

AD 727007



# LONG-LINE LOITER: PERSONNEL RETRIEVAL SYSTEM

EDWARD A. BEHLING, CAPT, USAF, BSC

MARCH 1971

DDC  
RECEIVED  
AUG 2 1971  
D

This document has been approved for public release and sale; its distribution is unlimited.

Reproduced by  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
Springfield, Va. 22151

AEROSPACE MEDICAL RESEARCH LABORATORY  
AEROSPACE MEDICAL DIVISION  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

## NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

ADDRESSOGRAPH	
WHITE SECTION	<input checked="" type="checkbox"/>
DIFF. SECTION	<input type="checkbox"/>
UNMAIL. GEN.	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
INT.	AVAIL. and/or SPECIAL
A	

Organizations and individuals receiving announcements or reports via the Aerospace Medical Research Laboratory automatic mailing lists should submit the addressograph plate stamp on the report envelope or refer to the code number when corresponding about change of address or cancellation.

Do not return this copy. Retain or destroy.

## DOCUMENT CONTROL DATA - R &amp; 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)		2a. REPORT SECURITY CLASSIFICATION	
Aerospace Medical Research Laboratory Aerospace Medical Div., Air Force Systems Command Wright-Patterson AFB, Ohio 45433		UNCLASSIFIED	
3. REPORT TITLE		2b. GROUP	
LONG-LINE LOITER: PERSONNEL RETRIEVAL SYSTEM		N/A	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)			
Final Report			
5. AUTHOR(S) (First name, middle initial, last name)			
Edward A. Behling, Captain, USAF, BSC			
6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS	
March 1971	19	12	
8a. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO. 7184	AMRL-TR-69-140		
c. Task No. 718405	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)		
d.			
10. DISTRIBUTION STATEMENT			
This document has been approved for public release and sale; its distribution is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY	
		Aerospace Medical Research Laboratory Aerospace Medical Div., Air Force Systems Command, Wright-Patterson AFB, OH 45433	
13. ABSTRACT			
<p>This report covers the use of fixed-wing aircraft employing innovations to free-fall and circling-line techniques in the rescue of personnel and delivery and retrieval of equipment. The technique involves the deployment of a line from the aircraft while a controlled turn is maintained, causing the line to describe a diminishing spiral earthward. Successful launches of dummy weights up to 203 pounds suggest this technique can feasibly be employed in personnel rescue. Included in the testing were various aircraft, altitudes, speeds, lines, and line lengths. Line tensions were measured. Proposed future efforts toward man-rating the system include measurements of launch G forces and the assessment of system reliability.</p>			
Key Words: Rescue Supply missions			

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

## 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 performed equipment design (Contract F33615-69-C-1687) and served as a pilot during flight tests. Mr. George Zelinkas of the Aeronautical Systems Division made required parachute modifications. First Lieutenant Michael Moran designed the latch assembly for the retrieval system, and the following personnel of the Aerospace Medical Research Laboratory made significant contributions as indicated: Lt Col John C. Simons (pilot), 2Lt Eric J. Jumper (data analysis), Mr. C. William Sears (contracts, field tests), TSgt Roland W. Fancher (field tests), TSgt Richard Blue (field tests), and SSgt Wayne W. Reffner (field tests). This report covers research performed between December 1968 and October 1969.

This technical report has been reviewed and is approved.

CLINTON L. HOLT, Colonel, USAF, MC  
Commander  
Aerospace Medical Research Laboratory

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
I	INTRODUCTION. . . . .	1
II	EXPLORATORY FLIGHTS . . . . .	2
	Aircraft Descriptions. . . . .	2
	Flight Test Results. . . . .	2
	Retrieval Pattern. . . . .	6
III	FUTURE EFFORTS. . . . .	
	U-6 Beaver With a Faking Barrel. . . . .	13
	U-6 Beaver With a Winch. . . . .	13
	C-130 System . . . . .	13
	BIBLIOGRAPHY . . . . .	17

## EXPLANATION OF TERMS

Area Loiter	An orbiting aircraft, a long-line, and a loitered object drifting with the wind in such a manner as to cover a large ground area.
Circling Line	Describes the basic long-line maneuver.
Closed Loop Delivery	An accurate delivery method suitable for establishing a moored loiter. The long-line forms a closed loop with both line ends at the aircraft. One end is wound on a winch, or attached to the aircraft, and the other attached to a weight. The plane makes a straight pass over the target at low (skip bomb) or medium altitudes and the weight is dropped and the aircraft immediately turns into a loiter orbit.
Double-Mass Delivery, Loiter	A second mass is attached behind the dropped mass for a closed loop delivery (Delivery). The second mass remains airborne while the low-mass is on the ground (Loiter).
Flying Line	Specially constructed long lines that have relatively high lift to drag ratios.
Footprint	Denotes the closed path a loitered object circumscribes.
Launch	To pick up a mass from the ground with the long line.
Lifting Surface	Any high lift over drag ratio body used to support heavy loitered loads or used to provide vertical launches.
Line Tension (Air or Ground)	The tension in line is measured at the aircraft or at the ground when the system is moored.
Linear Loiter	A linear loiter is performed by flying the aircraft in a straight path and trailing the long line and loitered object. The object may be a remotely controlled drone if greater positioning accuracy is desired.
Line Stall	A condition caused by a low airspeed for a portion of the line, where the line hangs nearly vertical.
Mass Slide	An object is attached to the long line, at the plane, and allowed to slide down the line to a loitered object or to the ground.

Moored	Line is attached or held on the ground.
Partial Stall	A condition caused by an airspeed (of the trailing object) too low to fly the mass and yet too high to completely stall the line.
Point Loiter	A loiter maneuver during which the loiter object circumscribes a circular path over a point on the ground.
SLAP	(Soft Landing and Pickup). A long line configuration in which a deployed parachute is suspended above the mass to be launched.
Yo-Yo	Mass Yo-Yo is vertical oscillation of the loitered mass caused by wind altering the aircraft speed and orbit parameters. The frequency is one oscillation per aircraft orbit.

SECTION I  
INTRODUCTION

Circling-line concepts were first explored in the 1930s. Although the basic circling-line technique is old, new innovations developed by the Aerospace Medical Research Laboratory have shown the practicality of using free-fall and circling-line techniques (long-line loiter) as a retrieval/rescue system. The advantages of using fixed-wing aircraft over a helicopter are speed and range. There is presently an operational retrieval system utilizing a fixed-wing aircraft (the C-130 Fulton system). This system, however, takes considerable setup time, exerts a high G load (6 to 8 G) on the person being retrieved, and is limited to a low-wind-condition operation. The long-line loiter retrieval system may significantly reduce peak G loads and the complexity of ground equipment.

## SECTION II

### EXPLORATORY FLIGHTS

#### AIRCRAFT DESCRIPTIONS

The following aircraft were employed in the exploratory flights:

1. Cessna 182. A high-wing, four-place airplane equipped with a 230-hp engine, variable pitch propeller and a fixed landing gear.
2. Cessna U-206. A high-wing, six-place airplane equipped with a 280-hp engine, variable pitch propeller and a fixed landing gear.
3. C-131B. A low-wing, twin-engine airplane equipped with two 2500-hp engines, variable pitch propellers and retractable landing gear.
4. U-6. A high-wing, six-place airplane equipped with a 450-hp engine, variable pitch propeller, and a fixed landing gear.

#### FLIGHT TEST RESULTS

Table I summarizes the aircraft, lines, and parachutes utilized with different weights of dummies during the early developmental stages of the long-line loiter retrieval system. In mid-November 1968, 68 pounds were lifted from the ground using the Cessna 182 and a 550-pound test nylon line. This marked the first pickup of significant weights. On 29 November 1968, the launch of a 49-pound dummy marked the first of many successful dummy launches. The dummy was very stable in tow, rotating only after moving in trail behind the aircraft.

After two dummy launches, a deployed parachute was added above the dummy. The long line was attached to the apex of the parachute, and the dummy was securely strapped into the parachute harness. This served to (1) provide additional lift for the dummy and (2) assist in avoiding excessive wear on the dummy during soft landings, which resulted in the Paraloiter maneuver discussed by Simons and Dixon.

Table I lists some launch and trail tensions (when recorded) obtained from a strain gauge readout in the aircraft. The success column indicates if the flight was successful. The first failure resulted from an unsuccessful opening of the 72-inch parachute on descent. This may have resulted from excessive tension in the long line because of too large a radius of turn of the aircraft. The launch was successful, but the expected soft landing did not occur. The 106-pound dummy with the deployed 28-foot canopy caused excessive tension, and the 550-pound test nylon line broke

TABLE I

AIRCRAFT	LINE	TYPE OF PARACHUTE (OPEN)	TENSION (#s)		DUMMY WEIGHT (#s)	SUCCESS
			(Launch)	(Trail)		
CESSNA 182	550 LB NYLON	72"			49	NO
		10'	---	---	49	YES
			125	100	106	YES
		28'	---	---	60	YES
			>150	100-150	70	YES
			>150	---	106	NO
	NONE	---	---	49	YES	
		150	90-120	60	YES	
		---	---	68	YES	
	8" OC- TAGONAL	80-115	---	25-105	YES	
	2500 LB PET	28'	---	---	106	YES
NONE		---	---	106	YES	
4MLB FULTON NYLON	NONE (OPEN)	---	---	65	YES	
1MLB DACRON	28'	250	120	65	YES	
CESSNA 206	550 LB NYLON	28'	---	---	60	YES
		---	---	70	YES	
	2500 LB PET	28'	---	---	154	YES
C-131B	550 LB NYLON	28'	---	>250	60	YES
U-6	4MLB FULTON NYLON	NONE	350	220	65	YES
			550	350	154	YES
			650	400	203	YES
	28'	725	~ 350	203	NO	

on each launch attempt. After the launch of the 203-pound dummy with an open parachute, the line apparently slid over the stabilizer after a severe oscillation of the dummy, inadvertently detaching the dummy from the line. Only one trial has been attempted with this system.

Lines utilized in dummy launches include 550-pound test nylon, 4000-pound test nylon, and 2500-pound test polyethylene (pet). A 4000-pound test polypropylene line was flown to test the flight characteristics of the line, but excessive knots in the line precluded launch attempts.

The launch and trail tensions shown in table I were examined in relation to the dummy weights and expressed as ratios as shown in table II.

TABLE II

Line and Parachute	(LT-TT)		LT/TT	TT/Wt	Line D
	LT/Wt	+Wt/Wt			
Nylon, 550 lb test, no parachute	2.16	1.42	1.24	1.75	
Nylon, 550 lb test, 10' parachute	1.20	1.24	1.25	0.94	3/16"
Nylon, 550 lb test, 28' parachute	2.14	1.36	1.20	1.79	
Nylon, 4000 lb test, no parachute	3.67	2.37	1.60	2.30	
Nylon, 4000 lb test, 28' parachute	3.57	2.85	2.07	1.72	1/2"
Dacron, 1000 lb test, 28' parachute	3.84	3.00	2.08	1.85	1/4"

The Launch Tension/Dummy weight (LT/Wt) ratio suggests the highest level of G obtained at the aircraft, but not its rate of onset. The Trail Tension/Dummy weight (TT/Wt) ratio is an indication of the amount of drag or lift added to the dummy by the parachute and by the line itself. The Launch Tension/Trail Tension (LT/TT) ratio provides an indication of excessive force necessary to accelerate the dummy from zero to trail velocity.

By subtracting trail tension from the launch tension, adding the dummy weight to this and dividing the result by the dummy weight, we get an indication of the G load at the dummy:  $\frac{(LT-TT)+Wt}{Wt} = G$  at the dummy.

The 550-pound test nylon line shows the smallest amount of G at the dummy. This may be due to a 20 percent stretch in the line at peak loads. Although the 4000-pound nylon line also has a 20 percent stretch at maximum loading, this line exhibited higher G forces; apparently because the load on the line was nowhere near maximum and the effects, therefore, closely resembled those of a low stretch line. The dacron line exhibits very little stretch and showed a higher G load at the dummy than the 4000-pound nylon line. If the line selected for live launches is greatly overstrength to meet certain safety margins, it could result in much higher G loads on the person being retrieved.

The ratios in table II may vary with changes in airspeed, type of line, length of line, and wind velocities. However, if these factors remain fixed, the ratios may prove useful in predicting launch or trail tensions for different dummy weights. It may be possible to plot nomograms for each type of line, showing the most favorable line length, airspeed and open parachute for a particular dummy weight. More conclusive data should be available at the completion of future acceleration and tow tension tests.

The ratios shown in table II suggest theories for consideration in future investigations. Although one of the reasons an open parachute was placed in the system was to provide lift to the mass being launched, the parachute could also produce enough drag to negate the lift capability. The 10-foot parachute with the 550-pound test nylon line apparently served well in giving the desired lift characteristics to the mass. The LT/Wt ratio is considerably less with the 10-foot parachute when compared to the ratios without a parachute and with the 28-foot parachute. Also, the TT/Wt ratio of the 10-foot parachute is less than 1, indicating a great amount of lift with the dummy in the full trail position. The ratios LT/Wt and TT/Wt for the 28-foot parachute and no parachute in the system are remarkably similar. This might indicate that the 28-foot parachute is causing considerable drag and no advantage is gained by using this size canopy in the system.

There are less reliable data on the 4000-pound test nylon line. The LT/Wt ratios are close enough to suggest that no advantage is gained by using the open 28-foot parachute in the system during the launch. The trail tension data is extremely unreliable with the 28-foot parachute, due to the severe oscillations that occurred, and, therefore, will not be discussed at this time.

The airspeed during the launch of these dummies varied between 70 and 125 mph. Although the C-131B flew higher speeds, the average launch speed for all aircraft was 85 to 90 mph. The aircraft altitude at launch varied considerably with the type of aircraft and length of the line. Usual launch altitudes of the aircraft were between 800 and 1200 feet above ground level (AGL) with optimum launch altitude at 1000 feet AGL. The greatest tension recorded on the line from inside the aircraft was 725 pounds, using the 203-pound dummy with a deployed 28-foot parachute in the system. The bank angle of the aircraft during orbit varied from 20 to 40 degrees. The angle of bank varied considerably because of changes in altitude, airspeed, length of line, wind velocity and pilot techniques.

Several critical decisions made on the basis of pilot techniques became evident as tests progressed. For example, how should the pilot change the orbit of the aircraft under strong wind conditions? Also, what should be done if ground tension increases to a point where the line cannot be hand held? The pilot can correct for wind by varying bank angle to maintain a constant radius of turn as shown in figure 1. Because the entire line is being blown downwind, the system is more responsive to wind than an aircraft without a long line.

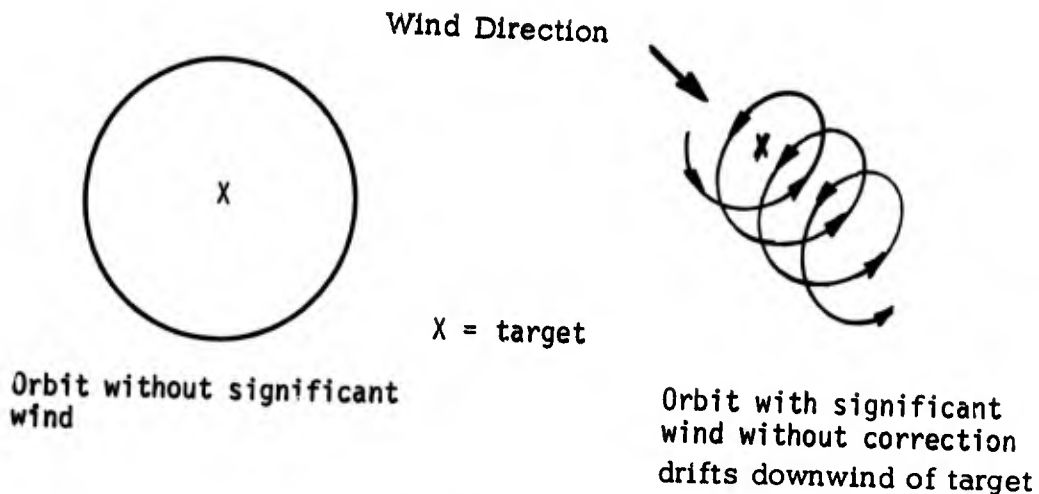


Figure 1.

If the ground tension gets very high, the pilot can immediately tighten the radius of turn, decrease airspeed by reducing engine power, and/or decrease altitude. After launch, the pilot must fly straight ahead. A shallow turn at low airspeeds while towing heavy masses will result in an immediate and dangerous descent of the mass. If practical airspeed and altitude should be increased before any turns are attempted while towing masses behind the aircraft.

The 4000-pound nylon line used in our tests is the same line used in the Fulton Recovery System utilizing the HC-130 aircraft. Hence, this line is already "man-rated." Results from our initial U-6 flights show a much lower line tension on heavy dummy launches than originally expected. The possibility of using lines with a high degree of safety (high breaking strength) causing a higher G force on the man than lines with less breaking strength has already been discussed. A 2000-pound nylon line will be tested during the acceleration and tow tension tests.

#### RETRIEVAL PATTERN

This section describes the retrieval system and methods of deployment, delivery, loiter and launch. The U-6 aircraft is fitted with a winch or a faking barrel (figure 2) with the line folded in it. The line is deployed for a closed-loop delivery, electrically with a winch or manually from the faking barrel (see figure 3). The mass end of the line is dropped (bombed) to the target on the ground, and the aircraft immediately begins 360° on-ylon turns or orbits (figure 3). One end of the line is in the aircraft; the other end, on the ground. The grounded end of the line is retrieved and held at the launch site.

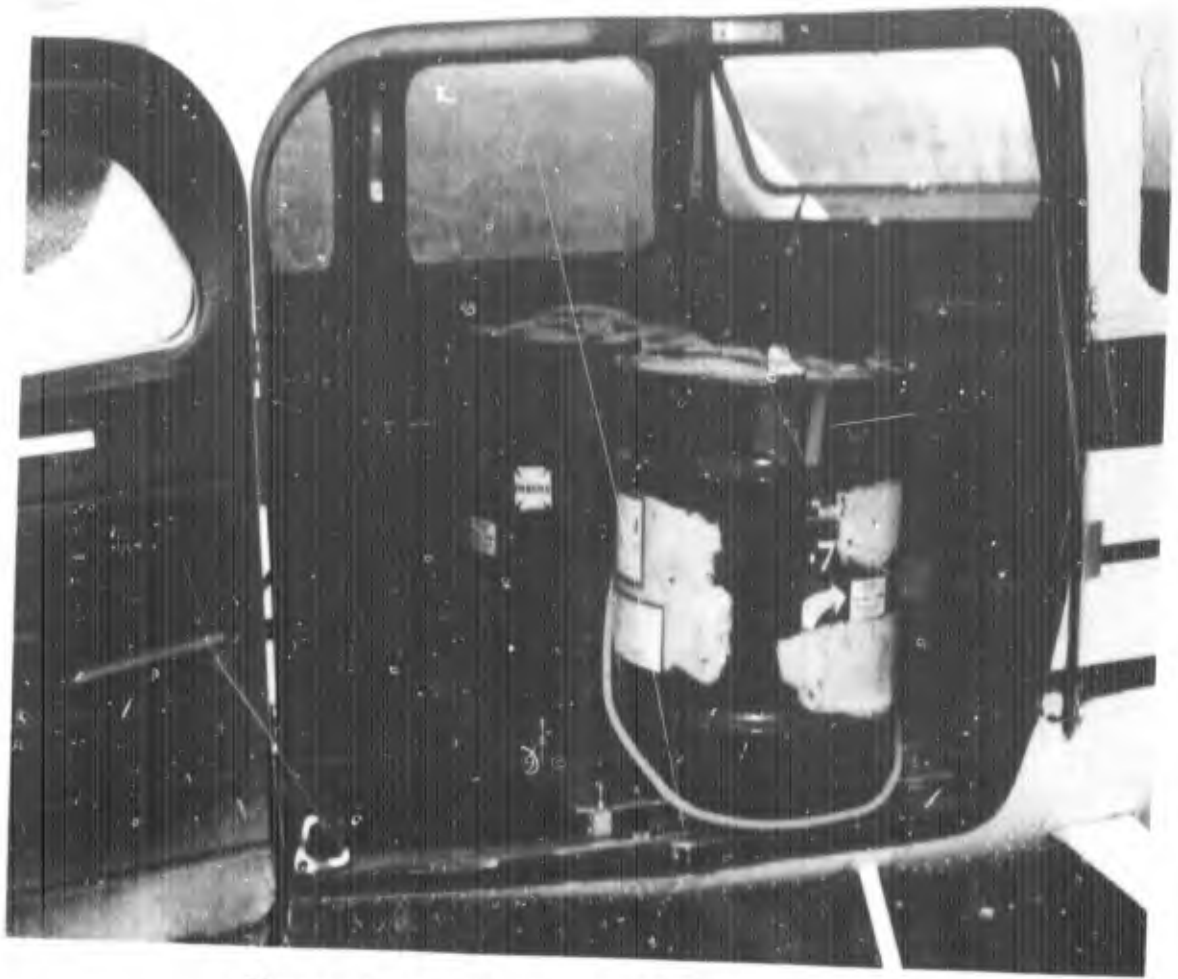


Figure 2. Cessna U-206 with Faking Barrels

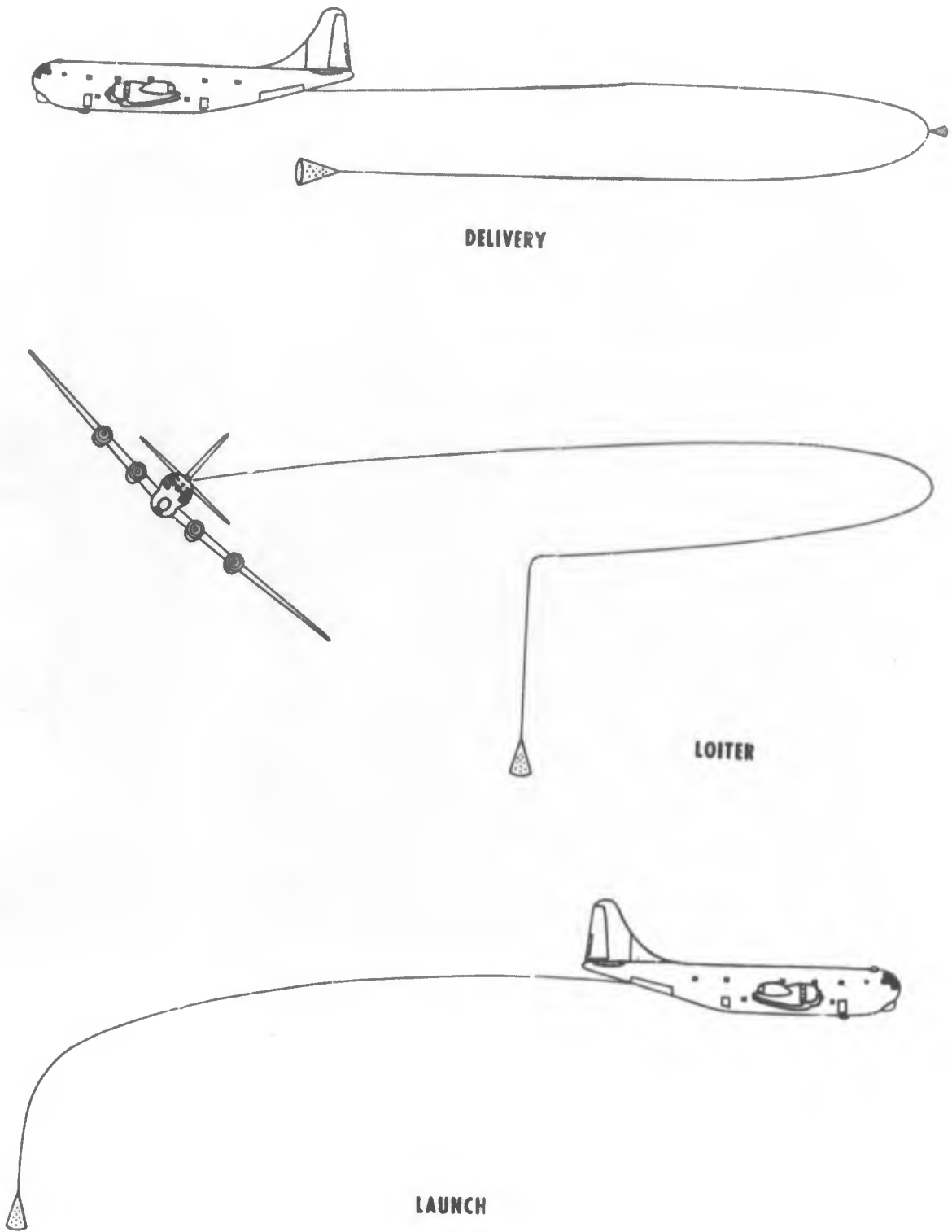


Figure 3. Long-Line Loiter

The dummy/man to be launched is harnessed in a modified B-18 parachute using a static line deployment (figure 4). A tow harness is sewn into the back of the parachute pack and extends 18 inches above the top of the parachute and terminates in the male portion of a specially designed latch (figure 5). The female portion of the latch will have been attached to the long line. After the main parachute is donned, the latch is mated and the static line attached. A reserve parachute will be added for live pickups. On a signal from the ground, the aircraft breaks orbit, flies directly over the target and into the wind, and the launch is effected (figure 3).

To release the dummy from the end of the line, a block is attached to the line at the aircraft, and slid down the line to activate the latch (figure 6). The dummy is separated from the latch, and the static line opens the parachute. During a live pickup, the man will activate the release mechanism by himself; and the weight slide will be used only in an emergency.



Figure 4. Modified B-18 Parachute

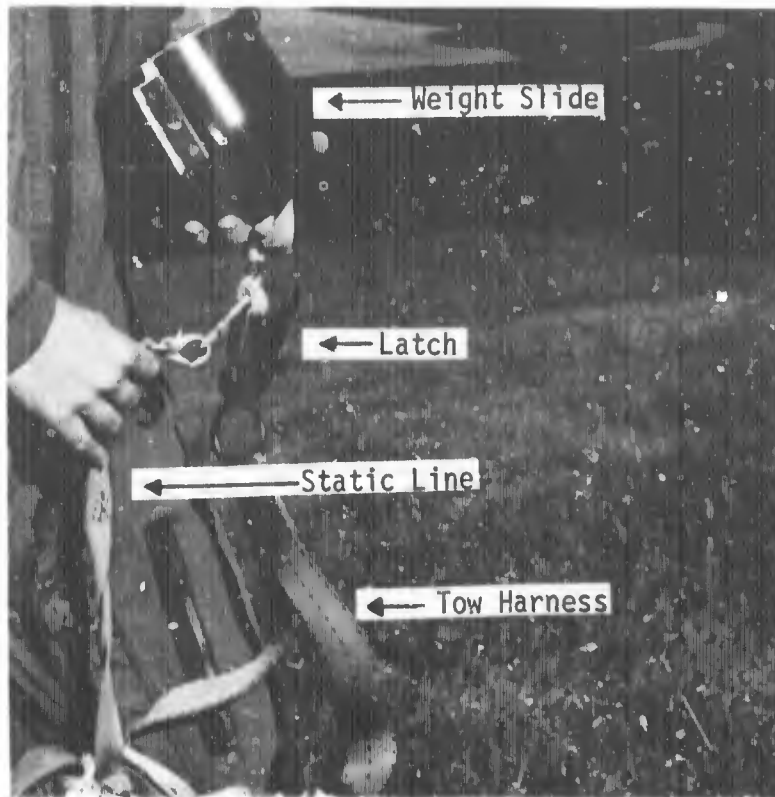


Figure 5. Long-Line Latch: Connected

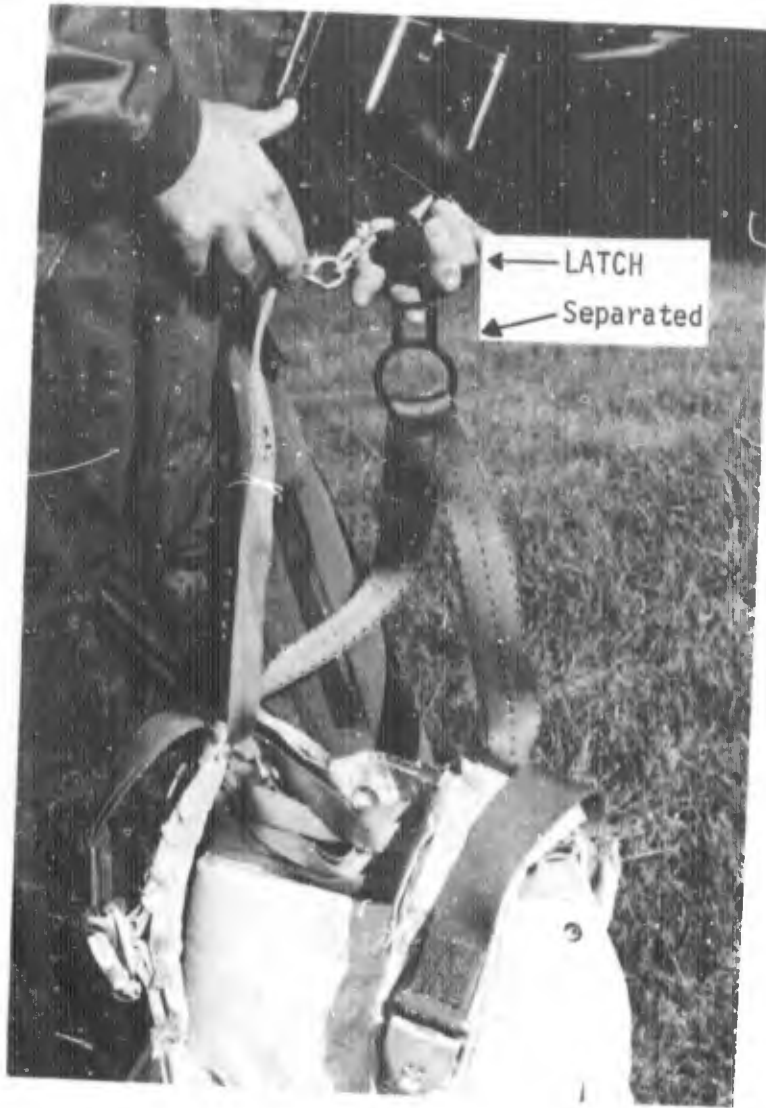


Figure 6. Long-Line Latch: Separated

SECTION III  
FUTURE EFFORTS

U-6 BEAVER WITH A FAKING BARREL (CHART I)

This system will be subjected to the following tests:

1. Acceleration Tests. These tests will determine acceleration levels at the dummy during launch and the line tension histories during launch and while the dummy is in trail.
2. Reliability Tests. After all concepts and equipment have been finalized, criteria will be established to differentiate a successful launch from a failure and a non-hazardous failure from a hazardous (to the man or aircraft) failure. The launches and deliveries will be conducted until a minimum of 90-percent reliability is achieved.
3. Live Pickup. Following completion of the acceleration and reliability tests and the approval of a medical protocol, a live pickup using this system will be attempted if the aircraft can meet predetermined rates-of-climb and engine failure criteria. A live pickup over water with this system is also contemplated.

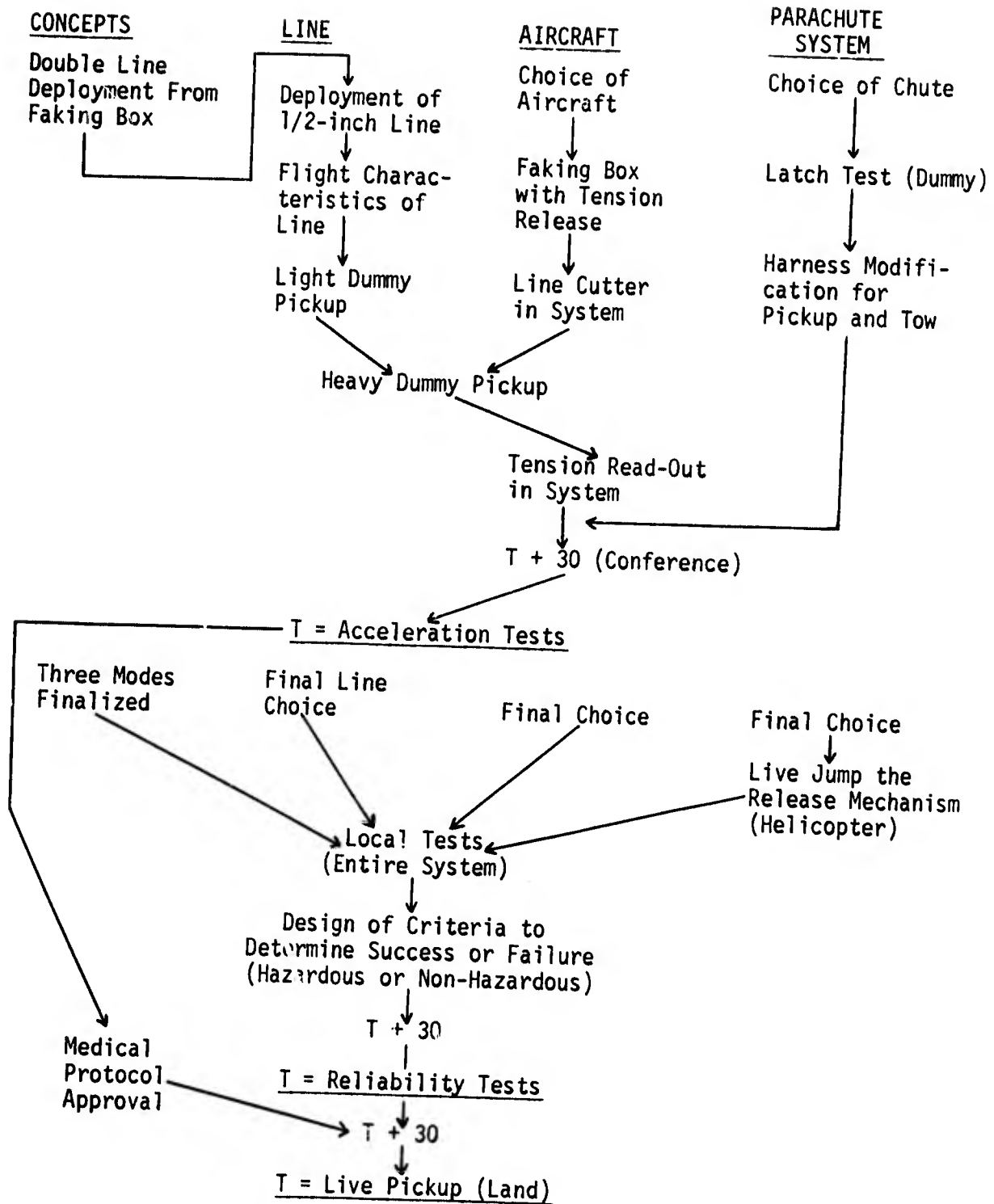
U-6 BEAVER WITH A WINCH

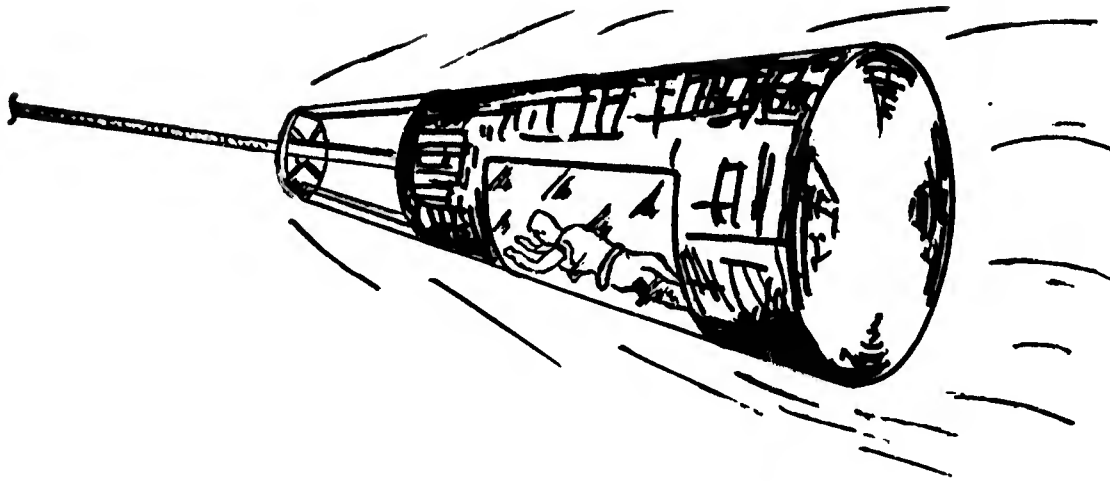
The testing of this system will be essentially the same as described above. One additional piece of hardware, the winch, will be man-rated by incorporating it into the system. The entire system will then be checked for reliability as previously described, and the data, along with the previously reported acceleration test results, incorporated into a medical protocol. The protocol will include plans for both land and water launches. In both cases, the subjects will board the aircraft rather than being paratropped following the pickup.

C-130 SYSTEM

This system incorporates a new aircraft, the C-130, into the already man-rated hardware. This system has the widest appeal as to its practicality and operational use. Procedures will follow as before with flight testing, reliability testing, and live pickups (land and water). A manned research cone is being considered for the C-130 exploratory flights and may prove to be an acceptable rescue vehicle at a later date (figure 7).

CHART 1





CONTROLS:

Pitch, Roll, Yaw  
Speed Brake  
Lifting Surface  
Communication

DISPLAYS:

Altitude, Airspeed, A of A  
Cameras, Optics  
Visibility

WORKSPACE:

Couch  
Reorientation

LIFE SUPPORT:

Ventilation

POWER:

Battery  
Manual

SAFETY:

Shock Absorber  
Auto Chute  
Bail Out  
Release  
Weak Link

Figure 7. Manned Research Cone

The personnel retrieval system to be examined during future acceleration and tow tension tests consists of the U-6A Beaver fitted with a faking barrel. The modified B-18 parachute as well as the open C-9 canopy will be tested with three different line types. This configuration is based on data gathered from many flight tests using several aircraft types. These data include aircraft speed, altitude of delivery and launch, launch and trail tensions, and line types.

Future efforts will include the reliability tests. This man-rating process should be followed by a series of live pickups.

## BIBLIOGRAPHY

Alternate Considerations for a Small Package Pickup System, M-1158, All-American Engineering Company, Wilmington, Delaware, March 1968.

Feasibility Investigation of the Yo-Yo Personnel Retrieval System, ER3406, October 1958.

GARDS, Ground Anchor Recovery-Delivery System, M-1061, All-American Engineering Company, Wilmington, Delaware.

Half-Moon Pickup and Delivery Systems, M-1016, All-American Engineering Company, Wilmington, Delaware, January 1965.

Initial Circular Flying Pickup Lines, ATI No. 46126, Dayton, Ohio, December 1948.

Line Retrieval Systems for Limited War Applications, PDP-OP-96, Grumman Operations Analysis Group, May 1964.

Recovery by Circling Line, All-American Engineering Company, Wilmington, Delaware, May 1961.

Simons, J. C., and B. C. Dixon, Project Tailchaser: Development of a Lateral Firing Concept, AMRL Technical Report 66-202, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, November 1967.

Simons, J. C., and B. C. Dixon, Long-Line Loiter: Improvement of Some Free-Fall and Circling-Line Techniques, ASD Technical Report 69-95 (Vol I), Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, September 1969.

Surface-to-Air Retrieval of Heavy Spacecraft by Fixed-Wing Aircraft, Volume I - Initial Feasibility Studies, PDR 306-1, Prepared for National Aeronautics and Space Administration (Manned Spacecraft Center), June 1962.

Wallis, E. E., Dayuma Story, Bungay, Suffolk, England: Hodder and Stoughton, Ltd., 1961.

White, E. L. et al., Study of Heavy Equipment Aerial Delivery and Retrieval Techniques, AFFDL Technical Report 66-97, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, January 1967.