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AGARD Flight Test Techniques Series
Volume 6
on
Developmental Airdrop Testing Techniques and Devices

by

H.J.Hunter

Edited by

R.K.Bogue

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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARDograph No.300 Vol.6

DEVELOPMENTAL AIRDROP TESTING TECHNIQUES AND DEVICES

by

H.J.Hunter

A Volume of the

AGARD FLIGHT TEST TECHNIQUES SERIES

Edited by

R.K.Bogue

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PREFACE

Since its founding in 1952, the Advisory Group for Aerospace Research and Development has published, through the Flight Mechanics Panel, a number of standard texts in the field of flight testing. The original Flight Test Manual was published in the years 1954 to 1956. The Manual was divided into four volumes: I. Performance, II. Stability and Control, III. Instrumentation Catalog, and IV. Instrumentation Systems.

As a result of developments in the field of flight test instrumentation, the Flight Test Instrumentation Group of the Flight Mechanics Panel was established in 1968 to update Volumes III and IV of the Flight Test Manual by the publication of the Flight Test Instrumentation Series, AGARDograph 160. In its published volumes AGARDograph 160 has covered recent developments in flight test instrumentation.

In 1978, the Flight Mechanics Panel decided that further specialist monographs should be published covering aspects of Volume I and II of the original Flight Test Manual, including the flight testing of aircraft systems. In March 1981, the Flight Test Techniques Group was established to carry out this task. The monographs of this Series (with the exception of AG 237 which was separately numbered) are being published as individually numbered volumes of AGARDograph 300. At the end of each volume of AGARDograph 300 two general Annexes are printed; Annex 1 provides a list of the volumes published in the Flight test Instrumentation Series and in the Flight Test Techniques Series. Annex 2 contains a list of handbooks that are available on a variety of flight test subjects, not necessarily related to the contents of the volume concerned.

Special thanks and appreciation are extended to Mr F.N.Stoliker (US), who chaired the Group for two years from its inception in 1981 and established the ground rules for the operation of the Group.

The Group wishes to acknowledge the many contributions of E.J.(Ted) Bull (UK), who passed away in January 1987.

In the preparation of the present volume the members of the Flight Test Techniques Group listed below have taken an active part. AGARD has been most fortunate in finding these competent people willing to contribute their knowledge and time in the preparation of this volume.

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CONTENTS

LIST OF SYMBOLS

A	Area, general (ft^2 or in^2)
a	Acceleration (ft per sec^2)
b	Constant, used in obtaining approximate weight value of a parachute canopy
C	Effective porosity (ratio of outflow velocity to inflow velocity through a porous fabric canopy)
c	Factor related to suspension line convergence angle
C_D	Drag coefficient, general
C_{Do}	Drag coefficient related to the surface area, So
C_{Dp}	Drag coefficient related to the projected (inflated) surface area, Sp
C_DA	Drag area of a body, general (ft^2)
$(C_DS)_{o,p}$	Drag area of the aerodynamic decelerator, based on either total surface (nominal) or projected (inflated) area (ft^2).
$(C_DS)_R$	Drag area of a reefed canopy $(ft)^2$
C_p	Pressure coefficient, general
C_N	Normal force coefficient, general
C_T	Tangential force coefficient, general
D	Drag (lb) or Diameter (ft), general
Do	Nominal diameter of the parachute canopy = $\sqrt{4So/\pi}$ (ft)
D_{R1}	Skirt diameter of reefed canopy (ft)
D_{Ro}	Diameter of reefing line of fully inflated canopy (equivalent to D_s) (ft)
D_S	Canopy skirt diameter (ft)
F	Total retarding force (lb)
F_c	Constant retarding force (lb)
F_o	Maximum opening force (lb)
F_s	Line Snatch force (lb)
g	Acceleration due to gravity (ft per sec^2)(32.2 at S.L.)
h	Height or altitude
L_R	Length of reefing line (ft or in)
L_S, ls	Length of suspension lines (ft or in)
l	Distance, general (ft or in)
M	Mach number, moment (ft lb)
m	Mass, general (slugs)
N, n	Number of gores in parachute canopy
N	Normal force (lb)
P	Pressure, general (lb per in^2 or lb per ft^2)
p	Static pressure (lb per in^2 or lb per ft^2)
q	Dynamic pressure ($=0.5\ \rho V^2$ (lb per ft^2)
r	Radius, general (ft)
S	Reference area, general (ft^2 or in^2)
S_o	Surface area of parachute canopy (ft^2 or in^2)
S_p	Projected (inflated) area of parachute canopy (ft^2 or in^2)

T	Temperature, general (°F or °R)
T	Tangential force (lb)
t	Time, general
t_f	Filling time for parachute canopy
V	Volume, general (ft^3 or in^3)
v	Velocity, general (knots or ft per sec)
v_o	Launch velocity (knots or ft per sec)
v_s	Terminal velocity (ft per sec)
W	Weight, general (lb)
X	Opening-shock factor denoting the relationship between maximum opening force and constant drag force (=Fo/Fc)
ρ	Air Density ($slugs/ft^3$)

GLOSSARY OF TERMS

Air Drop	A method of air movement wherein, personnel, supplies or equipment are unloaded from aircraft in flight.
Anchor Cable	A cable in an aircraft to which the parachute static line or other straps are attached
Apex	The center and topmost point of a parachute canopy
Bag, Deployment	A container, usually of fabric, in which a parachute is stowed for deployment.
Canopy	The portion of a parachute consisting of the drag producing surface and the suspension lines extended to one or more mutual confluence points.
Chute	A term used interchangeably with the word "parachute".
Container, Air Drop	A container designed for the purpose of dropping equipment and supplies by parachute. It may or may not incorporate a suspension harness.
Deployment	That portion of a parachute's operation occurring from the initiation of ejection or release to the instant the suspension lines are fully stretched, but prior to the initial inflation of the canopy.
Disconnect, Ground	A device that instantaneously releases the canopy from the suspended load upon ground contact. Also called a ground release device.
Force, Snatch	A force of short duration that is imposed by the sudden acceleration of the canopy mass at the instant of complete extension of the suspension lines or similar components of a parachute system prior to inflation of the canopy.
High Velocity Drop	Air delivery of supplies or equipment from an aircraft in flight where the rate of descent exceeds that of "standard (low velocity drops) but is less than terminal velocity (free fall).
Keepers	Length of webbing sewed on risers to prevent relative movement of the risers (lines)
Line, Reefing	A length of cord or line passed thru rings on the skirt of the canopy to delay or control the opening of the canopy.
Line, Static	A line, cable, or webbing, one end of which is fastened to the pack, canopy, deployment bag, and the other to some part of the launching vehicle. It is used to open a pack or deploy a canopy.
Malfunction	A complete or partial failure of a system or component thereof, due to design deficiency or human error.
Oscillation	The pendulum-like motion of a parachute suspended load during descent.

Parachute	An assembly consisting of a canopy, risers, or bridles, deployment bag and in some cases, a pilot chute.
Pilot chute	A small parachute used to aid and accelerate main-canopy deployment.
Rate of Descent	The vertical velocity, in feet per second, of a descending object.
Rigging	The method of preparing a particular piece of equipment or load of supplies for heavy airdrop.
Rings Reefing	Metal rings attached to the skirt of a drag-producing surface at the suspension-line connecting points, through which a reefing line is passed.
Riser	That portion of the suspension system between the confluence point of the suspension lines and the point of attachment to the load.
Shock, Opening	The maximum force developed during inflation of the canopy.
Skirt	The reinforced hem forming the periphery of a drag-producing surface.
Test, Airdrop	A test to determine the working efficiency of a parachute and or its systems by releasing it from an aircraft in flight.
Tie Down	A chain or strap and binder assembly used to restrain supplies or equipment to an airdrop platform or to restrain a platform or vehicle to the aircraft floor.
Time, Filling	The time elapsed between the full extension of the suspension lines and full opening of the canopy.
Time, Opening	The elapsed time between initiation of canopy deployment and full opening of the canopy.
V-Ring	A metal fitting in the form of a closed letter V used with snaps to secure or attach a deployment bag to a fitting or a load to a canopy.

AGARDograph No. 300 Vol VI
DEVELOPMENTAL AIRDROP TESTING TECHNIQUES AND DEVICES

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SUMMARY

This volume in the AGARD Flight Test Techniques Series deals with the practical aspects of planning, conducting and reporting on developmental airdrop tests made from cargo transport type aircraft. Typical cargo aircraft Aerial Delivery systems, parachute extraction systems and special devices and rigging techniques are described in detail. Typical instrumentation systems for obtaining aircraft and parachute systems force data are also described and piloting techniques for various airdrop methods are briefly discussed. The author also uses a scenario of a typical parachute Tow Test to demonstrate the application of these techniques and the use of challenge and response checklists among the flight crewmembers. Finally the use of reports are discussed and appendices are included with many useful charts and calculations that are readily applicable in research and development (R&D) airdrop testing.

1 INTRODUCTION

Airdrop testing techniques and devices are those specialized procedures, methods and hardware developed for use in developmental airdrop testing. Airdrop as addressed in this volume will embody the concept of using parachute systems for aerial delivery of supplies and equipment, ultimately designed for use in combat situations although many of the techniques and hardware are directly applicable to rescue work and other noncombatant roles. Also if we consider airdrop testing in general to embody both the art and the science of this broad field of endeavor, then techniques would make up the art, and the volumes of theoretical research information, which itself is based to a very large extent on empirical data, would constitute the science of it. Application of sound, safe airdrop testing techniques presupposes that the diligent test engineer, technician or loadmaster has done his homework and researched some of these volumes of available information gathered over the past 35 years, and which are amply referenced in this document. The science of parachute/airdrop systems testing may be learned from these voluminous works---the art, the testing techniques, can be acquired only by doing. This volume tries to give the reader the benefit of experience gained by the author and other test personnel in developmental airdrop testing over the past 30 years. During these years these techniques have been successfully applied on thousands of developmental airdrop test missions without serious injury to test personnel or extensive damage to the airdrop aircraft.

Initial R&D airdrop testing of parachutes and aircraft aerial delivery systems is an extremely demanding and unforgiving task. No eventuality of malfunctions may be overlooked because contact between parachute systems or test vehicles and the airdrop aircraft can cause serious damage or loss of the aircraft. It is serious business. Therefore, a new parachute system must be airdrop tested under stringent safety constraints while continuing to duplicate those aspects such as size, weight, function, rigging and flight conditions, of the final system as much as feasible. However, at no time should the safety of test personnel or the flight safety of the airdrop aircraft be jeopardized unnecessarily. In other words, it is imperative that the flight test program be designed to move in an orderly, controlled sequence from the least hazardous to the most hazardous test, employing whatever hazard abating devices, equipment, facilities and techniques that are available to the testing organization. This orderly progression is in itself the fundamental technique upon which sound, safe, meaningful airdrop testing must be based. Time and economy, though they are becoming increasingly constraining in this business of R&D testing, must never be permitted to preempt safety considerations; not through ignorance nor by design. And, therefore, those organizations which are engaged in the early phases of R&D airdrop testing must have at their disposal the resources, in the form of experienced personnel, and safety devices and techniques, required for this type of testing. The extent to which an organization can perform safe, meaningful flight/ airdrop testing of parachutes and aircraft aerial delivery systems will be driven by that organization's command of these resources.

Let us then examine some of the types of aircraft and airdrop testing techniques which have been used in the past 30 years in testing parachutes and cargo aircraft aerial delivery systems for a great variety of applications. Keep in mind that we are looking at initial R&D testing, and once a component or system has been initially tested and determined to be functionally safe many of these safety devices and rigging techniques may be discarded in the interest of timeliness or economy.

Airdrop testing is a broad subject and has gone through a substantial evolution during the past 35 years. Some of the earlier cargo aircraft used in this work such as the Fairchild C-119 "Flying Boxcar" and the British "Argosy" and "Beverly" have since relinquished their role to the current generation of cargo aircraft. One of these, the C-130 "Hercules", has been the mainstay of the developmental airdrop testing fleet for the past 30 years and may well continue in this role well into the 1990s. There are other cargo airdrop aircraft which have been used in developmental airdrop testing over the last 20 years and their use has helped in broadening the spectrum of airdrop capabilities and fostered the development and application of new techniques to use the longer cargo compartments and higher airdrop speed capabilities of these aircraft. Notable among these are the C-141 "Starlifter" and the C-5A "Galaxy", both of which went through extensive developmental airdrop programs to demonstrate their capabilities. The C-141A increased the maximum cargo load capacity from 42,000 pounds previously the limit of the "Beverly" to 70,000 pounds, and raised the airdrop altitude limit to 20,000 feet in 1965, when airdrops of 25,000 pound platforms were made at speeds up to 192 KIAS. In late 1965 a C-130E aircraft was put through a rigorous airdrop capability program which demonstrated a capability to airdrop platforms weighing up to 50,000 pounds each, [Ref 1.] It was not until 1974 that an aircraft was able to better this capability. In the Fall of that year, a C-5A aircraft was used to airdrop three simulated minuteman missiles at weights of 86,000 pounds each and a live missile at the same weight rigged on a special airdrop cradle/platform, extracted by parachute. In the 1970's new airdrop aircraft were tested; some went on to be produced in quantity, others like the YC-14 and YC-15 were never put in production. The aircraft that were bought however, included the "Transall" and the Aeritalia G-222. These are currently being used by the UK, the Federal Republic of Germany, France, Belgium and Italy.

The evolution of the airdrop systems onboard these aircraft has progressed from the basic fixed-pin manually operated systems on the early C-130A Hercules to the sophisticated pressure lock rail systems found on the G-222, Transall, C-130E, C-141A, and C-5A. Three of these aircraft and their aerial delivery systems will be fully described in this volume.

Airdrop techniques and special devices have also kept pace with the new aircraft in the developmental arena with early development of Low Altitude Parachute Extraction System (LAPES) by the US and Canada as early as 1963. LAPES testing introduced the need for tow plates and other safety devices to protect the aircraft and crew during airdrops at high extraction rates. In a search for a capabilty to airdrop at lower than standard altitudes, extractions were made with the main (recovery) parachutes, thereby eliminating one system but creating new problems of applying reefing techniques and reducing platform oscillation. Combinations of parachutes and retro-rockets were tested by the US Air Force with some success in the 1960s and 1970s. However, for the most part the US, UK and other NATO nations have concentrated on "mains extraction" systems development for lower altitudes (up to 600 ft) and LAPES for ground proximity (5-10 ft) tests, while continuing components development to enhance the standard method of airdrop currently used on large scale airdrop operations.

Parachute extraction systems have evolved from simple ribbon parachutes and webbing lines to different types of canopy designs employing reefing techniques and multiplied lines designed for tensile loads in excess of 100,000 lbs. Nylon rope lines have also been tested as well as several designs of extraction force transfer devices. Current operational systems are much safer and hardware materials are "state of the art" as a result of these developmental tests.

Finally, as airdrop testing moved from the early years to the present, pilots, and other crewmembers have concentrated on teamwork, each trying to understand the others apprehensions and requirements. Much has been done in developing joint procedures and checklists as well as special techniques to be employed under various emergency flight conditions, brought on by failed extraction systems or loose platform restraints onboard the aircraft.

Future chapters will explore where we are today and some of the pitfalls we may avoid because of the wealth of experience which has been gained and the techniques that have been developed over these past 35 years to make developmental airdrop testing both as safe and productive as possible.

2 TEST PLANNING

2.1 Cargo Aircraft Airdrop Test Planning

In addressing Test Planning, one might ask, "what does test planning have to do with testing techniques"? It has everything to do with it. It is here in the planning stage that a test engineer must develop his techniques for handling any malfunction of the test system or any other eventuality that may occur onboard the aircraft. These events will occur so quickly and with such force that unless every action on the part of the entire crew has been preplanned the entire crew's safety could be jeopardized by one false move within the space of a few seconds. Therefore, the test engineer must know exactly how his test aircraft systems are designed to function, and he must know the stability characteristics of the aircraft. He must know his entire parachute system thoroughly and he must apply any special devices and techniques he can in planning his test, to reduce the hazards of his tests. Whether we are testing a new aircraft system to determine its airdrop capability or merely a component for use in airdrop, the R&D test engineer or technician should get to know all he can about the aircraft, its capabilities and its limitations. If it is a new aircraft, he should consult with the aircraft designers to determine the aircraft handling qualities, and he should review any available wind tunnel test data or analyses. He should go into the aircraft cargo compartment and carefully study the interior of the aircraft, then he should have the aft ramp and exits opened, so he can see exactly what the exit shape will be for a platform which is being airdropped. In this way, he can see the design features of the exit area which are potential problem areas. For example, if one were to stand in the cargo compartment of a C-141 aircraft with the ramp lowered and aft cargo door and petal doors in the airdrop configuration one would see that the petal doors (which are really large fairings for the afterbody to give the aircraft smooth laminar flow along its afterbody at high subsonic speeds) when opened for airdrop are vulnerable to being contacted by flailing extraction lines or platform suspension systems if special care were not taken. Again, if one were going to be testing a new extraction force transfer device, which has an inherent potential for premature release, he would look at the 90-ft long cargo compartment of the C-141B as a vulnerable area if such a premature release should occur as has happened in the past. In looking at the general design of the airdrop aircraft one assumes that it has been designed to satisfy certain specifications provided by the Air Force or Army as the case may be, and that lessons learned from earlier designs, have been applied. However, in every design there must be compromise, and no design can do all things to 100 percent of the desired maximum. If it is required to fly at 550 mph petal doors are needed; if it is required to fly in and out of unprepared, short landing fields we must have relatively heavy landing gear and high lift wings, and so on. The designers must compromise to give the customer an aircraft which they hope will do all things well, but none of them as well as they would like. He will try to give his aircraft those design features which he believes will satisfy the customers highest priority requirements based on the intended use of that aircraft. If an aircraft will be used for airdrop only 5 percent of its life but for rapid transport of personnel and/or standard equipment for 95 percent of its flying life, then naturally airdrop must be considered a lower priority. Such was the case with the C-141A, as was evidenced by its phenomenal record of achievement in troop transport and rapid resupply missions during the Vietnam war. On the other hand the C-130E Hercules which was designed for airdrop approximately 80 percent of its life has been the aircraft used by both Air Force and Army of many NATO nations for 90 percent of their airdrop operations. This is even more pronounced in the area of R&D Airdrop testing where the C-130 aircraft is even more dominant in its use for component testing of prototype items.

Therefore, in looking at the aircraft interior, the airdrop engineer should look for those vulnerable areas, for he is the best judge of the degree of their vulnerability. He should visualize a platform of maximum weight and volume being extracted, then try to picture what it would look like if one or another system malfunctioned at the most critical instant. Are there hydraulic lines adjacent to the frame of the exit? Are there hydraulic lines for control surfaces in the overhead structure or out in the "beaver tail" area or tailcone, which could be struck by flailing extraction lines or hardware during parachute deployment and platform extractions? Are there actuators, door hinges, door latches, ramp edges, anchor cables, parachute release mechanisms in a region where they may be struck and damaged by parts of the extraction system? Is the ramp truly coplanar with the cargo compartment floor during platform exit, and are there any sharp edges on the roller conveyor sections which might snag the under-surface of an airdrop platform? Finally, are there precautions which may be taken to reduce the possibility of damage or to eliminate it completely? These are all questions the airdrop test engineer must ask himself as he studies the aft ramp and exit area.

He should then move forward in the aircraft, testing the tension in the static line anchor cables by pulling down on them to test the firmness of their attachment. He should slowly run his hand along several different sections of the cable to check for smoothness or broken wires, which could add to the friction between static line devices and the cable during platform extraction. Too little tension in the anchor cable could cause it to vibrate at extreme amplitude during sequential airdrops and thus cause a static line to become wrapped about the anchor cable, resulting in a premature transfer of the extraction force to the deployment of the large recovery parachutes while the load is still onboard the aircraft.

The siderails restraint lock systems should be checked and their operation completely learned. If there is an emergency release system included, this should be thoroughly understood. The roller conveyor systems must be checked to assure they are well attached to the cargo floor. If they are attached only at the ends of their span (usually 7-8 ft in length), he should be prepared for problems with their popping out of the floor. Temporary solutions to prevent this happening may be needed for the test project. Cargo loading winches used for pulling heavy platform loads onto the aircraft, and static line retrieval winches should be checked. They should be played out all the way to the edge of the aft ramp to see if they could become entangled in roller systems or during retrieval operations.

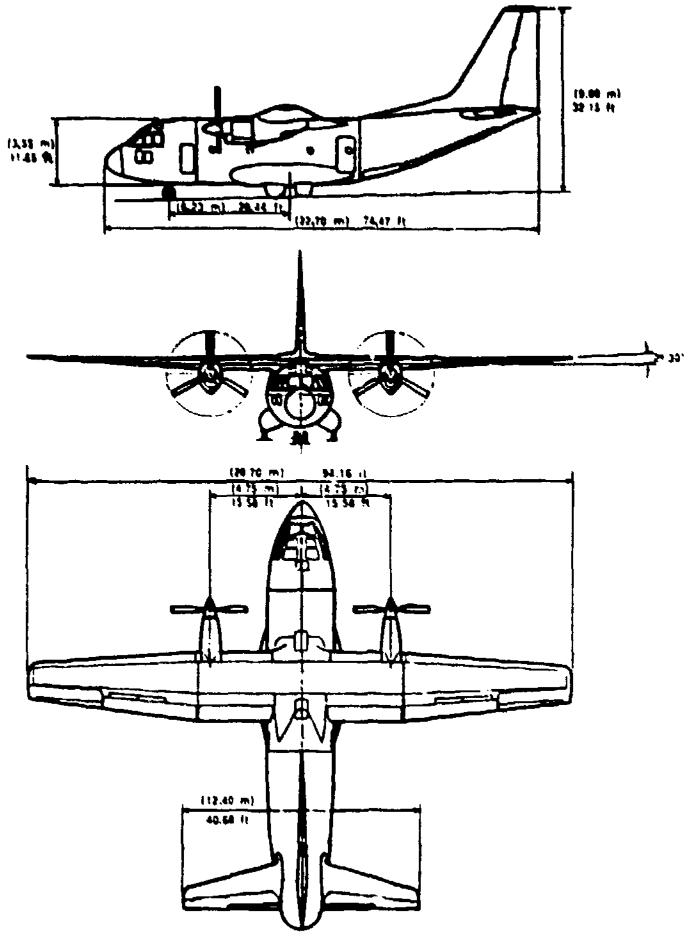
These are features that the experienced test engineer will check on the airdrop aircraft during the test planning phase. Whether the aircraft is undergoing its initial airdrop capability testing or is being used as the airdrop aircraft to test a new airdrop technique, system, or component, it is imperative that a test engineer know how the airdrop system is designed to function.

Rather than go into the functioning of the cargo airdrop systems for each of the aircraft currently being used for R&D testing, the author has selected three of these which are representative of the entire size and capability spectrum and are also representative of the simpler and the more complex airdrop systems. The cargo airdrop systems for the Aeritalia G-222, the Lockheed C-130E and the Lockheed C-5A will be described in detail. Figures are provided to assist in the explanation of the interface betweeen airdrop platforms, roller conveyors, siderail restraint latches, parachute release devices and static line anchor cables. Brief descriptions of the siderail systems for the

TRANSALL (French Version) C-160F, and the C-141B aircraft are shown in Appendix A.

2.1.1 The Aeritalia G-222 Aircraft

The G-222 (Figure 1) is a twin-turboprop high-wing aircraft with a maximum takeoff gross weight of 58,000 pounds (26,500 kg) and a maximum transportable load of 19,820 pounds (9,000 kg). It is capable of airdropping unit platform loads of up to 11,000 pounds (5000 kg). The cargo compartment is 28 ft (8.58m) long, 8 ft (2.45m) wide, and 7.3 ft (2.25m) high. The cargo floor is designed to support a loading of 1000 lb/ft (1500 kg/m). Airdrops maybe performed at speeds ranging from 110 to 140 KIAS. The G-222 is equipped with a Brooks and Perkins automatic airdrop system 1700-J-100. (Figure 2).



AIRCRAFT
Wing Span 28.70 m (94.16 ft);
Max length 22.70 m (74.47 ft)
Max height 9.80 m (32.15 ft)

WEIGHTS
Operational empty weight (zero fuel)
15,700 kg (34,400 lbs)
Max take-off weight 26,500 kg (58,400 lbs)
Max landing weight 26,500 kg (58,400 lbs)
Max transportable load 9,000 kg (19,820 lbs)
Max available fuel 9,400 kg (20,600 lbs)
(corresponding to 12,000 lt approx.)

FUSELAGE
Diameter (approx.) 3.55 m (11.65 ft)
Length 22.70 m (74.47 ft)
Minimum height from the ground of:
- Crew entrance (approx.) 1.25 m (4.1 ft)
- Paratroops door (approx.) 1.00 m (3.28 ft)
- Load compartment floor (at load ramp) 1.00 m (3.28 ft)

Dimensions of:
- Crew entrance door (approx) 1.52 x 0.70 m (4.98 x 2.29 ft)
- Paratroops door (approx.) 1.92 x 0.91 m (6.29 x 2.98 ft)
- Total loading clearance 2.25 x 2.24 m (7.38 x 8.04 ft)

Figure 1 Aeritalia G-222 Multipurpose Transport

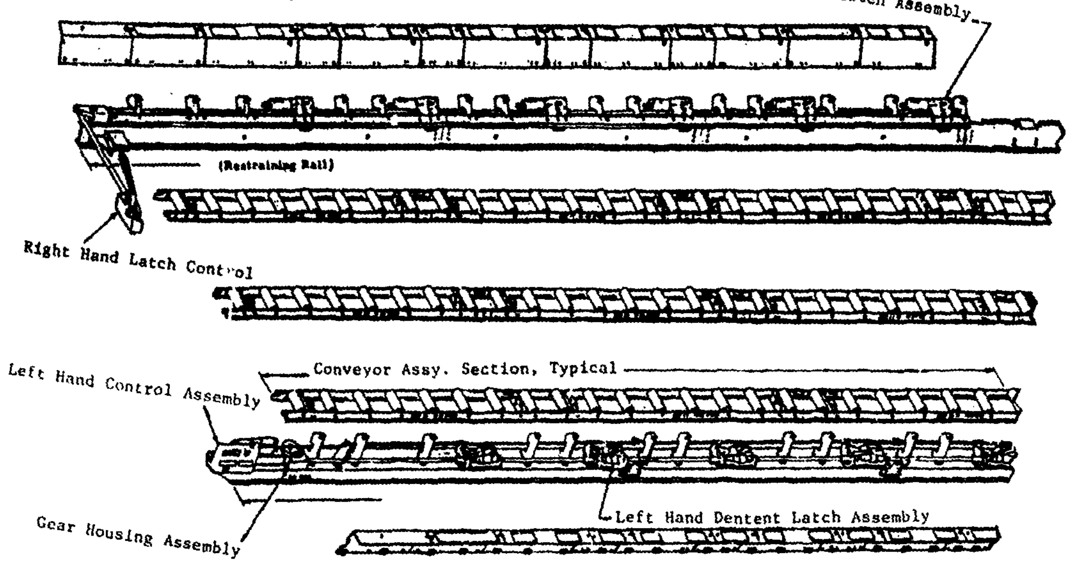


Figure 2 Automatic Airdrop System 17800-J-100 used in AERITALIA G-222 Transport

The 17800-J-100 system consists of 10 outboard restraint rail assemblies and 15 roller conveyor assemblies Ref 2. The outboard restraint rails provide vertical restraint and lateral guidance for pallets or platforms, while detent latches in the siderails provde longitudinal restraint. Rollers in the conveyor assemblies give vertical support and facilitate movement fore and aft during loading and airdrop. The roller conveyor sections are bolted to the cargo compartment floor by a tethered "T" handle pin that passes thru the frame and into the floor.

Six Right Hand (RH) detent latches (Figure 3) are mounted outboard and above on the RH restraint rails, two each on Sections 2, 4 and 6. Each detent provides a constant forward restraint of 20,000 pounds to pallet or platform. The aft restraint is variable to a maximum of 4,000 pounds per detent. When the aft force exerted against the detent exceeds the preset value, the detent will retract and remain retracted. A precompression screw, load indicator and scale are provided as part of the latch assembly to adjust the latch for the desired aft restraint. A detent may be locked out and kept retracted by manually opening the lock and inserting a lock-out pin through the housing and detent body. The RH control assembly is located forward of the roller conveyor sections and inboard of the RH rail (Figure 4). The lever marked "RH EMER REL" operates the RH detent latches by means of drawbars. The lever is released by means of a thumb button at the top of the handle and the lever has 4 positions:

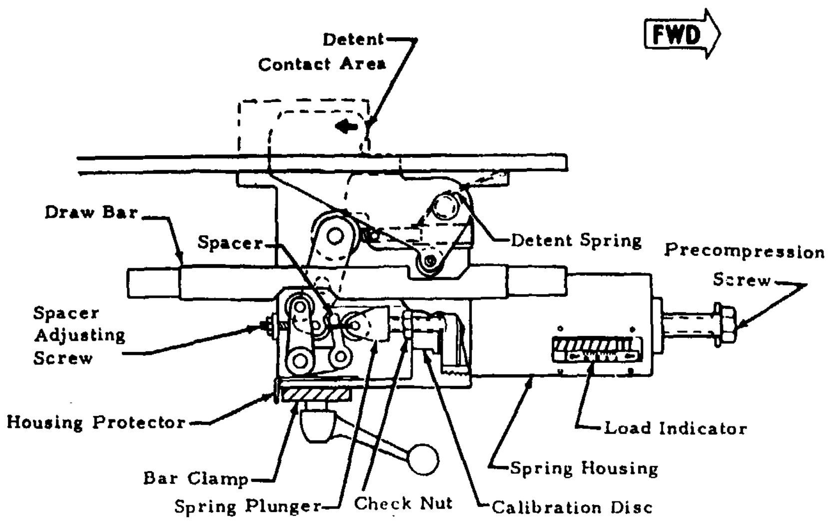


Figure 3 Right Hand Detent Latch Assembly

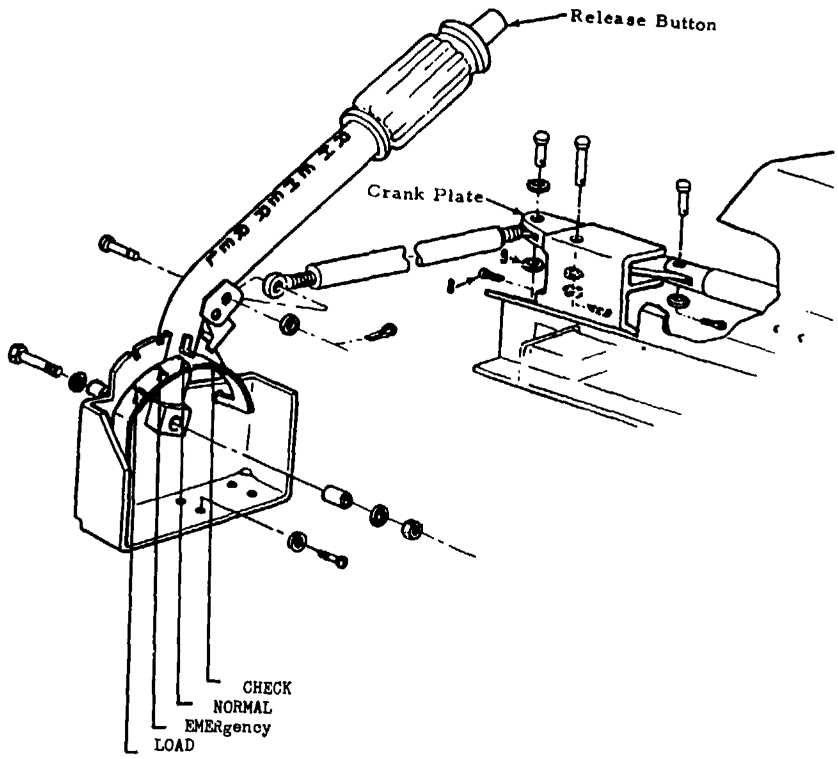


Figure 4 Right Hand Latch Control Assembly

a CHECK. This position is used to insure that all RH detents are properly extended.

b NORM. The normal (locked) position of the lever allows all of the RH detents to lock, securing the platforms in both forward and aft directions within the limits of their restraint settings as shown in Figure 3.

c EMER. When the lever is placed in the EMER position, all aft restraint is removed, while forward restraint is retained. The detents are lightly spring-loaded to the closed (extended) position, but any slight pressure will cause them to retract.

d LOAD. This position retracts the detents and keeps them outboard of the siderails for on loading of platforms, or pallets.

Six left-hand (LH) detent latches are mounted outboard and above on the LH rails. Each detent provides a constant restraint to platforms or pallet of 20,000 pounds fore and 10,000 lbs aft. The latches may be operated by either of two methods: simultaneous or sequential. The LH control assembly located on the forward end of the LH restraint rail contains the manually operated controls that act upon the LH detent latches. The two controls are the "LH SIMUL" handle and the "SEQ LOCK" ratchet handle (Figure 5). A definite sequence of actions by these controls will result in the LH latches being placed in the following states:

a disengage all latches simultaneously

b engage all latches sequentially, starting at the forward most latch.

The LH Simultaneous Handle (LH SIMUL) is a four-position handle. The positions are as follows:

a Stowed Position: This is the full down position with the pin in place. No mechanical action is transmitted to the latches. They are allowed to open normally or close by light spring-loaded action.

b Operate Position: This position is automatically obtained by removing the quick-release pin on the housing assembly (Figure 5). The handle is ready for use, but no mechanical action is transmitted to the latches and they are allowed to close by light spring-loaded action.

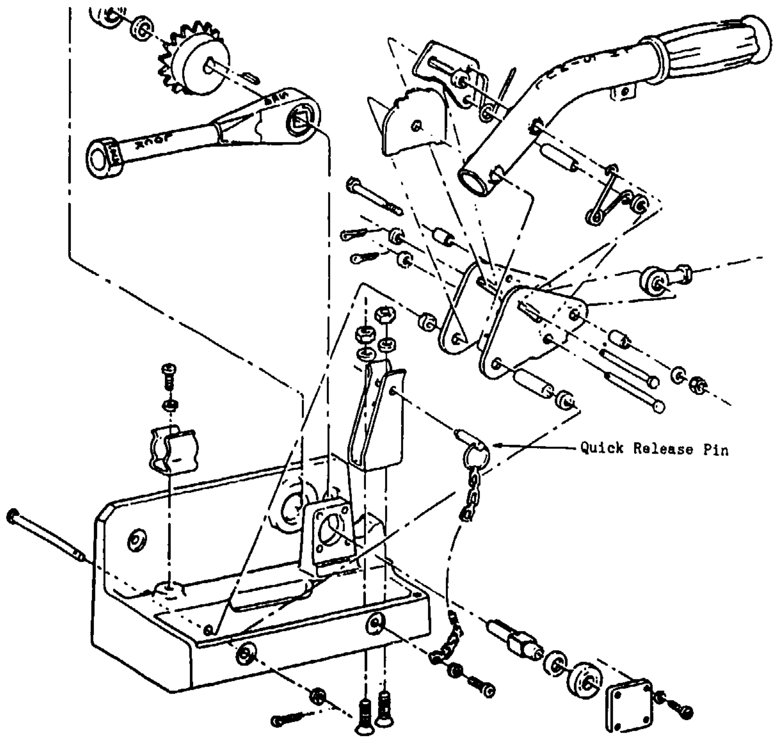


Figure 5 Left-Hand Master Control, 17000-J-100 System

a The Aft Restraint Release Position: In this position only aft restraint is removed. This is the position of the restraint locks just prior to initiating an airdrop sequence.

b Open Position: This is the fully forward extended position of the handle and retracts the detents into the rail.

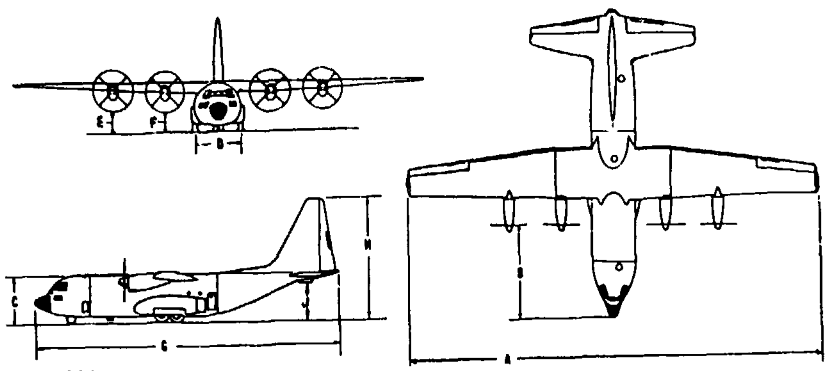
Release of the LH latches is attained by the force transmitted from the LH SIMUL handle to the attached simultaneous release rods. On each latch, the rods are connected to simultaneous release arms. When the rod is moved forward, the arm pulls the bell crank, the detent hook is disengaged from the restraint pin; thus all aft restraint is removed from the detent and it is retracted back into the restraint rail.

By ratcheting the SEQ LOCK handle, the LH latches are engaged or disengaged depending on the position of the control knob at the end of the handle (Figure 5). In the LOCK position with the flat portion of the knob facing up, the latches engage beginning with the forward most latch as the handle is rotated forward once for each latch. By rotating the knob to the UNLOCK position with the flat portion facing down, the latches disengage in the same manner, starting with the aft most latch. Thus for a sequential platform airdrop all LH latches may be released at the 3-minute warning allowing the platforms to be held in position by the RH pressure latches only.

The LH latches are operated by a series of drawbars which are connected to a rack at the forward end. The teeth of the rack mesh with a gear which is operated by the SEQ LOCK handle through a sprocket and chain drive. Each LH rail section has one drawbar which controls the sequential action of all detent latches in that section. The latches are acted upon in proper sequence because of the length and position of notches in the drawbar.

2.1.2. The Lockheed Georgia Co. C-130 E Hercules

The C-130 series aircraft (Figure 6)(Ref 3) are four-engine turboprop, high-wing aircraft. The "E" model is currently most often used for airdrop testing. The C-130E has a maximum takeoff gross weight of 155,000 lbs (70,215 kg) and a maximum transportable load of 50,000 lbs (22,650 kg). It is capable of airdropping unit platform loads of up to 50,000 lbs (22,650 kg). The C-130E cargo compartment is 41 ft (12.5 m) long, 123 in (3.12m) wide and 108 in (2.74m) high. However, as in all cargo aircraft, this full space is not available for airdrop because of the limitation to the width of the siderails, 108 in (2.74m), and the requirement that personnel be able to move from the forward to the aft part of the cargo compartment with a rigged airdrop load onboard the aircraft. The cargo compartment floor is designed to support a loading of 2800 lbs/lin ft (4170kg/m) to 3200 lb/lin ft (4750 kg/m) across the 8-ft wide rail system, depending on the location in the cargo compartment. Airdrops may be performed at speeds from 110 to 150 KIAS. On specially equipped C-130E aircraft (high speed ramp), airdrops may be performed at speeds up to 250 kts. The C-130 E is equipped with the AAR Brooks and Perkins A/A32H-4A cargo handling system.



C-130A

DIM	Without Radome	With Radome	C-130D	RC-130A	C-130B	HC-130B	C-130E and C- 130H
A	132'8"	132'8"	132'8"	132'8"	132'8"	132'8"	132'7"
B	27'4"	29'11"	29'11"	29'11"	29'1"	29'1"	29'1"
C	15'	15"	15'10"	15'	15'	15'	15'3"
D	14'3"	14'3"	19'9" (SKIS)	14'3"	14'3"	14'3"	14'3"
E	5'8'	5'8"	6'5"	5'8"	6'7"	6'7"	6'8"
F	5'	5'	5'9"	5'	5'10"	5'10"	6'0"
G	95'2"	97'9"	97'9"	97'9"	97'9"	97'9"	97'9"
H	38'8"	38'8"	38'8"	38'8"	38'5"	38'5"	38'3"
J							11'3"

Figure 6 Lockheed C-130 "Hercules" Transport

2.1.2.1 A/A32H-4A System

The A/A32H-4A system consists of eight outboard guiderail assemblies with manual control handle assemblies for locking and unlocking latch assemblies contained in the siderails and 20 sections of roller conveyors (Ref 3). The siderail assemblies, which are bolted to the aircraft floor at right and left butt line 59.70, provide a continuous guide down both sides of the aircraft and with their flanged tops and latching mechanisms they prevent transverse, vertical, and fore and aft movement of the platforms and pallets, once the latches have been engaged (Figure 7). The siderail-installed latch mechanisms are equipped with detents which engage indentations in the sides of standard platforms and pallets currently used for airdrops.

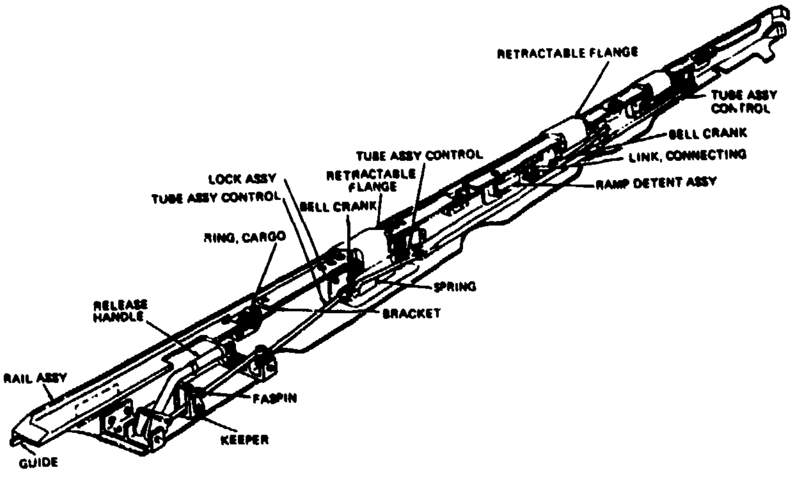


Figure 7 Left Side Rail Assembly, System A32H-4A used in C-130E Transport

Each of the 11 latching mechanisms which are mounted on the outboard side of the right siderail provides a 20,000-lb (9,060 kg) restraining force in the forward direction a variable aft restraining force of up to 4,000 lbs (1812kg). Two sets of controls which are attached to control handles at the forward end of the siderails are used to lock and unlock the latching mechanisms. There are also 11 detent latches mounted outboard on the left siderail.

Each left-hand detent latch provides a constant restraining force of 20,000 lbs (9,060 kg) forward and 10,000 lbs (4,530 kg) aft. The left-hand master control device consists of a SIMUL OPEN control, and the LOCK-UNLOCK sequence control handle (Figure 8). The acuation of the left-hand master control, depending on the position selected, will provide the following operations.

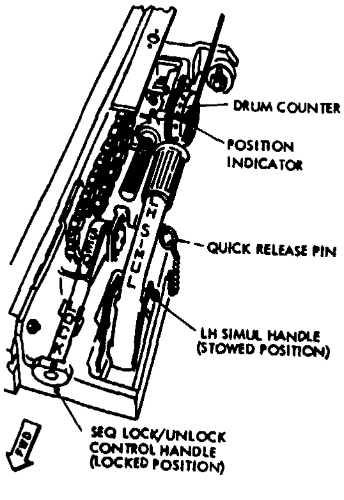


Figure 8 Left-Hand Master Control A/A32H-4A

a Engages and locks all left-hand detent latches sequentially, starting at the forward most latch.

b Unlocks and disengages all left-hand detent latches simultaneously.

c Unlocks and disengages all left-hand detent latches sequentially, starting at the aftmost latch.

d Retains detents in an unlocked position until relocked.

The SIMUL OPEN control handle (on the left side rail) is a four-position spring-loaded device which controls the actuation of the detent latches that have been locked by the use of the LOCK-UNLOCK sequence control handle. The four positions are as follows:

a Stowage position - This is the full down-and-locked position which locks in all the latches simultaneously.

b Operation position - This position is automatically attained by removing the quick release pin on the housing assembly.

c Aft Restraint Release Position - In this position, aft restraint is removed but forward restraint is still in effect.

d Simultaneous Position - This is the full forward extended position. Both forward and aft restraint are removed from the detent body.

The right-hand master control is at the forward most section of the conveyor system and to the right of the left-hand master control (Figure 9). The master control is actuated by the RH EMERG REL handle. This handle is a four-position mechanical device that acts upon the right-hand detent latches as follows:

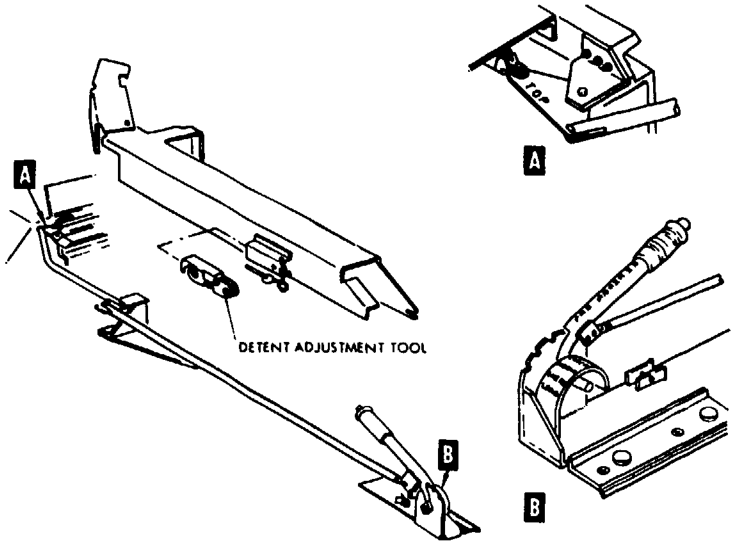


Figure 9 A/A32H-4-A Right-Hand Master Control

a The first position, CHECK, is the full down location. This position is used after loading to insure all right-hand detents are properly engaged in the platform or pallet indentations.

b The second position, NORM, is the normal or locked position. This position locks the right-hand detent latches to provide both forward and aft restraint.

c The third position, EMERG, eliminates the aft restraining force by removing the spring-loaded force applied to the detents.

d The fourth position, LOAD, completely retracts the detents, thereby removing all restraining forces in both forward and aft directions. This position is used for cargo loading on the ground.

In case of an emergency during airdrops this handle is moved to the EMERGency position thus overriding the latch spring tensions and releasing the platforms. A pre-compression adjusting bolt and a variable restraint preload index are provided on each right-hand latch to adjust for the desired restraint force (Figure 10).

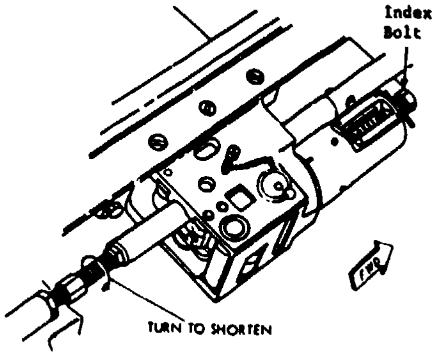


Figure 10 Right-Hand Detent Latch Assembly

Twenty sections of roller conveyors are located in four rows along the cargo floor at right and left butt lines 15.15 in (359.4 mm) and 40.08 in (1.02m) (Figure 11). The sections consist of U-shaped channels, approximately 6 in (152.4mm) wide with aluminum rollers in the upper (open) side. The aluminum rollers are 2.5 in (63.,5 mm) in diameter and 4.75 in (120.7mm) long. When installed, the rollers form a rolling surface parallel with the aircraft cargo floor and 2.625 in (66.7mm) above it. These rollers are designed for a loading of 3000 lbs each at 3000 revolutions/minute. Heavier rollers at the end of the ramp have the same exterior dimensions but are designed for a bearing load of 10,000 lbs/roller at 3000 rpm.

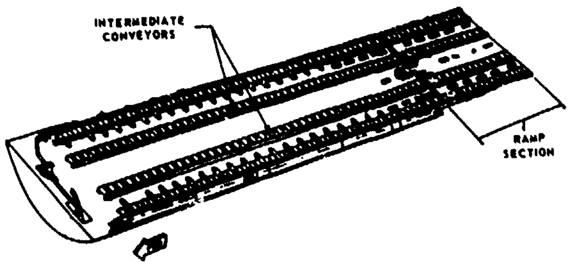


Figure 11 Roller Conveyor Sections and Rail System Used in C-130 Transport

2.1.2.2 Extraction Parachute Release Mechanism

The extraction parachute pendulum mechanism (Ref 4) consists of a MA-4 bomb release rack mounted to a metal frame equipped with a cocking handle and a parachute pivot arm (Figure 12). An extraction parachute equipped with V-ring attachments is placed in the bomb rack located in the aft ceiling of the C-130 aircraft cargo compartment. A pendulum line attached to the parachute bag is hooked into a pivot clip in the end of the pivot arm. When the parachute release cable is pulled to initiate an airdrop, the packed parachute falls from the rack and swings aft in an arc on its pendulum line to a point where it releases from the pivot clip. This aft and downward trajectory of the packed parachute ensures the parachute pack will fall clear of the edge of the ramp and down through the turbulent air just aft of the ramp edge. The drag on the parachute pack as it moves aft deploys the extraction line from the ramp on which it is stowed. Once the extraction line is fully deployed the parachute is removed from the bag and deploys.

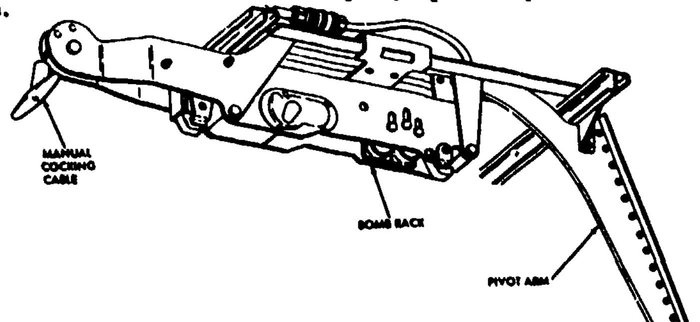


Figure 12 Parachute Pendulum Release

Static line anchor cables on the C-130E are attached at fuselage station 245 and 913 and at a height of approximately 6.5 ft above the cargo floor. The steel cables are of seven strand construction with an O.D. of 3/8 in and capable of loading up to 10,000 lbs in tension. A stop at the aft end of the cable prevents damage to the attachment fitting from constant impact of static line hardware during airdrops. The static line retriever system consists of a winch, forward retriever cable assembly and an aft retriever cable assembly for both right and left sides of the aircraft.

2.1.3 Lockheed Georgia Co. C-5A Galaxy

The C-5A aircraft (Figure 3)(Ref. 5) is a four-engine turbofan jet aircraft of high-wing design. The C-5A has a maximum takeoff gross weight of 769,000 lbs and a maximum transportable load of 220,000 lbs (99,660 kg). It is capable of dropping unit platform loads of up to 86,000 lbs (38,958 kg) and sequential loads of up to 160,00 lbs (4 ea 40,000 lbs platform). The cargo compartment is 121 ft 2 in long (35.38 m), 19 ft (5.77m) wide and 114 in (2.89 m) high in the airdrop configuration. Airdrops have been performed at speeds from 125 KIAS to 175 KIAS at altitudes up to 20,000 ft. The Airdrop System (ADS) for the C-5A was designed as a kit to be installed for airdrops or transported until needed on a specially designed wheeled trailer which may be secured in the forward end of the cargo compartment.

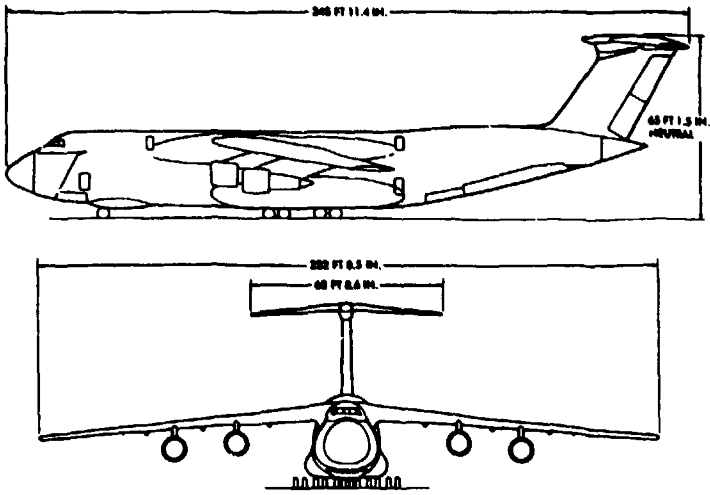
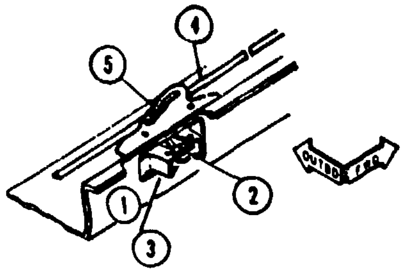


Figure 13 Lockheed C-5A "Galaxy" Transport

The C-5A ADS kit consists of right and left side restraint rails, guide rails, roller conveyor assemblies, anchor cable assemblies, an extraction parachute release mechanism, ADS links and an ADS kit trailer. The right and left siderails are fixed to the floor of the aircraft with quick-disconnect fittings rated at 20,000 lbs (9,060 kg) each and provide lateral and vertical restraint for platforms and pallets.

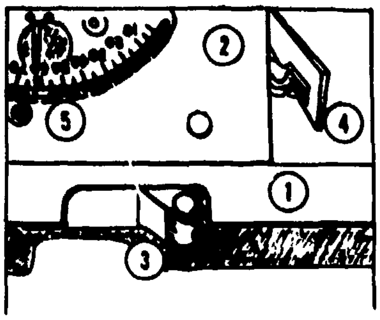
The right siderail incorporates 37 latching assemblies spaced 40 in (1.1 m) apart. These right rail latches are an integral part of the rail assembly (Figure 14) and are connected through a control rod to one of four control handles evenly spaced along the right restraint siderail. Each right-side detent provides 15,000 lb of longitudinal restraint both forward and aft and are used to restrain the platform(s) or pallets during flight to the drop zone. They are designed to be unlocked prior to airdrop of the platforms.

The left-side restraint rails also incorporate restraint latching mechanisms as an integral part of the rail (Figure 15), Ref 6. The latch assemblies like those in the right siderail, contain steel detents that engage indentations cut in platform siderails. The left latch mechanisms are located laterally across from the right latch mechanisms. The left side latches provide positive forward restraint for platforms during flight, variable aft restraint to control the airdrop, and a sequencing feature to permit airdrop of a partial load of cargo. Each left side detent provides 10,000 lb of forward restraint and a variable aft restraint up to 4,000 lb. Engaging, locking, and adjusting of the variable aft restraint is accomplished at each latch assembly.



1. Right-hand Restraint Rail
2. Right-hand Lock/Unlock Mechanism
3. Lock Detent
4. Control Rod
5. Overcenter Point

Figure 14 Right-Hand Restraint Lock



1. Left-hand Restraint Rail
2. Left-hand Lock Assembly
3. Lock Detent with Roller
4. Reset Lever
5. Load Setting Scale (Point shows a Setting of 63)

Figure 15 Left-Hand Restraint Lock

Guide rails are provided longitudinally along the forward ramp extension, the forward ramp, and the aft ramp floor when the airdrop system is installed in the aircraft. The guide rails at the forward ramp extension are flared to form a funnel to aid in alignment of platforms during loading. The guiderails on the aft ramp are also flared to permit unobstructed exit of a platform if any lateral force components are imposed during extraction of a platform from the aircraft during airdrop operations. The guiderails are attached to the floor by the use of quick-disconnect pins and fittings.

Four rows of ADS rollers are provided. The four rows of rollers are located symmetrically across the cargo compartment at right and left butt lines 19.70 and 45.20. Each section consists of a U-shaped channel which is flat on the bottom and contains aluminum rollers in the open side. The U-shaped channels are 4.2 in wide and are either 7.0 ft or 8.25 ft in length. The aluminum rollers are bearing mounted on 10 in centers and are 2.0 in in diameter at their slightly crowned centers, and 3.75 in long. When installed in the cargo floor, the rollers project upward 2.25 in above floor level. The aftmost rollers in each row on the aft ramp are teeter rollers (Figure 16). The teeter rollers are designed to accommodate the entire platform load as it teeters momentarily while being extracted during an airdrop. They are mounted in four pairs and each teeter roller is 4.5 in long and 4.0 in in diameter at its highest point. The ramp floor when in the airdrop configuration is slightly below the plane of the cargo floor while the tops of all the rollers are coplanar. The primary rollers and the teeter rollers are slightly crowned to prevent grooving of the flexible undersurface of the US Army type II modular platforms during loading and airdrop operations. The primary rollers have a static design strength of 7,500 lb each and the teeter rollers have a static design strength of 25,000 lb each and 15,000 lbs at 3000 rpm.

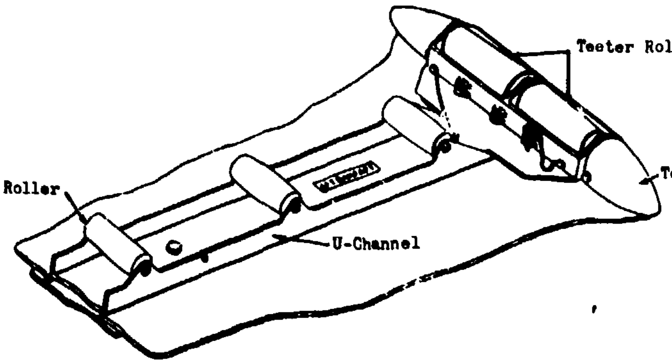


Figure 16 C-5A Teeter Roller System

Two anchor cable assemblies are provided as part of the ADS kit (Figure 17). Each cable assembly consists of a cable attaching bracket, pulley bracket and pulley, a cable tensioning handle and bracket, and a cable assembly with a quick disconnect device and an adjusting turnbuckle. The anchor cable assemblies extend the full length of the cargo compartment. The anchor cable is 1/4 in diameter steel with a breaking strength of 6,000 lb. However, the forward attachment fitting on the forward ramp extension limits the assembly strength to approximately 1,500 lbs.

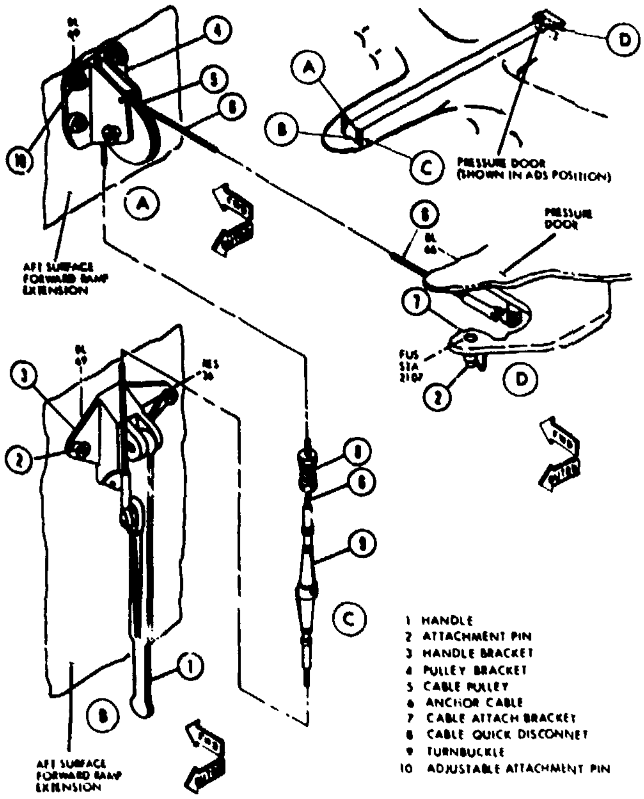


Figure 17 Anchor Cable Assemblies

The extraction parachute release mechanism (Figure 18) consists of a target assembly, attachment linkage, a release assembly, and an actuator assembly. The parachute release assembly is designed to support and release up to three extraction parachutes simultaneously, each weighing up to 167 lbs each for a total weight of 500 lbs. The target assembly, the release assembly, and the attachment linkage are attached to the forward face of the aft pressure door. The actuator assembly is attached to the fuselage frame at fuselage station 2084. The target assembly and the release assembly are connected by the attachment linkage. When the aft pressure door is opened to the airdrop position (overhead), the target assembly is aligned with the actuator assembly. With the aft pressure door open, the extraction parachute(s) installed on the release assembly are approximately 42 inches aft of the ramp trailing edge. The normal electrical release of the extraction parachute(s) is controlled by a switch on the navigator's ADS panel. When the switch is activated, the actuator rod extends inboard and depresses the target assembly which, in turn releases a cocked spring at the release assembly and this releases the extraction parachutes allowing them to fall aft of the ramp to be deployed. The actuator rod then returns to its retracted position so that it will not interfere with the operation of the pressure door when it is moved to the closed position. A manually actuated secondary release system is provided for use in case of electrical system failure.

Two ADS links are provided. They are scissor-type links that limit the downward travel of the aft ramp to the correct position for airdrop. They also carry the load on the ramp as a platform exits the aircraft. The link assemblies consist of a support beam, quick-disconnect fittings, a lower link, an upper link, and an attachment clevis. The lower end of the link assembly is attached to the floor of the aft ramp with a quick-disconnect fitting, while the upper end is attached to a fitting on the aft fuselage sloping longeron with a quick-release pin.

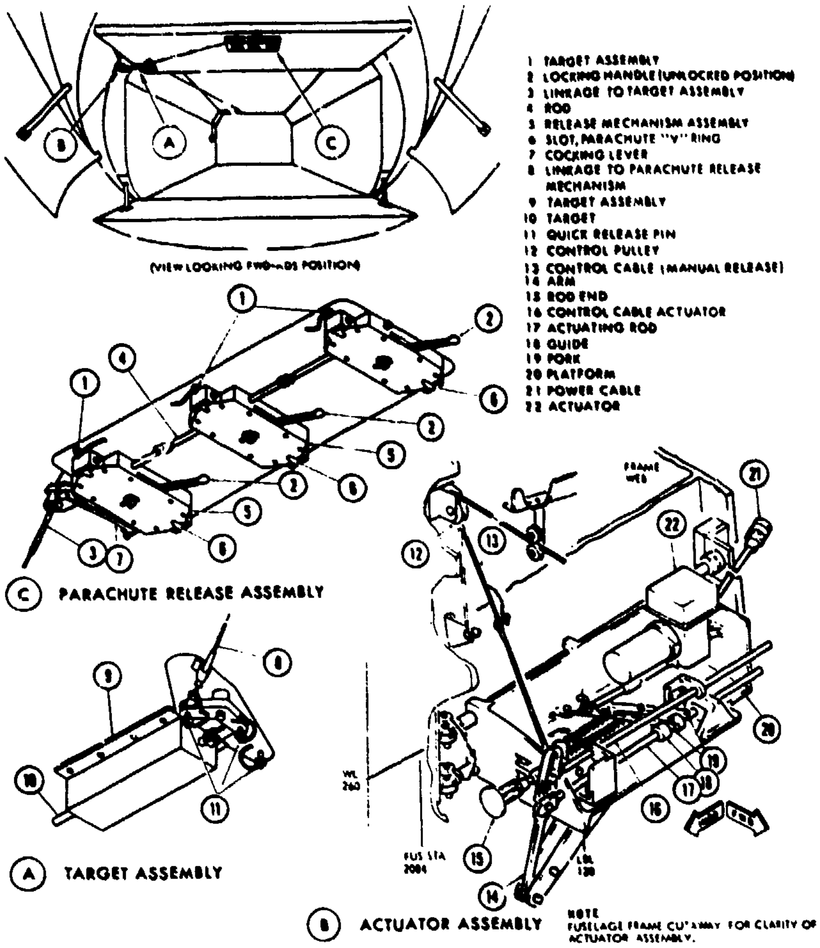


Figure 18 Extraction Parachute Release Mechanism

2.2 Design and Function of Current Parachute Systems for Cargo Airdrop Testing

Parachutes by their nature are extremely unpredictable in the way they function and impossible to mass produce in identical items. Even when many parachutes are constructed from the same templates and by the same person it is impossible to exactly duplicate them. Extraction parachutes and extraction systems in general are the most critical system used in airdrop testing. Even in the case of smaller parachutes which may have been previously tested in a wind tunnel or from a drop tower there remains an element of uncertainty as to performance of the entire extraction system during the dynamic environment of actual flight. For this reason flight testing of a system will always be that necessary final proof of the complete system. Sample calculations for some parachute inflation dynamic are contained in Appendix B. In R&D airdrip testing where the system may be used for the first time at a particular condition, extreme care must be exercised in the planning stage to assure that all aspects of the deployment and inflation of the system as well as its structural and aerodynamic limitations are known and considered when formulating a test plan and designing an extraction/recovery system. Because of this unpredictability of performance even between parachutes of the same nominal diameter, and geometric shape, new extraction parachutes to be used for R&D airdrop tests must be tow tested at several airspeeds in sufficiently large sample sizes to obtain a good drag curve. A minimum of three samples at 5-knot intervals over the entire intended speed range for the parachute should be planned. Since most airdrop tests are made between 130 and 150 KCAS, one should plan on conducting approximately 15 tow tests on a new extraction parachute as a minimum. The extraction portion of any airdrop test is the most critical because the airdrop aircraft and crew safety are involved. No matter which of the basic airdrop methods or techniques is employed, special care must be taken in choosing and implementing the extraction system. There are certain basic considerations which must be kept in mind when choosing the right technique to apply in testing a new system. This is true whether it is a new aircraft in a full blown Aerial Delivery System evaluation or a brief program to test a new attachment link for an extraction system. Choice of airdrop aircraft may be restricted to those available to the organization performing the tests. However, common sense leads one to use the smallest, most economical airdrop aircraft that will safely perform the operation and yet provide the flight conditions (airspeed, altitude, etc) to assure a meaningful evaluation. The entire spectrum of airdrop testing may be performed using the current airdrop aircraft ranging from the G-222 to the C-5A, the aerial delivery systems of which were previously described. However, in choosing the test technique to apply, a great deal will depend on the design objective of the airdrop system and the experience of the organization which will be conducting the test program. Generally, any item which can be loaded in and out of the aft cargo doors and ramp of the aircraft, and which is within the limits of weight and roller loading for that aircraft, can be safely airdropped from the aircraft. If the airdrop is to be made into a restricted (by size) area, then an accurate rate method such as LAPES, GPES or MAINS extraction should be used. If several items are to be airdropped on a single pass over the drop area, then the standard sequential or "mains" sequential techniques should be considered. If higher altitude and accuracy are desired, then one must use the high-altitude, rapid-descent systems such as the barometric/timer systems or a retro-rocket system. There are many variations of these basic techniques which have been successfully applied over the past 35 years. Reports on these test programs are available and are listed in Reference 10, Appendix 1. The basic techniques will be described shortly but a few general facts about extraction systems in general should be remembered. Parachute extraction systems are most critical when choosing and/or modifying a technique to suit a new application or requirement. Knowing the strengths and limitations of each component of the extraction system is most important for literally, "the system is only as strong as its weakest link." As a rule of thumb, most test organizations fix the limit at which they will use a metal link at 66% of its ultimate design strength (UDS) and at 50% of the UDS for webbing and fabric items. In other words a safety factor of 1.5 for metal items and 2.0 for fabric and webbing items is the accepted norm. When instrumentation wires are to be led along an extraction line to links or clevises within that line it is important to remember that type X and type XXVI nylon webbing lines will stretch to approximately 1.5 times their unloaded length when a tensile load of approximately 50% of the design strength of the line is applied. Therefore if electrical wire (which does not stretch is being taped along the extraction line, the extraction line elongation must be allowed for and the wire "S" folded along the line. The elongation in KEVLAR lines is considerably less. However, KEVLAR should not be used for extraction lines. Because of its reduced elongation, KEVLAR does not attenuate the shock of rapid force buildup experienced in extraction systems application. In recent applications of KEVLAR in systems which previously used nylon, metal link failures occurred at forces (total) which had not previously been a problem. These failures have been attributed to the lack of shock attenuation which had been inherent in the nylon lines. Unless volume of the system is critical, cargo airdrop systems should restrict KEVLAR use to subcomponents of the parachute and smaller components of the system. Hybrid sytems using a mixture of nylon and KEVLAR components have been successfully used in a wide variety of test applications. In using metal links to attach multiplied concentric designed lines together experience has dictated that for 2 plies (1 or 2 loops) the minimum diameter of the pins should be 1 inch; for 3 or 4 should be 2.0 inches. (Note that this diameter includes the bolt and the spacer bushing around which the webbing is placed). For 8 or more plies (4 loops) in which 4 or more plies of webbing would be placed around the pins, it is recommend that webbing separator plate clevises be use. The efficiency of multiplied lines falls below 60% when more than 3 plies are placed on top of each other around the same pin. This failure is caused by compression from the outer plies as well as tension in all plies and a subsequent heating of the nylon causing failure well below the cumulative strength of the multiple plies. Separator plate clevises are described in References 17 and 18. Twelve-ply type XXVI nylon extraction lines up to 215 ft in length were successfully used with webbing separator plate clevises to airdrop 50,000 lbs platform loads. Another consideration is associated with the relationship between the platform/aircraft siderail restraint setting and the expected parachute forces which will trip the aircraft siderail pressure locks and initiate platform movement. Normally, in standard airdrops, the pressure locks cumulative holding force is set equal to 0.5 times the weight of the platform to be airdropped. When using normal airdrop extraction systems this would be satisfactory. However, in R&D testing it is preferable to use a value of 0.5 times the maximum expected extraction force, for example:

If a 24,000-lb load using a standard extraction system was being airdropped, a siderail setting which would provide 12,000 lbs of platform restraint would be used.

At standard airdrop speed of 150 KCAS, the single 28-ft diameter extraction parachute would develop 6000 lbs "SNATCH" FORCE then go on to develop a maximum extraction force of 22,000 lbs approximately 1.5 seconds later, (extraction ratio of $\frac{22,000}{24,000} = 0.92$)
and approximate extraction velocity of 50 ft/sec (from a C-130 aircraft).

If this was a 24,000-lb load used to test the aircraft during higher velocity airdrops at 170 KCAS and a 1.5-extraction ratio ... and the same criteria for setting the siderail lock were used 12,000 lbs restraint force in the locks would again be used but the following could result.

At a speed of 170 KCAS, an extraction chute developing a maximum force of 36,000 lbs at 170 KCAS would be needed. This would require a 37-ft diameter parachute.

Because of the heavier weight of the chute and the higher velocity of the aircraft the snatch force of the chute becomes 12,000 lbs, then increases to 36,000 lbs approximately 1.6 seconds later (extraction ratio of $\frac{36,000}{24,000} = 1.5$, and an approximate extraction of 65 ft/sec.

Note that the restraint force was set at 12,000 lbs and the snatch force developed was 12,000 lbs, therefore, the platform could have been out of the locks before the chute started inflating. Therefore, the platform would be extracted while the chute was inflating at considerably less than a 1.5 extraction ratio.

For this reason, in R&D testing the lock setting should be based on the expected maximum extraction force; in this case 18,000 lbs in lieu of 12,000 lbs. Therefore, let us look at these basic methods so as to have a good idea of what they are designed to do and how they function as an interactive force between the airdrop aircraft and the cargo to be airdropped. There are several basic methods or techniques applied in airdrop testing today. These are used by the R&D airdrop test engineer or technician as a starting point when he begins to plan his test program.

2.2.1 Standard Airdrop (low velocity) System (Figure 19)

The standard airdrop systems used by the U.S. and other NATO nations for many years and still the U.S. standard, consists of an extraction system, a recovery system, a platform, and some means of transferring the extraction parachutes forces to deploying of the recovery parachutes. The extraction system consists of an extraction parachute of ring-slot, ribbon, or cross canopy design in sizes, from approximately 15-ft to 35-ft diameter (Appendix C). Extraction lines for these parachutes are constructed from 2, 4, 6 or 12 plies of Type X or Type XXVI nylon webbing constructed in concentric loops with keepers at each end. The parachute hardware varies depending on the user. R&D organizations usually design and use their own hardware to satisfy their test requirements. The recovery systems consist of clusters of 61-ft, 64-ft, 66-ft or 100-ft diameter parachutes. For a standard airdrop, a load, vehicle or special test tub is rigged on a platform which is designed for use with the aircraft siderail restraint and latching system and conveyer rollers. The recovery parachutes are restrained on top of the load and suspension risers are atached from the parachutes to the four corners of the load (at six points on heavier loads). The handles of the bags in which the parachutes are packed, are connected to a deployment line which in turn is connected to an extraction force transfer (device) coupling (Figure 20). This extraction force transfer device is a three-way connector with one pin attached to the load, a second pin attached to the extraction parachute and the third pin attached to the deployment line from the recovery parachute bags. During a standard airdrop, the extraction parachute (packed in its bag) is released from the parachute relea e device and falls behind the aircraft where wind drag on the bag causes the extraction line to deploy off the cargo ramp. When the line is fully deployed the high force generated (snatch force) breaks the parachute out of the bag and it deploys and inflates. As the drag force of the inflating parachute(s) reaches that force which was pre-set in the restraint rails, the latches open allowing the platform to be extracted out of the aircraft. As the platform moves aft, the extraction force transfer device is activated releasing the attachment to the load, and the extraction force from the parachute is now transferred through the other pin to the deployment line. As the load moves out behind the aircraft, the recovery parachute bags are lifted off the load and as the load continues its trajectory the extraction parachute(s) deploys the recovery parachutes out of their bags annd they inflate to recover the load. Figure 19 shows the sequence of events in a standard airdrop. Standard airdrop tests are usually made at altitudes from 1000 to 5000 ft above ground level. Standard airdrops are more widely used at this time in mass airdrop demonstrations and maneuvers. This is also the basic method used in testing new parachutes and or their components. It affords the safety of more altitude, 1000-5000 ft, in the event the aircraft handling qualities have been adversely affected by a malfunction in the parachute extraction system or airplane siderail restraint system. This method is also the one from which the most data has been obtained in previous testing and operational use. Therefore, there is a larger information base from which to draw. This method also is a basis for design of much of the hardware and webbing components later applied to other systems. For sequential airdrops using this method several dynamic conditions are added and need to be considered when applying rigging techniques. Three major areas of consideration are the static line anchor cables/static lines, stowing of subsequent extraction sytems, and sequential setting of siderail locks. There are oscillations set up along the static line anchor cables by the sudden release of the tensile load in a static line at time of its activation. If there are other static lines attached to the anchor line cable when such an oscillation is caused, (as in the case of a sequential airdrop of two or more platforms) the static lines are intermittently jerked and slackened, unless special precautions are taken. This could cause a static line to wrap itself around the anchor line cable and become entangled at that location (well within the aircraft cargo compartment). If this should occur during a sequential airdrop, it would cause the static line to activate the extraction force tansfer device while the platform was still within the aircraft. The resultant deployment of the recovvery parachutes within the aircraft could damage the aircraft siderails or roller conveyors thus affecting any remaining loads. Since there is no way (except one), which is explained later, to interrupt a sequential airdrop if a malfunction occurs after the sequence has started, the results could be catastrophic. To prevent static lines from becoming entangled around the anchor cable a drag line may be used. The drag line is run parallel to the static line but is tied to the load at one end and to the bottom ring of the static line stiff leg near the anchor cable. This will allow the drag line to move with the static line along the anchor cable as the platform is being extracted. The drag line keeps an even tension on the static line stiff leg preventing it from wrapping itself around the anchor cable. A loop of 550-lb T.S. nylon cord has been satisfactorily used as a drag line on many sequential airdrops made by the U.S. Air Force. Appendix D-1 shows a method of rigging a drag line. Airdrop testers at the USAF Flight Test Center have eliminated this problem completely by going to a floor-mounted static line anchor strap. This shown in Appendix D-2. Another area of concern in rigging for a sequential platform airdrop is the stowing of the extraction systems for the subsequent platforms. The extraction line and parachute for each plaform should be stowed on the forward end of the platform to be previously extracted. No platform should have its own extraction line stowed on its own aft end. In this way the line will be deploying off the previous load as it is extracted and relatively strong stowing ties may be used to prevent spillage onto the floor, without the possibility of the parachute pack being prematurely ripped off the moving platform and left on the aircraft cargo floor. Appendix D-3 shows the details of this technique. Riggers should also note that the extraction parachute packs attached to the platforms should be attached to the load with heavy ties (a minimum of 1 turn of 550-lb T.S nylon at each of the corners of the closed end) while leaving the end of the bag containing the opening free to allow free movement of the packed extraction parachute as the load tumbles upon leaving the aircraft ramp just prior to chute deployment. The third major area of consideration applies to those airplane siderail systems equipped with a lock sequencing system. The point to remember here is that all platforms to be dropped in one sequence must have their locks set so that all the permanent (as opposed to pressure released) locks may be released prior to the airdrop. Some systems involve placing sequencing pins in a numbered hole. It is imperative that these locks be visually checked to ensure they have been released prior to initiating the airdrop sequence. If one siderail lock is left engaged it will be broken at the time the platform is being extracted or (in the case where the parachute force is less than the value of the strength of a single lock) the platform will remain locked onboard the aircraft with a deployed extraction chute attached. If the lock was damaged during the sudden impact loading it may not release when the emergency handle is pulled and the only recourse left is to manually cut the towed chute away; a hazardous task in the best of conditions. One way of interrupting a sequential airdrop after it has started is to include a manual override to the extraction force transfer system in conjunction with a go-nogo open link clevis on each platform. This system has been successfully used in all initial sequential airdrop task made form new U.S. cargo airplanes starting with the C-141A in 1965. The system is described in References 6 and 17.

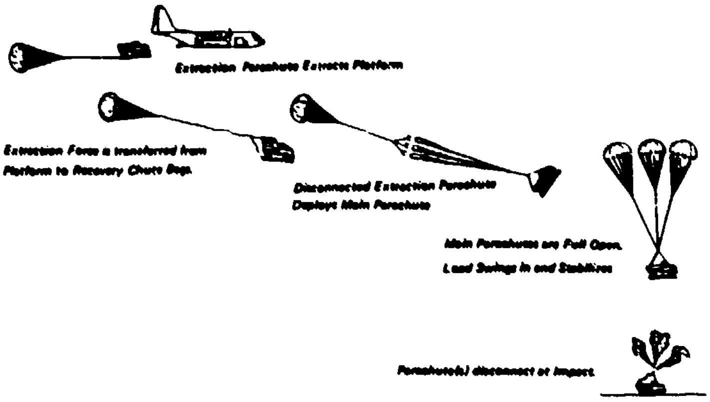


Figure 19 Standard Airdrop Method

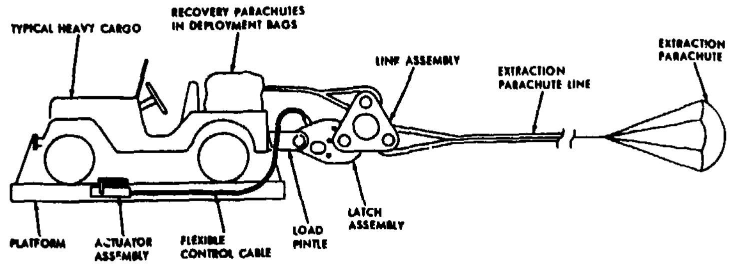


Figure 20 Extraction Force Transfer (Device) Coupling

2.2.2 LAPES Extraction System

A second airdrop method used today which requires special techniques is the Low Altitude Parachute Extraction System (LAPES) first tested by the U.S. Air Force in 1963. In the LAPES system, the aircraft is flown at ground proximity from 5 to 10 ft above the ground with wheels down. A special platform equipped with skids and a ski nose is used and special rigging of the load on the platform is employed to provide correct platform attitude before it contacts the ground. A small drogue chute (10-to 15-ft diameter) is deployed behind the aircraft several seconds before the airdrop is to be made. This parachute is attached to a tow plate device which functions much as the extraction force transfer device on a standard airdrop. When the airdrop point is reached, the tow plate is activated to release the drogue chute. The drogue which is attached through a web line to the large extractor/decelerator chutes, lifts them off the ramp and deploys them behind the aircraft. When the large parachutes inflate they extract the load and decelerate it as it goes through a very flat trajectory and touches down then slides to a stop. (Figure 21 shows the sequence in a LAPES airdrop.) The LAPES method is currently used in the U.S.A., France, Germany and Italy while a similar system called Ultra-Low Level Airdrops (ULLA) is used in the U.K. Reference 8. There are certain hazards in a LAPES airdrop against which one must be constantly on guard. The first is obvious and nothing can be done about it. It is the fact that the airplane is flying at 5-10 feet above the ground at 130 kts, towing a chute providing about 4000 lbs of drag force. The second hazard involves the high rate of extraction. In higher altitude airdrops an extraction ratio (the ratio of parachute drag force to platform weight) is from 0.75 to 1.25 resulting in a platform exit velocity from 40 to 60 ft/sec, depending on the location of the platform in the aircraft cargo compartment at the time extraction is initiated. However, for LAPES airdrops the extraction ratio should be between 2.00 and 3.00. This is done for two reasons. First, on heavier loads, the quicker the platform moves out, the less influence on the aircraft stability. This is important while the aircraft is in proximity to the ground. The second reason is to reduce platform velocity at time of ground impact. At the higher extraction ratios, a platform's forward speed (aircraft speed-platform exit speed) may be as much as 25-40 ft/sec slower than it would be with an extraction ratio of 1.25 to 0.75. Therefore, the slide out of the platform is reduced (shorter field requirements) and the probability of rolling or tumbling over rough terrain is reduced. The hazards of LAPES airdrops stems from the higher forces and speeds during parachute system deployment and platform movement. The better LAPES employ larger parachutes such as 35-ft to 64-ft diameter solid canopy chutes, reefed for the extraction phase (higher speed/smaller drag area) then disreefed to fill as the speed decreases and the larger drag area is needed to keep the total drag force as even as practical. The LAPES method has been proposed for delivery of personnel capsules. With the advent of the C-17 aircraft which may be able to make LAPES airdrops at speeds as low as 110 kts the personnel capsule may become a highly practical option.

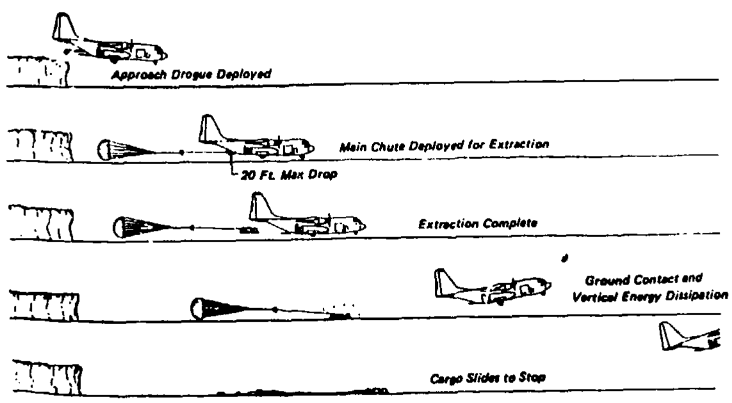


Figure 21 "LAPES" Airdrop Method

2.2.2.1 Abbreviated LAPES

An abbreviated LAPES has been tested by the French at their Bretigny Sur Orge facility. In this system the drogue and tow plate device have been eliminated and the airdrop is similar to a standard low velocity airdrop but, made in proximity to the ground. The system has some advantages and some limitations. The elimination of a tow plate device and drogue parachute greatly simplify the rigging and reduce probability of components malfunction. It also eliminates the requirement for an approach with a drogue parachute in tow. These are all definite advantages and readily applicable to the G-222 and C-160 aircraft. The limitations are related to the extraction parachutes, and apply to airdrop platforms of approximately 10,000 pounds and more. With this abbreviated system, the heavier extraction chutes would not be deployed by a given force and therefore may contact the ground during extraction line deployment. For aircraft larger than the Transall, where platforms exceeding 10,000 pounds require larger, heavier extraction parachutes, these heavier parachutes in their bags will, in fact, bounce on the ground if they are not actively deployed by a drogue parachute. Also, most parachute release devices are design limited to a maximum parachute weight of approximately 100 pounds and could not be used to eject 28-ft or 35-ft diameter extraction parachutes. Currently, as platform weights increase above 35,000 pounds, tow plates for standard LAPES are being designed for larger drogue parachutes because 15-ft diameter drogues have not provided sufficient drag force at 130 KIAS to prevent the larger, heavier 28-ft and 35-ft diameter extraction parachutes (in their deployment bags) from striking the ground during extraction line deployment. The abbreviated LAPES shows great promise, however, for platforms up to 6 Kg extracted from Transall C-160 or G-222 aircraft. The rigging for the system tested by the French is shown in Appendix D.

2.2.3 "MAINS" Extraction System

The system most widely used in Europe at this time for Development Airdrop Testing is the "Mains" extraction system (Figure 22), Reference 9. For this system the load is rigged similarly to that for a standard airdrop except that the recovery parachutes are rigged on the aircraft aft cargo ramp or on top of the load to be extracted. To initiate a "mains" extraction airdrop, a drogue chute is released from the pendulum release device and when it inflates it pulls the main parachutes, contained in their deployment bags, off the ramp or load. As the parachutes deploy out of their bags and inflate they (the mains) extract the cargo load. As the load leaves the ramp one or two anti-oscillation parachutes which were rigged on the forward end of the load, are deployed by static line(s) attached to the aircraft anchorline cables. As the load swings down under the main recovery parachutes its swing is retarded by the anti-oscillation parachutes which will have inflated. The "Mains" extraction method is being constantly refined as various test oganizations move their airdrop requirements down toward 300 ft altitude. Some techniques being applied to accelerate recovery of the loads are vent lines, anti-oscillation chutes and the use of short burning retro-rockets. A vent line consists of a heavy nylon strap attached to the apex of a larger canopy and is somewhat shorter than the suspension line system. During the packing of the chute, the (center) vent line is attached to the confluence point of the suspension lines and the vent is pulled down within the canopy. When the chute deploys during an airdrop, the inverted cone formed by the pulled down vent forces inrushing air toward the skirt thereby forcing the skirt out and speeding up the opening.

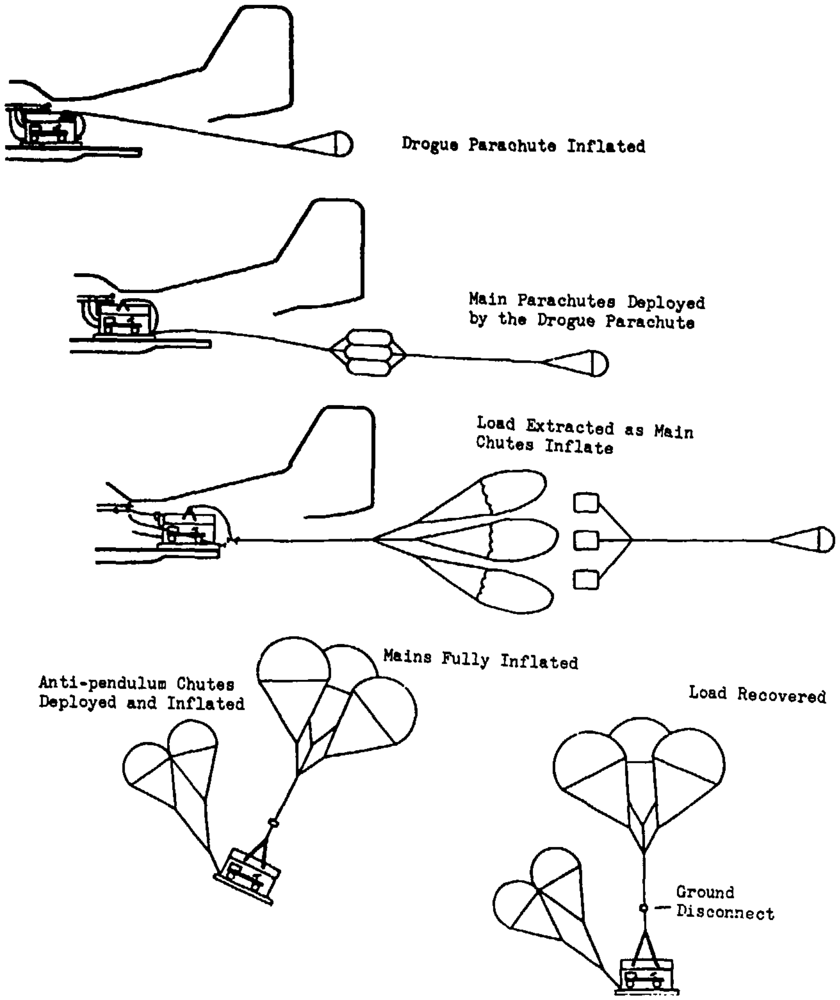


Figure 22 "MAINS" Extraction Airdrop Method

2.2.4 <u>GPES Extraction System</u>

Another method of cargo airdrop which has been tested is a variation of the LAPES called the GPES or Ground Proximity Extraction System (Figure 23). For this type of airdrop, no parachutes are used, but extensive ground preparations are needed. Hydraulic impellers are imbedded in the approach end of a drop zone, one on each side and a wide nylon belt is wound around a drum on top of each impeller. The ends of the belt are attached to a cable which stretches across the end of the drop zone. The cable is kept approximately 4 inches off the ground by discs spaced approximately 10 ft apart through which the cable passes. When the cable is snatched by a hook, the impellars rotate within water filled housings applying a braking force through the nylon belts to the cable. The airplane installation is as follows: A LAPES type platform, (with skids and ski nose) is rigged onboard the airdrop aircraft and an extraction line attached to the aft end of the load or platform is stowed on the ramp with its other end led down along a pole (approximately 20 feet long) which is attached to the ramp of the aircraft and sticks out behind it so that the end of the pole is approximately 10 ft below the aircraft ramp. On the end of the pole is a hook to which the extraction line is attached. In operation the aircraft flies in as on a LAPES test, but with the pole and its hook trailing instead of a chute. The aircraft is brought down to ground proximity until the hook contacts the ground and starts dragging lightly over the ground. When the hook reaches the cable, it snatches it and the braking force of the hydraulic impellars on the ground deploy the extraction line it separates from the pole and draws the platform out of the airplane as it flies away from the load. The load continues to be decelerated in a flat trajectory then contacts the ground and slides to a stop.

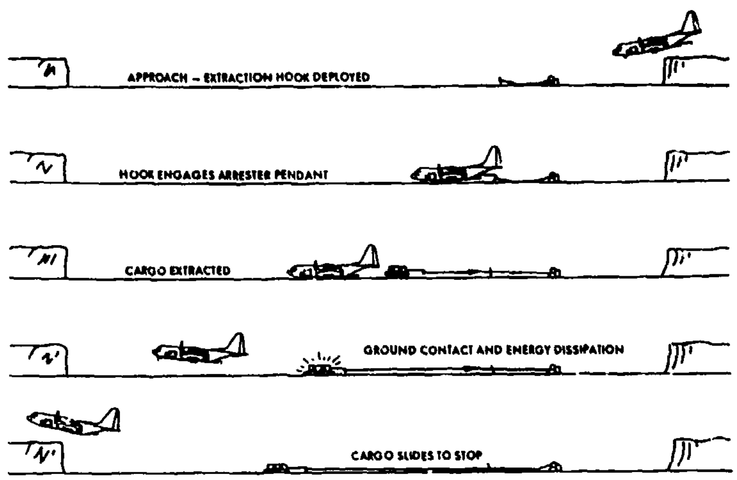


Figure 23 Ground Proximity E..raction System (GPES) (Ground Based Energy Absorbers)

2.2.5 Parachute/Retro-Rocket Recovery Systems and Other Hi-altitude Recovery Systems (Reference 10)

In the early 1960s when the Vietnam conflict was raging, much developmental testing was done with airdrop systems that would allow cargo to be airdropped from a height of 10,000 - 12,000 feet where the aircraft was out of reach of small arms fire, and yet be able to drop the needed resupply cargo on a relatively small drop area (within a compound). Therefore, a rapid descent for the first 9000 - 14,000 ft was desired for two reasons: to obtain the needed accuracy from minimal wind drift, and secondly, to leave the cargo exposed on the way down, a minimum of time. The parachute/retro-rocket deceleration system is one means of accomplishing this (Figure 24). A cluster of smaller parachutes which will allow the cargo to fall at a rapid rate of descent (from 50 to 75 ft/sec) is rigged on the load as for standard airdrop. However, a cluster of rockets are rigged in the suspension slings confluence point with offset nozzles so that the rocket blast, once the system is in descent and the rockets fired, will not impinge on the cargo and damage or destroy it. Electrical connections between the rocket pack and deployable probes on the four corners of the platform will ignite the rockets when the probes, usually about 30 ft in length, contact the ground. In operation the load is extracted and the cluster of smaller recovery parachutes are deployed. The cargo falls at a rapid descent rate with minimal drift. The probes which were deployed as part of the recovery parachutes deployment sequence, contact the ground when the load is 30 ft away and the rockets immediately ignite and burn for a very brief period (usually 1/10 to 1 sec) depending on the rate of descent and weight of the load. The load is decelerated to approximately 10-15 ft/sec descent rate at ground contact.

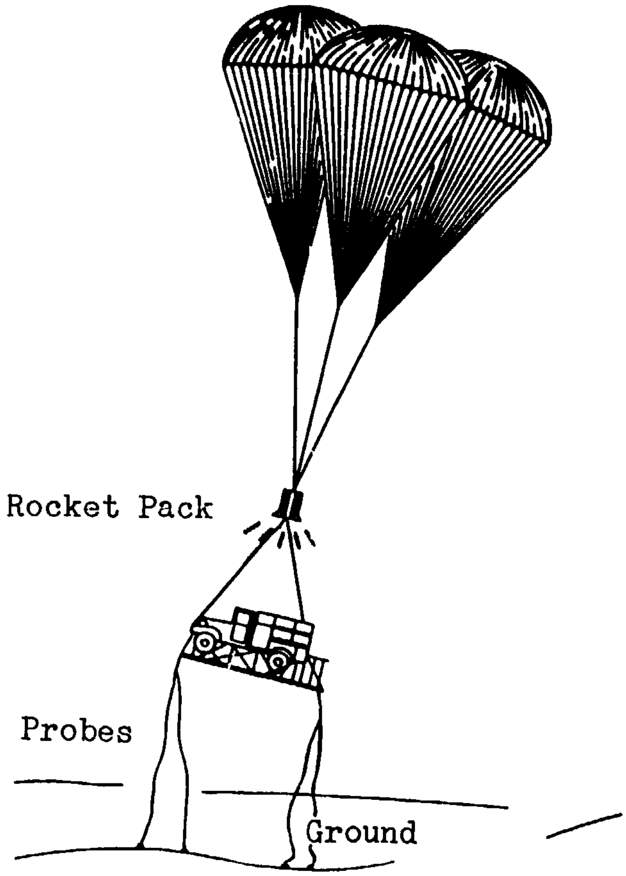


Figure 24 Parachute Retro-Rocket Delivery System

2.2.6 Timed or Barometric Activated Device

Another system developed during this time which proved more feasible was a system employing a timed or barometric activated device in place of the retro-rockets (Figure 25), Reference 10. This system was developed exclusively for use with A-22 resupply containers weighing approximately 2000 lbs each. In operation a single G-12, 64-ft diameter parachute was rigged on each A-22 container. A small stabilization chute was connected to the cutter strap and also to the deployment bag for the G-12D parachute. In the line to the cutter strap was the cutting device which was set either for a specific elapsed time or to a set barometric pressure. In operation, several containers, rigged in this manner would be gravity dropped from 12,000 to 15,000 feet with the small stabilizer chute rigged to be deployed by static line. As the A-22 containers rolled off the aircraft ramp the small chutes were deployed and the A-22 containers fell at 100 to 150 ft/sec. At the pre-set time or altitude, usually 1000 to 1500 ft above the compound, the cutter would be activated and the 64-ft G-12D parachute deployed. The load would decelerate rapidly so that at ground impact it would be travelling at 25 to 30 ft/sec.

In both systems special care must be taken because of the pyrotechnics and rockets being carried in the cargo compartment of the aircraft. Especially in the case of rockets, it is imperative that no electrical charge whether direct connection or induced can reach the rockets' ignition system before the rockets are well clear of the airdrop aircraft. In other words, it is not a safe practice to arm the rockets system during the extraction phase. Retro-rockets should never be armed until the end of the parachute deployment sequence, or later.

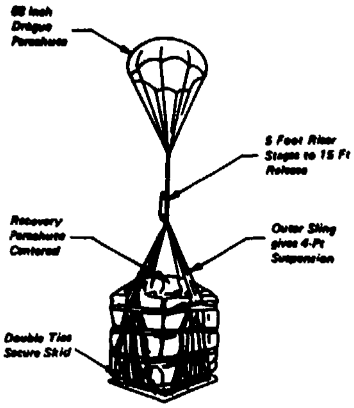


Figure 25 Time/Barometric Activated Recovery System

2.2.7 <u>Sled-Mounted Missile Extraction System</u>

Another system which is often used in airdrop developmental testing employs a special sled or platform for extracting and dropping a boat or bomb or missile. This involves separating the bomb, missile or boat from the sled, and stabilizing or repositioning it prior to impact. Usually for a bomb, boat, or missile, separation is executed by cutters attached to the airplane to cut restraint straps between the object and the sled, while the extraction parachute attached to the sled, pulls the sled from under the object (Figure 26), Reference 11. Once separated, the recovery parachutes/stabilization parachute may be deployed by a deploymnt line attached to the sled, or if the recovery parachutes are rigged on the sled they are deployed out of their protective bags as the sled and object separate. In planning airdrops of small boats for use in rescue work or fire fighting where nearby lakes may be used, care must be taken to use compression members across the boat so as not to collapse or damage gunwales or ribs during the opening shock of the recovery parachutes at which time 2 G forces may be experienced in the suspension slings. Both the U.S. and U.K. have made successful airdrops of small boats for these types of operation.

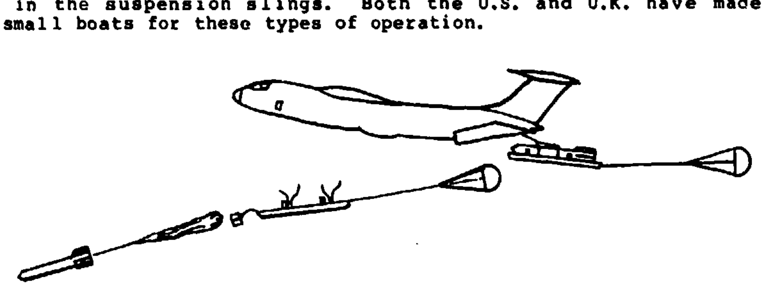


Figure 26 Sled-Mounted Missile Extraction System

2.2.8 Longer Extraction Systems and PLIES

Quite often in R&D testing we are to extend the airdrop envelope of aircraft or to go to longer extraction systems or to higher airdrop speeds. For example, in extending the C-130 Hercules single-platform airdrop capability to 50,000-lbs special precautions had to be taken in planning these tests for several reasons. The stability of a 93,000-lb airplane when airdropping a 50,000 lb platform was a situation where everything had to function properly or the result would have been catastrophic. When the length of extraction lines were increased first from 60 ft for the C-130 to 105 ft for the C-141 and finally to 215 ft for the C-5A, new problems arose which had not been encountered previously. It is in situations such as these that developmental test engineers' and technicians' ingenuity and inventiveness are tasked to their fullest. Truly in these situations "Necessity, becomes the mother of invention". For example, it became necessary to go to a 215-ft long extraction line for the C-5A because that was the distance from 12 ft aft of its cargo compartment forward bulkhead to 20 ft aft of its tail cone. However, in the case of the extraction system required for a 40,000-lb platform, the 12-ply 205-ft nylon line and two 35-ft diameter ring slot parachutes weighed approximately 500 lbs. As this heavy system deployed aft of the C-5A decelerating all the way, and then was suddenly accelerated back up to the speed of the aircraft upon full deployment, this force (snatch force) was sufficiently high (up to 40% of peak drag force) to cause concern that a load might be released from the latches before extraction chutes were deployed. This could result in platforms far aft in the aircraft being extracted by partially inflated chutes and therefore being subjected to excessive tumble. The PLIES system of rigging the extraction line in a bag to which the chute was attached was developed and worked satisfactorily to reduce snatch force. (Reference 6.)

2.2.9 Tow Plates and Extraction Force Transfer Devices

Tow plates, as mentioned earlier, have been used for 22 years in developing the LAPES. However as extraction systems became heavier and longer, and as the Mains extraction method became more widely adopted, tow plates have taken on added importance. There are several designs currently in use but they all operate similarly. Therefore, the following generic description of its function is provided. A tow plate is a mechanical device attached to the aft ramp floor, through which a relatively small (15-ft or 22-ft diameter) drogue parachute is attached for towing to initiate a LAPES aerial delivery. The tow plate contains a knife cutter (usually powered by a spring which is activated by a solenoid). The tow plate may also be activated by cable connected to handle forward of the airdrop platform, which may be pulled by a loadmaster should the electrical system fail. A basic tow plate system is shown in (Figure 27). Starting at the aft end of the ramp the riser from the drogue parachute is attached to a triple-pin connector at the aft most pin. A second pin attaches to the riser that leads forward to the extraction parachutes which are placed on top of the tow plate. The third pin is used to attach the connector to the tow plate through a cutter web (made of 6,000 lb T.S. nylon when a 15-ft drogue chute is used). In the tow plate shown, the cutter web is placed around a slotted pin and within the confines of a knife bracket. The knife slips through the slot in the pin where it is safetied from slipping forward under the platform and is attached to a spring/solenoid system. The system is electrically connected to a switch on the co-pilot's flight controls. A tow plate manual control handle is placed aft of the spring/solenoid system and attached to the same cable. In operation the drogue parachute is released from the pendulum release system, it swings out and down below the aircraft, deploys and inflates. The drogue is thus towed through its attachment to the tow plate until the aircraft is at its designated spot for the LAPES delivery. To initiate a delivery the co-pilot pushes the button on his flight controls, the solenoid pulls the cable which draws the knife forward breaking the safety tie and through the slotted pin to cut the cutter web. When the cutter web is cut, the three-pin connector is pulled aft by the drogue and the drogue force is transmitted through the riser to the extraction parachutes (packed in their deployment bag). The extraction parachutes are pulled out of the aircraft and deployed to extract the platform. Other newer tow plates have replaced the slotted pin and knife with mechanical jaws, however, the principle is the same. Extraction Force Transfer Devices function similarly to tow plates but they are much sturdier to withstand the forces of extraction parachutes developing drag forces up to 10 times those to which tow plates are normally subjected. The Extraction Force Transfer Device (EFTD) is normally attached directly to the load to be airdropped (Figure 28). It contains a latch to which a triple-pin connector is attached. The latch is normally activated through a cable release assembly mounted on the airdrop platform siderail. In operation, the extraction line from the inflated extraction parachutes transmits the force between the first and third pins of the triple-pin connector. The third pin is attached to the EFTD. As the platform moves aft, an arm on the cable assembly which is spring loaded to rotate downward, rides along the top of the aircraft restraint siderail. When the platform leaves the airplane the arm is free to rotate downward and it does A cam within the assembly pulls the cable which in turn releases the eFTD allowing the extraction parachute(s) drag force to be transmitted through the triple-pin connector to the main parachute deployment line which is attached to the second pin. The main parachutes are thus deployed to recover the load. A device such as this can be a hazard to the aircraft should a premature release occur, but this will be discussed in the next section on hazard reducing safety hardware.

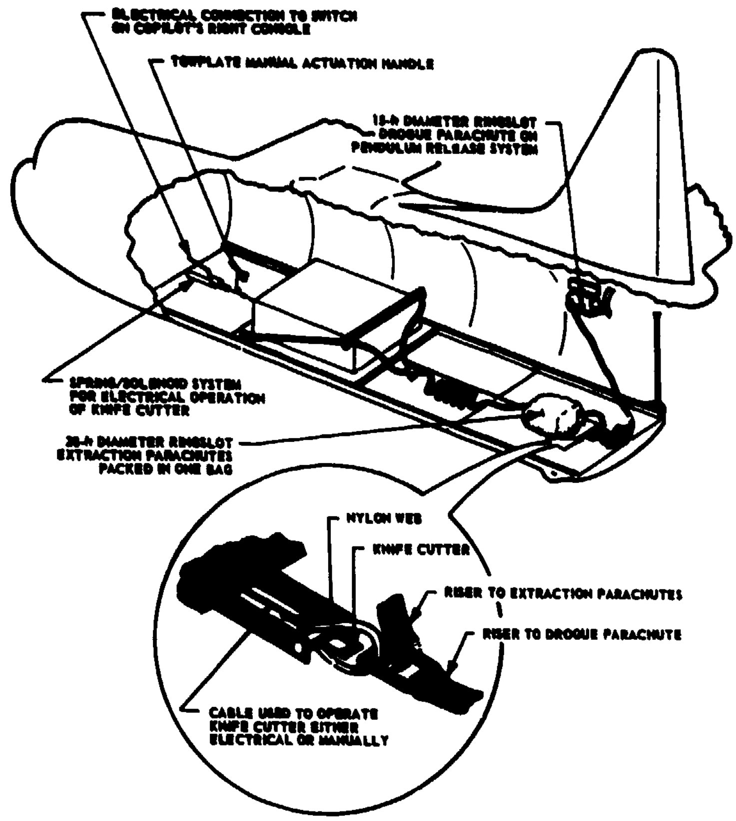
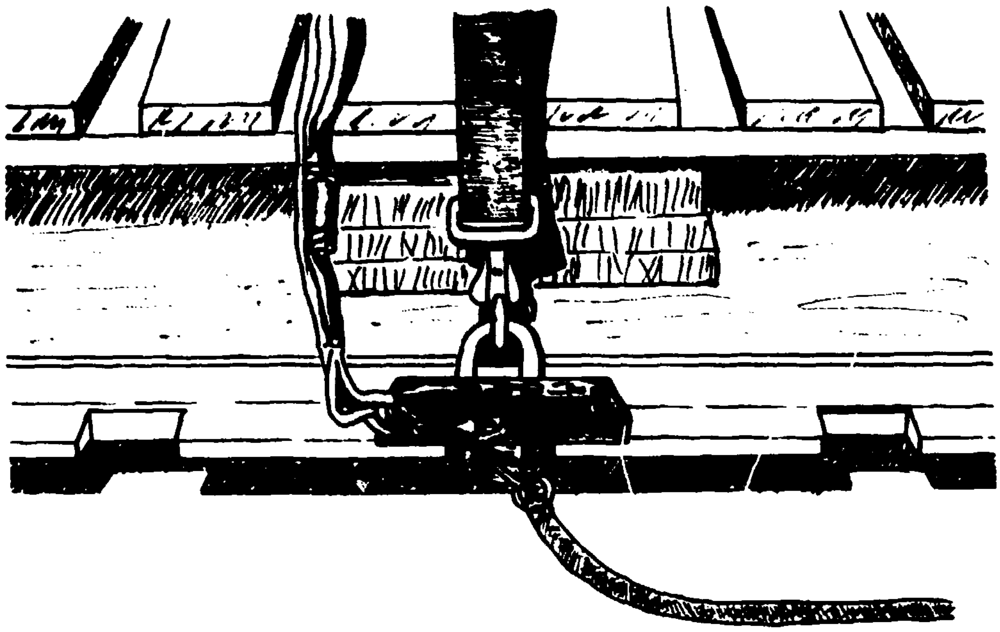


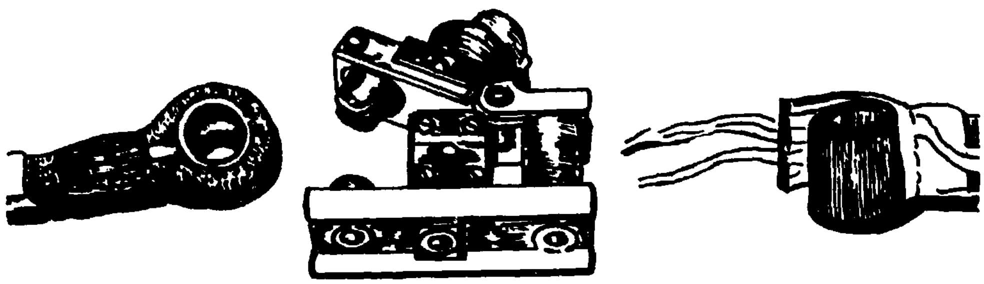
Figure 27 Extraction System Tow Plate

2.2.10 Recovery Systems Ground Disconnects

These ground disconnects are devices placed on airdropped loads to release the recovery parachutes from the load after ground impact and thus prevent surface winds from keeping the canopies inflated to topple the load and damage it. In the case of strong surface winds it prevents the chutes from dragging the load on the ground. Although they are not a critical interface part between the aircraft and extraction sytem, they could become a part of the recovery system and should be considered when planning airdrop test in areas where higher surface winds are common. They do pose a threat to the load if they should prematurely release in midair thus causing the load to fall free to its ultimate destruction upon impacting the ground. One system which has been successfully used in Germany by the Erprbungstelle 61 in Manching, is the pyrotechnic ground release (Figure 28), Reference 9. This system is armed by a lanyard which is pulled when the platform leaves the aircraft. Upon ground impact, a pyrotechnic device is fired releasing the main parachute risers and they are free to float away. Most of the ground releases used in the U.S. are armed when the parachutes are lifted off the load to start deploying. The parachute risers are attached to a pin which is held in place by the tension of the risers. Upon ground impact the riser tension is relaxed, the pin disconnects and the parachute is free to float away. These latter devices have been known to prematurely release parachutes in midair.



Ground Released Button, connected and safe



Ground Release with Ground Release Sling Part 1 and Part 2 (Ends Only)

Figure 28 Ground Release Device, German

2.3 Design and Functioning of Special Hazard Reducing Interface Hardware

As was mentioned earlier, an airdrop test engineer or technician, in designing his test airdrop system must look at all the available hazard reducing devices and procedures at his disposal so as to assure, should any malfunction occur in his test system, he will have taken every precaution possible to reduce the hazards. And many devices and specialized airdrop platforms themselves incorporating safety features, have in fact been designed over the years to do exactly this, to keep hazards to a minimum. In starting with the largest single hazard minimizing piece of equipment, namely the platform, let me say, that most NATO nations have designed and used their own version of these special platforms, test beds or whatever special nomenclature with which they have been tagged. They all satisfy the basic requirements for that particular test organization. These organizations also recognised the need for safety features for emergency use with the critical force transfer functions. These will be described shortly. Other devices which have been used in Developmental Airdrop Testing include go-nogo safety devices, the Trianco Restraint and Release Assembly (TRARA), the Extractor Parachute Emergency Release Unit (EPERU), Floor-Mounted Anchor Lines, breakaway static lines, and many other minor items such as special covers for knives, anchor cable tiedowns and so forth. These will be discussed in future sections.

2.3.1 Special Test Platforms (Reference 11)

In discussing the desirable features of a test platform, the test tub used by the U.S. Air Force successfully for 30 years has been selected only because it is the platform with which the author is most familiar. The U.K. and Germany have test platforms with similar features and discussion of desirable features will be kept as generic as possible. Figure 29 shows a test tub (6511th Test Group Dwg No. 68E1493). It is constructed of steel I beams and welded steel plate. The tub is 24 in high, 80 in wide and comes in lengths of 8, 16 or 24 feet. A specially designed guillotine knife system, Figure 30, is attached to the aft end of the weight-test tub. The guillotine blade could be activated by a lanyard tied to the anchor line cable or floor or it could be activated manually by lanyard at a point forward of the platform. The weight-test tub had rounded corners and steel posts to which suspension slings could be attached. Steel plates of 500 lbs each were added to vary the weight and center of gravity location of the test tub. The tub had a row of holes drilled in a 1/2-in thick steel plate welded to the side of the tub through which restraint fittings could be led to restrain the tub to the base modular airdrop platform. This standard weight tub was used (in the three available sizes) to simulate vehicles weighing from 5,000 to 50,000 lbs.

1 LOAD-BEARING PLATFORM
2 PAPER HONEYCOMB
3 WEIGHT-TEST PLATFORM
4 CHAIN OR WEBBING TIEDOWN:
4-G AFT RESTRAINT, 8-G FWD RESTRAINT
5 PARACHUTE TRAY
6 SUSPENSION BLOCK
7 SUSPENSION RISERS
8 G-11A CARGO RECOVERY PARACHUTES
9 PARACHUTE RESTRAINT 6000-LB NYLON WEBBING WITH KNIVES
10 G-11A CLEVIS
11 DEPLOYMENT LINE, 8-PLY, TYPE XXVI, 8 FT LONG
12 GO-NO-GO SAFETY CLEVIS
13 ACTIVATION LANYARD, SAFETY CLEVIS
14 SPRING-POWERED KNIFE ASSEMBLY
15 ACTIVATION LANYARD, SPRING-POWERED KNIFE ASSEMBLY
16 MANUAL ACTIVATION LANYARD SPRING-POWERED KNIFE ASSEMBLY
17 SPRING-POWERED KNIFE ASSEMBLY CUTTER WEB
18 FOUR-POINT CLEVIS
19 STRAIN GAGE LINK
20 TWO-POINT STRAIN GAGE LINK ADAPTER LINK
21 EXTRACTION LINE

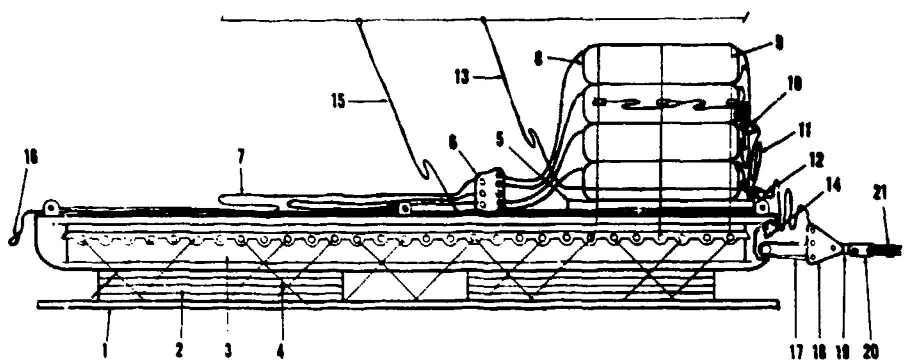
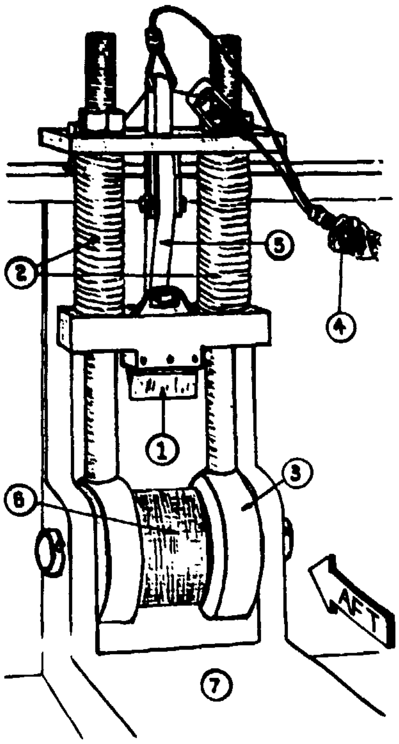


Figure 29 Test Tub for R&D Airdrop Tests

2.3.2 Guillotine Force Transfer Device (Figure 30)

The Guillotine Force Transfer Device has probably been used more often than any other system for R&D aerial delivery system testing. Its reliability lies in its simplicity of design. It is nothing more than a powered knife (two concentric springs on each post) which is driven down to cut several plies of nylon webbing which are passed around a heavy steel spool which also forms an anvil. Up to four plies of type XXVI nylon webbing (a thickness of 5/6 inch) with no tension applied, have been cut by this system. The knife is cocked with a special lever bar and safe tied to prevent premature release from vibration during flight prior to the airdrop. A small knife is affixed to the safety tie and is pulled to cut the tie when the guillotine lanyard is pulled during an airdrop test. A second lanyard is led forward along the weight tub and may be pulled manually by a loadmaster in case of emergency, or to cut a towed parachute away to end a tow test.



1. Knife Blade 2. Springs 3. Spool 4. Lanyard 5. Trigger 6. Cutter Web to Extraction Line 7. Weight-test Platform

Figure 30 Guillotine Knife, System Spring Powered

2.3.3 Floor-Mounted Anchor Line Reference 12

With the advent of larger airdrop aircraft with longer cargo compartments, a new phenomenon came upon the scene. The bowstring effect on anchor line cables. When static lines applied tensile loads to the anchor line cable then suddenly released this tensile load the cable rebounded in various vibratory patterns, all of which caused reactions in other static lines for subsequent platforms. Static lines could be caused to flip over the anchor line cable and become entangled. To prevent this happening during R&D testing, a floor-mounted anchor line was developed. Any tendency to vibrate was dampened by the cargo floor. Also anchor cables attached to the floor could be put under much more tension than those attached to the lighter aircraft structures. Therefore, static lines were no longer limited to a maximum tensile strength of 3000 lbs.

2.3.4 GO-NOGO Safety Clevis

The most important safety device developed in the last 25 years was the GO-NOGO Safety Clevis and its couunterparts in the U.K. and Germany. The current version of the GO-NOGO Safety Clevis as it was used by the 6511th Test Group (USAF) since 1968 is shown in Figure 31, Reference 13. It protects the airdrop aircraft. The GO-NOGO safety device is essentially an open link placed in the deployment line to the recovery parachutes. It remains open until activated by a lanyard (static line) which releases a spring-loaded pin or camm allowing it to close the link. Since the lanyard or static line is only pulled after the platform has moved aft to the edge of the ramp, the main recovery parachutes cannot be deployed onboard the airplane even if a premature release of the extraction force transfer device should occur. With a GO/NOGO safety clevis rigged in the deployment line, the guillotine system may also be manually activated to cut a towed extraction parachute away in the event a platform becomes jammed in the rail system. In operations, the male end of the device attaches to the deployment line coming from the extraction force transfer device three-pin link. The female end of the GO-NOGO clevis attaches to the deployment line going to the recovery parachute bags. The female end has a flat undersurface with slots through which the device is secured to the airdrop platform. When the lanyard is pulled, the open link closes and deployment of the recovery parachutes is assured.

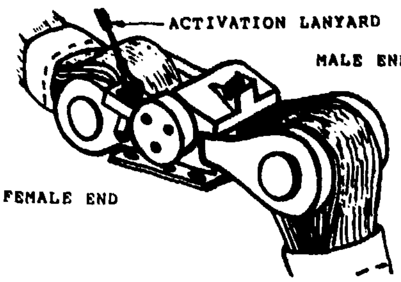


Figure 31 GO-NOGO Safety Clevis

2.3.5 Trianco Release and Restraint Assembly (TRARA) (Figure 32) (Reference 8)

As in the case of the GO-NOGO safety device, TRARA is designed so that it is impossible for the main parachutes to be released before the platform has been released from the aircraft rail system. In operation TRARA functions as follows: immediately prior to extractor parachute release (Figure 32 Stage 1), TRARA is positioned so that:

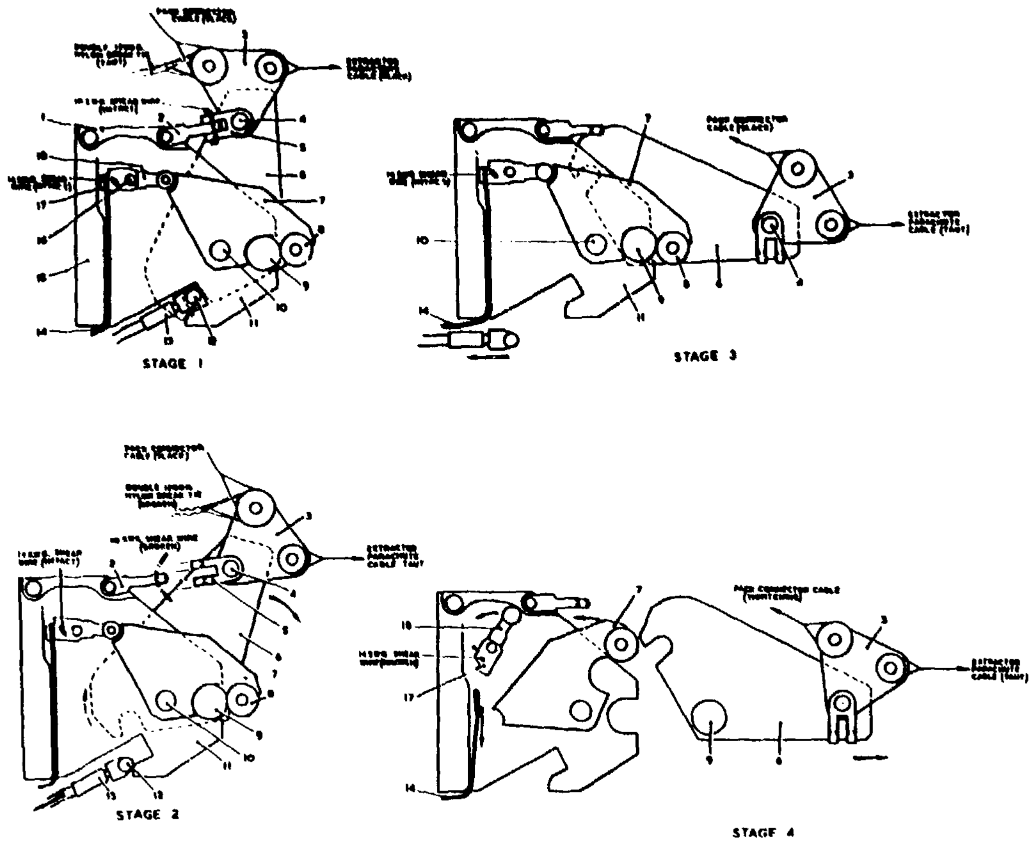


Figure 32 "TRARA" Operational Sequence

a Extractor parachute line is slack as in the parachute pack connecting cable.

b Transfer release cable (14) is slack.

c The double 1200-lb nylon break tie from parachute adapter (3) to platform is taut.

d Shear wire bush fork (2) and wire fork 5 are connected to copper shear wire.

e Transfer operating lever (17) and latch locking lever (18) are held in horizontal position by shear wire through lever and plate (11) of unit body.

f Roller at aft end of latch locking lever (18) engaged in recess of floor the hook latch (17).

g Release floor tie hook (6) is in vertical position with spindle (9) held in slots by rollers (8) of the floor tie hook latch (7).

In this position, aft restraint is being applied to the platform through the floor tie assembly, the release floor tie hook and the floor tie hook spindle.

Stage 2 - The extractor parachute starts to develop and the extractor parachute cable tautens (Stage 2) to exert an aftward pull on the parachute adapter (3). When the drag of the parachute is sufficient to break the double 128#-lb nylon break tie the force is transferred through the floor tie hook pin (4) to the shear wire fork (5). The shear wire breaks and the release floor hook (6) rotates. After a few degrees of rotation the notched forward end of the hook frees the trunion pins (12) of the floor, the assembly thus freeing the platform from aft restraint.

Stage 3 - The platform continues to move aft (Stage 3) in the aircraft guide rails being pulled by the extractor parachute. During this period the transfer release cable, anchored at its forward end to the aircraft floor is being pulled from its stowage loops at the forward end of the platform. The transfer release cable does not tauten, however, until the platform is clear of the ramp edge (Stage 4). When the forward end of the platform clears the ramp edge the transfer release cable (14) tautens and causes the operating lever (17) to rotate downward annd frees the floor tie hook latch (7) and thus frees the spindle (9). The drag of the extractor parachute is thus transferred to the recovery parachute(s) pack and pulls the packs off the platform to deploy and recover the load.

2.3.6 Extractor Parachute Emergency Release Unit (EPERU) (Figure 33) (Reference 8)

The EPERU is designed to function as an emergency release for the extractor parachute while leaving the load to be extracted safely secured onboard the airdrop aircraft. The unit is secured on the ramp of the aircraft between the extraction line and the deployment line from the main parachute deployment bag's handles. A link and shear pin at the forward end of the unit is used to secure it to an aircraft floor tiedown shackle. There are three different ways in which the EPERU can function:

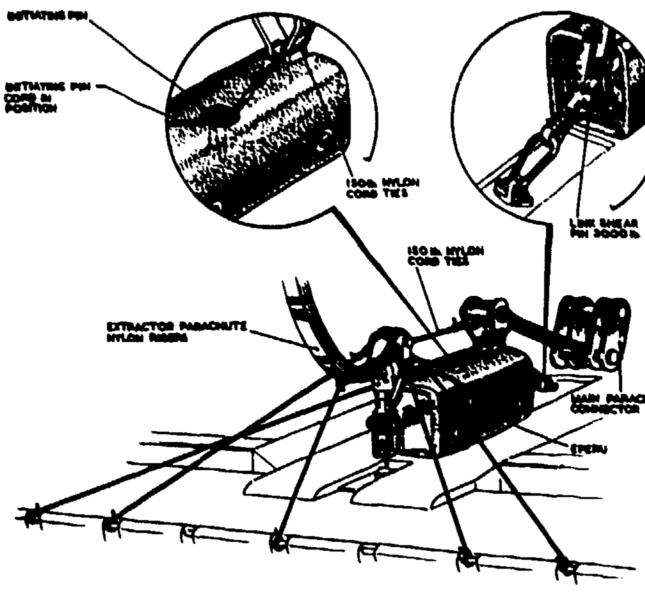


Figure 33 "EPERU" Installed in an Aircraft

2.3.6.1 Normal Airdrop

In a normal airdrop when the extractor parachute is released, it breaks the tie cord between the fore and aft links and extracts a pin to start the mechanical timer. The extractor parachute develops and the force shears the anchor pin and the EPERU is jerked aft causing the manual arm release system (MARS), assembly to move forward within the EPERU. This allows a stop lever to pivot and prevent a linear activator from working. This locks the EPERU and the extraction force is transmitted through the EPERU to the main parachute packs and they are extracted.

2.3.6.2 Hesitant Release

With a hesitant release, the initiating pin is pulled and the timer started as in a normal drop. After a pre-set time, the linear actuator operates and if the extractor parachute has developed at this stage the anchor pin is sheared before the link bar has been released. As the EPERU is jerked aft and the mass assembly moves forward, the stop lever moves too late to arrest the linear activator. However, a lever catch is pivoted to engage the locking levers which engage top pins on a link bar and prevent the EPERU from releasing. Pawls on the mass assembly lock the lever catch in position and the EPERU provides a secure link to extract the main parachutes.

2.3.6.3 Jettisoning the Extractor Parachute

If an extractor parachute fails to develop, there is insufficient force to shear the anchor pin (3000 lb), the EPERU is not extracted and the mass assembly is not disturbed. The initiating pin is pulled starting the timer and after the preset time the linear activator functions to disengage the link bar trunions from the hook since the mass assembly has not moved. The locking levers are free to pivot without arresting the movement of the link bar and the link bar separates from the EPERU and allows the extractor parachute to go free.

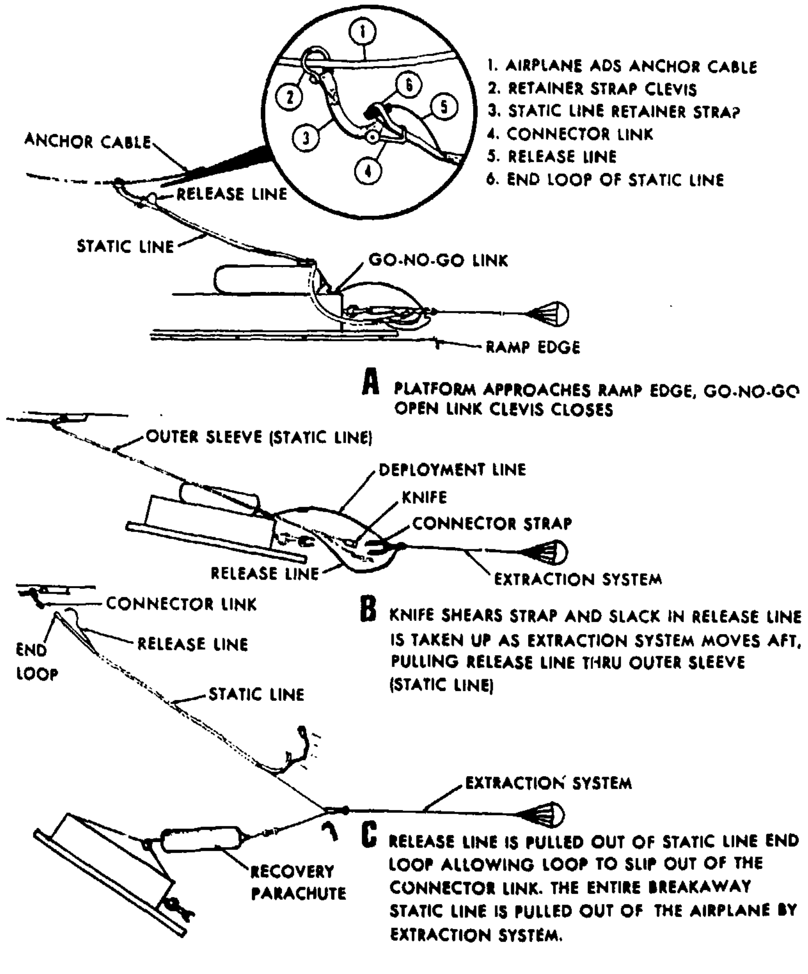


Figure 34 Breakaway Static Line Operational System

2.3.7 Breakaway Static Lines

Although they have been in use for many years and have become a part of many standard airdrop systems in the U.S., breakaway static lines are still used extensively in R&D testing because they prevent damage to the aft body of the airdrop aircraft. Static lines in general usually incorporate a knife or other piece of hardware at their free end. After an extraction and the static line (if attached to the airdrop aircraft) is flailing around in the turbulent air immediately behind the aircraft ramp, some damage to the aircraft may be caused by the hardware striking the aircraft afterbody denting it or puncturing the skin. Static lines have also become entangled in aft cargo door fittings or activators before they (the static lines) could be retrieved back into the aircraft. The breakaway static line is constructed of a cotton sleeve through which a nylon release line is led. Once the static line has accomplished its task (whether to pull a pin, cut a restraint strap, etc) the sleeve tension is released and the core line which is still attached to the airdropped load pulls out of the loop in the aircraft end of the static line allowing the entire line and core to be extracted out of the aircraft leaving only the short (6- to 12-in) strap attached to the anchor line cable. Figure 34 shows the sequence of operation.

The foregoing sections have described some of the major interfacing hazard reducing items available to the airdrop testers in R&D work. Many other minor items are conceived or adapted by the tester as dictated by his particular project. It is the responsibility of the test engineer/technician to use these items when they will reduce hazards but he must always be conscious of the fact that the more items one places between the extraction parachute and the main parachutes the higher the probability of a malfunction. Therefore, the astute R&D test engineer/technician should strive to keep his systems safe yet simple.

2.4 Test Instrumentation for Cargo Airdrops

The successful accomplishment of R&D airdrop testing requires specialized instrumentation for acquiring performance data. Since the design of new airdrop systems and the improvement of existing ones depend largely on the performance characteristics of the various systems, the availability and utilization of accurate and reliable data recording instruments or systems cannot be overemphasized. The choice of this instrumentation by the test planner will depend on his budget and the accuracy to which he believes the performance parameters must be measured. For purely feasibility evaluations he may be content with some basic self-contained recording units which will provide an overall accuracy of ±5 to 10 percent. However for most R&D airdrop testing, magnetic tape multichannel recording or telemetry systems which are accurate to within ±2 percent should be used. The most often used sensing element is the transducer. Basically, a transducer is a device which measures a physical quantity such as acceleration, force, pressure, speed, strain, temperature, etc, and converts it into an electrical signal, which is either recorded on magnetic tape onboard the aircraft or airdropped load, or telemetered to a ground station where it is recorded on magnetic tape.

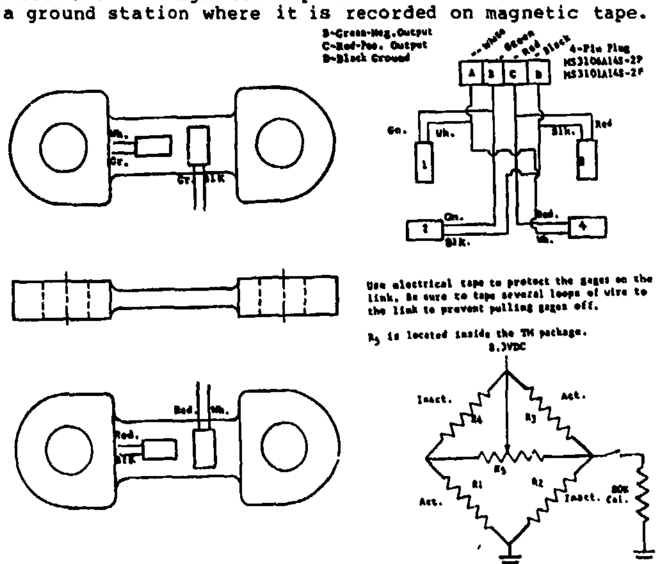


Figure 35 Typical Electrical Strain Gage Force Transducer

Measurement of strain in a parachute canopy should not be attempted in R&D airdrop testing. Usually when a canopy has reached the flight testing stage, it will have gone through wind tunnel tests and extensive analysis. Cargo airdrop parachutes are usually constructed from well-known and tested materials and therefore little would be gained from this type of instrumentation. Measurement of force in a parachute riser is usually done with a calibrated load cell or load link. Figure 35 above shows details of a load link employing a strain gage with a resistance bridge as the transducers element bonded to the load link surfaces. The working range is a function of the strength and electric limit of the load-bearing member. Strain gage links of this type having a working range as high as 75,000 to 120,000 lbs tensile load have been used successfully on airdrop developmental tests. These load cells must be installed so as to avoid bending moments in the stressed beam. For this reason they should be installed only between webbing risers and not be restrained between side plates directly affixed to the platform.

Measurement of pressure may be done by a strain-gage force transducer driven by a sealed piston, calibrated to measure force per unit area. Other pressure sensing transducers may operate through displacement of a diaphragm, Bourdon tube or sulphon bellows. However, measurement of altitude pressure may be accomplished by drop aircraft instruments. Dynamic pressure is measured by the pitot-static tube as the differential between the total pressure and the static pressure, and translated mechanically/electrically into equivalent airspeed units based on sea level air density. True airspeed may then be calculated using this known air density.

Often during developmental airdrop testing it is necessary to obtain gravitational forces, "g", along one or more of three orthogonal axes. Accelerometers oriented along these three axes are normally placed at the center of gravity of the platform although they may be used to measure "g" forces on parachute packs, force transfer devices or any other object experiencing rapid acceleration. These accelerometers are commercially available in a wide range of values. The accelerometer transducer uses strain-gage bridge, force sensing semiconductors or piezo-electric element principles which involve deformation under the inertia forces of moving mass.

2.4.1 Multichannel Magnetic Tape Recording System

The multichannel magnetic tape recording system (8-12 channels) which is used particularly for heavy-cargo drop tests, contains all components within one unit. Eight to 12 or more data channels, power supplies and a reference frequency channel are included in this sytem. A DC power supply, usually 24-volt is used to power the electronic components and the tape recorder, Reference 10. Airplane power 28-volt DC may also be used as a power source. A calibration unit should be included so that it is possible to simulate full-scale deflection on sensing elements by switching precision resistors into the sensing element input circuit. This is used in calibrating the system on the ground prior to takeoff when all sensing elements have been rigged in the test system. A magnetic tape playback system converts the frequency modulated signals recorded previously on magnetic tape into analog voltages through discriminator action. Onboard recorders similar to this have been used on airdrop platforms or special test vehicles by the U.S., U.K., Germany and France. However, telemetry systems have become more widely used at test organizations suitably equipped with ground receiving stations because the test data will be intact whether or not the test vehicle is destroyed following a system malfunction.

2.4.2 Airdrop Aircraft Instrumentation

Telemetry may be defined as a system that takes measurements at a remote location, transfers and reproduces them at a base station in a form that is suitable for display, recording, or insertion into data-reducing equipment. Simply put, a sensor located at the remote location (e.g., a strain link in an extraction line) produces an electrical signal which is processed and applied to a transmitter. The transmitter output is carried by the connection (radio) link to the receiving terminal (base) where it is processed for the combined use of display, storage, and later computer analysis and display, or is fed directly into the computer. The use of telemetry is controlled by Inter-Range Instrumentation Group (IRIG) which adopted "frequency modulation" (FM) as the method for signal transmission. Three frequency bands: P-Band (216-260 MHz), L-Band (1435-1540 MHz), and S-Band (2200-2300 MHz) are currently assigned. In designing a TM pack, the higher transmission frequencies are desirable because they afford shorter wave length and wider bandwidth. Short wave lengths permit shorter antennae on the platform or test vehicle at higher transmission efficiency. The wide bandwidth favors greater transmission capacity and accuracy. However, the higher frequency transmitters and receivers are heavier and more expensive. Modulating techniques vary with the requirements of the test and test range. Until recently FM/FM telemetry was used exclusively e.g., remote measurements were converted into subcarrier frequency modulated messages and transmitted on a common FM carrier frequency. The required bandwidth per subcarrier (channel), limits the number of continuous measurements transmissable to between 8 and 12 for practical consideration. FM/FM through extensive use has reached a high state of development and reliability and with 8 to 12 channels should satisfy 90 percent of R&D system requirements. If more channels are required, a test engineer may consider Pulse Code Modulation (PCM), Pulse Amplitude Modulation (PAM), or Pulse Duration Modulation (PDM). The PAM/FM and PDM/FM systems provide greater flexibility and capacity than FM/FM and accuracies within 2 to 2 1/2 percent. PCM/FM provides the same flexibility as PAM/FM but with an even higher degree of accuracy. PCM/FM would be ideal for carrier aircraft TM measurements as in the case of a new aircraft being evaluated for airdrop capability where 100 to 200 or more channels may be desired. A typical onboard telemetry pack is shown in Figure 36, Reference 14. Typical locations for various instrumentation sensors for R&D airdrop testing are shown in Figure 37, (Reference 15). Instrumentation of the airdrop test aircraft will vary depending on the scope of the testing. If a new aircraft is being evaluated in the airdrop role, this instrumentation will be extensive, but if testing is of a parachute system or if some new hardware is being developed, most of the instrumentation may be contained in one of the airborne instrumentation packages described above. Onboard instrumentation for developmental airdrop testing for new cargo aircraft is rapidly becoming computerized. Small computers are replacing visicorders and they are equipped with strip chart recorders for displaying data onboard the aircraft during test missions. These computers tap into the recorded data stream which is also being telemetered to a ground station. When programmed with a proper data base the computer converts this "raw counts" data to data displayed in engineering units for quick engineering analysis. Test engineers will no longer have to land and evaluate their test data to determine if they should move to the next test. The computer may also be programmed to predetermined data limit values. If the test data exceeds these values, a flag is inserted on the displayed parameters at the point the predetermined limit is exceeded. If the test engineer/technician wishes to raise the limit for the next test, he may do so through the computer keyboard. He may also combine test data as required by summation of two or more parameters. Parameters displayed on the computer monitor may be changed during flight to meet changing test conditions; this includes sampling rate, and ranges of the data being recorded. The recording/computer station may also be set up to include a hard copy printer(s) to engineering units. Appendix E shows typical lists of aircraft and parachute airdrop testing instrumentation.

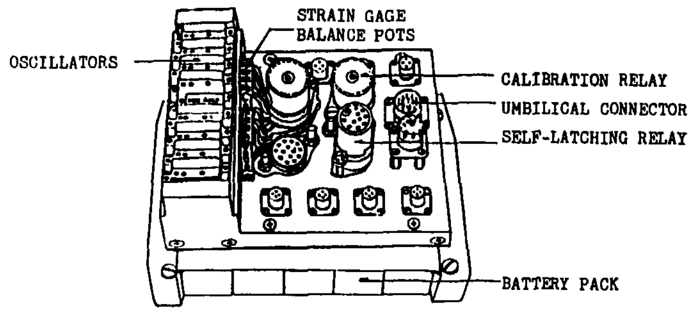


Figure 36 Telemetering Pack for 6 FM Channels

2.4.3 Onboard Photographic Equipment

The use of special test platforms for R&D testing may be enhanced by the use of onboard photograpic equipment. Cameras usually capable of up to 200 frames per second may be used as fixed installations in the aircraft cargo compartment to photograph extraction parachute release, deployment, extraction force transfer and platform movement out of the aircraft. These 16-mm cameras are available in many models from the relatively inexpensive GSAP camera to the Photo-Sonics 1F which can operate successfully under loadings as high as 100"g's" at frame rates from 200 to 1000 frames/second. These cameras operate on 6 to 28 volts DC or 10 to 48 volts DC and contain a timing light which makes event sequencing analysis possible.

2.4.4 Chase Aircraft Photographic Equipment

Quite often when a new extraction system is being tested or a new extraction force transfer device or extraction parachute is being evaluated, photographic coverage from a vantage point at the same level from the side is best for a functional evaluation. the only way to obtain this coverage is by using a photo-chaser aircraft. Normally a 16-mm camera with frame rates up to 400 frames/second is used. A frame rate, usually 200 frames/second or higher is needed in the event turbulent air or excessive chase aircraft vibration are encountered. The camera should also be sufficiently light and compact to be manageable should the photographer be subjected to increased accelerations during diving turns or pull-ups to follow the test system after it has left the airdrop aircraft. The Milliken DBM-5A camera has been extensively used in the U.S. but any comparable camera would be well suited to this role.

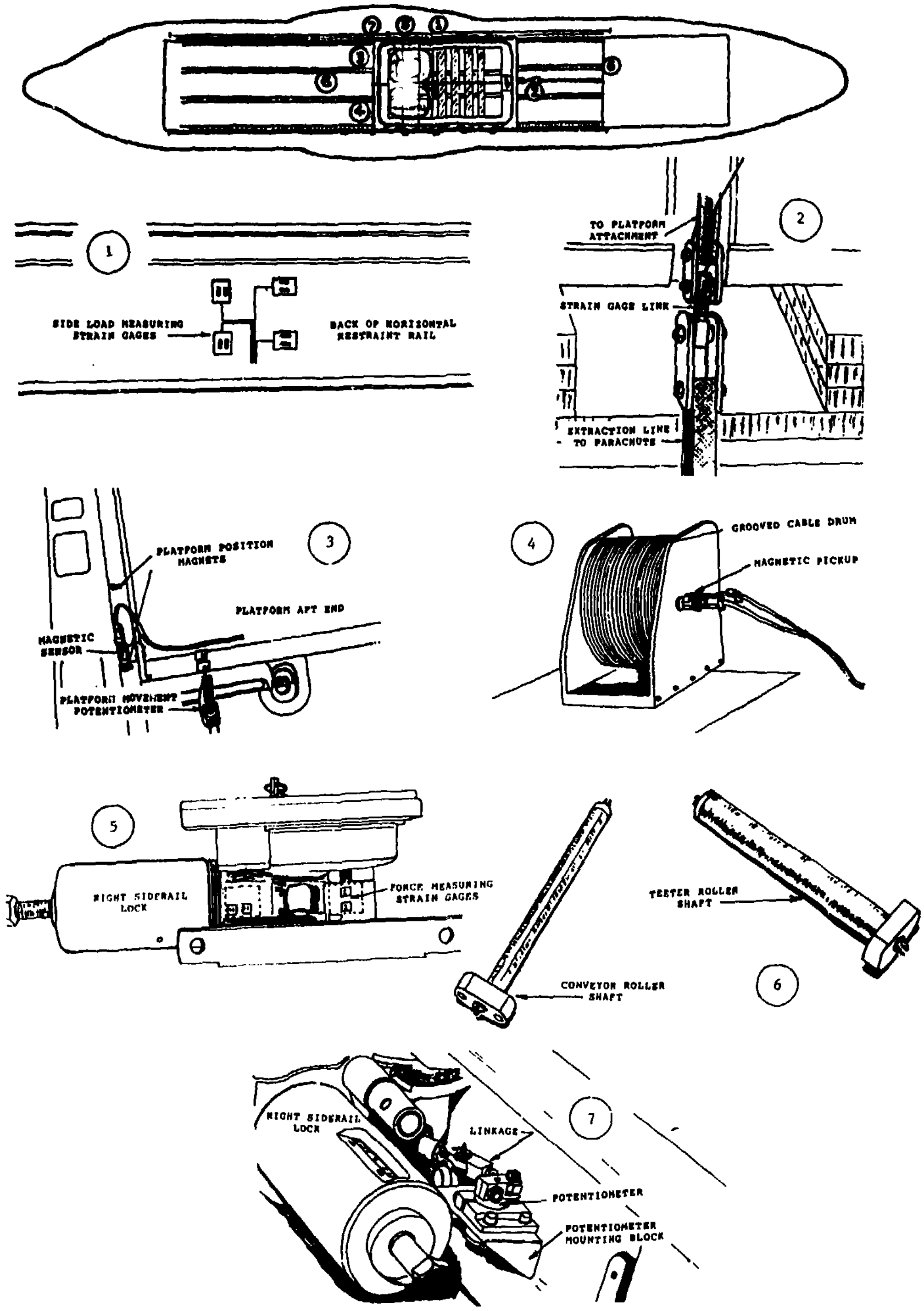


Figure 37 Typical Locations for Onboard Instrumentation Used in Developmental Airdrop Testing

2.4.5 Time Correlation

Time correlation on most ranges is controlled by IRIG systems. The timing system generates pulse rates, cinetheodolite control pulses and accurately synchronized time codes which are transmitted and simultaneously captured on ground station motion picture, telemetry, radar, television, or other records. The airborne cameras require an independent timing reference which can be correlated with the ground-based IRIG system. Such correlation is important for proper definition of airdrop events such as line stretch, time of snatch force, extraction force transfer and platform exit. These data are even more important in cases of anomalies or failure in the test system. In order that test analysis be meaningful, data from all measurement gathering sources should be properly time correlated.

2.4.6 Space Positioning or Optical Tracking by Cinetheodolites

Space positioning or optical tracking by cinetheodolites is designed to provide angular measurements of the line-of-sight from the instrument to the airdrop test platform. The test platform or parachutes, angle data and timing are recorded on film simulataneously by a minimum of two instruments along the flight path. Cinetheodolites are a prime source of platform trajectory information, e.g., positon, velocity and acceleration. Data may be obtained at rates up to 30 frames per second with Contraves cinetheodolites. Each film frame registers transmitted signals for correlation with other types of instrumentation.

2.4.7 Ground-Based Motion Picture Cameras

Ground-based motion picture cameras with lenses of various focal lengths may be used on tracking mounts to obtain events and parachute inflation performance data during the entire airdrop sequence. These instruments may also vary in frame rates and film sizes (16-, 35- and 70-mm) and make possible very detailed step by step analysis of deployment and inflation sequences.

2.4.8 Closed Circuit Television Systems

Some ranges may be equipped with closed circuit television systems providing real-time viewing of the airdrop test with high resolution coverage originating at selected sites on the range. Video signals are transmitted by microwave to the master control station of the range where video tape recorders may be used for replay on demand.

2.4.9 Tracking Radars

Tracking radars may be used to skin track the airdrop aircraft or to beacon track the aircraft or platform. Radar may also be used to track Rawinsonde or other meteorological balloons prior to or after an airdrop test or to provide range safety surveillance. In most airdrop tests where the aircraft landing field is removed from the drop zone, radar may be used to vector the aircraft to a predetermined release point so that the airdropped platform will impact the drop zone (range) in an optimum position for cinetheodolite and motion picture camera coverage. The test range ground controller should examine predicted trajectories obtained from data provided by the test engineer for all-work and all-fail conditions so he can plot the release point. The radar should track the airdrop aircraft until the platform exits, then it should stay on the platform to obtain a plot of altitude versus time for rate of descent computation.

2.5 Simulation Systems

Flight testing requirements stem from a need for basic research where no other laboratory type testing is practicable or from a need to verify predicted design specifications of a particular airdrop system. Parachute design and performance prediction are still a predominantly empirical science from which derived coefficients and reliability figures, factors, etc, feed mathematical models in an attempt to show reasonable agreement with experimental data. Complex computer programs have been developed to predict parachute opening forces and internal loads but complete airdrop systems flight testing remains the ultimate test. But economic aspects more and more have dictated more and more simulation. Such tests may reduce the number of total systems required to demonstrate airworthiness or to qualify an airdrop system. Several different computerized analytical methods for parachute performance may be found in Reference 4. Very little has been done in simulating the airdrop aircraft response during airdrop tests, although aircraft manufacturers have conducted these analytical studies during the aircraft's design phase. A simulation program was, however, conducted at the close of C-5A airdrop capability testing in 1972 by the U.S. Air Force Flight Test Center in which empirical aircraft and parachute performance measurements during an actual airdrop test were used to set up a simulator model, Reference 16. The model was then fed into a flight simulator and an extraction airdrop was simulated. Figure 38 shows the results of this simulation. Data from this simulation was then used with extrapolated values for a 70,000-lb platform airdrop. Again with the known aircraft input parameters for comparison the simulator model again followed the actual very closely. An analog computer three degrees-of freedom (of) simulation which was generated to represent a C-130E engaged in LAPES testing, is described in Reference 15.

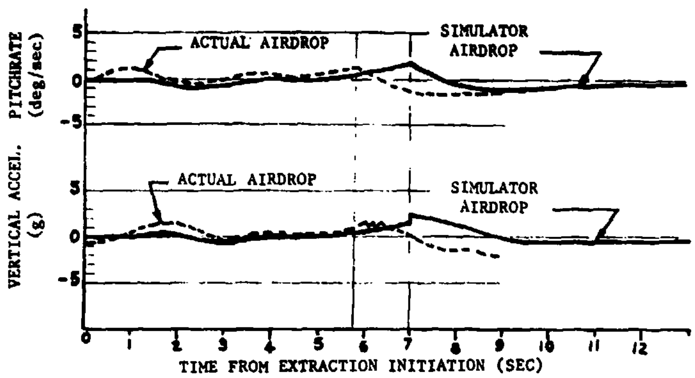


Figure 38 C-5A Airplane Response Simulated vs Actual

2.6 Safety Considerations in Developmental Airdrop Test Planning

In the introduction of this volume it was stated that airdrop systems flight testing should be safe yet productive. Research and Development airdrop testing by its nature is hazardous in that the test system probably has never been flight tested previously and also that the outer edges of the system's performance envelope are being explored. Many hazard minimizing test devices are available and have been previously described. However, there are other basic elements which should be considered when planning an airdrop test program. Some of these fundamentals of test planning are briefly discussed here.

2.6.1 Experienced Aircrews

Assuming that R&D airdrop testing will be performed only by organizations which are sanctioned by the government of the various NATO nations to do this type of work, only aircrews trained for this type of operation should be used. Wherever possible the most experienced aircrew, including the loadmasters and flight test engineers/technicians, should be used for the more hazardous tests. This is imperative for two reasons:

the operational risk and the technical risk involved. The operational risk is that risk inherent in the test because of hazard to life or damage to the aircraft in the event of malfunction. The technical risk is that risk which is involved because of the complexity of the test or possible human errors which would lead to the nonaccomplishment of the test objective or only partial accomplishment thereof. Therefore, whenever possible, the best qualified aircrew available should be used.

2.6.2 Safety Reviews

All R&D test organizations with which this volume was discussed, include safety reviews of some kind during the test program's test plan review/coordination cycle. These may range from simple informal reviews among test engineers and flight crews, to full blown formal Safety Review Boards conducted by the test range at which the test program is to be conducted. An important addendum to the pretest safety review is the continued monitoring of safety aspects for the duration of the program. Postflight briefings must be conducted immediately following each flight (airdrop) to review the operational aspects of the test. The entire flight crew should be involved in these briefings and should be free to say what they observed or wrote in their flight notes. Flight notes should be written immediately following a test while the sequence of events is fresh in their memories. These flight notes will form the basis of "quick look" reports (discussed in a later section) that are required in some of the larger or critical test programs.

2.6.3 Orderly Test Progression

Another way of making a test program as safe as possible is to start the program with the safer conditions then progress to the more hazardous conditions after evaluating the results of the previous tests. This progression should involve aircraft as well as test systems because a more hazardous test from the aircraft stability aspect may not be hazardous from that of the test system. However in all instances, aircraft flying safety should take priority and for that reason it is imperative that aircraft test pilots be directly involved with the test engineer when the airdrop test program is being written.

2.6.4 Malfunction Analysis Charts

Probably the best tool for pretest analysis of an airdrop test has been the malfunction analysis chart or fault tree analysis. An example of a malfunction analysis chart is shown in Figure 39. In this analysis, the initiation of the test is shown in the first block and a sequence of events which must take place for a successful test is shown with their effects and the corrective action that should be taken by crewmembers. These charts should be discussed and understood among all crewmembers so that everyone will know what he has to do in the event of one of the malfunctions shown on the chart. These charts also form the basis for the inflight checklists used between flight crew and loadmasters during all test operations (Appendix F), these charts depict the emergency actions called out in the emergency check list, in graphic form.

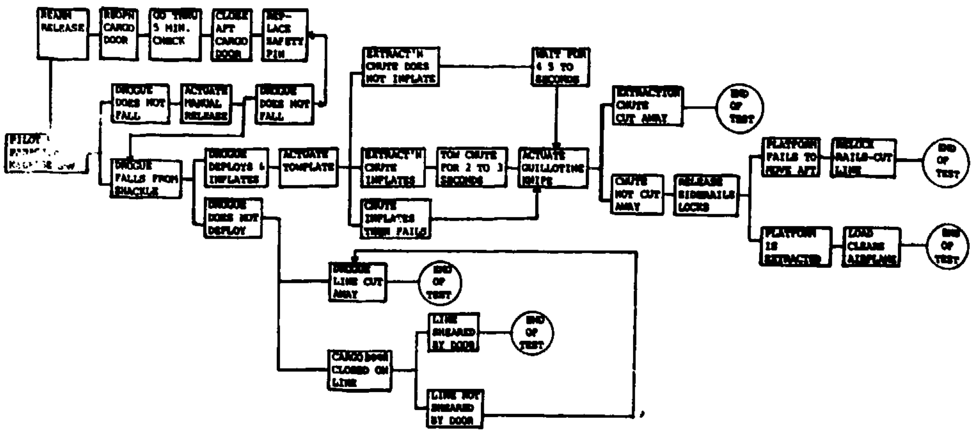


Figure 39 Malfunction Analysis Chart for Tow Testing

2.6.5 Flight Simulators

On major airdrop test programs where a new aircraft is being flight tested initially in the airdrop role to verify its design capabilities, it may be possible to have the flight crew (pilots and co-pilots) get some time in a flight simulator through which are fed the conditions they might expect during an actual airdrop from the prototype aircraft. Besides being a great confidence builder for the pilots, it helps them in providing input to the test engineer when he is designing the airdrop test program. In the case of simulators and models for predictive analysis to assure safety, where new untested parachute prototypes are involved the prudent engineer will take no one's word for what the strength of a parachute may be, but will personally check the design analyses. There are several cases on record where parachute designers have claimed capabilities for their prototype parachutes which could not be met in flight testing. This is another reason why a build-up from the center of the systems performance envelope with a gradual expansion to the edges of the envelope, is recommended.

2.6.6 Preflight Briefings

Finally, preflight briefings of all personnel involved in the airdrop test are mandatory. All personnel need not be briefed at the same time. In fact, it may be impossible to have all involved personnel present at the same briefing on a large program. However, all personnel must be briefed prior to the test so that each one knows what his part is and how it interfaces with the other support units and personnel. Just prior to takeoff, the aircraft commander and test engineer/technician should call the crew together at the aircraft and assure that everyone understands what the mission plan involves and what emergency actions will be taken when required. In the interest of safety all personnel involved in the test including the pilot, co-pilot, test engineer, and loadmasters should be wearing headsets with microphones so that the challenge and response checklists may be executed and heard by everyone. The test engineer/technician or loadmaster (depending on the way the checklist is written) should keep the pilots apprised of the progress of the test as the events occur because they (the pilots) have no way of knowing what is ensuing in the cargo compartment except by the aircraft reactions. Also, because the pilots are the only ones speaking with the range ground controller in most cases, they should keep the other members of the test team in the cargo compartment informed on the general progress of the flight.

3.0 TEST CONDUCTING

The saying that "Testing is 99 percent preparation and 1 percent execution" is certainly true of R&D airdrop testing. After months of test plan preparation, accumulation of test support hardware, test platform rigging, parachute extraction and recovery Systems Design, load rigging, flight operations and range support coordination, the aircraft is loaded, the load is checked, the aircraft takes off, and the airdrop test (excluding the 20-minute, 10-minute, 3-minute checks) may last about 1 minute. The actual extraction sequence usually lasts no more than 10 seconds for a single platform airdrop, and seven 10,000-lb airdrop platforms were sequentially extracted from a C-141A aircraft in less than 30 seconds, Reference 17. But there is a lot that goes on between the final load rigging sketch which is part of the planning procedure and the rigging of a load for an airdrop test. The simplest way to understand what must be done in the actual conducting of a test is to follow a hypothetical test platform through the final rigging and airdrop phases of the test.

In the hypothetical test program the test organization has been requested to test the feasibility of airdropping a 15,000-lb vehicle at 200 knots to determine if the current minimum airdrop altitude of 500 ft AGL could be reduced. The only stipulation is that the rate of descent at ground impact be less than 30 ft/sec. Assuming that all the planning work has been accomplished using items discussed in section 2, a C-130E Hercules has been chosen as airdrop test aircraft, since it is the only one capable of 200 kts with cargo door open. A U.S. 6511th TG test tub was chosen because it will double as a tow test anchor point to test the drogue chute. G-12 recovery parachutes (64-ft diameter) were chosen as "mains" recovery parachutes and the test engineer has drawn up a test program of 12 tow tests and 8 airdrops as follows:

TABLE 1

TOW TESTS

No. Tests	Airspeed (KCAS)	Test Parachute
2	150	15 ft ribbon
2	175	chute reefed to equivalent
2	190	drag area of a 10-ft diameter
4	200	parachute (Appendix A)
2	210	

TABLE 1 (Continued)

AIRDROP TESTS

No. Test.	Platform Location In Aircraft	Airspeed (KCAS)
1	AFT	150
1	FWD	150
1	AFT	175
1	FWD	175
1	AFT	190
1	FWD	190
1	AFT	200
1	FWD	200

This is designed as a program of either 11 flights or 7 flights as follows: 4 tow tests may be conducted in each 1-hour flt. (The first test being rigged prior to takoff, and three, 15-minute inflight reriggings of the system). The airdrops, if feasible to rerig the EPERU or other force transfer system in 45 minutes, may be made two to a flight. If rerigging is not feasible, then one airdrop per flight will be made. Based on these assumptions, the tow test and airdrop test platforms will be checked on the ground, then loaded, the final rigging onboard the aircraft, will be completed and finally the flight tests will be conducted.

3.1 Ground Test/Checkouts

3.1.1 Platform Rigged

Figure 40 shows a platform rigged for conducting parachute tow tests. The platform consists of a test tub sitting on four layers (3-in thick) of paper honeycomb material for ground impact attenuation in the event the drogue parachute cannot be released and the platform is extracted and recovered. The platform is rigged for recovery although that is not the intent. A manually activated guillotine system is incorporated in the aft end of the tub and will be used to cut the towed chute away to end a test. The following must be checked prior to transporting the tow test platform to the aircraft:

1 LOAD-BEARING PLATFORM
2 PAPER HONEYCOMB
3 WEIGHT-TEST PLATFORM , BASE WEIGHT 7 500-LB
4 TIEDOWN CHAINS, 10,000-LB CAPACITY, 20 CHAINS AFT RESTRAINT/10 CHAINS FWD RESTRAINT
5 PARACHUTE TRAY
6 SUSPENSION RISERS: 4 EACH ,24 FT LONG 10-PLY, TYPE XXVI; 2 EACH,21 FT LONG 8-PLY, TYPE XXVI
7 SUSPENSION BLOCKS
8 G-11A CARGO RECOVERY PARACHUTES, 3 EACH
9 G-11A PARACHUTE RESTRAINT, 1-TURN 6,000-LB NYLON WEBBING WITH CUTTER KNIVES
10 DEPLOYMENT PARACHUTES , 2 EACH
11 T-10 DEPLOYMENT LANYARD (TO ANCHOR CABLE)
12 SPRING-POWERED KNIFE ASSEMBLY
13 SPRING-POWERED KNIFE ASSEMBLY CUTTER WEB
14 THREE-POINT CLEVIS
15 STRAIN GAGE LINK
16 TWO-POINT STRAIN GAGE LINK ADAPTER LINK
17 EXTRACTION LINE
18 MANUAL ACTIVATION LANYARD SPRING-POWERED KNIFE ASSEMBLY
19 ANCHOR CABLE

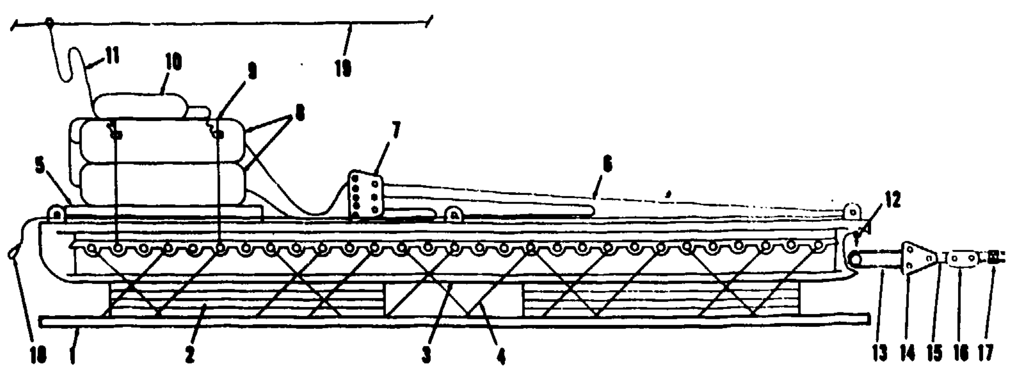


Figure 40 Parachute Tow Test Platform Rigging Sketch

Check the condition of the base platform.

(1) Are the siderail notches free of burrs that might prevent or hinder proper interface with aircraft siderail latch detents?

(2) Are platform restraints too taunt so that bowing of the platform is evident? If so, have them loosened until the platform has been locked in the aircraft siderails.

(3) Are there sufficient restraint straps (or chains) for the required safety margin (1.0) for the maximum force the parachute can exert at the test airspeed?

(4) Are the recovery parachutes well restrained and the cutter knives to cut the restraints well safetiod?

(5) Attachment of the T-10 deployment parachute(s) to the recovery parachute bag handles should be checked and attachment of the recovery parachutes risers to the suspension block closely inspected and the sideplate nuts checked for security.

(6) The suspension risers should next be checked to assure they are connected to the correct suspension points.

(7) The guillotine should then be ground tested as follows: (Figure 30)

(a) Place a strap of cotton around the spool and then place four layers of type X or type XXVI nylon webbing on top of the cotton web, with the guillotine cocked and safetied.

(b) Remove the safety ties, assure everyone is clear of the knife, then have the lanyard at the front end of the tub pulled. It should take no more than 15 to 25 lbs of pull force.

(c) When the guillotine activates, check to see if it has cut through all four plies of nylon. If it has not, recock the guillotine with its cocking bar (lever), safety tie the blade block, then remove the guillotine knife and replace it or sharpen it.

(d) Repeat the ground check until it is successful.

(8) Leave the guillotine in the fired mode (springs in the relaxed condition) until the load has been placed on the aircraft.

(9) Lay out the entire extraction system(s) to be tow tested and check every component from the guillotine cutter web, through the connecting hardware to the parachute.

(10) Assure that the instrumentation strain gage link is clearly labeled for identification with a particular tow test. Check to see the lead is sufficiently long.

(11) Since there are to be four tow tests on this flight assure that there are four complete systems placed with the load for transport to the aircraft.

(12) The load is now ready to be transported to the airdrop aircraft. However before loading on the aircraft, the aircraft siderails and roller conveyors should be checked as follows:

(a) ADS siderails - Check for general condition, cleanliness, and inspect each latch individually. One loadmaster should then go through the complete cycle of operation for the left-hand rail latches by using the SIMUL OPEN control handle to unlock all left-hand detent latches simultaneously. The second loadmaster should walk forward assuring that all detents are indeed retracted. The loadmaster should then move to the right siderail and complete the following check. One Loadmaster should move the right-hand Master control handle through the four positions, CHECK, NORM, EMERG, AND LOAD, leaving the handle in the LOAD position in preparation for loading.

(b) Roller conveyor sections - Conveyor sections should be checked to assure they are firmly anchored in the floor and closely inspected for any foreign objects or sharp edges that might damage a platform during loading.

(c) Moving aft, the parachute release device should be checked. An extraction parachute should be placed in the release (without hooking up the pendulum line) and the release manually activated to allow the parachute pack to fall where it may be caught (or land on the ramp). The anchor line cable should also be checked for tension by pulling down on it.

(d) The interphone headsets should be checked (power should be turned on in the aircraft). Assure there are a sufficient number of headsets/microphones for all test participants, and parachutes for all personnel in the cargo compartment.

(e) The loadmaster should then set the right-hand latches he plans on engaging in the tow test platform right-hand siderail at the maximum setting to assume 4000-lb restraint for each right-hand detent. Note however that these detents should still all be in the retracted position for on loading of the platform.

(f) Finally one of the loadmasters should play out the cable on the cargo loading winch all the way to the ramp edge in the event it is needed to draw the load onboard the airdrop aircraft. With the cargo doors open and the ramp lowered to the airdrop position the aircraft is now ready for on loading of the Tow Test Platform.

3.1.2 Preflight Briefing and Inflight Checklist

A preflight briefing as mentioned in 2.6.6 should be accomplished either the day prior to, or if time permits, the day of the test. This briefing should be in two parts: the operational aspects, which should be presented by the pilots, and the technical aspects to be given by the test engineer/technician.

3.1.2.1 Pilots' Briefing

Some of the items which should be covered in the pilots' briefing are:

a The flight plan, including times for crew to show up, engines start, takeoff and target test times.

b Maneuvering in the test location to attain test conditions and Range coverage.

c Airspace use and any chase aircraft involvement must be face to face briefed with chase pilots.

d Inflight emergencies of a normal operating manner during test operations such as engine problems could result in termination of the mission.

e Communication channels between drop aircraft and chase and drop aircraft and the range.

f Emergency bailout or ditching procedures will also be briefed.

3.1.2.2 Test Engineers' Briefing

Some of the items to be covered in the test engineers' portion of the preflight briefing are:

a The objectives of the test and conditions, such as airspeed, altitude and duration of the tow test.

b The expected sequence of events and forces to be expected under normal or extreme conditions.

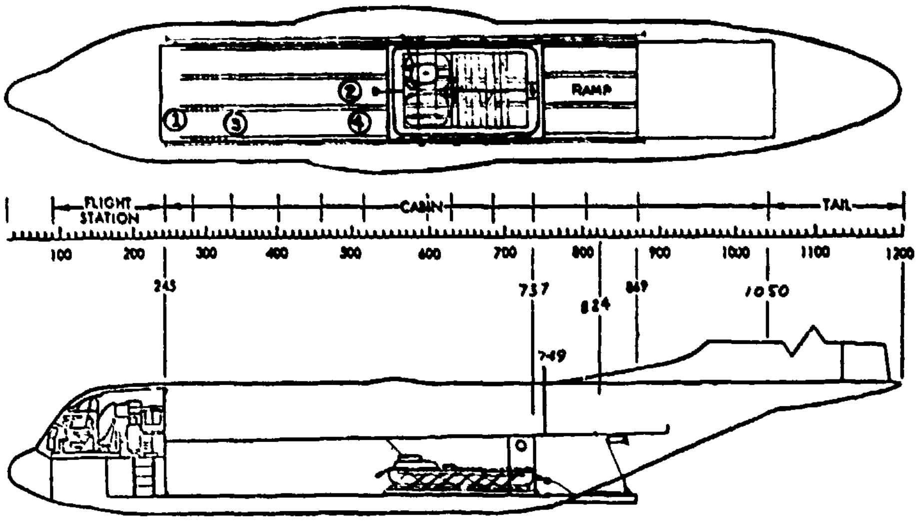
c The position of all personnel in the cargo compartment (Figure 41) and what their jobs are.

d Brief the malfunction flow chart and assure that each player fully understands his role in any of the emergencies that may arise.

e The flight crew challenge/response checklist should be briefed.

f The test engineer/technician also briefs the photo chase photographer(s) (if one is to be used) on the coverage required, and the Range camera crews on the object(s) to be tracked.

g Range instrumentation (telemetry ground station) when to be used, should also be briefed on the number of tests, duration, and measurement ranges as required. Normally these requirements are provided at the time the test is scheduled on the range, but it is always good procedure to cover this item in the preflight briefing.



1 Loadmaster No. 1
2 Loadmaster No. 2
3 Loadmaster No. 3 (Optional)
4 Test Engineer/Technician

Figure 41 Crew Positions in Cargo Compartment for Airdrop Test

3.1.3 Bringing the Load Onboard the Aircraft

When possible (and this will vary with the test organization) an airdrop load should be loaded on the day of the test, preferably within a few hours of the takeoff. One good reason for this is to prevent anyone who might be moving around in the cargo compartment, from inadvertently disturbing any one of the several special ties and rigging details which must be completed after the load has been placed onboard and locked into the siderails. The major steps involved in bringing an airdrop platform onboard which has been rigged for performing tow tests or for a heavy airdrop are provided here.

3.1.3.1 Cargo Loader

The cargo loader should be lined up with the aircraft cargo siderails (sight along the siderails if necessary), so as to minimize the chances of damage or unnecessary wear to the aircraft siderails from the leading edge corners of the airdrop platform siderails if the platform is started onboard in a skewed direction. Also if a platform is skewed it places side loads on rollers as a longer, heavier platform is forced to realign itself within the confines of the aircraft siderails while being pulled onboard. Loadmasters should bring the platform(s) onboard slowly, especially when using the aircraft onloading winch, and assure that all lock detents, on both sides are retracted before starting the loading operation. Once onboard and locked in the preselected position for the test, the test engineer and loadmasters are ready for their onboard rigging operation. As much rigging of the platform as possible should have been accomplished in the rigging area prior to bringing the load to the aircraft. Only those items to be interfaced with the aircraft in some way, should be left for onboard rigging. In the example chosen to illustrate a test, all that was left to be done was the final attachment of the test extraction chute to the pendulum release device, cocking of the guillotine spring loaded cutting device, attaching of static lines as required, retightening the platform restraint straps/chains, setting the RH pressure locks, and then conducting a complete system check from the quillotine lanyard to the extraction parachute release device. The following is a good example of the type of checklist used by all the NATO organizations consulted in preparation for this AGARDograph. Some checklists are shorter; others may be more detailed, especially when special devices such as the EPERU and other safety devices are to be employed. Checklists used by AERITALIA and ERPROBUNGSTELLE 61, for different phases of the testing effort are included in the appendix section and in Reference 19. Figures 40 and 41 would be useful in following the steps of the following checklist.

PREFLIGHT ONBOARD PLATFORM RIGGING CHECKLIST

The Aerial Delivey System Test Engineer and the No. 1 Loadmaster will make the following checks:

1.	Extraction parachute deployment bag secure in the release mechanism	Checked
2.	Extraction parachute clevis and ties	Checked
3.	Extraction lire checked for damage	Checked

4.	Strain gage link and attachment clevises secure; electrical lead wire intact	Checked
5.	Guillotine knife (spring powered), safety ties and cutter web.	Checked
*6.	Recovery parachute deployment line	Checked
*7.	GO-NOGO safety device, open and safety wire in place	Checked
*8.	Lanyard from guillotine to anchor line cable, free moving (no binding)	Checked
9.	Lanyard from guillotine to forward end of platform (manual release), no binding	Checked
10.	No excess lines or protrusions anywhere on the load which might snag on aircraft	Checked
11.	Right-hand siderail lock detents engaged and set to correct setting (max for tow tests)	Checked
12.	Left-hand siderail detents engaged in platform, all detents aft of platform retracted	Checked
13.	No obstruction or foreign objects in siderails or roller conveyors	Checked

The Test Engineer should then check the checklist for completeness then sign it.

[Note that sign-off procedures vary by organization, however the test engineer should, in some way certify that this test load is ready for the airdrop test.]

*The asterisked items should be bypassed when the platform is being used for tow testing as they would not be applicable.

3.1.4 Emergency Procedures

At this point in conducting the example tow test, the preflight briefing, load rigging, loading of the platform load, and onboard rigging would be complete. The flight crew should arrive at the aircraft in sufficient time to perform a crew briefing and the necessary preflight checks.

3.1.4.1 Brief Emergency Bailout

The pilots should brief flight emergency bailout and ditching procedures, point out primary and secondary emergency exits, and review the flight plan briefly. The test engineer/technician should then brief the test procedures, forces expected, period of tow at full parachute inflation, and the emergency procedures to be followed in each of the possible cases, Figure 39.

3.1.4.2 Three Emergencies

Basically there are three emergencies that may occur during a tow test of this kind; they are:

The extraction parachute release device fails to release, and the extraction parachute hangs there in an unknown state of release.

The extraction chute falls away but does not deploy, does not inflate; or it inflates then immediately fails so there is minimal drag on the extraction line.

The extraction parachute inflates but the guillotine system fails to cut it away to end the test.

3.1.4.3 Emergency Steps

The steps to be taken in each event are shown in Figure 39. These emergency procedures are also called out in the challenge and response checklists used by all the organizations some of which are included in the appendices to this volume. As each new test is planned these R&D checklists must be revised. However, if a chart such as the one shown in Figure 39 is used to develop these checklists, then all eventualities will be covered.

3.1.5 Location of the Crew in the Cargo Compartment

Location of the crew in the cargo compartment is shown in Figure 41. Again this may vary, however it is mandatory that test personnel man all emergency activators and that the test engineer/technician be in position to see how the test parachute is functioning so he may direct the emergency procedures. To clarify this extremely important aspect of airdrop testing techniques a scenario of an actual malfunction on the example tow test will be discussed in real-time.

3.2 Scenario of an R&D Extraction Chute Tow Test

Referencing the test program as shown in Table 1, assume that the first four tow tests at speeds of 150 and 175 knots were successfully completed on the first flight and the crew are about to fly the second flight. Also assume that an off-the-shelf ribbon parachute of 16-ft nominal diameter was chosen and was reefed (permanently) to an equivalent drag area (See Appendix B) of a 10-ft diameter chute because the target speed of 200 kts called for this size of chute. This was done so as to be in the desired extraction speed and force ranges. The following is a profile of the flight as it would occur starting with the drop aircraft already airborne and the 10-minute (T-10) checklist about to begin.

3.2.1

At this time the test crew should be wearing parachutes (or alternate equipment, such as restraint harness) used by the particular test organization. All test personnel should be wearing headsets and a communication check should have been completed prior to takeoff, and again shortly thereafter.

10-Minute Check

The following key to flight personnel is used

PILOT (P), CO-PILOT(CP) NAVIGATOR (N), FLIGHT ENGINEER (FE), AIRDROP TEST ENGINEER (OR TECHNICIAN) (TE), LOADMASTER IN POSITIONS 1, 2, OR 3, (LM-1), (LM-2), (LM-3).

1. "10-minute check" (CP) "Acknowledged" (ALL)

2. "AIRSPEED" (CP) "ADJUSTING TO 200 (P)

3. "FLAPS" (CP) "SET 0%" (P)

4. "PARACHUTES" (CP) "ON" (TE, LM-1, LM-2, LM-3)

5. READY TO OPEN RAMP (CP) "CLEAR" (LM-1)
AND AFT CARGO DOOR "COMING OPEN" (LM-2)
"RAMP AND CARGO DOOR OPEN" (LM-1)

5-MINUTE CHECK

1. "5-MINUTE CHECK" "ACKNOWLEDGED" (ALL)

At this time LM-1 and the TE would be on the left side of the cargo compartment and LM-2 on the right side. Starting at the aft ramp and moving forward they would continue with the 5-minute check as follows:

2. EXTRACTION PARACHUTE(S) (CP) "CHECKED" (TE)

3. GUILLOTINE SAFETY TIES (CP) "REMOVED" (LM-2,TE)

4. CAMERA LIGHTS (IF USED) (CP) "ON" (LM-1)

5. LOAD AND ANCHOR LINES (CP) "CHECKED" (TE,LM-1,LM-2)

6. INSTRUMENTATION (CP) "CHECKED" (TE)

7. LEFT-HAND LOCKS (CP) "CHECKED" (LM-1)

8. RIGHT-HAND LOCKS (CP) "CHECKED" (LM-2)

9. CARGO COMP'T PERSONNEL (CP) "IN POSITION" (TE,LM-1,LM-2)

10. "5-MINUTE CHECK IS COMPLETE (CP)

WARNING: NO PERSONNEL SHOULD GO AFT OF THE LOAD FROM THIS POINT ON. PERSONNEL SHOULD BE IN POSITION AS SHOWN IN FIGURE 41.

3-MINUTE CHECK

1. "3-MINUTE CHECK" (CP) "ACKNOWLEDGED (ALL)

2. "LEFT-HAND LOCKS" (CP) "ARMED" (LM-1)

(NOTE that LM-1 is positioned between the LH and RH Master controls and arms the LH locks so that if required he can release the platform. He can then also release the pressure locks in one stroke if they have not been overcome by the chute force.)

3. "CARGO COMPARTMENT PERSONNEL" (CP) "IN POSITION" (LM-1)

4. "3-MINUTE CHECK COMPLETE" (CP)

1-MINUTE CHECK

CAUTION: If any unsafe condition is observed by any crewmember, he will state "no drop".

1. 1-MINUTE WARNING (CP) "ACKNOWLEDGED" (ALL)

2. AT THIS TIME THE PILOT WILL RECEIVE HIS FINAL CLEARANCE TO DROP (TEST) FROM THE DZ CONTROLLER.

3. "CLEARANCE TO DROP" (CP) "RECEIVED" (P)

4. "30-SECOND WARNING" (C) "ACKNOWLEDGED (ALL)

5. "CHUTE ARMED" (CP) "ARMED" (N, LM-2)

COUNTDOWN

1. "T-10 SECONDS" (CP)

2. 5-4-3-2-1 (CP)

3. "CHUTE RELEASED" (TE)

The assumption is made that the test parachute released, inflated, then immediately disreefed to a full 16-ft diameter and a drag force of 11,000 lbs instead of the expected 4,300 lbs in the reefed state, was developed. (Appendix B.)

Following the emergency procedures briefed from Figure 39, the loadmaster stationed at the front end of the platform should then pull the guillotine lanyard to cut the towed chute away.

If the guillotine should fail to cut the line away, the test engineer should call for platform release.

The loadmaster (LM-1) stationed at the two release handles then releases the left-hand locks, then the right locks (if the drag force is in excess of their cumulative pre-set value, the platform will be extracted). But let's assume the guillotine functioned to cut the chute away.

The TE will keep the pilot, co-pilot, navigator and flight engineer (if one is onboard) appraised of what is happening. For example he would say something like "CHUTE RELEASE", ... CHUTE MALFUNCTION, FULLY INFLATED, ... GUILLOTINE ACTUATED ....CHUTE CUT AWAY .... At which time the pilot or co-pilot would probably say something like "EVERYONE OK?" "ACKNOWLEDGED" (ALL).

The Post-Drop Test Checklist should then be executed as follows:

POST-TEST CHECKLIST

1. "LEFT-HAND LOCKS" "SAFE" (LM-1)

2. "AFT DOORS" (CP) "CLEAR" (LM-2)

3. CLOSE RAMP & CARGO DOOR (CP) "COMING CLOSED .... RAMP & CARGO DOOR CLOSED AND LOCKED" (LM-1, LM-2)

4. "CAMERA LIGHTS: (CP) (IF USED) "OFF" (TE)

In this case the test engineer would state that the mission should be terminated until he could determine why the parachute reefing failed. The test aircraft would then clear the Range and return to base and land.

3.3 Aircraft Handling Qualities

The stability and control, primarily the longitudinal response of an aircraft during airdrop operations, is affected by the following factors: the aft movement of the aircraft center of gravity due to the platform moving aft, elevator input, aerodynamic moments, and power setting of the engines. A fifth factor, the ground effect is added for LAPES airdrops.

The platform aft movement speed is determined by the total extraction ratio which consists of the parachute extraction ratio (average parachute force during extraction divided by the platform weight) and extraction ratio due to the aircraft pitch attitude and acceleration. Extraction ratio effects may be more readily understood when we visualize an airdrop as the aircraft flying away from under the platform which is being decelerated by the parachute (developing a drag force in some cases, as high as twice the thrust of the aircraft). In gravity type airdrops where no drag force is being provided by a parachute, aircraft pitch angle and increased thrust (by adding power) provide the platform aft movement. Airdrop testing from C-130E aircraft has shown that a pitch angle of 5 degrees resulted in an extraction ratio of 0.09. An application of aircraft power increased the extraction ratio by as much as 0.12 in C-130 aircraft. (Reference 1.) The rearward travel of the aircraft center of gravity increases with increasing ratio of platform weight to aircraft weight. Transient cg positions as far aft as 96 percent MAC have occurred during a 50,000-pound platform airdrop from a C-130 aircraft at a post-extraction aircraft gross weight of 90,000 pounds. Once the aircraft cg had moved aft of the neutral point (38 percent MAC) the aircraft was statically unstable.

As the cg moved aft of the neutral point the aircraft tended to diverge more rapidly as the airspeed increased; for a given airspeed the aircraft became more unstable as the cg moved farther aft. As airspeed was increased the severity of the aircraft response to the platform aft movement depended on a tradeoff between the increased elevator power available and the increased destabilizing aerodynamic moments. For loads weighing 25,000 pounds or less, elevator power dominated, and aircraft response was less severe at higher airspeeds (over 130 KIAS). Since the aircraft cg moved farther aft for loads weighing more than 25,000 pounds, the destabilizing aerodynamic moments became more dominant, and the aircraft response was more severe at higher airspeeds. Similar aircraft response has been recorded in C-141 and C-5A aircraft during platform airdrop maneuvers, although they were less severe due to the much lighter platforms relative to the post-airdrop weights of the aircraft. It is assumed that similar response has been observed during heavy platform airdrops from C-160 and G-222 aircraft. To control the aircraft, particularly during low extraction ratio airdrops, various elevator control technicques have been applied. The optimum condition would be for the airdrop aircraft to maintain a constant 4- to 5-degree noseup attitude during the entire airdrop. The elevator position that would provide this response would be the ideal elevator position. However, this position could be reached only up to the point where the required position of the elevator exceeded the fixed full aircraft nosedown trim. It was, therefore, the pilot's reaction time and ability to sense and control the aircraft while he still had sufficient additional elevator control available, that determined the aircraft pitch rate when the platform exited the cargo ramp. This is why it is mandatory that a well-trained and experienced flight test crew are onboard in heavy platform low-extractin ratio airdrops. The test personnel in the cargo compartment must keep the pilots appraised of exactly what is happening to the platform and parachutes on a second by second basis. In most cases a full-nosedown elevator aircraft response can be predicted prior to take-off knowing the aircraft configuration, platform weight, extraction ratio, cg location, and airdrop airspeed. The peak pitch rate experienced during an airdrop is the sum of this predicted aircraft response and the pilot input elevator position. Therefore by pre-trimming the aircraft based on the predicted response, the required pilot response may be reduced.

Power setting of the engines may also affect the aircraft pitch attitude. At 130 KIAS, a C-130 aircraft nose-up trim change due to Military Rated Power (MRP) application required approximately 0.8 degrees more aircraft nosedown elevator to trim as compared to power for level flight. However, this small loss of available nosedown elevator to arrest the pitchup due to platform aft movement, was more than offset by the aft acceleration of the platform due to adding power. Applying MRP at 130 KIAS in a C-130E aircraft increased the platform extraction ratio due to aircraft acceleratin by 0.12 for a 50,000-pound platform and a post-airdrop aircraft gross weight of 90,000 pounds. Low extraction ratio airdrops of 45,000-pound platforms were performed at 145 KIAS and 130 KIAS with C-130E aircraft to investigate the airspeed effect on aircraft pitchup. these tests showed that less elevator control force was required to attain the required elevator input at the lower airspeed. (Reference 1).

Ground effect during a LAPES airdrop, with the aircraft undersurface approximately 10 feet above the ground, had the following results: Compared with normal airdrops (above 600 ft), flight in ground effect (LAPES airdrops) resulted in more aircraft noseup elevator being required. This increased the aircraft nosedown elevator available to the pilot to arrest the noseup pitching during low extraction ratio airdrops. The pitch angle (and angle of attach) required to fly level at the same airspeed decreased in ground effect. (Reference 1).

No unsatisfactory handling qualities should be expected when making normal extraction ratio (0.5 to 1.0) airdrops. Mild noseup pitching should be expected as the platform moves aft in the aircraft cargo compartment, then an abrupt nosedown pitching as the platform leaves the cargo ramp. Platforms weighing up to 50,000 pounds have been satisfactorily airdropped from C-130E aircraft at 130 KIAS at normal extraction ratios with little elevator input by the pilot required. Even during LAPES airdrops, the abrupt nosedown pitching caused by pilot input to counter the aircraft pitchup during the airdop, is not normally a problem. This is because the large decrease in aircraft gross weight (after the platform clears the ramp) and the pilot input prevent loss of altitude.

Sequential platform airdrops at low and normal extraction ratios resulted in C-130E aircraft handling qualities similar to single-platform airdrops under similar conditions. However, airspeed varied more during sequential airdrops due to the variations in parachute drag forces. Also, the longer extraction periods allowed more time for the airspeed to vary. However, sequential airdrops are more critical than single-platform airdrops if a malfunction should occur. During a heavy platform sequential airdrop, if a malfunction should occur to cause the second platform to be retained onboard (whether intentionally or unintentionally) the aircraft center of gravity could be forward of the published forward cg limit. Therefore, prior to conducting these tests, aircraft cg limit studies should be conducted to see if the aircraft would be flyable at reduced airspeed, as in landing, or in pullups from a LAPES drop zone. Pullups, power-off stalls, landing approaches through flare, and landings should be conducted at cg positions well forward of the platform loading positions to be used in the airdrop test program, if the aircraft is a new design. If the aircraft has been in use for airdrop testing for many years, these data are usually available from the manufacturer or test organization, and should be studied.

3.4 Special Piloting Techniques for R&D Airdrop Tests

As mentioned earlier in this volume there are two major areas of concern which must be protected against. These were: (1) Aircraft damage or personnel injury caused by a malfunction of the test parachute or the aircraft aerial delivery system. (This has been discussed in detail in the foregoing sections.) (2) Unpremediated flight maneuvers necessitated by aircraft reaction to parachute or aerial delivery system malfunction. To help remedy this situation it has been suggested that only the more experienced airdrop tert pilots be used on the more hazardous tests. In general piloting techniques are developed by pilots during the stability and control portions of a flight test program on new aircraft. However, those tests do not normally include the positioning of loads outside of the design cg limits of the aircraft. Quite often, then, these tests are conductd as part of the Aerial Delivery System Evaluation on new cargo aircraft. Minimum trim changes, minimum pilot distraction during the delivery, and crewmember team work all help to make this process easy and natural for the pilot. For LAPES deliveries, there is the added requirement that the pilots develop a repeatable capability to deliver the payload at a wheel height between 5 and 15 feet. There are other hazard minimizing techniques which have been developed by test pilots who have flown these test programs and these are described here.

3.4.1 Tow Tests

When flying tow tests where a target airspeed and altitude are requirements, the consensus is that the test conditions be established somewhere between T-30 sec and T-10 sec check points. The aircraft should be trimmed to fly with a noseup deck angle of from 2 deg to 4 deg at time of test initiation. In the case where a small parachute (drag $\leq$ 0.25 T_{avail}) is to be towed for 5 to 10 seconds at full inflation, the procedure should be to not increase power, but allow the airspeed to decay. The exception of course would be if target tow speed were within 1.2 V_{stall}. In the case where larger chutes are to be towed, the procedure should be to add power as needed as soon as the drag is felt. Tow tests of parachutes developing drag forces as high as two times the available maximum thrust of a C-130A were safely conducted with a reliable parachute line cut away system. In one case, a C-130 decelerated 20 kts in 2 seconds at full parachute inflation under a drag force starting at 49,000 lbs, Reference 18. This is why tow testing of large heavily constructed extraction parachutes should never be attempted by inexperienced test organizations or without a reliable cutaway or release system and a reliable rail system that would allow release of the platform immediately if the chute release failed. In general, tow tests should be conducted at a minimum of 5000 ft AGL as an added precaution. Often in longer cargo aircraft when a lighter or higher lift parachute is being towed the chute may rise behind the aircraft so that the extraction line is dangerously close to the aircraft tail cone which could be damaged by the hardware at the platform end of the line when the line is released to end the test. Since this would only be true in the case of a lighter, smaller chute, the test engineer should ask the pilot to drop the nose of the aircraft, thus bringing the extraction line down towards the ramp momentarily. The test engineer can then call for chute cutaway or release.

3.4.2 Standard Low Velocity Airdrops

The approach to a standard airdrop should be similar to that described for tow testing. In this type of airdrop, the pilot technique will vary depending on the cg of the load, the cg of the aircraft, the weight of the load, the parachute expected lock release force and the expected exit speed of the load. However, the pilot should enter the range with a trim setting with which he feels comfortable for heavy airdrop. The pitch attitude for a heavily laden C-130 aircraft flying at 130 KIAS and 50 percent flaps would be approximately 4 deg noseup. This noseup attitude will provide a significant aft acceleration of the platform which would be helpful in reducing aircraft responses during low extraction ratio airdrops. The consensus for heavier platforms is to apply MRP immediately upon feeling the drag of the extraction parachute and allow the airplane to pitch up. The pilot should monitor airspeed, adjusting the pitch angle; the angle of attack should remain at approximately the trim value after power application, thus he should retain at least the same stall margin as he had at trim. In the emergency case where a heavy platform lost its extraction force immediately after siderail locks had been released, and the platform is moving aft slowly, the pitch rate may become alarmingly high even with application of elevator. However, as the deck angle increases the platform accelerates and the entire process should not take over 3 seconds for a C-130, Reference 1. This technique has provided a load exit speed for a C-130 aircraft, equivalent to that of an extraction parachute providing an extraction ratio of 0.12. Reference 1, Figure 42.

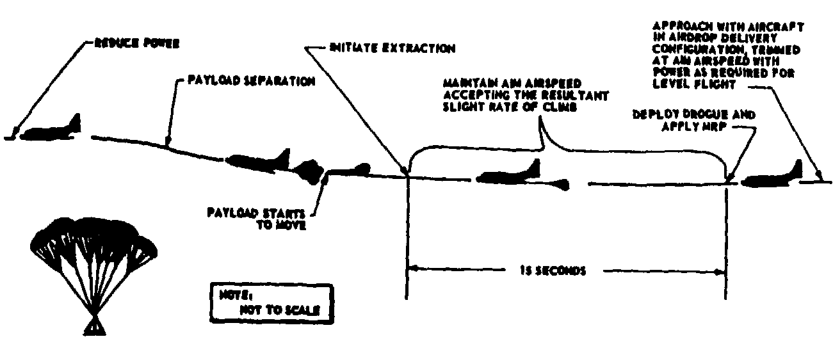


Figure 42 Recommended Pilot Airdrop Technique for "Standard" or "Mains" Heavy Airdrops

3.4.3 Low Exit Speed Airdrops (Gravity Airdrops)

For those tests in which low exit speeds exist (an extraction ratio of load weight/extraction force <0.25), test pilots should allow the aircraft to pitch up as the platform moves aft. This will allow the platform to accelerate due to gravity. However on heavier loads he should keep his eye on his pitch rate assuring he still has sufficient yoke movement to arrest the pitch rate should it increase too rapidly. Another reason for not pushing the yoke forward immediately to arrest the pitch up is that by doing so he would be forcing the aft ramp edge up into the platform when it is already sustaining the maximum load from the platform as it teeters on the teeter rollers. This is an example where the communication between the test engineer and the pilots would let them know exactly where the load is and if there are any impending emergencies. In most cases where a heavy platform is being jettisoned or there has been an emergency caused by a failed extraction system, the pilot should be advised as the emergency procedures state - he should add power cautiously so as not to aggravate this nose up pitch moment. In some cases test pilots have pretrimmed the aircraft for such an eventuality and have experienced no real difficulties as long as the platform continued to roll out of the aircraft. However there have been cases, quite recently where heavy platform loads moved aft at a slow rate, ran over obstructions on the ramp, jammed at that point, and caused the aircraft to crash when it became unflyable. Techniques for "Mains" extraction airdrops are similar to those for the standard airdrop except that the aircraft may be at an altitude of 500 ft AGL or less. Therefore recovery time is greatly shortened.

3.4.4 LAPES Piloting Techniques

Prior to entering the drop zone, the aircraft should be trimmed at the LAPES airspeed approximately 200 to 300 ft above the terrain (terrain permitting). Again a positive pitch angle of 2 to 4 degrees seems to be preferred with 4 degrees being the maximum for a C-130 to prevent the ramp edge from contacting the ground in the case of a firm touchdown at flare. A pitch angle of less than 2 degrees is also prohibitive, especially when sequential LAPES is being conducted because after the first platform is extracted the pitch attitude in level flight would be negative at the lighter weight; a firm touch-down at this attitude with a nose heavy aircraft could cause damage to the nose gear.

The following technique has been followed for R&D heavy platform LAPES testing. In discussions with pilots at A&AEE, Erprobungstelle 61, Aeiritalia and Centre de Essais, en Vol, their techniques are similar.

Shallow descents should be made into the LAPES drop zone, deploying the drogue approximately 15 to 20 seconds prior to extraction initiation (EI) and adjusting power to maintain airdrop speed. Approximately 5 seconds prior to EI, the pilots should shift their attention to outside references only to determine the height above the ground, aiming for a wheel height of about 5 feet above the ground at EI. Usually with the drogue deployed a C-130 will descend at about 1000 ft per minute in a shallow descent. A gradual flare may be started about 40 feet above the ground but this will vary by aircraft.

Maximum effort climbouts should be used for heavy platform LAPES although the pilots should modify their technique to suite the aircraft response. For a C-130 dropping a 35,000-lb platform by a LAPES, as soon as the pilot is assured that the load has left the ramp (aircraft starts to rotate towards nosedown) he should simultaneously apply military rated power and rotate the aircraft to approximately 20 degrees noseup pitch attitude observing the aircraft 2-g normal acceleration limit. The climb should be bled off to the maximum effort obstacle clearance speed called for in the C-130 Flight Manual, T.O. 1C-130E-1, at which time the climb should be terminated. Figure 43 shows the LAPES piloting technique in graphic form, however, note that descent and climbout are exaggerated to compress the sequence of events to a single page. The maneuver is much more benign than the figure depicts, (Reference 1.)

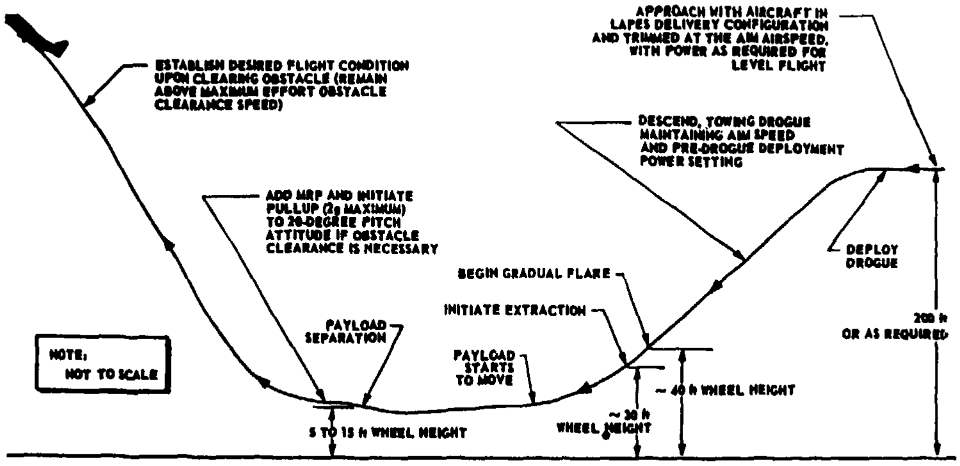


Figure 43 Recommended Heavy Weight "LAPES" Pilot Airdrop Technique

4 TEST REPORTING

"No job is done until the paperwork is complete." This axiom holds doubly true for technical testing such as has been discussed in this volume. Whether the report is brief and made verbally such as a post-flight briefing, or covers the entire technical efforts of a test team over an entire test program and requires many coordination signatures on a formal technical report, the report is the statement of the test results. It answers the question, how did we do in relation to what we planned to do? There are several forms of report for which R&D airdrop test personnel are responsible and these are briefly discussed here.

4.1 Post-Flight Briefing

The post-flight briefing should be conducted as soon after the aircraft has landed as practicable. Usually the pilots may wish to speak with the maintenance crew chief immediately after engines shutdown unless the maintenance writeups "squawks" are part of the post-flight briefing. Then they should be available for the post-flight briefing. These briefings should be brief but everyone participating in the test should be heard from if he has something to add. Normally it is a good practice for the test engineer to write up notes on his test immediately after the cargo doors are closed in flight and while the test is fresh in his mind. In discussions with test engineers/technicians from the NATO organizations it was determined that they all made notes during the flight and used their own versions of a form similar to that shown in Figure 44. The test engineer should brief how the system functioned and any comments he may have on test procedures. The loadmasters should also make their comments at this time. These comments should be incorporated to the "quick look" report as appropriate.

4.2 Formal Reports

4.2.1 "Quick Look" or Post-Test Report

On larger test programs where the magnitude of the support requires notification of a higher echelon or organization a "quick look" or post-test written report may be required within 24 to 48 hours following a test. This report should be brief but should contain all the pertinent data available prior to extended scientific or engineering analysis. The data for this report usually comes from the post-flight briefing. For many of the shorter accelerated programs, written reports after each test are not required but the data are accumulated and provided periodically or at the close of a phase of the testing.

4.2.2 Periodic or Summary Reports

Periodic or Summary Reports may be required every month or quarter depending on the frequency of tests or they may be required only at the completion of a phase of the testing effort. For example, in the sample program shown in Section 3 a written report may be required after the tow tests, but normally a short program such as this would require a written report only at the end of the entire program. However, on a full-scale aerial delivery system evaluation on a new cargo airplane summary/periodic reports may be required after each phase such as tow tests, single-platform airdrop tests, sequential platform airdrop tests, LAPES single platform tests and so forth. Again the various NATO organizations that were consulted in preparation for the writing of this volume each had its own philosophy regarding the writing and dissemination of technical reports. However, they all agreed on the need for some intermediate reporting.

4.2.3 Final Technical Reports

The final technical report is the most important document that will probably come out of an R&D airdrop test program. The final report should contain data from the engineering viewpoint and from the operational viewpoint. In those cases where only one technical discipline is involved such as the aircraft mechanical airdrop kit, with no aircraft performance involved there may be a single author. In this case the mechanics of the report writing are simplified since consistency in evaluation is not a problem. However, when several disciplines are involved, such as parachute engineers, mechanical systems engineers, aircraft performance engineers and pilots, there will be inconsistencies where these disciplines interface and it should be the primary author's responsibility to weave these evaluations together into a comprehensible and clearly written document. Often test organizations have opted for separate sections to a report with one section being written by the test engineers and another by the pilots. Nevertheless, both disciplines have important contributions to the worth of the technical report and their input should reflect the writers tone as well as his technical arguments, conclusions and recommendations. Several organizations, recognizing the importance of the final technical report as the end product of the testing effort, have published technical report writing handbooks to assist the authors in this necessary yet tedious task. (Reference 20.)

4.2.4 Malfunction Reports

Malfunction Reports are usually only required if someone is injured or the malfunction resulted in loss of expensive or accountable equipment, or in the case of a suspected safety violation. In R&D airdrop testing where new devices, parachutes or procedures are being tested, malfunctions are to be expected and are included as part of the test results. On larger airdrop programs, malfunction reports are required more as a means of explaining the loss of accountable equipment such as airdropped vehicles or weapons or damaged aircraft hardware. A well-written test program, which as been safety briefed usually accounts for all eventualities, therefore no one in the test community should be surprised if on a hazardous test there is some aircraft damage or some expensive telemetry equipment is destroyed.

4.2.5 Service Reports

Service reports are seldom required in R&D airdrop testing except in the case of a new airdrop aircraft or a new major weapon system which is nearing a production cycle. In these instances, it is cost effective to identify troublesome parts as early as possible so they may be changed prior to the production cycle. For this reason, service reports are submitted even in the early developmental phases of the testing effort. However the test engineer should be sure before submitting service reports (unsatisfactory material reports) that the system components are not performing up to the specifications in the manufacturers contract. As a rule service reporting during R&D airdrop testing should be approached with caution and only after consulting the contracts personnel of the organization when organizations exterior to the test organization are involved. Quite often quality assurance in-plant inspections by teams from Program Offices are included in the development contract and service reporting could conflict with inspection procedures if not properly coordinated with the System Program Office.

ENGINEERING FLIGHT TEST
FLIGHT TEST NOTES

A/C NO. __________ MODEL __________ FLT NO. __________

OBSERVER ____________________ FLT DATE ____________________

FLT CREW: PILOT __________ COPILOT __________ NAV __________ FLT ENGR__________

TEST CREW: TEST ENGR ______________ LM 1 ______________ LM 2 ______________

LM 3 ____________ OTHER ____________

RUN	TIME	AIRSPEED KTS	ALT FT	FLAPS %	EVENT NO.	TYPE TEST	EXTR CHUTE	RECOV CHUTES	PLATFM WT.
1 DRY									
2 HOT									
3 HOT									
4 HOT									
5 HOT									

PLTF'M LOCATION IN AIRCRAFT C.G. SIDERAIL LOCKS

TEST RUN NO. REMARKS TEST ENGR/TECH.

Figure 44 Flight Test Notes

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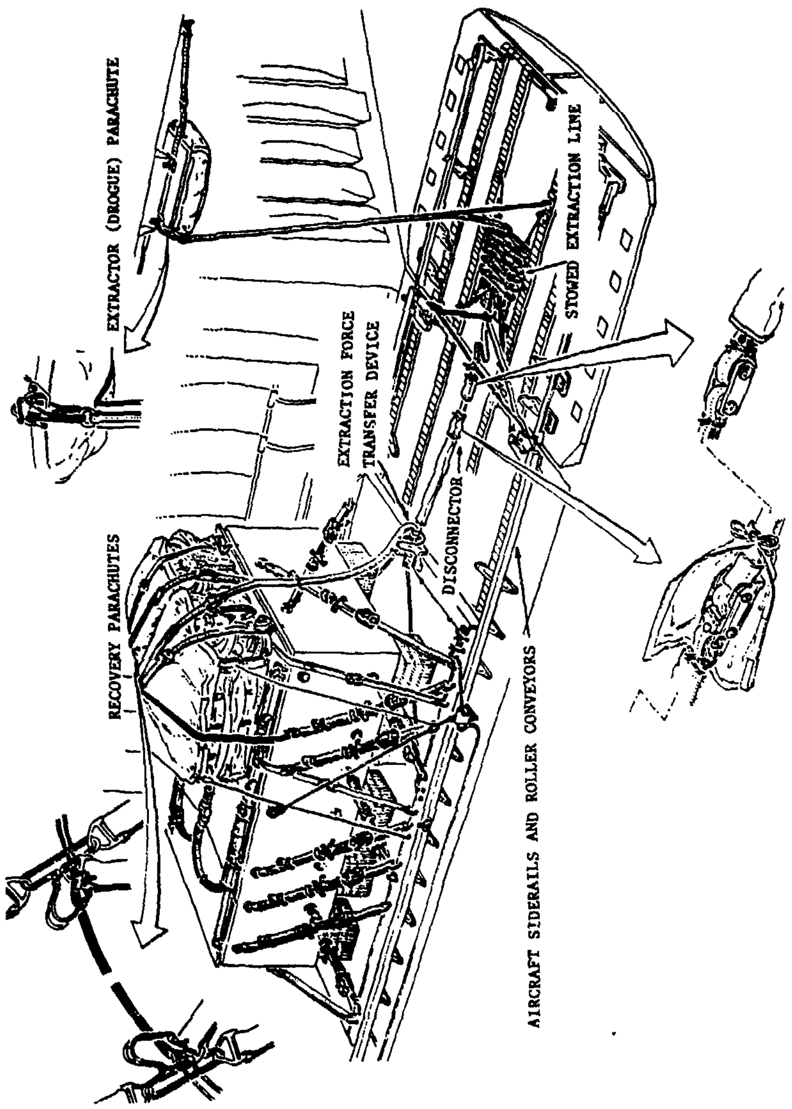
Appendix A

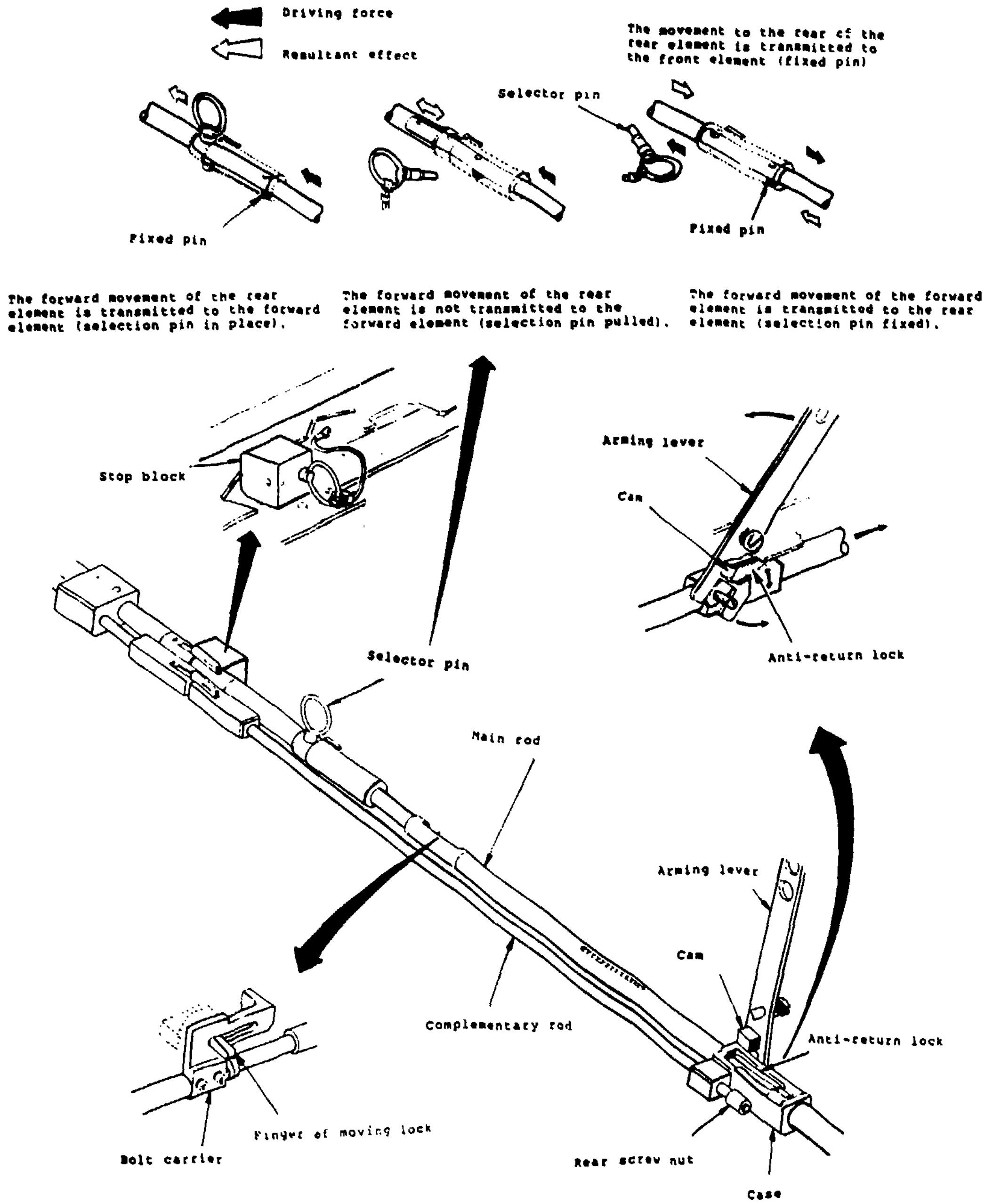
Transall C-160F, C-141A Transport Aerial Delivery Systems

TRANSALL C-160-F/STARLIFTER C-141-A TRANSPORT AERIAL DELIVERY SYSTEMS

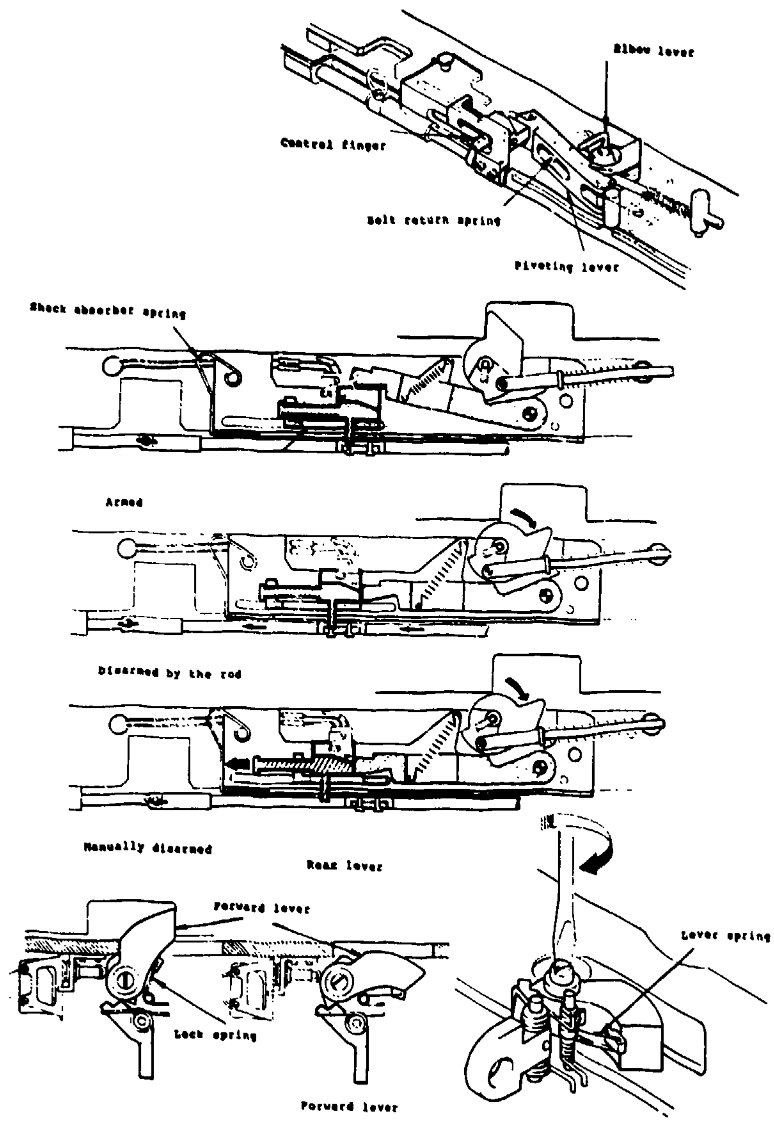
Transall C-160-F Transport Aerial Delivery System



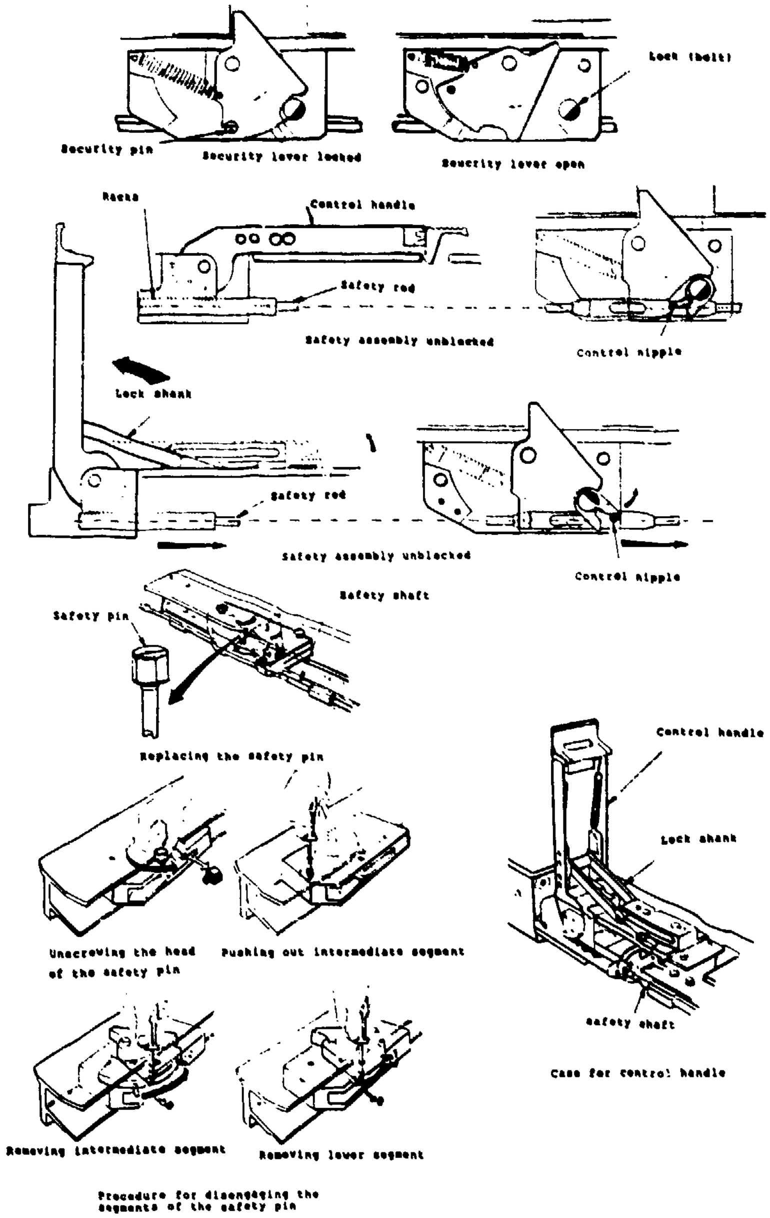
General View of a Cargo Airdrop Load Rigged onboard a TRANSALL Aircraft



SIDERAIL LOCK MECHANISM

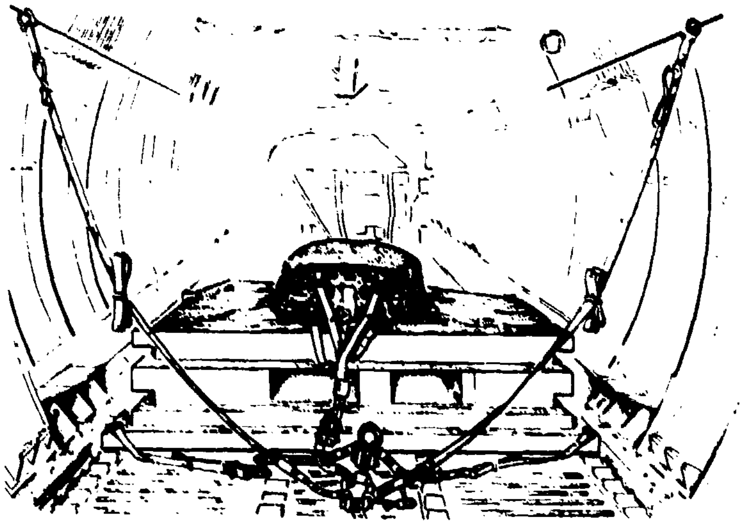


SIDERAIL LOCK MECHANISM

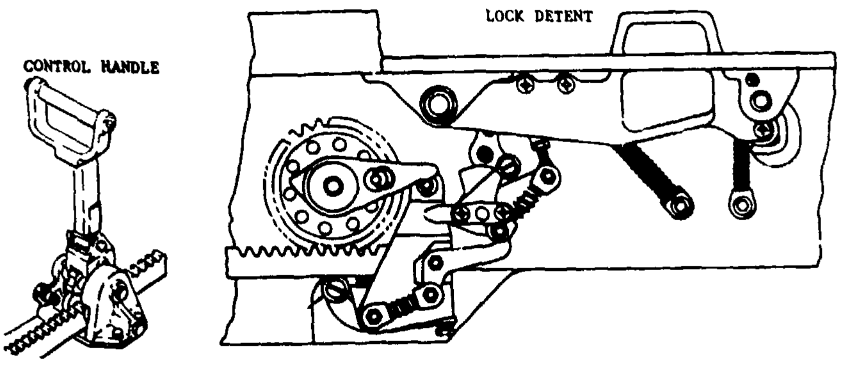


SIDERAIL LOCK MECHANISM

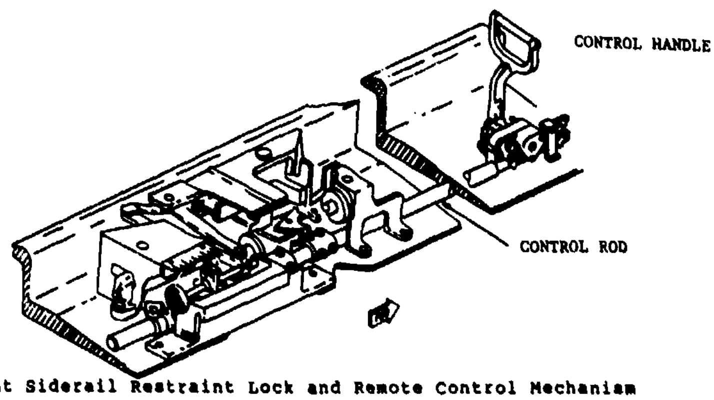
Starlifter C-141-A Transport Aerial Delivery System



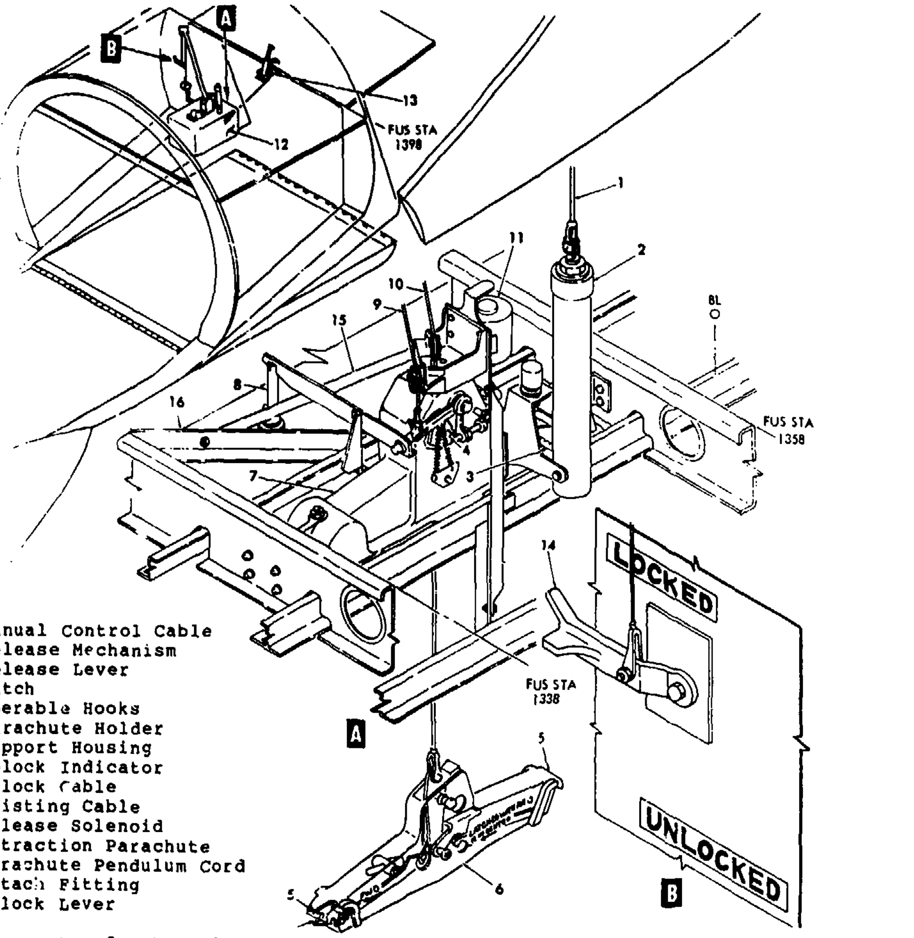
Platform Restrained in C-141A Siderail Restraint System. Four Rows of Roller Conveyors are visible at Right and Left Buttlines No. 15 and 51



Left Siderail Restraint Lock and Forward Remote Control Mechanism

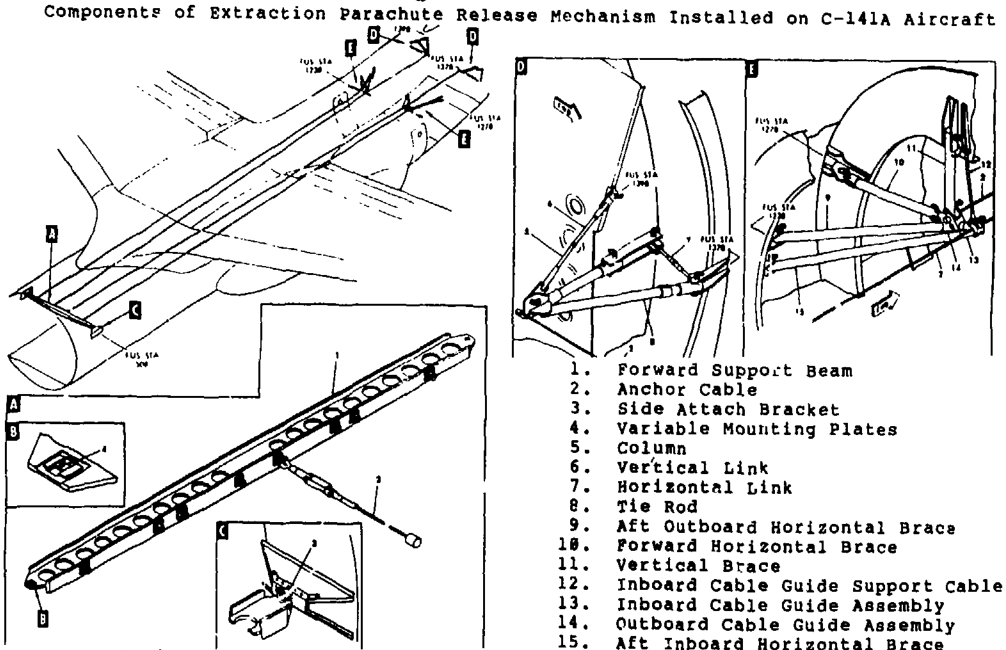


Right Siderail Restraint Lock and Remote Control Mechanism



1. Manual Control Cable
2. Release Mechanism
3. Release Lever
4. Latch
5. Operable Hooks
6. Parachute Holder
7. Support Housing
8. Uplock Indicator
9. Uplock Cable
10. Hoisting Cable
11. Release Solenoid
12. Extraction Parachute
13. Parachute Pendulum Cord Attach Fitting
14. Uplock Lever

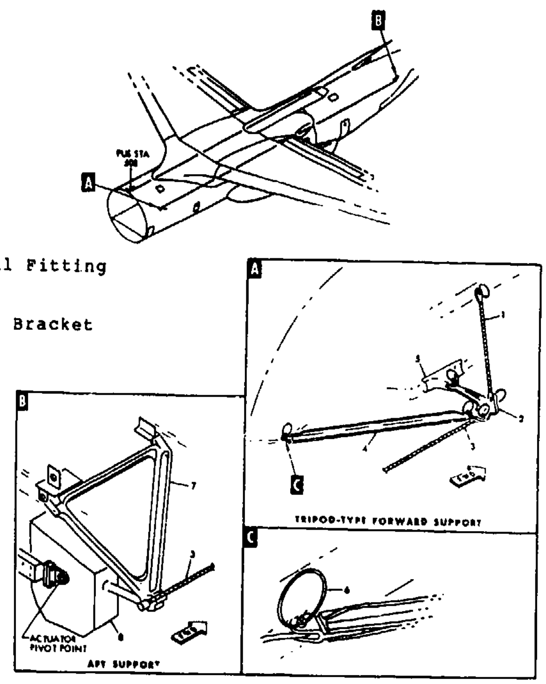
Components of Extraction Parachute Release Mechanism Installed on C-141A Aircraft



1. Forward Support Beam
2. Anchor Cable
3. Side Attach Bracket
4. Variable Mounting Plates
5. Column
6. Vertical Link
7. Horizontal Link
8. Tie Rod
9. Aft Outboard Horizontal Brace
10. Forward Horizontal Brace
11. Vertical Brace
12. Inboard Cable Guide Support Cable
13. Inboard Cable Guide Assembly
14. Outboard Cable Guide Assembly
15. Aft Inboard Horizontal Brace

Anchor Cable Forward Support, Beam and Tripod-Type Support Brackets

1. Tension Strut
2. Anchor Cable Terminal Fitting
3. Anchor Cable
4. Compression Strut
5. Forward Strut Attach Bracket
6. Quick-Release Pin
7. Aft Support
8. Aft Support Actuator



Anchor Cable Forward Support, Tripod-Type, and Retractable Aft Supports

Appendix B

Sample Calculations for Drag Force, Steady State Drag Force, Reefing Line Length

A very useful tool for the developmental airdrop test engineer/technician when planning his test program is the wealth of accumulated test data available in the publications which are referenced in Section 5 and elsewhere. Notable among these are the documents referenced in Reference 10. That Technical Report is often called "The Parachute Handbook" in the U.S. and contains design characteristics and performance data based on literally thousands of wind tunnel and flight tests. Many useful equations are derived and charts are provided based on these empirical data.

A few of the basic equations are provided here which are directly applicable to the types of testing described earlier in this volume. If the reader wishes to pursue the theory of the various aspects of aerodynamic decelerators (parachutes) in more detail he should obtain a copy of The Parachute Handbook, (Reference 10).

1 DRAG FORCE

The basic drag equation may be used for predicting the drag to be expected for various types and sizes of parachutes. When the chute is to be towed by an aircraft weighing many times as much as the total drag of the parachute, the infinite mass principles apply.

Using the sample tow test described in paragraph 3.2a 16-ft diameter chute (reefed to an equivalent drag of a 10-ft diameter chute) was to be towed at a speed of 200 knots at an altitude of 5000 feet.

Drag then, is an aerodynamic force which is defined by the equation

$$D = C_D S q$$

where C_D = Drag coefficient of the chute

S = Reference area of the parachute canopy

q = Dynamic pressure

Dynamic pressure is further defined as

$$q = 1/2\, \rho v^2$$

where ρ = Density of the fluid

v = velocity of the moving canopy (ft/sec)

For the chosen example, the steady-state drag force would be

$$D = 0.5(200)q$$

At 5000 ft altitude $q = .001(336^2) = 113\ \text{lb/ft}^2$

Therefore in the example tow test, the steady-state drag force at 200 kias would be

$$D = 0.5(200)113 = 11{,}300\ \text{lbs}$$

2 OPENING SHOCK LOAD

However, at opening, the chute will experience an additional opening shock load. This load has been verified by many tests and is based on these experimental values.

If Fo is used to denote the maximum opening force and the constant velocity or steady-state velocity, force with a fully inflated canopy, expressed as Fc

$$\text{with}\quad F_C = (C_C S)_{o,p} q_s$$

where subscripts o,p refer to the nominal and projected areas of the canopy, and q_s denotes q at the start of canopy inflation.

And if X is an amplification factor denoting the relationship between maximum opening force, Fo and the steady-state constant drag force Fc expressed as $X = \frac{Fo}{Fc}$

then the maximum opening shock or opening force is

$$Fo = (C_D S)_{o,p} q_s X$$

where X is a dimensionless factor, the value of which has been established experimentally for various types of canopies. For a ribbon canopy $X \geq 1.05$

In the example, the 16-ft diameter ribbon chute being tow tested at 200 kts would have its expected steady-state drag force of 11,300 lbs increased by this factor, resulting in a maximum predicted drag force of 11,300 X 1.05, or 11,865 lbs.

In the sample case an extraction parachute force of approximately 4500 lbs was required, therefore it was decided to use a 16-ft diameter chute that was readily available (Section 8). By reefing this chute to an equivalent diameter of 10 ft, the result was a drag force

$$D = 0.5(73)113 = 4125 \text{ lbs}$$

or a maximum drag force of

$$Fo = 4125 \times 1.05 = 4330 \text{ lbs}$$

NOTE: It is important for flight safety reasons when using a reefed canopy to know the potential total drag for the canopy in the unreefed state in the event there is a failure in the reefing system and the chute fully inflates. Therefore, all components of the parachute system should be sized for the higher drag force of the unreefed canopy until the entire system's reliability has been proven. In the example case, tow test components to withstand a force of 12,000 X 2.0 safety factor, or 24,000 lbs should be used.

3 REEFING LINE LENGTH

When a smaller drag area is needed temporarily, as in a case where the required size of canopy is not available off-the-shelf, it is possible to obtain the desired drag force to test a system by reefing a similar parachute of larger diameter to an equivalent drag area. This required diameter may be determined as the diameter of the reefing line, D_{RL} where:

D_o = Nominal diameter of the unreefed canopy = 16 ft

D_{RL} = Diameter of the reefing line of the reefed canopy

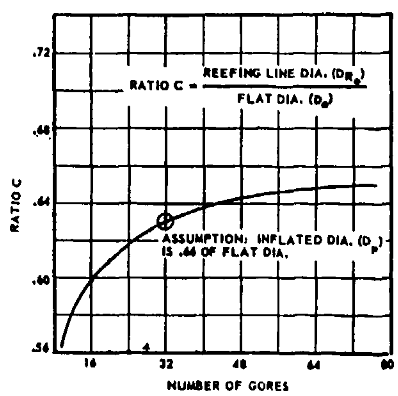
$(C_DS)_R$ = Drag area of the reefed canopy = 50 ft^2

$(C_DS)_O$ = Drag area of the unreefed fully inflated canopy = 100 ft^2

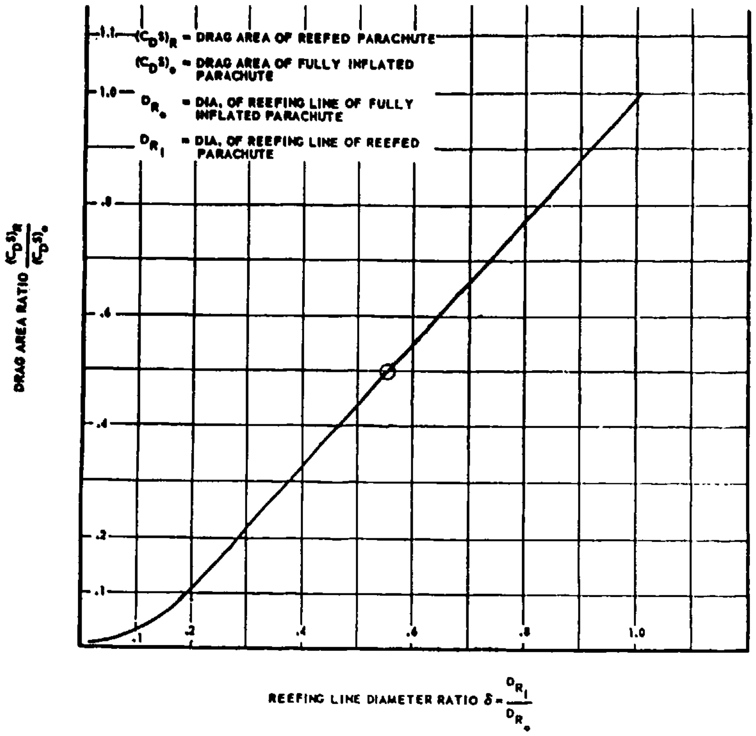
C = Ratio of the reefing line diameter to the nominal canopy diameter D_{RO}/D_{RL}

δ = Ratio of reefing line diameter D_{RL}/D_{RO} to various drag area ratios, depending on number of gores and the shape of the parachute canopy.

In the example, a 16-ft diameter ribbon chute with 32 gores was selected, therefore from the figure below for a flat circular design canopy of 32 gores, the ratio C = 0.63



and since the drag area ratio $(C_DS)_R/(C_DS)_O$ for the sample case = 50/100 = 0.5 by entering the chart below with a drag area ratio of 0.5



Then the reefing line diameter $\delta = \frac{D_{RL}}{D_{Ro}}$ is 0.55

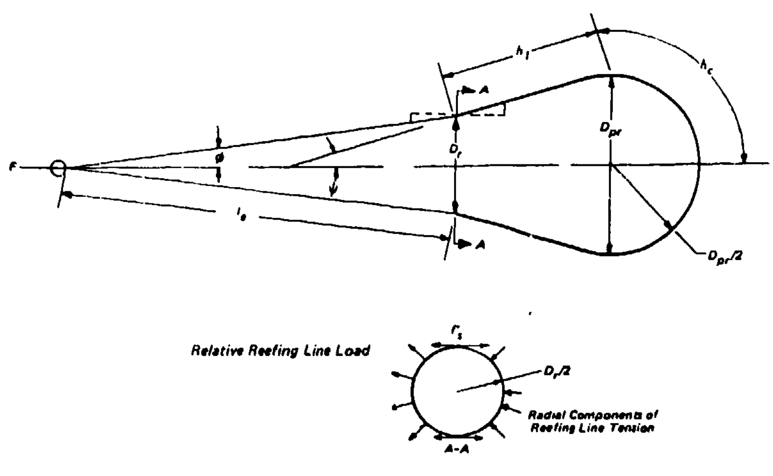
Therefore for the sample case:

$$D_{RL} = D_oC = 16(0.63)0.55 = 5.56\text{ft}$$

and $\pi D_{RL} = \pi\, 5.56 = 17.48$ ft

4 REEFING LINE LOADS

Tension begins to build-up in the reefing line at that moment in the inflation process when the angle of the canopy radial members, ψ, become greater than the convergence angle of the suspension lines, ϕ. From this point on, the ratio of the instantaneous loads in the reefing line and the parachute riser can be approximated from the geometry given in the figure below:



$$f's/F = (\tan\psi - \tan\phi)2\pi \qquad (1)$$

where $\phi \approx \sin^{-1}(D_r/2l_e)$

$\psi \approx \sin^{-1}[(D_{pr} - D_r)/2h_1]$

$h_1 \approx (Do/2) - h_c$

$h_c \approx \pi Dpr/4$

Equation (1) derives from the simple relationship for hoop tension in a flexible band

$$f's = pr$$

where $p = F(\tan\psi - \tan\phi)\pi D_r$ = distributed radial component of F

$r = D_{r/2}$

Although f's (max) occurs a short time after F(max) a conservative result will be obtained by assuming they are coincidental.

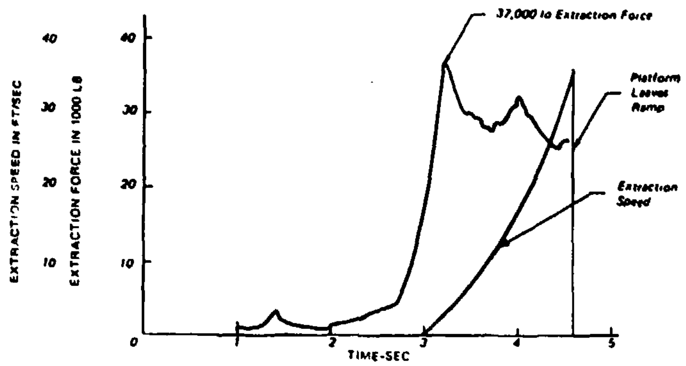
Appendix C

Typical Airdrop Parachutes and Webbing Characteristics

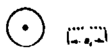
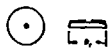
Drag Forces Developed by Standard Cargo-Extraction Canopies

Aircraft Release Velocity Knots IAS	15' Ring-Slot (Reefed To Size Representing 10' D_o Canopy)	15' Ring-Slot (Reefed To Size Representing 12' D_o Canopy)	15' Ring-Slot	22' Ring-Slot	28' Ring-Slot	35' Ring-Slot
110	1,690	2,430	3,800	8,200	13,300	20,800
120	2,010	2,900	4,500	9,700	15,500	24,600
130	2,430	3,380	5,400	11,400	19,500	28,600
140	2,720	3,950	6,100	13,300	23,200	33,700
150	3,140	4,520	7,050	15,200	26,200	38,600

Parachute Extraction Force and Extraction Speed vs Time for a 35-ft Parachute Extracting a 50,000-lb Load



Slotted Textile Parachutes

Type	Constructed Shape: Plan	Constructed Shape: Profile	$\frac{D_c}{D_o}$	Inflated Shape $\frac{D_p}{D_o}$	Drag Coef. C_{D_o} Range	Opening Load Factor C_X (Inf. Mass)	Average Angle of Oscillation	General Application
Flat Ribbon			1.00	.67	.45 to .50	~1.05	0° to ±3°	Drogue, Descent, Deceleration
Conical Ribbon			.95 to .97	.70	.50 to .55	~1.05	0° to ±3°	Descent, Deceleration
Conical Ribbon (Varied Porosity)			.97	.70	.55 to .65	1.05 to 1.30	0° to ±3°	Drogue, Descent, Deceleration
Ribbon (Hemisflo)			.62	.62	.30* to .46	1.00 to 1.30	±2°	Supersonic Drogue
Ringslot			1.00	.67 to .70	.56 to .65	~1.05	0° to ±5°	Extraction, Deceleration
Ringsail			1.16	.69	.75 to .90	~1.10	±5° to ±10°	Descent
Disc-Gap-Band			.73	.65	.52 to .58	~1.30	±10° to ±15°	Descent

Aircraft Deceleration Parachutes

Type	Aircraft	Diameter (ft)	Type	No. of Gores	Deployment Velocity KIAS
*MB-5	F-5	16	Ringslot	20	190
MB-6	F-101	15.5	Ringslot	20	200
*MB-7	F-104	16	Ringslot	20	200
MB-8	F-105	20	Ribbon	24	225
A-28A-1	F-106	14.5	Ringslot	20	220
----	F-5	15	Ringslot	20	180
*MB-1	B-47 (approach)	16	Ringslot	20	195
*D-1	B-47	32	Ribbon	36	160
*---	B-58	24	Ringslot	28	190
----	F-16	23	Ribbon	24	200
----	TA-7E	15	Ringslot	20	180

* Have been used in Developmental Airdrop Testing

Webbing Material for R&D Testing

NYLON WEBBING

Data from MIL-W-2088 and MIL-W-27265 (Impregnated)

Type	Min Break Str. (lbs)	Width (inch)	Max. Weight (oz/y)	Thickness (inch)	Yarn denier & filament	Ply W	Ply B	Ply F	Min. Warp ends	Picks per inch
I	500	9/16+1/32	0.28	.025-.040	420/68*	1		1	92	34
Ia	600	3/4+1/32	0.32	.025-.035	420/68*	1		1	108	34
II	600	1+1/32	0.42	.025-.040	420/68*	1		1	134	34
III	800	1 1/4+1/32	0.52	.025-.040	420/68*	1		1	168	34
IV	1,800	3+1/8	1.20	.025-.040	420/68*	1		1	400	34
VI	2,500	1 23/32+1/16	1.15	.030-.050	840/140	2		2	114	21
VII	5,500	1 23/32+1/16	2.35	.060-.100	840/140	2	1	2	256	26
VIII	3,600	1 23/32+1/16	1.60	.040-.070	840/140	2		2	166	18
VIIIa	6,300	3+3/32	2.80	.040-.070	840/140	2		2	280	18
VIIIb	4,500	2+1/16	1.80	.040-.070	840/140	2		2	192	18
VIIIc	5,300	2 1/4+1/16	2.10	.040-.070	840/140	2		2	222	18
IX	9,000	3+3/32	4.00	.065-.100	840/140	3	2	2	288	28
X	8,700	1 23/32+3/32	3.70	.105-.140	840/140	3	1	2	288	22
XII	1,200	1 23/32+1/16	.85	.025-.040	420/68*	1		1	277	34
XIII	6,500	1 23/32+1/16	2.90	.080-.120	840/140	2	1	2	315	24
XIV	1,200	1/2+1/32	.80	.070-.100	210/34	7		7	91	36
XV	1,500	2+1/16	1.25	.035-.050	840/140	2		2	88	15
XVI	4,500	1 23/32+1/16	2.00	.045-.080	840/140	2		2	198	17
XVII	2,500	1+1/16	1.15	.045-.070	840/140	2		2	114	15
XVIII	6,000	1+1/16	2.05	.100-.160	840/140	2		2	260	18
XIX	10,000	1 3/4+3/32	4.10	.100-.130	840/140	2		2	280	18
XX	9,000	1+3/32	3.25	.170-.210	840/140	5	1	3	188	19
XXI	3,600	1 1/4+1/16	1.70	.065-.085	210/34	5		10	260	25
XXII	9,500	1 23/32+3/32	3.50	.090-.120	840/68	3		2	259	18
XXIII	12,000	1 1/8+3/32	3.70	.200-.300	840/140	3	2	3	315	15
XXIV	5,500	1 15/16+3/32	2.25	.055-.075	840/140	2		3	244	17
XXV	4,500	1+1/16	1.50	.080-.125	840/140	2	1	2	189	12
XXVI	15,000	1 3/4+1/16	4.90	.150-.180	840/140	5		3	236	16
XXVII	6,500	1 23/32+1/16	2.90	.085-.110	840/68	3		2	215	24
XXVIII	8,700	2 1/4+3/32	3.80	.080-.110	840/140	3	1	2	288	22

* Values for warp yarns only. Filling yarns for these webbings are 840/140

COTTON WEBBING

Data from MIL-W-5665

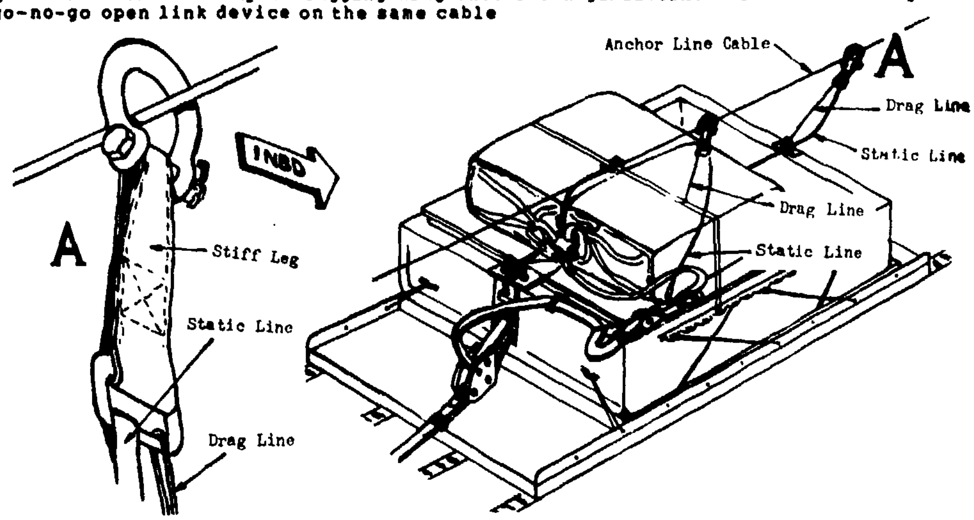
Type	Min Break Str. (lbs)	Width (inch)	Max. Weight (oz/yd)	Thickness (inch)	Warp Ends ply	Warp Ends number
I	350	9/16+1/16	.40	.040-.050	4	68
II	575	1+1/16	.75	.040-.050	4	122
III	750	1 1/4+1/16	.90	.040-.050	4	158
IV	1900	3+1/8	2.50	.050-.100	3	220
V	3100	5+1/8	4.30	.050-.100	3	350
VI	1800	1 3/4+1/16	3.00	.070-.090	5	116
VII	2600	1 3/4+1/16	3.00	.140-.170	7	122
VIII	2900	1 3/4+1/16	3.00	.075-.095	7	132
IX	4500	3+1/8	4.65	.090-.115	6	175
X	5000	1 3/4+1/16	3.60	.130-.160	6	160
XII	1000	1 3/4+1/16	1.25	.040-.060	4	220
XIII	3400	1 3/4+1/16	3.40	.095-.130	6	126
XV	4500	1 3/4+1/16	3.50	.130-.150	6	150
XVI	2700	1 3/4+1/16	2.60	.090-.115	7	124
XVII	1000	1+1/16	1.25	.075-.095	5	70
XVIII	1250	2 1/2+1/16	1.40	.050-.060	4	270
XIX	2500	2+1/16	3.68	.120-.150		139
XX	200	5/8+1/16	.45	.075-.095	3	40

Appendix D

Rigging Techniques

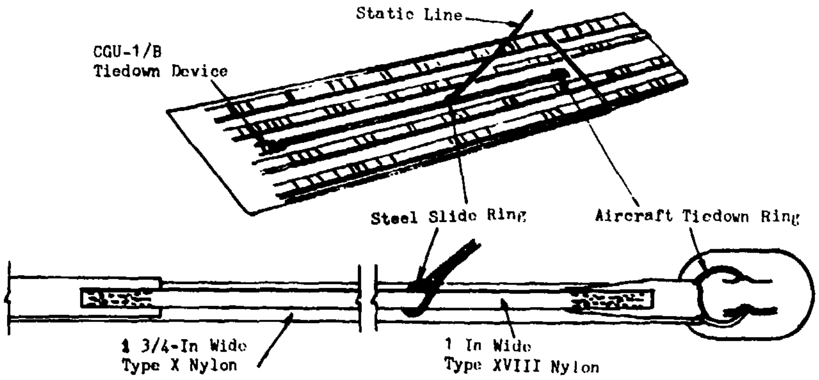
1. **Rigging a Drag Line**

During sequential airdrops in which the aircraft anchor line cable is used to anchor the static lines, it is necessary to rig a drag line to prevent oscialiation of the anchor line cable and the subsequent entangling of static lines about the cable. The figure below shows a way of rigging draglines for a guillotine force transfer system and a go-no-go open link device on the same cable



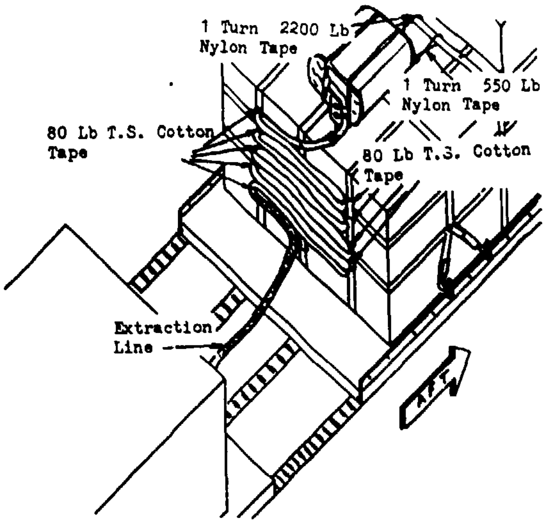
2. **Rigging a Floor Mounted Anchor Line**

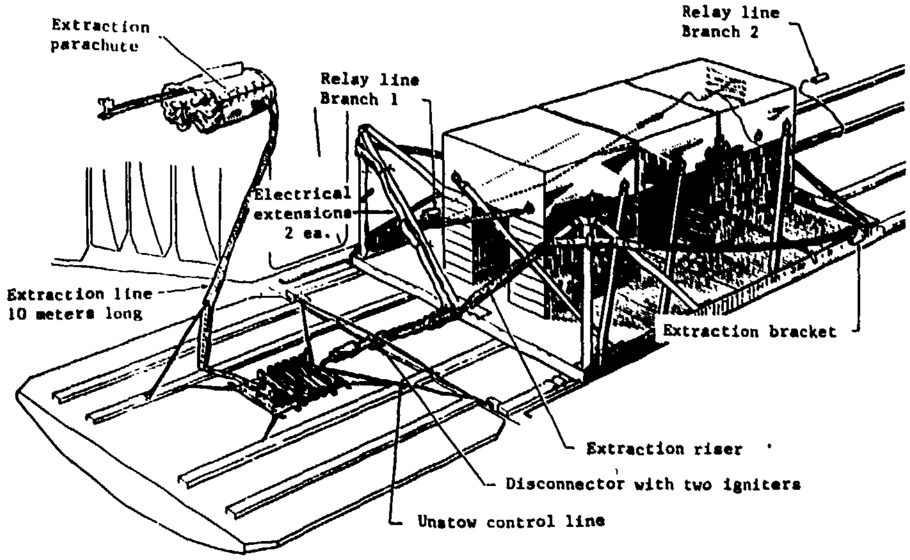
The problem noted above may be eliminated if the anchor line is rigged along the center of the cargo floor.



3. Stowing of Extraction Lines for Sequential Airdrop

In stowing the extraction lines for subsequent platforms "S" folding may be used either vertically or horizontally but each stow should be tied to assure orderly deployment of the line. The extraction chute deployment bag should be tied at the closed end only to allow the bag to move at the free end and align itself with the extraction line when the platform rotates. A typical method is shown below.





Rigging Sketch for Abbreviated LAPES Used on Transall C-160 Aircraft

Appendix E

Typical Test Instrumentation Lists

Test instrumentation onboard the airdrop test aircraft will vary in accordance with the extent of the testing effort. If a newly designed aircraft is being tested to evalute its capabilities as a an airdrop aircraft, much of the instrumentation may be installed by the manufacturer during the aircraft assembly. The instrumentation listed below, however, assumes that the aircraft has completed structural and performance testing and is being instrumented for airdrop testing, using carry-on type recording equipment.

1. Instrumentation lists have been divided into the following two categories:

a. Aircraft Flight Instrumentation

Aircraft flight instrumentation can be quite extensive and may include the following parameters.

LIST OF PARAMETERS	RANGE
Airspeed	50 to 350 kt
Pressure altitude	0 to 50,000 ft
Radar altitude	0 to 1000 ft (for LAPES)
Turbine inlet temperature (4 engines)	0 to 1000 deg C
Flap position	0 to 100 pct
Outside air temperature	-40 to +60 deg
Angle of attack	-10 to +30 deg
Angle of sideslip	20 deg ANL to 20 deg ANR
Vertical acclerometer	-1.5 to +4 g
Stop watch (10-second sweep)	------------
Elevator trim tab position	25 deg up to 10 deg down
Time correlation	0 to 99999 counts
Events	as required

PARAMETER	RANGE
Angle of pitch	+ 40 deg
Angle of bank	60 LWD to 60 deg RWD
Angle of yaw	20 deg left to 20 deg right
Pitch rate	+ 40 deg/sec^2
Roll rate	+ 40 deg/sec^2
Yaw rate	+ 20 deg/sec^2
cg vertical acceleration	-1 to +4 g
Elevator position	40 deg up to 15 deg down
Longitudinal stick force	+ 200 lbs
Aileron position (right only)	25 deg up to 15 deg down
Rudder position	35 deg left to 35 deg right
Radar altitude	0 to 1000 ft
cg longitudinal acceleration	-0.5 to +1.5g
Angle of attack	-10 deg to +30 deg
Angle of sideslip	20 deg left to 20 deg right
Time correlation	as required
Events	as required

b. Aerial Delivery System Instrumentation

Aerial delivery system insrumentation may also be tied in to the onboard computer/recorder and may include the following parameters:

PARAMETER	RANGE
RH lock preload	0-4000 lb
Drogue chute force transfer (event)	as required (for LAPES)
Extraction chute release (event)	as required
*Parachute extraction force	0 to 15,000 lbs 0 to 30,000 lbs 0 to 75,000 lbs
RH latch movement (7 latches)	full movement range
RH latch release force (7 latches)	0-4000 lb
Platform movement	1/2 inc fore and aft
Platform velocity (8 stations)	full length of compartment
Platformposition	1 ft intervals fore and aft
Rail sideload	0-6000 lbs
Conveyor-roller load (4 rollers)	0-4000 lb
Teeter-roller load (4 rollers)	0-15,000 lb
Ramp arm (ads link) loads (2 sides)	0-25,000 lb
Platform first movement (time)	as required
Events for time correlation	---------

2. A small onboard telemetry pack (described in section 2.4.2) may be mounted on the platform or vehicle to be airdropped. This pack will record parachute extraction and load suspension forces and movement during extraction and recovery.

ON BOARD TELEMETRY PACK

PARAMETER	RANGE
Extraction Force	standard, 0 to 1.5 X Platform wt. LAPES, 0 to 3.0 X Platform wt.
Recovery chute force (individual)(4)	0 to 20000 lbs
Recovery system force (total)	0-30,000 as required 0-60,000 as required
Platform suspension sling force (4)	0 to $\frac{\text{Load weight}}{\text{\# slings}}$ X 2
Vertical acceleration	-2 to +4g
Lateral acceleration	-2 to +2g
Longitudinal acceleration	0 to 3.0g
Event-Extraction chute release (from pendulum)	-----------
Event-Platform first movement	-----------
Event-Platform clears edge of ramp	-----------
Event-Rate reel	-----------

The force/load and acceleration parameter ranges depend on platform weight, speed and chute size. Event times are typically provided by a switch opening or closing, which is activated by a lanyard and pull pin. Events may also be generated by electrical circuits being opened by a lanyard and quick-disconnect plug.

The rate reel consists of a grooved cylinder (Figure 37), with a circumference (measured at the bottom of the groove) equal to 1 foot. Wire (22 gauge) is wound in the groove and the end is attached to the leading edge of a platform to be extracted. During extraction, the wire causes the cylinder to rotate 1 revolution per foot of platform travel. A magnetic pulse is generated by a magnet and pickup on each revolution, with time between pulses decreasing as rate reel rotational speed increases. The extraction rate may then be determined.

*Provided by a strain gage metal link, available in 3 sizes. (Figure 35)

Appendix F

Inflight Checklist for G-222 and C-160 Transports

AERITALIA
FLIGHT TEST

L.A.P.E.S. AIRDROP OF HEAVY LOADS

PILOT ACTIONS	COMP	COMUN
10 MINUTES BEFORE DROPPING		
P to L.M.: 10 minutes		
L.M. to P: Checks carried-out		
6 MINUTES BEFORE DROPPING		
P to L.M.: 6 minutes A/C depressurized		
L.M. to P: Checks carried-out Ready to ramp and door opening		
P to L.M.: Red light, ramp and door opening		
L.M. to P: Ramp and door open		
P: Electrical winch stby switch: ON		

L.A.P.E.S. AIRDROP OF HEAVY LOADS

LOAD MASTER ACTIONS

10 MINUTES BEFORE DROPPING

L.M. TO P.:
10 Minutes: received

L.M.:
1. B. & P. system handles:
   a. LH Sequential handle: stowed
2. Drogue chute safety line:checked
3. Tow-plate
   a. Normal control lever in proper position
   b. Emergency control lever in proper position
4. Check that all personnel are forward of the load
5. Removal of restraining chains

L.M. to P.:
Checks carried out

L.A.P.E.S. AIRDROP OF HEAVY LOADS

PILOT ACTIONS	COMP	COMUN
2 MINUTES BEFORE DROPPING		
P. to L.M.: 2 minutes		
L.M. to P.: Checks carrried out		
P to L.M.: Ready for "slow down" -Landing gear down -Flaps: as required -Speed: as required -Landing lights: ON		
30 SECONDS BEFORE DROPPING		
P. to L.M.: -30 sec - Drogue deployment -Dive start -Drogue release 3-2-1: Deployment the Drogue		
L.M. to P.: Drogue: Normal opening (otherwise see EMERG. A1 or A2		

L.A.P.E.S. AIRDROP OF HEAVY LOADS

LOAD MASTER ACTIONS

6 MINUTES BEFORE DROPPING

L.M. to P.:
6 minutes received

L.M.:
-Check the complete clearance on the rollers

L.M. to P:
-Checks carried out
-Ready for ramp and door opening

L.M. to P.:
-Red light
-Ramp and door open

2 MINUTES BEFORE DROPPING

L.M. to P.:
2 minutes received

L.M.:
1. Tow-plate consolle:
   a. Normal handle stowed and saftied
   b. Shear knife connected to electrical winch
   c. Emergency handle stowed and safetied

L.A.P.E.S. AIRDROP OF HEAVY LOADS
LOAD MASTER ACTIONS
2. Unlock LH detent latches and check 3. Remove pin on the bomb rack release handle 4 Remove drogue chute safety-line 5. F.T.I.: ON L.M. to P.: Checks carried-out
30 SECONDS BEFORE DROPPING L.M. to P.: -30 seconds: received -Remove safety pin on TOW PLATE CONSOLLE L.M. to P.: Drogue-Normal opening (otherwise see Emerg. A1 or A2)

L.A.P.E.S. AIRDROP OF HEAVY LOADS		
PILOT ACTIONS	COMP	COMUN
ON THE TARGET P. to L.M.: -Ready for green light (otherwise see Emerg B) -3-2-1 GREEN L.M. to P.: -Load out -Green light off -Close ramp and door P.: -Landing lights: OFF -Audio signal -Ramp and door close -Light off		

L.A.P.E.S. AIRDROP OF HEAVY LOADS
LOAD MASTER ACTIONS
ON THE TARGET P. to L.M.: -3-2-1-GREEN! (otherwise see Emerg B) L.M. to P.: -Load out (otherwise see Emerg. C1 or C2 or C3 or C4) -Green light OFF -Close ramp and door L.M.: -F.T.I.: OFF

L.A.P.E.S. AIRDROP OF HEAVY LOADS

EMERGENCY PROCEDURES

EMERGENCY A 1 - DROGUE CHUTE NOT RELEASED FROM BOMB RACK

DUTY	ACTION
L.M.	Pull manual bomb rack handle
L.M.	Inform the pilot: Drogue Normal opening

EMERGENCY A 2 - DROGUE CHUTE NOT OPENED (OR PARTIALLY OPENED)

DUTY	ACTION
L.M.	-Inform the pilot: Drogue not opened -Pull Emergency tow plate handle RED -Check positive disconnection between extraction parachute and tow-plate -Restrain the load with LH Sequential lock -Inform the pilot: Ready to Drogue jettison
P	-Ready to drogue jettison 3-2-1 GREEN
L.M.	-Inform the pilot: -Drogue jettisoned -Green light off -Close ramp and door

L.A.P.E.S. AIRDROP OF HEAVY LOADS

EMERGENCY PROCEDURES

EMERGENCY B: PILOT ABORTS THE MISSION

DUTY	ACTION
P.	-Inform L.M.: Abort mission
L.M.	- Acknowledged - Pull emergency tow plate handle (RED) - Check positive disconnection between extraction parachute and tow-plate - Restrain the load with LH sequential lock - Inform P: Ready to drogue jettison
P.	- Ready to drogue jettison 3-2-1 GREEN (*)
L.M.	- Inform the pilot: - Drogue jettisoned - Green light off - Close ramp and door

(*) IF ELECTRICAL WINCH FAIL

DUTY	ACTION
L.M.	- Inform the pilot: - Electrical winch failure
P.	- Ready to manual jettison 3-2-1 GO!
L.M.	- Cut the safe tie of the normal tow-plate handle (green)

NOTE: In case of mechanical failure of tow plate the L.M. cut the drogue harness when authorized by the pilot.

L.A.P.E.S. AIRDROP OF HEAVY LOADS

EMERGENCY PROCEDURES

EMERGENCY C 1: FAILURE IN DROGUE DISCONNECTION FROM TOW-PLATE

SEE EMERGENCY B

DUTY	ACTION
L.M.	- Inform the pilot: PARACHUTE not opened - Set the RH Emerg. Rel. handle to "EMERG" - Inform the pilot: load free
P.	-Control for positive attitude
L.M.	- Inform the pilot: - Load out - Green light off - Close ramp and door

L.A.P.E.S. AIRDROP OF HEAVY LOADS

EMERGENCY PROCEDURES

EMERGENCY C 3: NON-MOVEMENT OF THE LOAD WITH THE EXTRACTION PARACHUTE OPEN

DUTY	ACTIONS
L.M.	- Set the RH Emerg. Rel handle to "EMERG." as quickly as possible - Inform the pilot: - load out - green light off - ramp and door close

EMERGENCY C 4: LOAD STOPPING ON THE RAMP (BLOCKED)

DUTY	ACTIONS
L.M.	- Inform the pilot: -LOAD BLOCKED!! -Ready to Emergency landing!
P.	- Control to Emergency landing

Low Altitude Aerial Delivery

Functional Check of Airdrop System

Adopt para 1 - 20 from GAF T.O. 1C-160-1 page 8-98.

Functional Check of Extraction Chute Pendulum

Adopt paras 1 - 5 from GAF T.O. 1C-160-1 page 8-100.

On-aircraft

1. Air-drop system 88	- Installed
2. Functional check	- Performed
3. Anchor cables L/H and R/H	- Check
a) Condition and installation	- Check
b) Cable tension for 12.50 m	- Ground clearance 1.70 m
c) Stop bolts-R/H anchor cable STA 18300	- Provided
d) Stop bolts-L/H anchor cable STA 20300	- Provided
4. 3 separable D-rings (stop devices of 800 kg anchor cable safety arrangement) - 2 on L/H and 1 on R/H anchor cable	- Mount to the anchor cables
5. Loading ramp/cargo door	- In delivery position
6. Safety lever	- Open
7. 400 kg break cords with rubber rings on the inner roller convey ors-ramp STA 20000-19999	- Installed and stretched
8. Restraint material for malfunctions	- Provided and prepared
9. Aerial delivery kit No. 9	- Complete

Check Ready-made Air-drop Load

1. Platform, condition	- Check
2. Restraint	- Check
3. Suspension strap attachment devices	- Check
4. Cargo Chutes	- Check
a) Condition	
b) Tied among one another (400 kg break cord), tied to the cargo with 100 kg break cord each, and with chute safety strap - SECURED	
5. Extraction shoe with cutter locked and secured in the extraction device	- Check
6. Release cable connected to extraction device and attached to the load	- Check
7. Release line connection to release cable	- Check
8. Additional loop of release line attached to restraint net with 25 kg break cord. Connect additional loop to eye with 7 kg break cord	- Check
9. Breaking point on extraction shoe with cutter	- Check
10. Cargo chute release strap to extraction shoe with cutter including web ring	- Attached
11. Cargo chute release strap to cargo chute release	- Connected
12. Clearance of cargo chute release bottom edge from platform bottom edge about 25 cm	- Check

13.	Cargo chute release	- Loaded and secured
14.	Extension straps in cargo chute release strap	- Stowed
15.	Deployment strap to connector straps 1.8 m	- Attached
16.	Connector straps 1.8 m to chute bridles	- Attached
17.	Capacity test on power supply box	
	a) Button switch	- Push briefly
	b) Check light	- ON
18.	14 m - extension strap with link	- Provided
19.	5 m - extension strap (sections III and IV of system)	- Provided
20.	Required extraction chutes	- Provided
21.	Connection of pilot chute extension line to separable D-ring (stop devices of 800 kg anchor cable safety arrangement) on L/H anchor cable. Short tying 400 kg and long tying 400 kg	- Check
22.	Pilot chute connection to antioscillation chutes	- Check
23.	Suspension strap attachment for stabilization-brake chutes	- Provided

When Dropping in Tandem Order

24.	Tandem discharge board to load within 8 x 400 kg break cord	- Attached
25.	Extraction chute and extension strap 14 m/5 m to tandem discharge board	- Attached/tied

Loading

1.	Loading documents	- Check
2.	Stations	- Determine
3.	Cargo	- Load
4.	Cargo	- Restrain
5.	DD Form 365 F	- Prepare

After Loading

1.	Crank handle	- Normal position
2.	Loading winch cable	- Reeled in
3.	Auxiliary loading devices	- Stow/restrain
4.	Attach unlock ropes to airdrop system and them to airdrop system by tying with 25 kg break cord	- Secure
5.	Distributor/electrical line connector (secured) with 50 kg break cord)	- Check
6.	Slack of electrical line up to platform bottom edge at least 10 cm	- Check
7.	Electrical line/power supply box electrical connectors	- Mate and secure with 50 kg break cord
8.	Connection from arming cord to power supply box connecting ring (200 kg break cord)	- Check

9. Release line (extraction device) to separable D-ring on L/H (in flight direction) anchor cable with 2 x 200 kg break cord (short and long tying) - Attach

10. Tension of release line (rubber tension line) - Check

11. Arming cord to separable D-ring on R/H anchor cable - Tie

    a) 1 x short tying with 50 kg break cord

    b) 1 x about 5 cm in the ring with 50 kg break cord

11a Tension of arming cord (rubber tension line) - Check

12. Tying of overlength of release arming cords to load with 25 kg break cord - Secure

13. Platform suspension strap brackets to the airdrop system cross members to be connected at the left and right side to cross members by tying with 400 kg break cord (in the ring)

When Dropping in Tandem Order

14. Extension strap to bridle of following load by link 45 mm - Connect

    NOTE

    Paras 4 - 14 shall be executed for each individual load; for the load to be delivered first para 15 to be executed in addition.

15. Extraction chute harness - Connect and check

    a) Extraction chute (7 kg break cord removed) - Suspend

    b) Chute strap in upper and lower suspension hooks by the retainer bands - Suspend - Check tension
    For suspension in lower hook use 400 kg break cord loop for retainer band.
    If extraction chutes are attached to both suspensions, the R/H one (No. 2 in flight direction) shall be secured with 400 kg break cord.

    c) 14 m extension strap to chute strap on loading ramp - Attach

    d) Stow 14 m extension strap on loading ramp and for proper arrangement - Check

    e) 14 m extension strap to bridle (in air-drop system section III and IV 5 m extension strap in addition) - Attach

16. All platforms - Locked

    a) Locking indications - Check

17. Hand lever for locking mechanism - In place

Before Taxiing
Adopt paras 1 - 9 from GAF T.O. 1C-160-1 page 8-104.

Preparation for Dropping (X - 8 minutes)

1. Preparation for dropping - Order (pilot)

2. Indicator lamps (pilot, navigator, loading master) (red) "VORBEREITEN" (prepare) - On

3. Inspection - preparation for dropping - Perform

    a) Cargo chute safety strap - Remove

    b) Safety pin of power supply box - Pull

    c) Blocking devices position up - Check

d) Visual inspection of load - Perform

e) Loading ramp/cargo door - Is clear

4. Inspection performed - Report

5. Toggle switch "VERSTANDEN/FLUG" (Roger/flight) - VERSTANDEN (Roger)

   a) Indicator lamps (pilot, navigator, loading master) (red) "VORBEREITEN" (prepare) - Off

---

Opening of Loading Ramp/Cargo Door (x - 2 minutes)

Adopt paras 1 - 3 from GAF T.O. 1C-160-1, page 8-105.

Dropping

Adopt para 1 - 7 from GAF T.O. 1C-160-1, page 8-105.

After Dropping

1. Rotary selector switch "AS" (extraction chute) - On

2. Indicator lamps (pilot, navigatgor, loading master) (red) "VORBEREITEN" (prepare) - Off

3. Toggle switch "ABSETZEN" (dropping) - Off (navigator)

   a) Indicator lamps (pilot, navigator, loading master) (green) "ABSETZEN" - Off

   b) Horn - Off

4. Closing of loading ramp/cargo door - Order

5. Report - Loading ramp/cargo door clear for closing

   Upon closing of loading ramp/cargo door:

6. Report - Cargo compartment is safe

MALFUNCTIONS WHEN DROPPING LOADS FROM LOW ALTITUDE

FAILURE OF ELECTRICAL CHUTE INITIATION/RELEASE

Procedure according to briefing

POWER FAILURE OF AIR-DROP SYSTEM

Procedure according to briefing

FAILURE MECHANICAL CHUTE INITIATION/RELEASE or

EXTRACTION CHUTE REMAINS ON LOADING RAMP

1. Button switch "VERRIEGEL. BLOCKIERT" (locking mechanism jamming) - Press

   a) Warning light (navigator) (red) "VERRIEGEL. BLOCKIERT" - On

2. Malfunction - Report

3. Toggle switch "VERSTANDEN/FLUG" (Roger/flight) - FLUG (flight)

   a) Indicator lamps (pilot, navigator, loading master) (red) "VORBEREITEN" (prepare) - On

4. Rotary selector switch "AS" (extraction chute) - On

   a) Indicator lamps (pilot, navigator, loading master) (green) "ABSETZEN" (dropping) - Off

5. Blocking devices down - Check

   a) If blocking devices are up - Secure load

6. Report - Loading ramp/cargo door clear for closing

WARNING

If during closing operation the extraction chute falls out of the aircraft, the cargo chutes will be extracted. Closing of loading ramp/cargo door shall be stopped immediately to prevent the extension strap from becoming caught. After about 3 seconds the cargo chutes will be de-reefed, and when exceeding a tow load of 8000 kp (about 78500 N) they will be automatically separated from the locked load. After closing of loading ramp/cargo door:

7. Report - Cargo compartment is safe

FAILURE OF UNLOCKING MECHANISM

LOAD JAMMING WITH CARGO CHUTE INFLATED (loading master)

1. Button switch "VERRIEGEL. BLOCKIERT" (locking mechanism jamming) - Press

   a) Warning light (navigator) (red) "VERRIEGEL. BLOCKIERT" - On

2. Malfunction - Report

NOTE

The cargo chutes are extracted and will be de-reefed after 3 seconds. When exceeding a tow load of 8000 kp (about 78500 N) they will be automatically separated from the locked/jamming load.

3. Toggle switch "VERSTANDEN/FLUG" (Roger/flight) - FLUG (flight)

   a) Indicator lamps (pilot, navigator, loading master) (red) "VORBEREITEN" (prepare) - On

4. Rotary selector switch "AS" (extraction chute) - 0

   a) Indicator lamps (pilot, navigator, loading master) (green) "ABSETZEN" (dropping) - Off

5. Blocking devices - Check

   If blocking devices are up - Secure load in dropping direction

6. Report - Load secured, loading ramp/cargo door clear for closing

   Upon closing of loading ramp/cargo door:

7. Load in flight direction - Secure

8. Report - Cargo compartment is safe

9. Load upon order (pilot)

   a) With loading winch in selected section - Move back and lock

   or

   b) with chains in jamming position - Secure

Annex 1

AGARD FLIGHT TEST INSTRUMENTATION AND FLIGHT TEST TECHNIQUES SERIES

1. Volumes in the AGARD Flight Test Instrumentation Series, AGARDograph 160

Volume Number	*Title*	*Publication Date*
1.	Basic Principles of Flight Test Instrumentation Engineering by A.Pool and D.Bosman (to be revised in 1989)	1974
2.	In-Flight Temperature Measurements by F.Trenkle and M.Reinhardt	1973
3.	The Measurement of Fuel Flow by J.T.France	1972
4.	The Measurement of Engine Rotation Speed by M.Vedrunes	1973
5.	Magnetic Recording of Flight Test Data by G.E.Bennett	1974
6.	Open and Closed Loop Accelerometers by I.Mclaren	1974
7.	Strain Gauge Measurements on Aircraft by E.Kottkamp, H.Wilhelm and D.Kohl	1976
8.	Linear and Angular Position Measurement of Aircraft Components by J.C.van der Linden and H.A.Mensink	1977
9.	Aeroelastic Flight Test Techniques and Instrumentation by J.W.G.van Nunen and G.Piazzoli	1979
10.	Helicopter Flight Test Instrumentation by K.R.Ferrell	1980
11.	Pressure and Flow Measurement by W.Wuest	1980
12.	Aircraft Flight Test Data Processing — A Review of the State of the Art by L.J.Smith and N.O.Matthews	1980
13.	Practical Aspects of Instrumentation System Installation by R.W.Borek	1981
14.	The Analysis of Random Data by D.A.Williams	1981
15.	Gyroscopic Instruments and their Application to Flight Testing by B.Stieler and H.Winter	1983
16.	Trajectory Measurements for Take-off and Landing Test and Other Short-Range Applications by P.de Benque d'Agut, H.Riebeek and A.Pool	1985
17.	Analogue Signal Conditioning for Flight Test Instrumentation by D.W.Veatch and R.K.Bogue	1986

Volume Number	*Title*	*Publication Date*
18.	Microprocessor Applications in Airborne Flight Test Instrumentation by M.J.Prickett	1987

At the time of publication of the present volume the following volume was in preparation:

Digital Signal Conditioning for Flight Test Instrumentation
by G.A.Bever

2. Volumes in the AGARD Flight Test Techniques Series

Number	*Title*	*Publication Date*
AG 237	Guide to In-Flight Thrust Measurement of Turbojets and Fan Engines by the MIDAP Study Group (UK)	1979

The remaining volumes will be published as a sequence of Volume Numbers of AGARDograph 300.

Volume Number	*Title*	*Publication Date*
1.	Calibration of Air-Data Systems and Flow Direction Sensors by J.A.Lawford and K.R.Nippress	1983
2.	Identification of Dynamic Systems by R.E.Maine and K.W.Iliff	1985
3.	Identification of Dynamic Systems — Applications to Aircraft Part 1: The Output Error Approach by R.E.Maine and K.W.Iliff	1986
4.	Determination of Antenna Patterns and Radar Reflection Characteristics of Aircraft by H.Bothe and D.Macdonald	1986
5.	Store Separation Flight Testing by R.J.Arnold and C.S.Epstein	1986
6.	Developmental Airdrop Testing Techniques and Devices by H.J.Hunter	1987

At the time of publication of the present volume the following volumes were in preparation:

Identification of Dynamic Systems. Applications to Aircraft
Part 2: Nonlinear Model Analysis and Manoeuvre Design
by J.A.Mulder and J.H.Breeman

Flight Testing of Digital Navigation and Flight Control Systems
by F.J.Abbink and H.A.Timmers

Aircraft Noise Measurement and Analysis Techniques
by H.H.Heller

Air-to-Air Radar Flight Testing
by R.E.Scott

Flight Testing under Extreme Environmental Conditions
by C.L.Hendrickson

Flight Testing of Terrain Following Systems
by C.Dallimore and M.K.Foster

Store Ballistic Analysis and Testing
by R.Arnold and H.Reda

Annex 2

AVAILABLE FLIGHT TEST HANDBOOKS

This annex is presented to make readers aware of handbooks that are available on a variety of flight test subjects not necessarily related to the contents of this volume.

Requests for A & AEE documents should be addressed to the Defence Research Information Centre, Glasgow (see back cover). Requests for US documents should be addressed to the Defence Technical Information Center, Cameron Station, Alexandria, VA 22314 (or in one case, the Library of Congress).

Number	*Author*	*Title*	*Date*
NATC-TM76-ISA	Simpson, W.R.	Development of a Time-Variant Figure-of-Merit for Use in Analysis of Air Combat Maneuvring Engagements	1976
NATC-TM76-3SA	Simpson, W.R.	The Development of Primary Equations for the Use of On-Board Accelerometers in Determining Aircraft Performance	1977
NATC-TM-77-IRW	Woomer, C. Carico, D.	A Program for Increased Flight Fidelity in Helicopter Simulation	1977
NATC-TM-77-2SA	Simpson, W.R. Oberle, R.A.	The Numerical Analysis of Air Combat Engagements Dominated by Maneuvering Performance	1977
NATC-TM-77-1SY	Gregoire, H.G.	Analysis of Flight Clothing Effects on Aircrew Station Geometry	1977
NATC-TM-78-2RW	Woomer, G.W. Williams, R.L.	Environmental Requirements for Simulated Helicopter/ VTOL Operations from Small Ships and Carriers	1978
NATC-TM-78-1RW	Yeend, R. Carico, D.	A Program for Determining Flight Simulator Field-of-View Requirements	1978
NATC-TM-79-33SA	Chapin, P.W.	A Comprehensive Approach to In-Flight Thrust Determination	1980
NATC-TM-79-3SY	Schiflett, S.G. Loikith, G.J.	Voice Stress Analysis as a Measure of Operator Workload	1980
NWC-TM-3485	Rogers, R.M.	Six-Degree-of-Freedom Store Program	1978
WSAMC-AMCP 706-204	—	Engineering Design Handbook, Helicopter Performance Testing	1974
NASA-CR-3406	Bennett, R.L. and Pearsons, K.S.	Handbook on Aircraft Noise Metrics	1981
—	—	Pilot's Handbook for Critical and Exploratory Flight Testing. (Sponsored by AIAA & SETP — Library of Congress Card No.76-189165)	1972
—	—	A & AEE Performance Division Handbook of Test Methods for assessing the Flying Qualities and Performance of Military Aircraft. Vol.1 Airplanes	1979
A & AEE Note 2111	Appleford, J.K.	Performance Division: Clearance Philosophies for Fixed Wing Aircraft	1978
A & AEE Note 2113 (Issue 2)	Norris, E.J.	Test Methods and Flight Safety Procedures for Aircraft Trials Which May Lead to Departures from Controlled Flight	1980

Number	*Author*	*Title*	*Date*
AFFTC-TD-75-3	Mahlum, R.	Flight Measurements of Aircraft Antenna Patterns	1973
AFFTC-TIH-76-1	Reeser, K. Brinkley, C. and Plews, L.	Inertial Navigation Systems Testing Handbook	1976
AFFTC-TIH-79-1	—	USAF Test Pilot School (USAFTPS) Flight Test Handbook Performance: Theory and Flight Techniques	1979
AFFTC-TIH-79-2	—	USAFTPS Flight Test Handbook. Flying Qualities: Theory (Vol.1) and Flight Test Techniques (Vol.2)	1979
AFFTC-TIH-81-1	Rawlings, K., III	A Method of Estimating Upwash Angle at Noseboom-Mounted Vanes	1981
AFFTC-TIH-81-1	Plews, L. and Mandt, G.	Aircraft Brake Systems Testing Handbook	1981
AFFTC-TIH-81-5	DeAnda, A.G.	AFFTC Standard Airspeed Calibration Procedures	1981
AFFTC-TIH-81-6	Lush, K.	Fuel Subsystems Flight Test Handbook	1981
AFEWC-DR 1-81	—	Radar Cross Section Handbook	1981
NATC-TM-71-ISA226	Hewett, M.D. Galloway, R.T.	On Improving the Flight Fidelity of Operational Flight/ Weapon System Trainers	1975
NATC-TM-TPS76-1	Bowes, W.C. Miller, R.V.	Inertially Derived Flying Qualities and Performance Parameters	1976
NASA Ref. Publ. 1008	Fisher, F.A. Plumer, J.A.	Lightning Protection of Aircraft	1977
NASA Ref. Publ. 1046	Gracey, W.	Measurement of Aircraft Speed and Altitude	1980
NASA Ref. Publ. 1075	Kalil, F.	Magnetic Tape Recording for the Eighties (Sponsored by: Tape Head Interface Committee)	1982

The following handbooks are available in French and are edited by the French Test Pilot School (EPNER Ecole du Personnel Navigant d'Essais et de Réception ISTRES — FRANCE), to which requests should be addressed.

Number EPNER Reference	*Author*	*Title*	*Price (1983) French Francs*	*Notes*
2	G.Leblanc	L'analyse dimensionelle	20	Réédition 1977
7	EPNER	Manuel d'exploitation des enregistrements d'Essais en vol	60	6ème Edition 1970
8	M.Durand	La mecanique du vol de l'hélicoptère	155	1ere Edition 1981
12	C.Laburthe	Mécanique du vol de l'avion appliquée aux essais en vol	16	Réédition en cours
15	A.Hisler	La prise en main d'un avion nouveau	50	1ère Edition 1984
16	Candau	Programme d'essais pour l'évaluation d'un hélicoptère et d'un pilote automatique d'hélicoptère	20	2ème Edition 1970
22	Cattaneo	Cours de métrologie	45	RÉedition 1982
24	G.Fraysse F.Cousson	Pratique des essais en vol (en 3 Tomes)	T1 = 160 T2 = 160 T3 = 120	1ère Edition 1973
25	EPNER	Pratique des essais en vol hélicoptère (en 2 Tomes)	1 = 150 T2 = 150	Edition 1981
26	J.C.Wanner	Bang sonique	60	
31	Tarnowski	Inertie-verticale-sécurité	50	1ère Edition 1981
32	B.Pennacchioni	Aéroélasticité — le flottement des avions	40	1ère Edition 1980
33	C.Lelaie	Les vrilles et leurs essais	110	Edition 1981
37	S.Allenic	Electricité à bord des aéronefs	100	Edition 1978
53	J.C.Wanner	Le moteur d'avion (en 2 Tomes) T 1 Le réacteur .... T 2 Le turbopropulseur	 85 85	Réédition 1982
55	De Cennival	Installation des turbomoteurs sur hélicoptères	60	2ème Edition 1980
63	Gremont	Aperçu sur les pneumatiques et leurs propriétés	25	3me Edition 1972
77	Gremont	L'atterrissage et le problème du freinage	40	2ème Edition 1978
82	Auffret	Manuel de médicine aéronautique	55	Edition 1979
85	Monnier	Conditions de calcul des structures d'avions	25	1ère Edition 1964
88	Richard	Technologie hélicoptère	95	Reédition 1971

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14. Abstract

This volume in the AGARD Flight Test Techniques Series deals with the practical aspects of planning, conducting and reporting on developmental airdrop tests made from cargo transport type aircraft. Typical cargo aircraft Aerial Delivery systems, parachute extraction systems and special devices and rigging techniques are described in detail. Typical instrumentation systems for obtaining aircraft and parachute systems force data are also described and piloting techniques for various airdrop methods are briefly discussed. The author also uses a scenario of a typical parachute Tow Test to demonstrate the application of these techniques and the use of challenge and response checklists among the flight crewmembers. Finally the use of reports is discussed and appendices are included with many useful charts and calculations that are readily applicable in research and development (R & D) airdrop testing. Keywords:

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Advisory Group for Aerospace Research and Development, NATO
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by Henry J.Hunter and edited by R.K.Bogue
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