Engineering Notes

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A 73-ft Cross Parachute for Cargo Delivery

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Introduction

A PARACHUTE system to deliver a 2400-lb resupply container from cargo aircraft at release speeds of 150 kcas and 25,000-ft altitude was desired by the U.S. Army Natick Laboratories. The ARIES parachute system developed by Sandia National Laboratories for the NASA Space Telescope appeared to offer many desirable features for this application. This Note presents data from development drop tests of the parachute system.

Parachute System Description

The parachute system consists of a 15-ft-diam ribbon-type first-stage parachute reefed by a 115-in.-long reefing line for 10 s, and a 73-ft-diam cross-type second-stage parachute, reefed for 10 s by a 290-in.-long reefing line. The 15-ft parachute has 16 gores and 16 suspension lines of 16-ft-long, 2000-lb braided Kevlar-29. The top 14, 2-in.-wide ribbons are 460-lb tensile strength nylon, with the remainder 300-lb, 2-in.-wide ribbons.

The 73-ft cross parachute has 60 suspension lines of 300-lb braided nylon 73-ft long. The canopy cloth is 1.1 oz/yd^2 nylon ripp-stop.

A more detailed description of the parachutes and test vehicle is given in Ref. 1.

Rigging and Packing

The parachutes and associated bridles are shown in Fig. 1. The 15-ft-diam ribbon parachute is packed in a 14-in.-diam bag. An 18-in.-long, 100-lb vent break cord is installed first. The canopy is held in the bag by a two-loop locking flap. A total of 16, 16-lb nylon thread line ties are used and another two-loop locking flap holds the lines in the bag. Four 1-in. split links are used to attach the ribbon chute to the 20-ft-long, two-ply, 13,500-lb Kevlar bridle. A 275-lb nylon cord is threaded through the four split links and through a cut knife attached to the bridle near the confluence of the four legs. This keeps the links with the bag until near bridle stretch. The 20-ft-long bridle is accordion folded and tacked with 16-lb nylon thread to the side of the bag.

A 18-in.-long, 50-lb vent break cord is tied ot the apex bridle and with 8.5-lb thread break cord from the vent apex bridle to the cloth apex. Two-loop locking flaps in the bag hold the accordion-folded canopy in the bag. The 60 lines are divided into two groups and 39-lb, ¼-in.-wide nylon ribbon is tied to the bag side loops every 24 in. at a total of 32 stations. A dust cover is tacked with 16-lb nylon thread to the forward end of the bag. The cover is tied with a turn of 550-lb cord to the confluence area of the 80-ft-long, four-leg bridle. The 8-ft bridle is accordion folded and tacked with 16-lb thread to the top rim of the bag. The two cut knife lanyards for the bag lacing are tied to the confluence area of the forward three-leg end of the 8-ft bridle.

Drop Tests

Two drop tests were conducted using the NASA finned ogive/cylinder (Fig. 2, Ref. 1). Drop test data are given in Table 1. The vehicles were loaded on the Naval Weapons Evaluation Facility A7 aircraft at Kirtland Air Force Base, Albuquerque, N. Mex., and dropped about one-half hour later at Stallion Site at the north end of White Sands Missile Range, N. Mex.

A unique solid-state recorder[2] was used to obtain the deceleration record shown in Fig. 2. A metal box 4.75 in. wide by 3.75 in. high and 10 in. long weighing about 8.3 lb contains the recorder and the power supply of the nicad batteries. After impact, a portable keyboard, printer, and battery pack were used to extract the digital data.

The first drop was made with a 2341-lb vehicle. The parachute system used on both of these drops was the same as that used on the prior two drops.[1] Release conditions were 250 knots calibrated airspeed at 20,000 ft above sea level. Equivalent dynamic pressure at release was 203 psf. There was no significant parachute damage on either drop test. The second drop was made to verify a three-can-strap load transfer

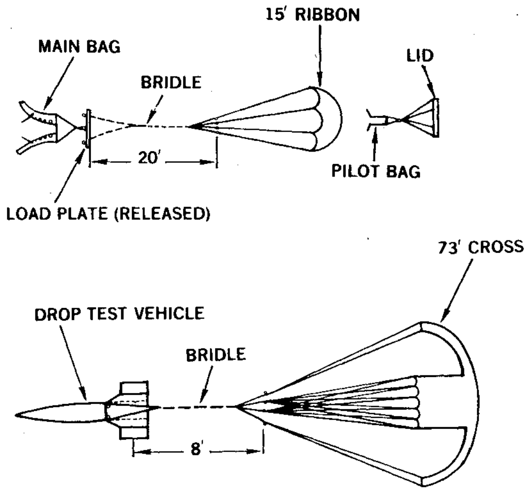

Fig. 1 Recovery system.

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Table 1 Sandia ARIES-II drops for UHLCADS

Drop no.	Test date	Time	q_0,[a] psf	V_0[b] kcas/ft/s		h_0,[c] msl	W,[d] lb	V_i,[e] ft/s	Results
1	5/12/83	12:17 p.m.	203	250	530	20,000	2341	30	Successful
2	6/9/83	10:32 a.m.	172	230	540	22,000	1600	25	Successful

[a] q_0 = dynamic pressure at release. [b] V_0 = velocity at release. [c] h_0 = altitude above sea level. [d] W = total vehicle weight. [e] V_i = impact velocity.

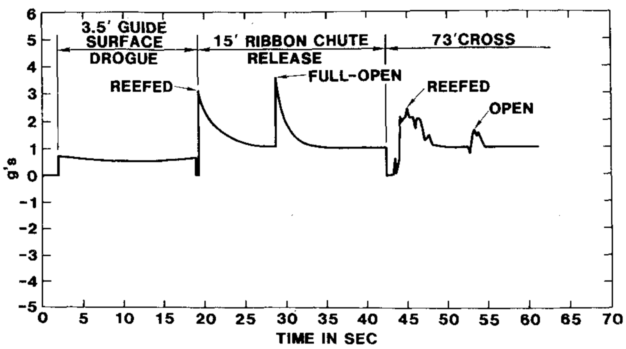

Fig. 2 Acceleration profile White Sands Test, June 9, 1983.

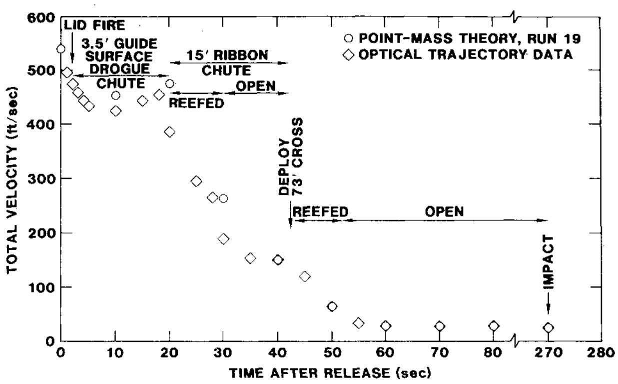

Fig. 3 ARIES-II drop No. 2.

method for the 3.5-ft guide surface drogue and 15-ft ribbon parachute. This eliminated the costly ball-lock load plate, and allowed staging by severing a double 5000-lb braided Kevlar pucker cord with a cable cutter fired by the clock timer in the vehicle. The deceleration record from the second drop is shown in Fig. 2. The positive load peaks shown in Fig. 2 are due to the aft parachute load force along the vehicle axis. The velocity decay with time after release, as obtained from phototheodolite tracking cameras, is shown in Fig. 3. Point-mass theoretical trajectory data shown as circles agree well with the diamond-shaped marks for the tracking data.

Conclusions

From two drop tests of the ARIES parachute system, it has been concluded that

1) The proposed 15-ft-diam ribbon first-stage and 73-ft-diam cross second-stage parachutes are well suited for the delivery application.

2) Impact velocity of the 2400-lb maximum weight container will be 30 ft/s at an altitude of 4700 ft mean sea level.

3) Maximum deceleration can be limited to slightly over 3 g's as requested.

Acknowledgments

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[2]Hauser, G.C. and Ryerson, D.E., "A Stored Data Acquisition System," Sandia National Labs., Albuquerque, N. Mex., SAND83-0132, Feb. 1983.

A Theorem on Swirl Loss in Propeller Wakes

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Introduction

THE wake of a propeller has tangential as well as longitudinal velocity relative to still air. The coarser the spiral the propeller carves in the air, the greater is the ratio of tangential to longitudinal wake velocity. As aircraft with propellers go faster, designers must use higher and higher ratios of pitch to diameter to keep the propeller tips below, or not too far above, the speed of sound. The higher thrusts required for higher speeds demand higher loading. All wake energy losses will rise, the swirl component more than the longitudinal component.

Swirl losses may appear particularly frightening because, as well as being a repository of kinetic energy, the swirling motion makes the wake a vortex, which, like any other vortex, has reduced pressure within itself. Added to the energy cost of creating the swirling motion, there appears to be a pressure drag due to the suction in the wake.[1] Fortunately, this is not true. In good approximation, the pressure drag is the way the swirl energy cost is paid for. The two do not add together.

The Proof

Commence with the general momentum theory of Glauert,[2] which he ascribes Joukowski. Glauert's Eq. (1.7) concerns a propeller with an infinite number of blades and gives the pressure depression at any radius r in the wake (Fig. 1). It is

$$p = (\rho/2)(V^2 - u^2) + \rho(\Omega - \omega/2)\omega r^2 \tag{1}$$

where p is the pressure in the wake minus the ambient pressure (p is always negative), ρ is the density of air, V the forward

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