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Preliminary Report on Development of an Interim Parachute Recovery System for a Re-entry Vehicle

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This is a report about tests conducted on a two-stage parachute system consisting of a 19-in. diameter ribbon parachute made of Kevlar-29 and a 3 ft diameter guide surface, second-stage parachute with a nylon canopy and Kevlar-29 suspension lines. A 1.75 ft^3 ram, air-filled flotation bag attached to the vent of the 3 ft guide surface parachute is used for ocean recovery of the 57 lb nose cone. Recovery was started by jettisoning 63% of the initial re-entry mass prior to deploying the parachute.

Nomenclature

A	= flotation bag inlet area, ft^2
C_{AU}	= lid; lid and bridle; or lid, reaction cup, and bridle drag coefficient based on lid area, 9.26 $in.^2$
C_D	= parachute drag coefficient based on S
d_c	= cone base diameter, ft
D	= parachute constructed diameter, ft
F	= flow coefficient or parachute drag force, lb
g_{max}	= maximum deceleration, g
m	= mass, slugs/ft^3
M	= Mach number
q	= dynamic pressure = $\frac{1}{2}\rho V^2$, lb/ft^2
r	= radius of flotation bag, ft
R	= range from upward ejection to impact, ft
S	= parachute constructed area = $(\pi D^2)/4$, ft^2
t	= time, s
T	= temperature
v	= volume, ft^3
V	= vehicle velocity, ft/s
W_T	= weight of test vehicle and parachute system, lb
x	= distance between cone base and parachute skirt, ft
γ	= trajectory angle, deg
Δ	= incremental value
λ_G	= geometric porosity, %
ρ	= air density, slugs/ft^3

Subscripts

a	= ambient
b	= flotation bag
c	= vehicle nose cone base
f	= filling time
F	= lid fire
i	= impact
o	= at upward ejection
T	= total
1	= first-stage parachute
2	= second-stage parachute

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Index categories: Deceleration Systems; Entry Vehicle Testing, Flight and Ground.

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Introduction

THE Interim Recovery System (IRS) is being developed to recover ballistic missile nose cones. For the IRS, recovery is initiated at about 22,000 ft. The system is similar to the Nose Recovery Vehicle (NRV) described in Refs. 1 and 2; each had three stages: mass jettison, a 19 in. diam ribbon parachute, and a 3 ft diam guide surface parachute with a flotation bag. The deployment dynamic pressure has been raised from 2400 lb/ft^2 in the NRV to 9000 lb/ft^2 in the IRS. This is possible by using Kevlar-29 material[3] to construct the ribbon parachute and its attachment bridle as well as the suspension lines and the attachment bridle of the guide surface parachute. This report describes the parachute system design and its testing.

Recovery System Concept

The IRS is patterned after the NRV system, i.e., at an altitude of about 22,000 ft; and after the vehicle has passed through a typical re-entry environment, the first deceleration is achieved at about Mach 14 by jettisoning 63% of the 140 lb re-entry mass of the vehicle. The goal was to start parachute deployment at an altitude of about 3300 ft when the vehicle with its recovery system would weigh 57 lb. Figure 1 illustrates the sequence of deployment.

Parachute System Design

First-Stage Parachute

The 19 in. diam first-stage ribbon parachute (Fig. 2) is similar to that of the NRV[1] except that it is made entirely of Kevlar-29, a new synthetic aramid that has a strength to weight ratio of 2.6 times that of nylon. The 20 deg conical parachute has 12 suspension lines made of braided Kevlar-29 with a rated strength of 2000 lb. Its body is made of 15 horizontal, continuous ribbons rated at 550 lb. Table 1 gives detailed specifications. An over-inflation line 48 in. long, made of 2000 lb braided Kevlar-29, was tacked with two turns of five-cord Kevlar-29 thread wherever the suspension lines intersected the skirt band. The parachute, with overinflation line, weighs 9.4 oz.

Bridle and Swivel

The first-stage parachute is attached to the vehicle with a two-leg bridle made from a spliced loop of braided Kevlar-29 cord with 10,000 lb tensile strength (Fig. 3). The installed spliced loop is 44 in. long. The parachute is connected to the bridle with a swivel.† For efficient aerodynamic operation, the skirt is located five cone-base diameters downstream from

†The swivel (Sandia Drawing No. R-03916) was designed by R. D. Fellerhoff, 1324, for a load of 18,000 lb.

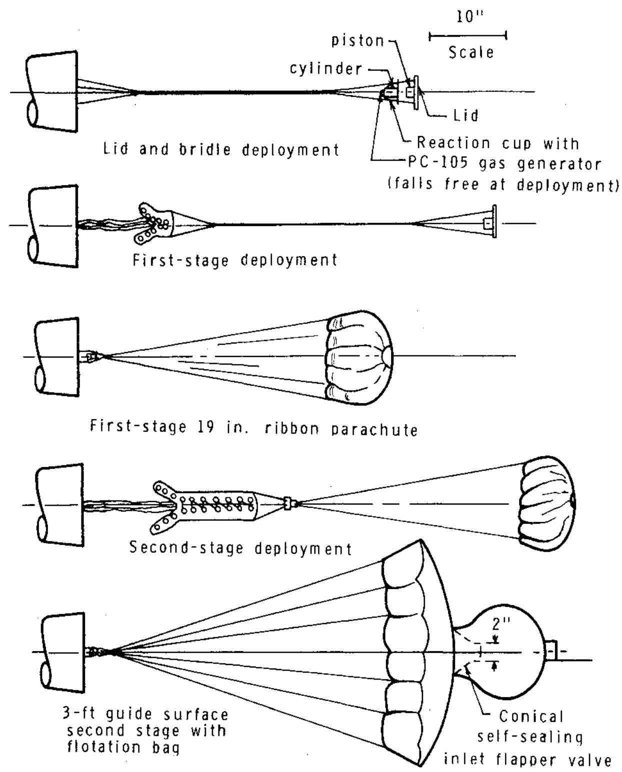

Fig. 1 Sketch of IRS parachute system operation.

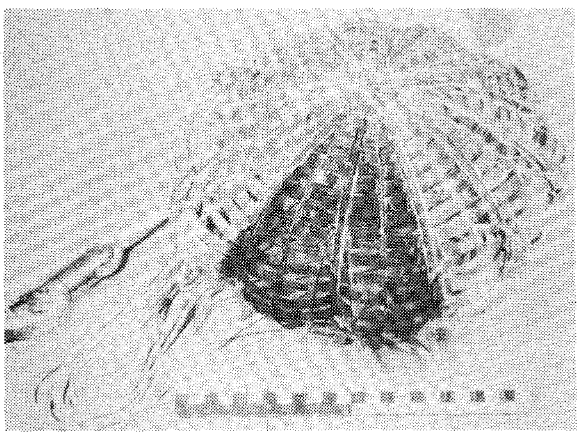

Fig. 2 First-stage 19 in. diameter parachute after deployment at $q = 7076$ lb/ft^2 (Mach 2.5).

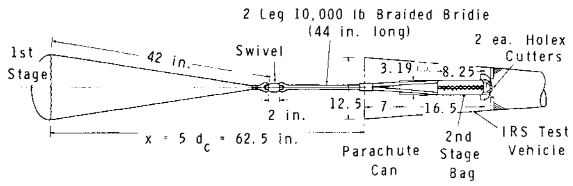

Fig. 3 First-stage bridle arrangement.

the nose cone base. The maximum tensile strength of the parachute is 18,000 lb (Table 2).

Interstage Cutter

The bridle and attachment arrangement (Fig. 3) allows either of two Holex 5801 cable cutters to release the first-stage parachute. In the tests the cutters were fired by an electrical signal from a timer 2.1 s after the first-stage deployment was initiated by firing the parachute lid cover. The cutters were held in place on the forward load plate by a rubber-cushioned bracket; the cutters had been tested at 1250 g with a 12 ms pulse length to simulate mass jettison.

Table 1 Parachute specifications for IRS

	First stage	Second stage
Type of parachute	Ribbon (continuous)	Guide surface
Constructed diameter, in.	19	36
Cone angle, deg	20	0
Number of gores	12	12
Suspension line strength, lb	2000	400
Braided, Kevlar-29		
Length, in.	42	36
Number of horizontal ribbons, ½ in. wide	15	...
MIL specifications, Kevlar-29	Type I, Class 2	...
Strength, lb	550	...
Number of verticals per gore	3	...
Braided, Kevlar-29		
Strength, lb	2×400	...
Canopy cloth strength, oz/yd^2	...	1.6
Vent diameter, in.	2.0	6.68
Skirt and vent band[a]	2×550	
Flotation bag, 1.75 ft^3	...	
Diam, ft	...	1.5
Fabric, 3.3 oz/yd^2 nylon twill coated with polyurethane		140 lb/in.
Sandia Drawing No.	T41328	T41341

[a] Same as horizontal ribbons.

Table 2 Tensile tests of IRS components

	Failure load, lb
First-stage lid-to-bag bridle	3400
First-stage bridle	18,000
First-stage parachute suspension lines	19,000
First-stage parachute swivel	18,000+
Second-stage parachute suspension lines	4100
Second-stage swivel	6200
Second-stage bridle	~6400
Flotation bag proof-tested to 5.5 psi	

Second-Stage Parachute

The second-stage parachute shown at the bottom of Fig. 1 is a ribless guide surface design 3 ft in diameter, having 12 suspension lines, each 3 ft long and made of 400 lb tensile strength, braided Kevlar-29 cord. The canopy is made of 1.6 oz/yd^2 nylon cloth (specifications are in Table 1). The parachute weights 9 oz. The suspension lines test to a failure load of 4100 lb.

Bridle and Swivel

The second-stage bridle is made of a sewn, continuous loop 9/16 in. wide tubular Kevlar-29 with a tensile strength of 4000 lb. Its finished length is 47 in. The skirt is located five nose cone-base diameters behind the vehicle base. The bridle tests to a failure load of ~6400 lb.

The second-stage swivel, called the Saguaro‡ type, tested to a failure load of 6200 lb, at which point the main shaft broke.

‡The Saguaro program was the first effort by Sandia to recover a high-altitude rocket payload at sea. The swivel used for the IRS second-stage is from the Saguaro design (Sandia Drawing No. N12476).

Table 3 Rigging specifications for IRS

	Breaking strength, lb
First stage (19-in. ribbon)	
Vent break cord	100
Canopy ties, 3 ea, 1 turn of FF size Kevlar thread (3 places)	60 ea
Canopy locking spider	...
Line ties, 7 ea, size 4 cord	36
Bag lacing	330
Overinflation line (48 in. long) tacked 12 places with 2 turns of 5 braided cord Kevlar	2000
Second stage (3-ft guide surface)	
Vent break cord FF nylon	16
Canopy tie, 1 turn of 3 size cord nylon	24
Line ties, 12 ea, 1 turn of 3 size cord nylon	24
Lid bridle (3 leg) each leg double 1500-lb Kevlar, 9/16 in. wide	1500 × 6
Second-stage bridle (2 leg)	4000 × 2
Lid bridle ties, 7 places of E size thread	8.5
Lazy leg for bag extraction (2 legs at 8 in.)	1500
Bag lacing	330

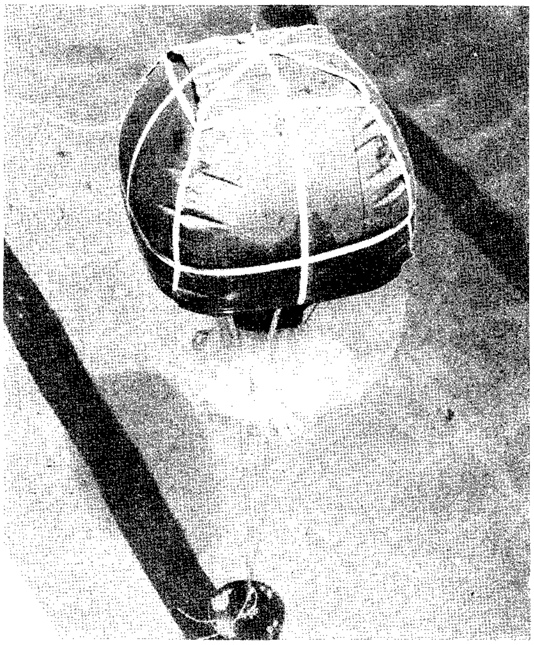

Fig. 4 18 in. diameter ram air-filled flotation bag.

Table 4 IRS component weights

		Weight, oz.
19-in. ribbon parachute		9.5
Felleroff swivel		10.0
Bridle, 10,000-lb braided Kevlar-29		7.5
Bag (5-in. long) 40-in.^{3}		
Lid bridle		6.0
Static cutters, lanyards, lacing		1.83
		~33.93
Packed 19-ft ribbon parachute	2.2 lb	
Deployment system		
Tail cover (with 3 lugs)		12.3
Thrust cup		1.1
Gas generator		0.5
Aluminum cap		0.1
		~14.0
3-ft guide surface		6.4
Bag (8.25-in. long) 66 in.^{3}		6.0
Swivel		5.0
1.75-ft diameter flotation bag		11.0
Static cutters (6 ea) and lacing		2.0
Holex No. 5801 cutter (2 ea)		2.0
Bag lacing		0.31
		~32.35
Packed 3-ft guide surface	2.0 lb	
Total weight	4.2 lb	

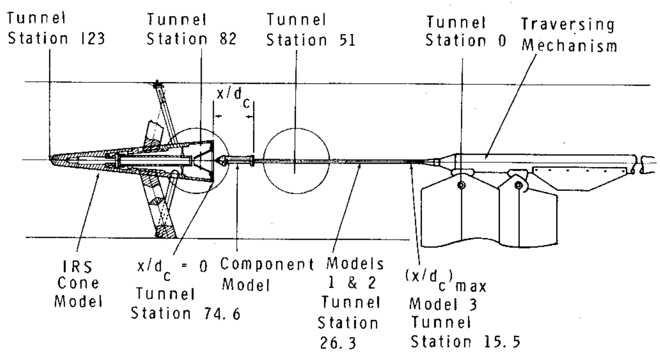

Fig. 5 IRS model in Vought 4 × 4 ft supersonic wind tunnel.

Deployment Method

The mass jettison system is similar to that of the NRV system.[2] The parachute can, shown in Fig. 3, is the inner of two telescoping tubes which are forced apart by firing a large gas generator. This generator is attached to the aft end of the outer tube which is part of the jettisoned mass. Several seconds after the mass is jettisoned, the lid of the parachute can is ejected (uppermost sketch, Fig. 1) at a velocity of about 125 ft/s, relative to the nose cone. A PC-105-2 gas generator ejects this lid by means of the piston and cylinder arrangement described in Fig. 1. The firing cable connects the PC-105-2 to the firing timer through a steel tube that has an elliptical cross section. The tube is cemented permanently in place to the inside wall of the parachute can. The firing cable passes through a sharp cut knife screwed to the tail cover. As the tail cover moves aft, the knife severs the firing cable. The three-leg bridle attached to lugs on the tail cover (Fig. 1) picks up the reaction cup, extracts it from the parachute can, and leaves a smooth wall for clean parachute extraction. Before ejection the lid is held in place by six No. 6 brass screws which require 2000 lb of force to shear.

Packing and Rigging

Both packing bags are of the two-leaf design, made of Kevlar-29 webbing and cloth. During packing, the two leaves are laced together with 375 lb nylon cord. Material descriptions for the bags are given in Sandia Drawing T-45333; materials used in packing are given in Table 3.

Parachute System: Weight and Volume

The first-stage parachute, with bag and bridle, weighs 2.2 lb and is packed to an unusually high density of 50 lb/ft^3, without considering the swivel weight. The highest peak density that has been achieved with a Kevlar-29 parachute was 55 lb/ft^3, by using a two-leaf bag and lacing the two leaves together as was done for these two packs. The second-stage parachute pack weighs 2.3 lb and is packed to a density of 62 lb/ft^3, including the swivel weight (component weights are listed in Table 4). The entire parachute system weighs 4.2 lb, 3% of the 140 lb total vehicle weight. The NRV system, which is made of nylon, weighs 5.3% of the total vehicle weight. Kevlar-29 has not only increased the maximum allowable dynamic pressure but has also reduced the weight percentage.

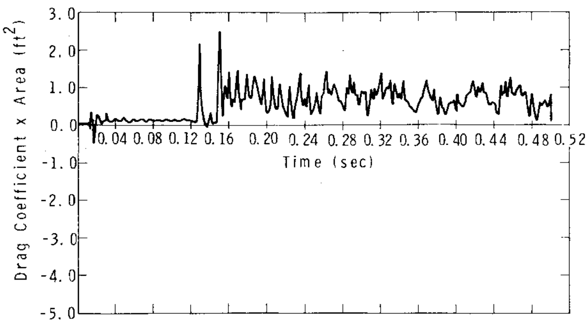

Fig. 6 19 in. diameter ribbon parachute drag area for Mach 2.5.

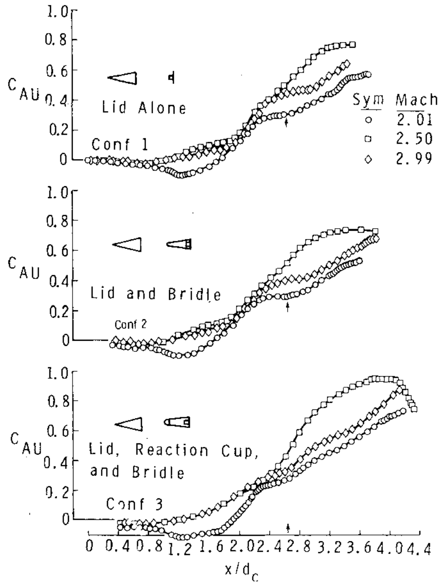

Fig. 7 Lid drag coefficient as a function of distance behind IRS vehicle.

Drop Tests on Water

On Dec. 14, 1977 two drop tests were made from a Beaver airplane over Conchas Lake in northeastern New Mexico. Release was at about 70 knots true air speed (TAS) and 1500 ft above the lake which is 4200 ft above sea level. The 52.5 lb test vehicle nose cones descended on the 3 ft diam guide-surface, second-stage parachutes each equipped with a 1.75 ft^3 ram air-filled flotation bag, pressure-tested to 5.5 psi. A vertical web welded into the spherical bag divided it into two equal compartments, either of which can float the payload. Both tests were successful; the bags floated about two-thirds out of the water similar to the swimming pool test (Fig. 4). The first system dropped was new; the second had previously been tested on a captive sled, at the maximum dynamic pressure of 400 lb/ft^2 for which it had been designed. On both Conchas Lake tests, two adjacent suspension lines of 400 lb tensile strength failed at the confluence point. This is considered minor damage at this water entry velocity calculated to have been 93 ft/s since at sea level the water entry velocity will be 85 ft/s.

Wind Tunnel Tests[4]

In August 1976, the IRS was tested in the Vought 4 × 4 ft High-Speed Blowdown Wind Tunnel. The full-scale IRS vehicle (Fig. 3) was suspended by diamond-shaped cross-section struts (Fig. 5). Test conditions in the tunnel were generally Mach 2.5 ($q = 1500$ lb/ft^2). PC-105-2 explosive gas generators deployed the lid and the first-stage ribbon parachute (Fig. 1). Parachute drag was measured with a strain gage balance having a maximum capacity of 7400 lb. The

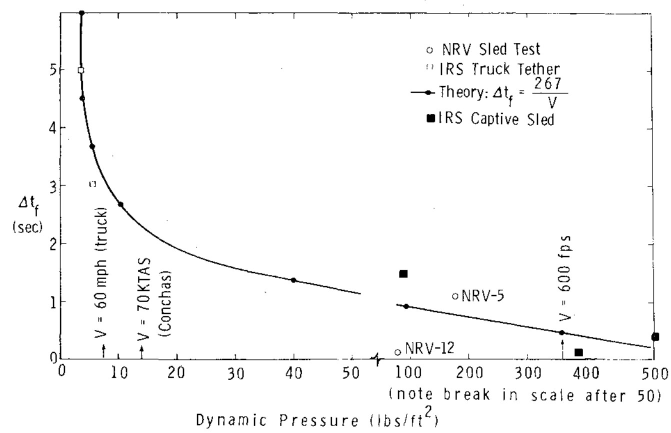

Fig. 8 Flotation bag filling time as function of dynamic pressure at deployment (note break in scale after 50).

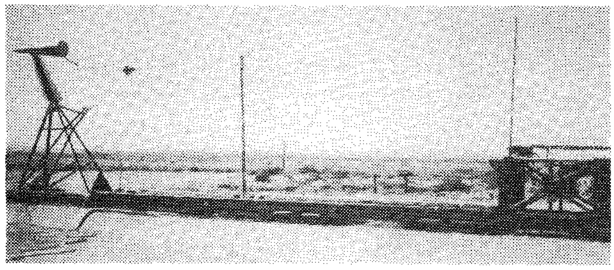

Fig. 9 Sled with nose cone captive on strut.

parachute was located between three and six body diameters aft of the body. The highest average drag was obtained from the configuration $x/d_c = 5$, $\lambda_G = 14\%$ (like sled test No. 5). Figure 6 shows the drag area variation with time for this best performing configuration. The average drag coefficient is 0.4 based on the constructed disk area of the 19 in. diam parachute. (Parachutes with porosities, or openings, of 8, 10, and 14% of total area were tested.)

The deployment drag of the lid was also measured (Fig. 7) by a strain gage balance that was mounted in a sting that traverses the wake centerline (Fig. 5). The stretch position of the bridle line is 2.64 base diameters aft of the vehicle. This is where the lid must start extracting the parachute pack of the first stage and where the lid measures a drag coefficient of 0.3 or greater.

Flotation Bag Filling Tests

Figure 8 illustrates how the time for filling the flotation bag varied with the dynamic pressure when the second-stage 3 ft guide, surface parachute was deployed. In this figure, the theoretical curve is based on the flow equation,

$$\frac{\Delta m_b}{\Delta t_f} = 32 F \rho A V \qquad (1)$$

where F is the flow coefficient for the parachute. Solving for the filling time and assuming a flow coefficient of $F = 0.3$, which includes decrease of velocity in the wake of the nose cone and an orifice coefficient,

$$\Delta t_f = 32 \frac{\Delta m_b}{F \rho A V} \qquad (2)$$

where

$$v_b = 4/3\pi (0.75)^3 = 1.75 \text{ ft}^3 \qquad (3)$$

and

$$\Delta m_b = 32 \rho v_b = 32(0.002)(1.75) = 0.112 \text{ lb} \qquad (4)$$

Table 5 Captive sled test results

Test No.	Test date	V_2, ft/s	q_2, lb/ft^2	F_{max}, lb	C_DS_2, ft^2	x/d_c	Results
1	10/12/77	...	1200	...	...	3	3-ft guide surface lines failed
2	10/24/77	490	480	1408	...	3	Parachute squidded
3	12/09/77	630	400	2470	5.44	5	Successful design q test
4	1/06/78	706	500	2970	5.5	5	Successful 25% overtest
5	1/16/78	310	95	636	5.5	5	Successful, no damage, minimum q

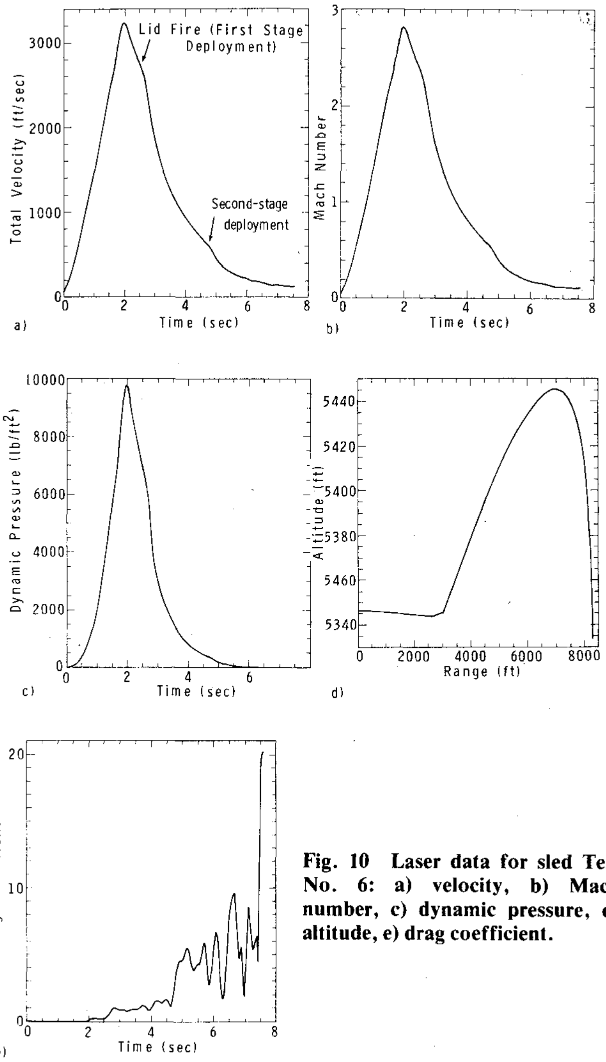

Fig. 10 Laser data for sled Test No. 6: a) velocity, b) Mach number, c) dynamic pressure, d) altitude, e) drag coefficient.

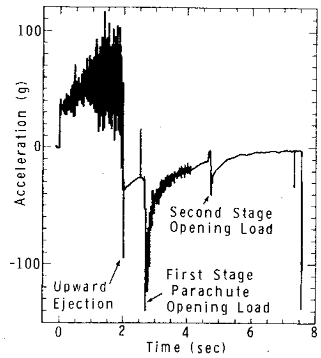

Fig. 11 Acceleration from telemetry for Test No. 6.

and substituting in Eq. (2),

$$\Delta t_f = \frac{0.112}{0.3(32\times 0.002)}\left(\frac{1}{12}\right)^2 V \tag{5}$$

$$\Delta t_f = \frac{267}{V}\,(\text{s}) \tag{6}$$

The second-stage parachute with its ram air-filled flotation bag was tethered to a panel truck and towed at 40 and 50 mph. Filling times obtained match the theory reasonably well. The IRS flotation bag filling times should be between 0.5 and 1.0 s over the anticipated operational range for dynamic pressure of 100–400 lb/ft^2, similar to the NRV data.

Captive-Sled Tests

Five captive-sled tests were conducted to optimize the design of the second-stage parachute and the flotation bag. The sled with the nose cone captive on a strut attached to the sled is shown in Fig. 9 and test parameters are listed in Table 5. In the first test, the parachute and flotation bag had already been deployed when the rocket fired. This test was performed to determine which component would fail. It turned out to be the suspension lines which failed at a dynamic pressure of 1200 lb/ft^2. For subsequent tests, the parachute with flotation bag was deployed at the dynamic pressures shown in Table 5. In the second test, when the parachute skirt was located three cone-base diameters behind the cone, the parachute did not inflate normally. The skirt was then moved back to five diameters for the remaining three tests and this action resulted in good inflation. In test No. 3, the system was tested at a pressure of 400 lb/ft^2, the maximum for which it was designed. Next, it was overtested by a factor of 25% at a dynamic pressure of 500 lb/ft^2. The 1.6 oz/yd^2 nylon tore somewhat at the radial seams, indicating that the parachute was about to fail. The fifth and last test was successful at the minimum pressure of 100 lb/ft^2. On the last three tests, the flotation bag was not damaged and it was filled properly by the ram air valve.

Sled Launched Free-Flight Tests

Sandia Laboratories at Albuquerque (SLA) has a dual-rail, sled track that is 1 mile long. It was used for 10 development tests of the interim parachute recovery system. In these tests, the 57 lb nose cone is ejected upward from the sled by a piston that is powered with compressed gas. The ejection velocity is about 120 ft/s. A half second afterward, the tail cover is ejected by the PC-105-2 explosive gas generator and the first-stage ribbon parachute is deployed. Results from the 10 sled tests are listed in Table 6 (see also Table 7). A laser tracker determined velocity, Mach number, dynamic pressure, altitude, range, and drag area (Fig. 10). A telemetry system in the sled was used to obtain longitudinal acceleration (Fig. 11). The first stage parachute is shown in Fig. 2 after deployment at Mach 2.5 and a dynamic pressure of 7076 lb/ft^2. The canopy had a permanent set to the inflated shape from the aerodynamic heating and loads but was relatively intact.

System Performance

First-Stage Loads

Figure 12 shows the maximum first-stage loads measured by telemetry as a function of dynamic pressure at the time the

Table 6 Sled launched free-flight test results

No.	Test date	W_T, lb	V_0, ft/s	x/d_c	ρ, slugs/ft³	Δt_F, s	1st-stage deploy M_1	V_1, ft/s	q_1, lb/ft²	g_{max}, g's	2nd-stage deploy V_2, ft/s	q_2, lb/ft²	g_2, g's	Impact γ_i, deg	V_i, ft/s	R_i, ft	*	Comments
1	3/24/76	52.8	2,346	3	0.001915	2.9	1.68	1,902	3,468	43	NA	NA	NA	−15	238	5,132	S	No second-stage deployment; battery was low.
2	4/28/76	67.2	3,000	3	0.001919	2.9	2.24	2,540	6,154	NA	NA	NA	NA	−5	1,000	8,800	D	Lid reaction cup failed; unit went free-flight.
3	6/09/76	~65	(2,950)	3	ND	2.9	(2.2)	(2,500)	(6,000)	NA	NA	NA	NA	ND	ND	ND	D	Explosive bolt wires failed; no upward ejection.
4	7/07/76	55.75	2,779	3	0.001859	2.9	1.93	2,222	4,545	65	703	455	28	−9	571	6,726	S	Second-stage bridle (2-×1500-lb nylon) failed.
5	7/30/76	56	3,182	5	0.001877	2.9	2.45	2,690	6,789	133	426	170	22	−18	137	5,509	S	...
6	8/31/76	57	3,246	5	0.001885	2.1	2.5	2,740	7,076	140	656	405	40	−23	134	5,563	S	Used flotation bag—failed.
7	10/06/76	57	3,804	5	0.001929	2.1	2.9	3,181	9,760	NA	NA	NA	NA	ND	ND	ND	D	Unit went free-flight; not enough lid velocity.
8	11/06/76	57	2,360	5	0.001971	2.1	1.8	1,968	3,817	ND	NA	NA	NA	ND	ND	ND	S	Only 2 of 3 Javelin rockets fired. 2nd stage didn't deploy. Antenna lead failed.
9	12/24/76	57	3,670	5	ND	2.1	2.74	3,000	9,000	180	680	462	20	ND	120	ND	S	Flotation bag came off.
10	3/07/77	67	4,000	5	J.001987	2.1	3.3	3,600	12,875	ND	NA	NA	NA	ND	ND	5,200	S	Shrapnel knocked TM out.

S = Successful, unit recovered. D = Unit destroyed. (Diget) = Desired conditions. NA = Not applicable. ND = No data. Δt = Time delay from lid fire to Holex cut.

Table 7 Drag area time function for final IRS design

Time from lid fire, s	$C_D S$, ft²
0	0.23
0.12	0.23
0.255	1.30
1.90	1.30
1.91	0.30
2.0	0.30
2.10	6.0
1000.0	6.0

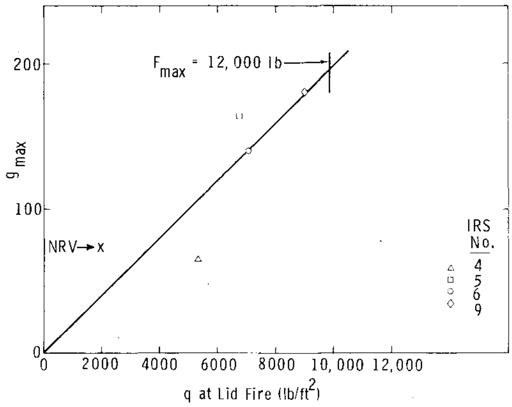

Fig. 12 Variation of first-stage peak deceleration with dynamic pressure at lid fire.

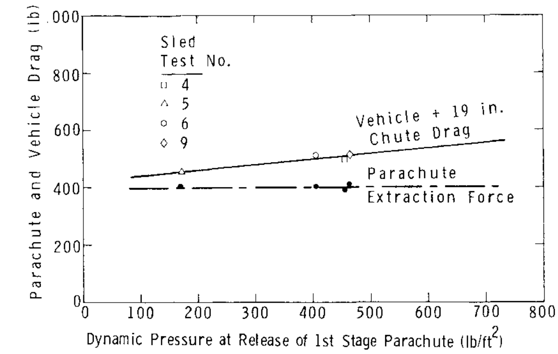

Fig. 13 Extraction force at deployment of second-stage parachute.

lid is fired. The maximum load expected is 12,000 lb at a dynamic pressure q of 10,000 lb/ft². The weakest link in the first stage is the bridle which has a failure value of 18,000 lb, thus providing a safety factor of 1.5; it was designed for a dynamic pressure of 10,000 lb/ft².

Disconnect Loads

Figure 13 shows the 19 in. parachute load that is available to extract the second-stage pack after the Holex cutter severs the bridle. The extraction force of the release parachute is a constant 400 lb over the tested dynamic pressure range. A static deployment test using a free-falling 100 lb weight deployed both stages successfully. Loads measured by a load cell during this deployment peaked at 150 lb, indicating that the system has a safety factor of 2.7.

Second-Stage Loads

The second-stage parachute was designed for deployment at a maximum dynamic pressure of 400 lb/ft². Figure 14 shows peak opening deceleration of the second-stage parachute as a function of dynamic pressure at the start of second-stage deployment. The maximum deceleration in the sled tests was

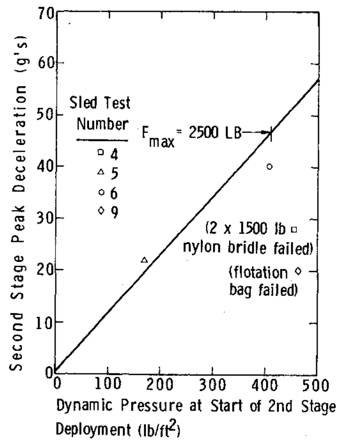

Fig. 14 Second-stage 3 ft guide surface parachute deceleration.

40 *g* (2200 lb) which provides a safety factor of 2.9; the bridle is rated for a load of 6400 lb. The maximum deceleration for the fourth and ninth tests is lower than the mean curve shown in Fig. 14 because the bridle in the fourth and the flotation bag in the ninth failed, opening the canopy vent area.

Aerodynamic Heating

When the Mach number rises above 2.0 during deployment, aerodynamic heating becomes an important factor. Kevlar-29, used in the first-stage parachute, has the advantage of being much more resistant to aerodynamic heating than nylon; it has 50% strength retention at a temperature of 550°F which is reached at Mach 2.25. There was evidence of aerodynamic heating on the first-stage parachute during the sixth test when the Mach number reached 2.5 and the stagnation temperature was 665°F. The melting point of nylon is 475°F and, indeed, the nylon splice wraps did show some melting. However, there were no structural failures due to aerodynamic heating.

Conclusions

Ten free-flight parachute deployment tests were conducted, using the sled and track in Area III at Sandia Laboratories, Albuquerque, N. Mex. Performance parameters were determined for a 19 in. diam first-stage ribbon parachute made of Kevlar-29 with a 3 ft diam guid surface, second-stage parachute that has suspension lines made of Kevlar-29. The recovery system is designed to recover a 57 lb re-entry vehicle. From this study it was determined that the system is qualified for first-stage parachute deployment over a dynamic pressure range of 800–9000 lb/ft².

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References

[1] Pepper, W.B., "Development of a Parachute Recovery System for a Reentry Nose Cone (NRV)," SAND 75-0564, Sept. 1977.

[2] English, E.A., "Nosetip Recovery Vehicle Postflight Development Report," SAND75-8059, Jan. 1976 (unlimited release).

[3] Pepper, W.B., "Preliminary Evaluation of Kevlar-29 Versus Nylon by SLAP/TV Free-Flight Deployment Tests of 12.5-ft Diameter Ribbon Parachutes," AIAA Paper 79-0416, A Collection of Technical Papers, AIAA 6th Aerodynamic Decelerator and Balloon Technology Conference, Houston, Tex., March 5-7, 1979.

[4] Pope, T.C., "Tests to Obtain Supersonic Deployment Data on Several Configurations of the Interim Recovery System Parachutes in the Vought High Speed Wind Tunnel," SAND76-7025, Nov. 17, 1976.