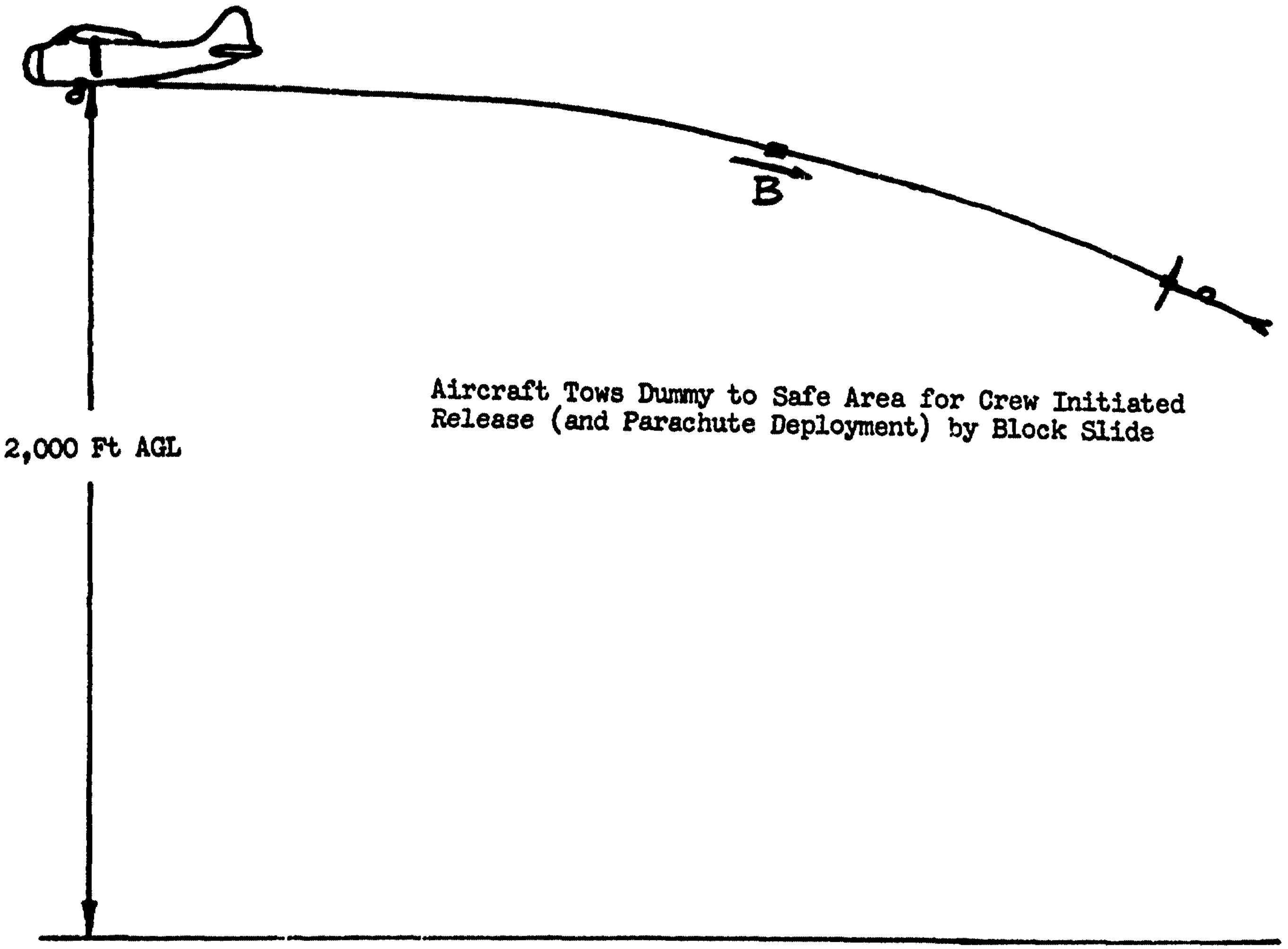


FIGURE 9 Dummy in Tow

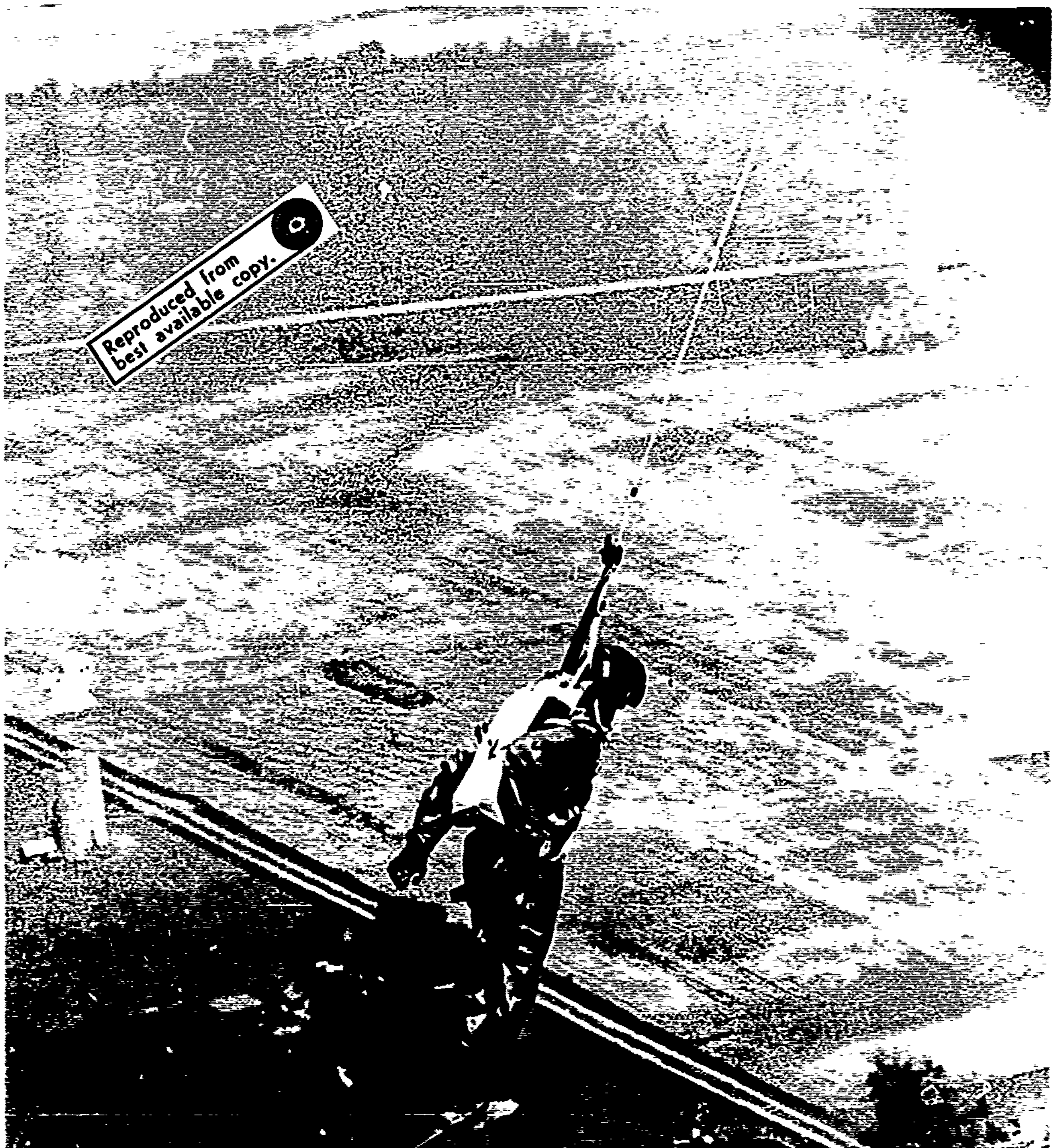
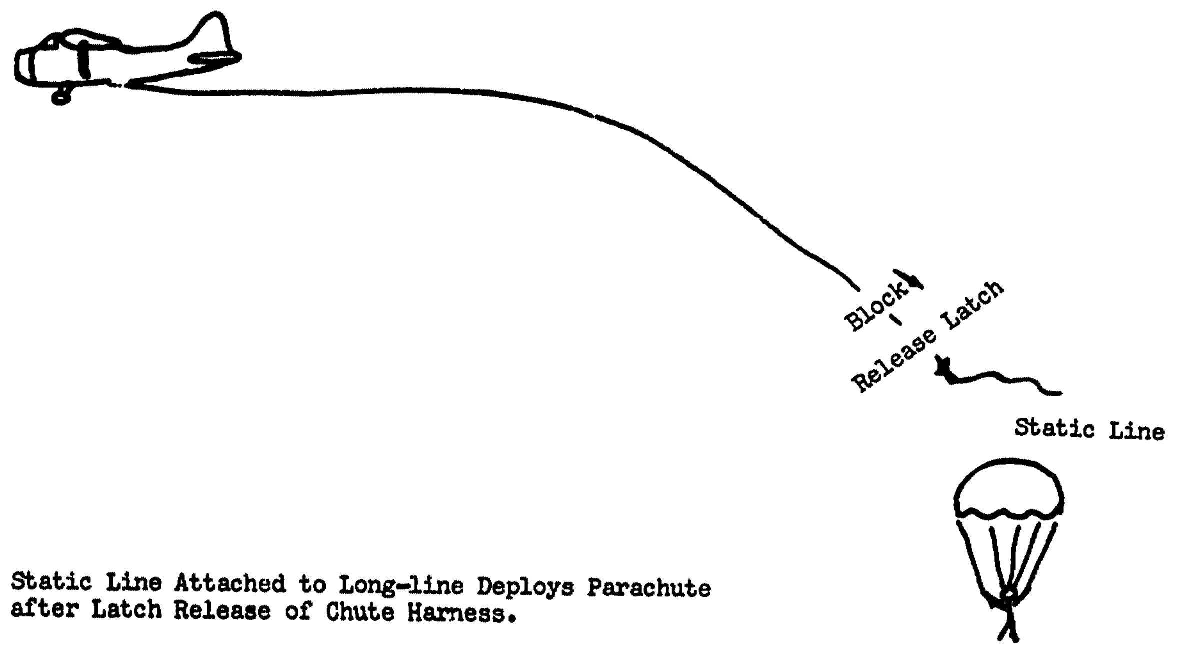


FIGURE 10 Dummy in Tow



Static Line Attached to Long-line Deploys Parachute
after Latch Release of Chute Harness.

FIGURE 11 Release and Parachute Deployment the yoke to the latch ring area was tacked with size #3 cotton thread (15-16 lb test) about every ten inches to prevent wind deployment of the parachute prematurely.

Details of the parachute hardware, including tow harness weight slide, latch release, and static line are provided in AMRL-TR-69-140.

Photographic coverage was by 5 x 7 and 8 x 10 still photos, and 16mm color motion pictures.

5. Acceleration and Tension Flight Profiles

Twenty-two launches were accomplished during nine U6-A flights; acceleration data was recorded on seven launches. Approximately fifteen launches were accomplished under a variety of weight and wind conditions to establish the best flying procedures and check of parachute hardware before instrumented launches were attempted. The major launch parameters are presented in Figure 12.

6. Instrumentation

Instrumentation was provided to measure and record the dummy accelerations in three axes during the initial 0-10 seconds of each launch. A triaxial chestpack acceleration package was fabricated to fit into the dummy's chest cavity (Figure 13). A 4-wire shielded cable connection was routed to the left foot of the dummy, where it was secured, leaving a pigtail about 18 inches long (Figure 14). The pigtail was fitted with a terminal break-away plug. A 600-foot cable of the same type was fitted with a mating breakaway plug and laid on the ground in the anticipated direction of launch, in a zig-zag fashion to the instrumentation vehicle, which was located

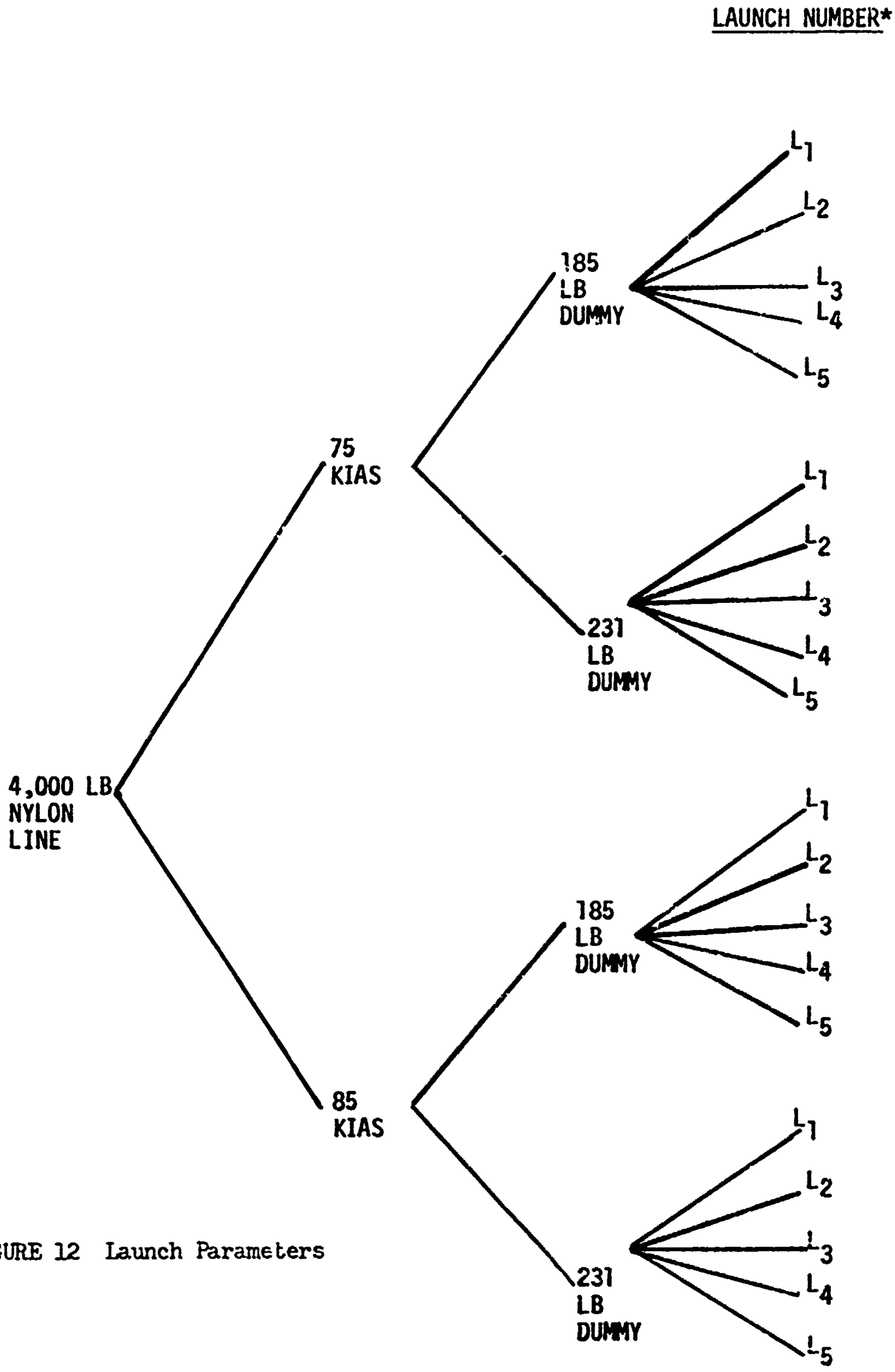


FIGURE 12 Launch Parameters

*Two Additional Launches Were Accomplished With Lighter Dummies

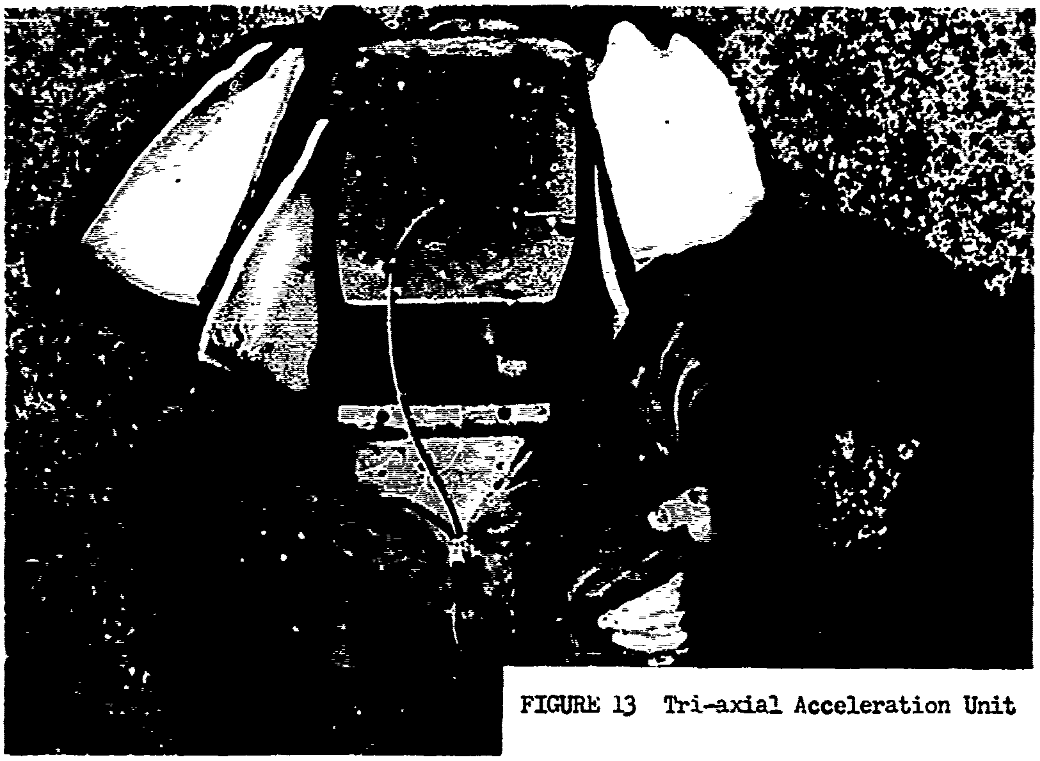


FIGURE 13 Tri-axial Acceleration Unit

FIGURE 14 Instrumentation Disconnect

approximately 150 feet from the launch site. During launch, the dummy moved toward the instrumentation vehicle and data was recorded until the dummy breakaway plug disconnected at 5-10 pounds tension. This varied from 5 to 13 seconds. The shorter time was due to one premature breakaway; the other recording times were all in excess of 5 seconds. The peak acceleration was reached before the cable was disconnected and satisfactory recordings were obtained on each launch.

The accelerometers used in the "X" and "Z" axes (conventional designation) were linear force balance servo instruments manufactured by Columbia Research Laboratories, Inc., (Model SA-102-B), with a range of ±10 g. The accelerometer used in the "Y" axis was a linear force balance servo instrument manufactured by Donner (Model 4310), with a range of ±1 g. A 1 g accelerometer was used in the "Y" axis because preliminary work indicated that there was no more than ±0.5G accelerations in this axis. None of the accelerometers reached maximum limit during these experiments.

Twenty-Eight VDC power for the accelerometers was provided by a Hewlett Packard Model 6205B regulated power supply. The acceleration signals were recorded on a Consolidated Electrodynamic Corporation (Model 5-124 eighteen) channel recorder (Figure 15). CEC 7-315 galvanometers were used, and the signals scaled to deflect the trace approximately 1 inch per g. One second timing (which was subsequently divided into shorter intervals) was recorded with an event trace to mark launch time. Power to operate the recorder and DC power supply was provided by a portable alternator with a 115-Volt, 60-Cycle, 1100-Watt output. A block diagram of the Signal Recording Circuit is provided in Figure 16.

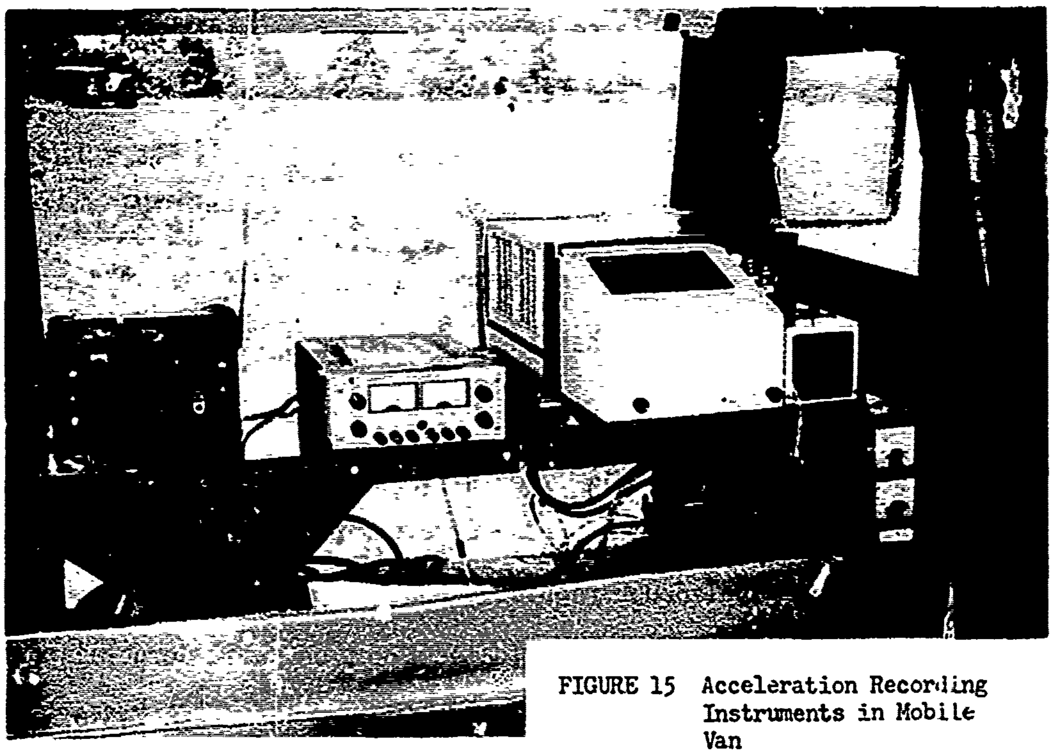


FIGURE 15 Acceleration Recording Instruments in Mobile Van

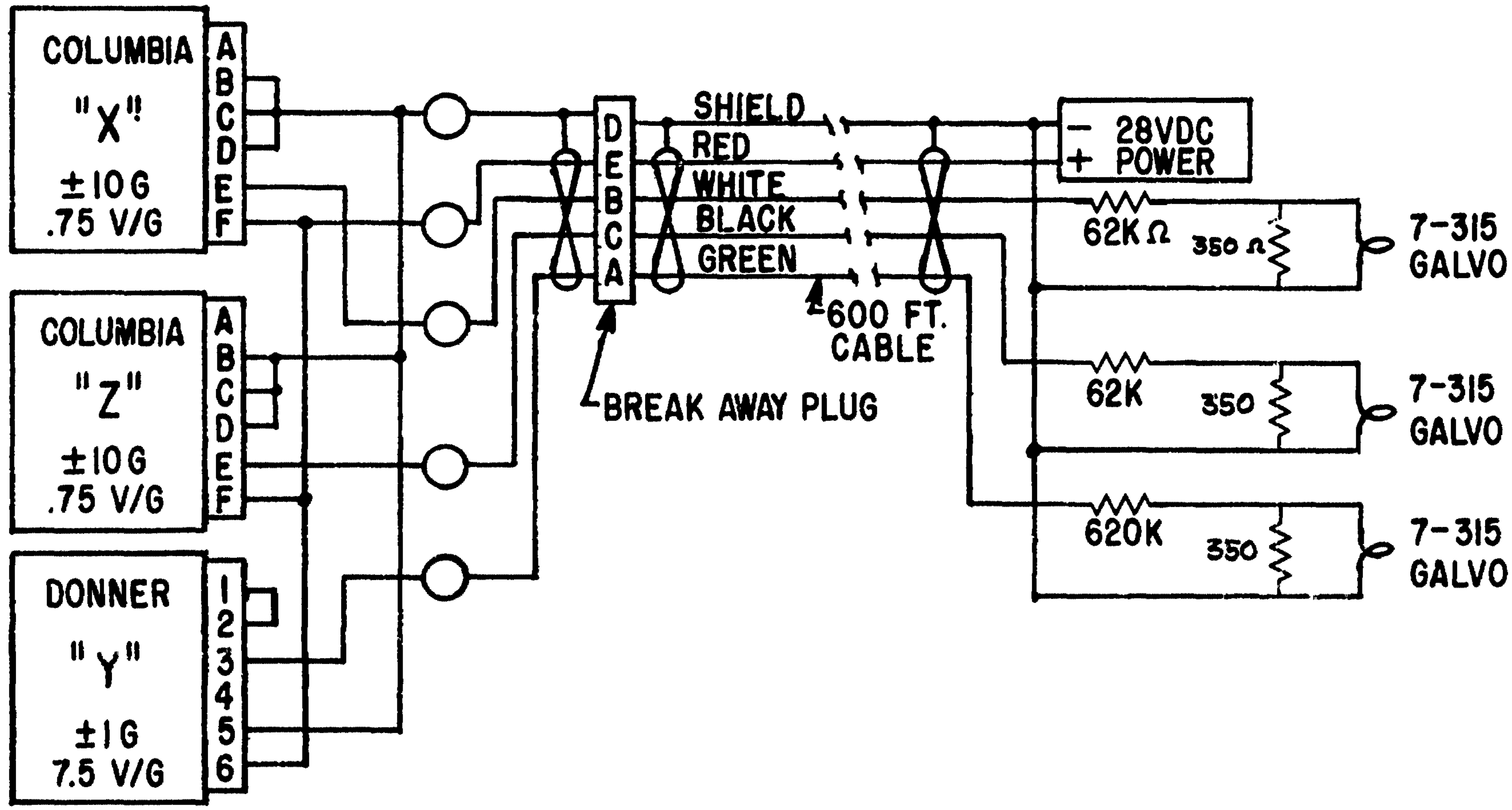


FIGURE 16 Tri-axial Pack, Signal Recording Circuit

SECTION III

RESULTS

1. Data Analysis

The raw data consisted of accelerometer output recordings from the CEC recorder as described in Section II. The recordings consisted of three parts: 1) an accelerometer laboratory calibration run made prior to each flight; 2) an accelerometer field calibration run made prior to each launch to assure accurate data reduction and 3) the X, Y, and Z events, plus time marker during each test launch (Figure 17 shows a typical record). The raw data was hand scored using a clear template with linear scales measured to match calibration runs. The data was then recorded at every 0.50 second interval. If that time span did not clearly define the events, (i.e., peak g not measured) hand selection of the maximum value for the interval was made. The table entries were then punched into data cards, and processed using a reduction program (Appendix I) on an IBM 360/40 computer.

Data Reduction contained the following:

(1) The value of the vector sum was computed using:

$$\text{Vector Sum} = X^2 + Y^2 + Z^2$$

Where X, Y, and Z are the values of the g load in the X, Y, and Z axes respectively.

(2) g onset was computed by approximating the derivative with respect to time by the linear forward differencing technique as follows:

$$\text{ONSET} = \frac{G_{T+0.5} - G_T}{T + 0.5 - T}$$

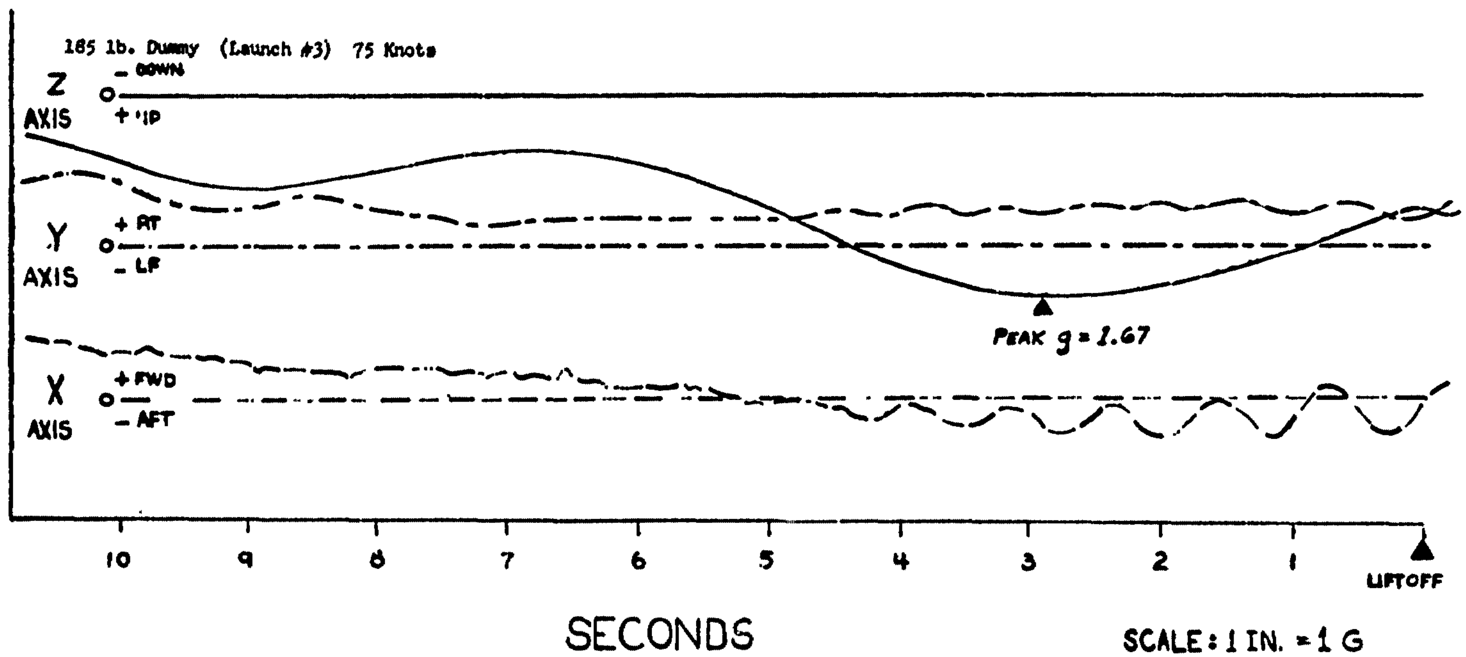


FIGURE 17 Acceleration Record

Where G_T - total g at some time T

$G_{T+0.5}$ - total g load at some new time $T_{+0.5}$

Reduced data table from the computer printout included the g load in the X, Y, and Z axes, the total g load, and the onset listed with respect to time. The maximum g load and maximum onset were listed at the end of the table for each run. A sample output is shown in Table 1 (complete reduced data is contained in Tables 4-10 in Appendix I).

In addition to the accelerometer output recordings, launch and trail tensions at the aircraft and time to peak tension at the aircraft were tabulated. Tension data were taken throughout the launch series even when accelerometer recordings were not recorded. A summary of this data is shown in Table 2.

A record was also made of aircraft settings following each launch. In general:

(1) Aircraft power was increased during launch from 22 inches to 35 inches of mercury (MAP) and from 2100 RPM to 2200 RPM.

(2) Flight altitude was increased slightly during launch.

(3) Peak launch line tension at the aircraft occurred between 2.3 - 5.9 seconds; mean approximately 3.8 seconds.

2. Interpretation of Data

Launch g load in three axes at .5 second intervals of dummies weighing 185 and 231 pounds are given in Appendix I. The X axis measured transverse g, that is, front to back; the Y axis measured lateral g, or side to side; while Z measured longitudinal or head to foot (positive) g. The vector sum value provided a resultant

ACCELERATION REORDINGS FOR 19 MAY 70

MASS, 231 LB DUMMY

TABLE 1

WINDS, 240° DEGS AT 6 KNOTS

LAUNCH SPEED 75 KNOTS

LAUNCH NUMBER 1

LAUNCH DATA

TIME IN SECONDS	ACCELERATICN IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	0.13	-0.17	1.01	1.032	0.0
0.500	-0.07	0.18	1.25	1.265	0.4648
1.000	0.08	0.07	1.40	1.404	0.2784
1.500	0.07	-0.10	1.58	1.585	0.3614
2.000	0.0	0.01	1.66	1.660	0.1506
2.500	-0.01	-0.13	1.69	1.695	0.0700
3.000	0.0	-0.02	1.64	1.640	-0.1098
3.500	-0.07	-0.11	1.50	1.506	-0.2689
4.000	-0.11	-0.02	1.20	1.205	-0.6009
4.500	-0.21	0.05	1.00	1.023	-0.3643
5.000	0.12	0.18	0.77	0.800	-0.4464
5.500	0.38	0.11	0.58	0.702	-0.1955
6.000	0.21	0.29	0.55	0.656	-0.0916
6.500	-0.20	0.33	0.56	0.680	0.0476
7.000	-0.29	0.37	0.58	0.747	0.1330
7.500	0.27	0.29	0.65	0.761	0.0293
8.000	0.20	0.37	0.74	0.851	0.1799
8.500	-0.20	0.31	0.82	0.899	0.0960
9.000	0.21	0.40	0.83	0.945	0.0916
9.500	0.29	0.34	0.80	0.916	-0.0573

PEAK G IS 1.6950G, OCCURRING AT 2.5000SECONDS
MAXIMUM POSITIVE ONSET IS 0.4648G/SEC, OCCURRING AT 0.5000SECONDS

TABLE 2

LAUNCH AND TRAIL TENSIONS OF LINE AT THE AIRCRAFT

Dummy Weight + Parachute	Airspeed	Launch Tension Mean	Launch Tension SD	Trail Tensions Mean	Trail Tensions SD
96 lb	75 knots	360*	-	245*	-
110	"	460*	-	250*	-
141	"	445	.500	263	12.5
185	"	481	46.3	338	16.8
231	"	588	40.1	378	22.5
141	85 knots	482	6.2	275	4.1
185	"	530	20.0	334	10.2
231	"	625	0.0	375	0.0

*One launch only.

TABLE 3

MEAN MAXIMUM G AT TIME INTO LAUNCH

AXIS	G VALUE	TIME	
X (Transverse G_x)	0.42	3.50 sec	(6 Launches)
Y (Lateral G_y)	0.38	6.00 sec	(6 Launches)
Z (Longitudinal G_z)	1.70	3.21 sec	(7 Launches)
TOTAL	1.70 ± 0.2	3.14 ± 2.8 sec	(6 Launches)

RATE OF ONSET FOR TOTAL G: 0.467 ± .19 G/sec.

or total g load at a given time. A summary of the launch data is given in Table 3. Negative values in tables in Appendix I represent jolt, rebound, or oscillation, and frequently occurred in the X and Y axes. Because the dummy was being launched upward, negative values are not seen in the Z axis. Total g load and Z axis g load, occasionally fall below 1 g; however, the trend was a slow increasingly dampened oscillation around the 1 g level. Thus, although launch perturbations were still evident upon instrumentation disconnect, the significant launch data were recorded, since dampened oscillations showed a trend toward the steady state at around 1 g.

Inspection of Table 3 shows the peak positive g ($+G_z$) was 1.50 - 1.89 g (Mean 1.70, S.D., .137), occurring at 2.0 - 6.0 seconds (mean 3.21 sec, S.D., 1.35). The difference in time for peak values was probably due to the launch angle departure of the dummy more than other factors.

SECTION IV

DISCUSSION

g load long the Z axis is presumably the most significant in terms of human tolerance. Positive g is directed toward the feet with greater effect on the circulatory system than either lateral or transverse g. In all cases, the greatest component of the vector sum came from the Z component. Physiological predictions, therefore, could be made on the assumption that nearly all g would be taken in the Z axis. (Severe lateral or transverse g could only occur with an improper launch, i.e., off the wind line.) The resultant (vector sum value) g load was never greater than 1.893, and in all cases, decreasing within ten seconds. A normal human subject should be able to tolerate two (2) gs positive (Z axis) for up to twenty minutes without difficulty (Reference 16). Because human tolerance for transverse (X axis) and lateral (Y axis) g is higher than for positive g, the X and Y axes values were so small they were considered relatively insignificant. If total g load were taken in the X, Y, or Z axes independently, the launches would still be within tolerance as recorded in these experiments.

The highest onset rate was .620 (Table 6 - Appendix I). This onset is not significant in relation to total g recorded. It is presumed that there is no danger of damage to the bone or muscle structure from this level of onset at a total of less than 2 gs.

Thirteen launches were at 75 knots, and nine were at 85 knots. Data on line launch and trail tension are given in Table 2. Tension is affected by airspeed, winds aloft, direction of the aircraft with relation to wind direction, line stretch and weight of the dummy.

From Table 2 it can be seen that minimum launch tension was approximately 2.4 times the dummy weight, and maximum tension was approximately 4.2 times the dummy weight. In general, launch tensions averaged about 2.7 times dummy weight and launch tension can be expected to increase with launch aircraft airspeed. Minimum launch tensions increased in all cases with airspeed.

There is considerable deviation in recorded line tension readings because of variable winds, but the results indicate a launch tension of approximately 481 pounds for the 185 pound dummy at 75 knots and 530 pounds at 85 knots. Trail tension is reduced to 333 and 338 pounds respectively.

The line tension at the aircraft during loiter with the end of the line held on the ground 150 $\pm$ 20 pounds. With no weight attached to the line, the trail tension of the line alone was 15 $\pm$ 10 pounds.

During launch, the aircraft increased power (2100-2200 RPM, 22-35 inches of mercury pressure) and flight altitude slightly, as mentioned previously, to insure a successful launch. The time of peak tension at the aircraft on ten launches was from 2.3 to 5.9 seconds or an average of 3.8 seconds.

g values recorded averaged less than those anticipated or by an approximation computed by the relationship:

$$\frac{(LT-TT) + wt}{wt} = g \text{ at dummy}$$

where LT = line tension

TT = tow tension

wt = weight of dummy

While earlier work (Table II, AMRL TR 69-140) indicated that g load with the 4,000 pound test line might be excessive (because line stretch of about 20% would not occur with lesser loading in relation to tension potential) the results indicate that the characteristics of this type of line (similar to that used in the Fulton recovery system) are well suited to future tests.

The altitude for initiation of block slide to release of the towed dummy was from 1500-2500 feet AGL. Six releases were initiated at 1500 feet, nine at 2000 feet, and four at 2500 feet. Mean time for block slide from release at the aircraft, until later engagement, was 24.4 seconds (S.D. 2.089 seconds).

Upon completion of the dummy acceleration tests, a rope dummy weighing approximately 65 pounds was attached to the end of the 2000 foot line without a parachute or other recovery aid. The object was to launch, tow and return the dummy to the gound with a soft landing using circling line techniques.

The rope dummy was launched in the same manner as other launches previously explained. With the dummy in tow, the aircraft climbed to 2000 feet AGL where an orbit was started to stall the line with the dummy suspended at the end of the line in the orbit center. The orbits were flown at 60 to 70 knots using 10 degrees flaps and approximately 45 degrees bank. After the line was stalled, power was reduced and a very slow descent of the dummy was started. During this time, there was about 100 feet of "yo-yo" observed by the dummy. The slow rate of descent (100 to 200 FPM) was continued until the dummy touched the ground softly when it was at the bottom of a yo-yo oscillation.

At this time, the line was cut at the airplane to leave the dummy on the ground which completed a simulated safe delivery of a man without the aid of a parachute.

During the delivery, it was virtually impossible for the pilot to judge the altitude AGL of the dummy unless the sun was shining. In this case, he observed the dummy shadow converging with the dummy and made a very good estimate of altitude and descent rate. During this particular delivery, the sun was shining and a ground team member kept the pilot informed on dummy conditions (altitude, yo-yo and descent rate) via radio at all times to aid in the delivery. This delivery was considered very successful and supports the theory that it is possible to accomplish a soft delivery of a moderately heavy mass using the LLL technique.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

1. The U6-A aircraft was ideally suited as a test vehicle because of its maneuverability and cargo area.

2. A large open area would be required for personnel retrieval using this system.

3. The double line and single line delivery system was not difficult to fly.

4. Live pick-ups at weights above 230 lbs, and airspeeds above 75 KIAS in this aircraft are not recommended because of its low rate of climb.

5. On future tests with this aircraft a support cable should be attached between the top of the vertical stabilizer and tip of the right horizontal stabilizer so that side load on the horizontal stabilizer will be equalized.

Future Efforts

a. Reliability Tests: Using improved parachute and line hardware, and 2,000 - 4,000 pound test line similar to that used in the acceleration test, criteria will be established to differentiate a successful launch from a failure. The launches and deliveries will be conducted until acceptable reliability is achieved.

b. Live Pick-Up: Following completion of the reliability tests, and the approval of medical protocol, it is planned that live pick-ups using this system will be accomplished if the aircraft selected can meet pre-determined rate-of-climb and engine failure criteria.

Upon completion of man-rating of the small aircraft retrieval system, a larger aircraft retrieval system involving OV-10 or C-130 with winch system would be explored (Figure 18).

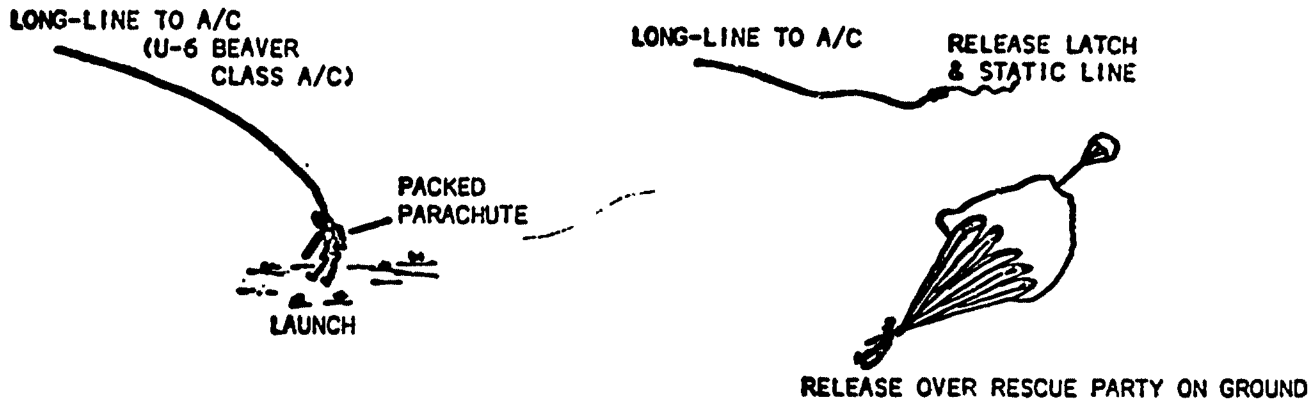


FIGURE : SMALL AIRCRAFT RE-DROP RESCUE SYSTEM

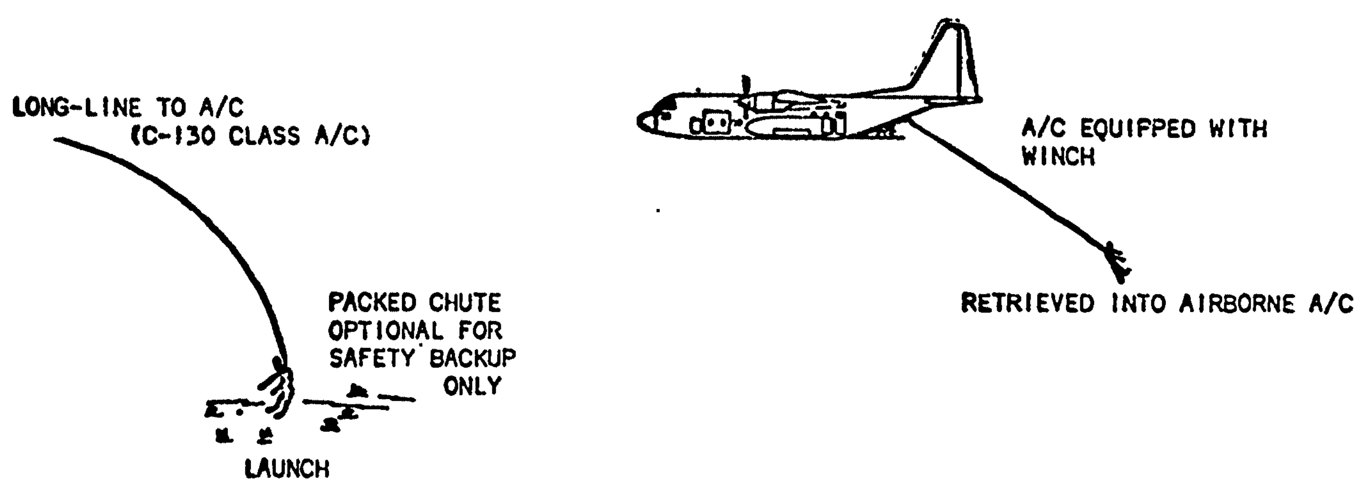


FIGURE 18 LARGE AIRCRAFT RETRIEVAL RESCUE SYSTEM

APPENDIX I

LAUNCH DATA TABLES 4-10

LAUNCH DATA TABLE 4

TIME IN SECONDS	ACCELERATION IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	0.12	0.0	0.95	0.958	0.0
0.500	0.18	0.08	1.04	1.058	0.2019
1.000	0.08	-0.01	1.11	1.113	0.1089
1.500	0.22	0.02	1.23	1.250	0.2735
2.000	0.21	-0.03	1.31	1.327	0.1548
2.500	0.14	-0.02	1.42	1.427	0.1999
3.000	0.11	-0.03	1.50	1.504	0.1546
3.500	0.17	-0.02	1.53	1.540	0.0704
4.000	0.22	-0.01	1.56	1.575	0.0718
4.500	0.18	0.0	1.51	1.521	-0.1096
5.000	0.17	0.0	1.41	1.420	-0.2010

PEAK G IS 1.5755G, OCCURRING AT 4.0000SECONDS
MAXIMUM POSITIVE ONSET IS 0.2735G/SEC, OCCURRING AT 1.5000SECONDS

ACCELERATION REORDINGS FOR 7 May 70

MASS, 185 LB DUMMY

WINDS, 140 DEGS AT 4 KNOTS

LAUNCH SPEED 75 KNOTS

LAUNCH NUMBER 2

LAUNCH DATA TABLE 5

TIME IN SECONDS	ACCELERATION IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	0.13	0.0	0.93	0.939	0.0
0.500	0.19	-0.10	1.11	1.131	0.3831
1.000	0.09	-0.19	1.20	1.218	0.1754
1.500	0.26	-0.09	1.48	1.505	0.5742
2.000	0.18	-0.33	1.50	1.546	0.0821
2.500	0.19	-0.10	1.64	1.654	0.2152
3.000	0.12	-0.11	1.63	1.638	-0.0318
3.500	0.11	-0.22	1.52	1.540	-0.1967
4.000	0.16	-0.05	1.41	1.420	-0.2397
4.500	0.17	-0.06	1.12	1.134	-0.5710
5.000	0.09	-0.05	0.92	0.926	-0.4173
5.500	0.10	0.09	0.71	0.723	-0.4062
6.000	0.08	0.12	0.58	0.598	-0.2499
6.500	0.07	0.19	0.50	0.539	-0.1164
7.000	0.07	0.22	0.41	0.471	-0.1378
7.500	0.05	0.21	0.51	0.554	0.1665
8.000	0.12	0.30	0.59	0.673	0.2378
8.500	0.26	0.26	0.66	0.756	0.1657
9.000	0.17	0.31	0.72	0.802	0.0932
9.500	0.19	0.40	0.67	0.803	0.0020
10.000	0.41	0.42	0.51	0.778	-0.0511
10.500	0.42	0.50	0.39	0.761	-0.0339

PEAK G IS 1.6540G, OCCURRING AT 2.5000SECONDS
MAXIMUM POSITIVE ONSET IS 0.5742G/SEC, OCCURRING AT 1.5000SECONDS

ACCELERATION REORDINGS FOR 7 [illegible] / 1970

MASS, 185 LB DUMMY

WINDS, 140 DEGS AT 4 KNOTS

LAUNCH SPEED 75 KNOTS

LAUNCH NUMBER 3

LAUNCH DATA TABLE 6

TIMB IN SECONDS	ACCELERATION IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	0.0	0.0	0.14	0.140	0.0
0.500	0.0	0.0	0.20	0.200	0.1200
1.000	0.0	0.0	0.27	0.270	0.1400
1.500	0.0	0.0	0.38	0.380	0.2200
2.000	0.0	0.0	0.49	0.490	0.2200
2.500	0.0	0.0	0.63	0.630	0.2800
3.000	0.0	0.0	0.80	0.800	0.3400
3.500	0.0	0.0	0.72	0.720	-0.1600
4.000	0.0	0.0	0.89	0.890	0.3400
4.500	0.0	0.0	1.20	1.200	0.6200
5.000	0.0	0.0	1.33	1.330	0.2600
5.500	0.0	0.0	1.44	1.440	0.2200
6.000	0.0	0.0	1.50	1.500	0.1200
6.500	0.0	0.0	1.48	1.480	-0.0400
7.000	0.0	0.0	1.35	1.350	-0.2600
7.500	0.0	0.0	1.11	1.110	-0.4800
8.000	0.0	0.0	0.81	0.810	-0.6000
8.500	0.0	0.0	0.60	0.600	-0.4200
9.000	0.0	0.0	0.49	0.490	-0.2200
9.500	0.0	0.0	0.45	0.450	-0.0300
10.000	0.0	0.0	0.49	0.490	0.0800

PEAK G IS 1.5000G, OCCURRING AT 6.0000SECONDS
MAXIMUM POSITIVE ONSET IS 0.6200G/SEC, OCCURRING AT 4.5000SECONDS

ACCELERATION REORDINGS FOR 17 May 70

MASS, 231 LB DUMMY

WINDS, 270° DEGS AT 6 KNOTS

LAUNCH SPEED 75 KNOTS

LAUNCH NUMBER 1

LAUNCH DATA TABLE 7

TIME IN SECONDS	ACCELERATICN IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	0.13	-0.17	1.01	1.032	0.0
0.500	-0.07	0.18	1.25	1.265	0.4648
1.000	0.08	0.07	1.40	1.404	0.2784
1.500	0.07	-0.10	1.58	1.585	0.3614
2.000	0.0	0.01	1.66	1.660	0.1506
2.500	-0.01	-0.13	1.69	1.695	0.0700
3.000	0.0	-0.02	1.64	1.640	-0.1098
3.500	-0.07	-0.11	1.50	1.505	-0.2689
4.000	-0.11	-0.02	1.20	1.205	-0.6009
4.500	-0.21	0.05	1.00	1.023	-0.3643
5.000	0.12	0.18	0.77	0.800	-0.4464
5.500	0.38	0.11	0.58	0.702	-0.1955
6.000	0.21	0.29	0.55	0.656	-0.0916
6.500	-0.20	0.33	0.56	0.680	0.0476
7.000	-0.29	0.37	0.58	0.747	0.1330
7.500	0.27	0.29	0.65	0.761	0.0293
8.000	0.20	0.37	0.74	0.351	0.1799
8.500	-0.20	0.31	0.82	0.899	0.0960
9.000	0.21	0.40	0.83	0.945	0.0916
9.500	0.29	0.34	0.80	0.916	-0.0573

PEAK G IS 1.6950G, OCCURRING AT 2.5000SECONDS
MAXIMUM POSITIVE ONSET IS 0.4648G/SEC, OCCURRING AT 0.5000SECONDS

ACCELERATION REORDINGS FOR 19 MAY 70

MASS, 231 LB DUMMY

WINDS, 240° DEGS AT 6 KNOTS

LAUNCH SPEED 75 KNOTS

LAUNCH NUMBER 1

LAUNCH DATA TABLE 8

TIME IN SECONDS	ACCELERATION IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	-0.85	0.02	1.30	1.553	0.0
0.500	0.01	0.26	1.55	1.572	0.0367
1.000	0.0	-0.07	1.71	1.711	0.2795
1.500	0.0	-0.13	1.85	1.855	0.2863
2.000	-0.01	-0.21	1.88	1.892	0.0743
2.500	0.05	-0.14	1.71	1.716	-0.3505
3.000	0.09	-0.01	1.47	1.473	-0.4873
3.500	-0.04	0.21	1.19	1.209	-0.5275
4.000	-0.15	0.20	0.88	0.915	-0.5885
4.500	-0.35	0.19	0.69	0.797	-0.2363
5.000	-0.32	0.29	0.55	0.699	-0.1948
5.500	-0.21	0.36	0.51	0.659	-0.0813
6.000	0.20	0.13	0.51	0.563	-0.1912
6.500	0.19	-0.32	0.59	0.698	0.2691
7.000	-0.40	-0.47	0.60	0.861	0.3264
7.500	-0.68	-0.36	0.77	1.089	0.4556
8.000	-0.41	0.40	0.79	0.976	-0.2254
8.500	-0.15	0.0	0.20	0.250	-1.4516

PEAK G IS 1.8917G, OCCURRING AT 2.0000SECONDS
MAXIMUM POSITIVE ONSET IS 0.4556G/SEC, OCCURRING AT 7.5000SECONDS

ACCELERATION REORDINGS FOR 19 May

MASS, 231 LB DUMMY

WINDS, 220° DEGS AT 8 KNOTS

LAUNCH SPEED 85 KNOTS

LAUNCH NUMBER 2.

LAUNCH DATA TABLE 9

TIME IN SECONDS	ACCELERATION IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	-0.08	0.12	1.05	1.060	0.0
0.500	0.17	0.0	1.17	1.182	0.2449
1.000	0.0	-0.01	1.33	1.330	0.2955
1.500	0.12	0.01	1.52	1.525	0.3895
2.000	0.0	0.0	1.68	1.680	0.3105
2.500	0.10	0.0	1.79	1.793	0.2256
3.000	0.09	0.0	1.87	1.872	0.1587
3.500	0.10	-0.01	1.89	1.893	0.0410
4.000	0.08	-0.01	1.79	1.792	-0.2017
4.500	0.0	-0.07	1.61	1.612	-0.3606
5.000	0.0	-0.06	1.21	1.211	-0.8001
5.500	0.0	-0.19	0.95	0.969	-0.4853
6.000	0.02	-0.20	0.65	0.680	-0.5769
6.500	0.23	-0.11	0.53	0.588	-0.1845
7.000	0.20	0.17	0.48	0.547	-0.0821
7.500	-0.40	0.48	-0.11	0.634	0.1747
8.000	-0.37	0.39	0.0	0.538	-0.1937

PEAK G IS 1.8927G, OCCURRING AT 3.5000SECONDS
MAXIMUM POSITIVE ONSET IS 0.3895G/SEC, OCCURRING AT 1.5000SECONDS

ACCELERATION REORDINGS FOR 19 MAY 70

MASS, 231 LB DUMMY

WINDS, 250 DEGS AT 8 KNOTS

LAUNCH SPEED 85 KNOTS

LAUNCH NUMBER 3

LAUNCH DATA TABLE 10

TIME IN SECONDS	ACCELERATION IN G,S X AXIS	Y AXIS	Z AXIS	VECTOR SUM (VALUE)	ONSET G/SEC
0.0	0.25	-0.20	1.23	1.271	0.0
0.500	-0.21	-0.25	1.48	1.516	0.4892
1.000	-0.11	-0.31	1.63	1.663	0.2945
1.500	-0.11	-0.36	1.70	1.741	0.1566
2.000	-0.01	-0.22	1.72	1.734	-0.0143
2.500	-0.20	-0.18	1.68	1.701	-0.0653
3.000	-0.22	-0.12	1.32	1.344	-0.7157
3.500	-0.13	0.0	1.25	1.257	-0.1737
4.000	0.33	-0.11	0.43	0.553	-1.4073
4.500	0.36	-0.32	0.63	0.793	0.4799
5.000	0.42	-0.20	0.59	0.751	-0.0834

PEAK G IS 1.7412G, OCCURRING AT 1.5000SECONDS
MAXIMUM POSITIVE ONSET IS 0.4892G/SEC, OCCURRING AT 0.5000SECONDS

ACCELERATION REORDINGS FOR 19 MAY 70

MASS, 231 LB DUMMY

WINDS, 250° DEGS AT 8 KNOTS

LAUNCH SPEED 75 KNOTS

LAUNCH NUMBER 4

APPENDIX II

DETAILS OF FLIGHT TECHNIQUE - COMMAND PILOT

A Standard US Army U6-A #57-6166 was used as the test vehicle. The left horizontal stabilizer was modified with a bracket and cables to prevent possible elevator jamming if the tow line became wedged between the elevator and horizontal stabilizer. The allowable gross weight and CG for the U-6 is 5100 pounds and 17.4 - 42% MAC. The take-off gross weights and CG during the tests were 4550 lbs and 32% MAC. The crew consisted of pilot, co-pilot and line operator. The project equipment including the nylon line, weighed 156 lbs. The CG of the aircraft with the 135-lb dummy undertow was 29% MAC; for the 185-lb dummy it was 32.2% MAC, and for the 230-lb dummy it was 34.5% MAC.

A slight pressure had to be applied to the left rudder to keep the aircraft in trim while the dummy was under tow, because the drag force being applied was not at the centerline of the aircraft. The maximum ball deflection was 1/2-ball width for the 230-lb dummy at 85 KIAS.

The double line method was accomplished by flying the aircraft over the target, into the wind at 75 KIAS, at an altitude of 1000 feet above the ground. At a point approximately 500 feet beyond the target, the weighted end of the looped 2000-ft line was released from the aircraft, and immediately a steep descending left turn (60° angle of bank) at reduced power was made, to an altitude of 700 ft above the ground. At the completion of 180-degree turn, the line made ground contact. A 20-lb weight was required to provide an accurate delivery especially if the surface wind was above 15 knots. The orbits were flown at air speeds of 55 to 85 KIAS. It was easier to fly orbits at a lower airspeed because the angle of bank was less. When the wind was over 15 knots, the orbit took on an elliptical shape rather than a circular pattern which required the upwind and downwind angle to be in the vicinity of 60°. To assist the pilot in maintaining minimum ground tension on the tow line while personnel were attaching the dummy and instrumentation, a downwind ground lay was provided. This ground lay was always visible to the pilot. The amount varied with the wind velocity. Below 10 knots it was approximately 100-200 feet; at 25 knots, 500-700 feet. As ground lay was reduced by flying into the wind, line tension would build up. Downwind turns were made while there was still ground lay, thus holding tension to a minimum.

The single line method was accomplished by flying into the wind approximately 1000 feet to the right of the target at 75 KIAS, at an altitude of 1000 feet above the ground. At a point approximately 1000 feet beyond the target, a left descending turn was made to an altitude of 700 feet above the ground. Keeping the target to the left, the aircraft was flown to a position downwind, approximately 500 feet abeam the target, at which time the orbit as mentioned above was accomplished. Ground contact usually occured within 3/4 of an orbit.

All pick-ups were made by flying directly over the target at 75 or 85 KIAS, and in a climb attitude. The dummies ascended nearly vertically. If the aircraft was off to the right of the dummy at lift-off, the dummy ascended vertically to the right before starting its forward flight. If there was too much ground lay of the tow cable, the dummy ascended vertically backwards before starting its forward flight. Ground lay was reduced by adjusting the last orbit before lift-off. If a low airspeed was flown in the orbit, the desired launch airspeed was obtained during the last orbit. It was quite common for the tow-line to rest on the elevator protective cable during launch, if the winds were above 20 knots. This cable ran between the top of the vertical stabilizer to the tip of the left horizontal stabilizer. This condition existed because of the steep turn (60° angle of bank) required to position the aircraft over the dummy at lift off. The line operator normally advised the pilot of the position of the tow line prior to lift-off, however, on several occasions, this was not the case and the pilot was unaware the tow-line was over the cable. There was no adverse effect on elevator control at lift off or during tow. Yawing the aircraft caused the line to slip off the protective cable and assume a position in trail below the stabilizer. For the weights tested it was difficult for the pilot to determine if a launch had been completed. Usually it was detected by the aircraft's rate of climb. This was not the case when dummy was released. Even for a light load (65 lbs) a definite lunge of the aircraft could be felt.

MetoPower (2200 RPM - 35" HG), and climb flaps were used for all pickups and climbs. The rate of climb for the 230-lb dummy at 75 KIAS was 275 ft/min and at 85 KIAS was 125 ft/min. The normal rate of climb at 75 KIAS was 650 ft/min.

While towing the 230-lb dummy to the drop area it trailed below the aircraft 600 feet, at 85 KIAS, 700 feet at 75 KIAS and 800 feet at 50 KIAS.

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