Engineering Notes

ENGINEERING NOTES are short manuscripts describing new developments or important results of a preliminary nature. These Notes cannot exceed 6 manuscript pages and 3 figures; a page of text may be substituted for a figure or vice versa. After informal review by the editors, they may be published within a few months of the date of receipt. Style requirements are the same as for regular contributions (see inside back cover).

Sounding Rocket Payload Recovery Systems

DONALD W. JOHNSON*
Sandia Laboratories, Albuquerque, N. Mex

THIS Note outlines the rocket payload recovery systems used by Sandia Laboratories. References 1–3 describe the early history and the design philosophy used for the recovery systems. These systems require control of the payload center-of-gravity location (45%–55% of body length at re-entry) to insure that the payload assumes a high drag configuration during and after re-entry.[3] Deployment of the recovery system is initiated at 15,000 ft (4572 m) by a baroswitch closure which explosively separates a heat shield/deployment device from the payload and deploys the first-stage parachute. The first parachute stabilizes the payload and reduces the payload velocity so the second-stage parachute and flotation gear can be deployed without damage. All of the recovery systems listed in Table 1 utilize dual flotation capability and include at least two active location aids.

Recent systems have eliminated the use of a CO_2 inflated bag. A one-way valve is inserted in the mouth of the ram air-inflated flotation bag to prevent the air from escaping, as shown in Fig. 1.

When the pressure inside the bag exceeds the pressure outside (no inward flow), the valve collapses to its flat condition and seals the inlet to the bag. In addition to the valve, a divider which separates the flotation bag into two compartments is included. This retains the redundant flotation capability. Elimination of the CO_2 bottle and plumbing has greatly increased the packing efficiency of the recovery systems.

Recently, the development of a recovery system capable of recovering payloads weighing up to 1000 lb (454 kg) was initiated.

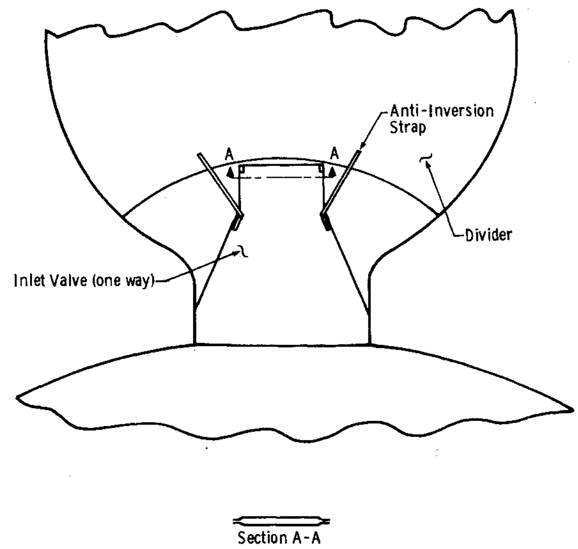

Fig. 1 RAM air-inflated flotation bag inlet valve.

The program is funded jointly by the U.S. Atomic Energy Commission, NASA Goddard Space Flight Center, and the German DFVLR organization. Since one of the goals of the program is to place minimum restriction on the payload center-of-gravity location, a maximum dynamic pressure of 1000 psf (47.9 kN/m^2) at the 15,000-ft (4572-m) deployment altitude was chosen as the design criteria. It is reasoned that these criteria were sufficient for the recovery of most payloads and still did not require an unreasonably heavy first-stage decelerator. The effective drag area ($C_D A_{eff}$) to weight ratio required to not exceed the design criteria is shown in Fig. 2 as a function of apogee

Table 1 Recovery systems parameters

Configuration system	Date, first flight test	Maximum payload weight (lb)	Maximum impact velocity (fps)	1st stage chute diam (ft)	2nd stage chute diam (ft)	Flotation bag volume: Ram air (ft^3)	Flotation bag volume: CO_2 (ft^3)	Packed system: Volume (in^3)	Packed system: Weight (lb)
1, 2, 2.1	7/67	275	80	3.5[a]	8	7	3.5	900	16
1a, 2a, 2.1a	9/67	325	30	3.5[a]	24[b]	...	...	900	17
3	6/69	500	70	4[a]	12[a]	14	7	1420	27
3a	7/72	375	27	4[a]	28[b]	...	...	1420	22
4	10/71	375	60	4[a]	12[a]	7	3.5	1190	23
5	8/70	125	70	2[a]	6[a]	3.5	...	470	8
5a	12/72	125	22	2[a]	20[a]	...	...	470	8
6	11/71	200	75	3[a]	7[a]	5.8	...	500	9.5
7	10/72	1000	50	8[c]	24[d]	35	...	2400	40

[a] Ribless guide surface.
[b] Flat circular.
[c] Conical ribbon.
[d] Personnel guide surface.

Presented as Paper 73-305 at the AIAA 3rd Sounding Rocket Technology Conference, Albuquerque, N. Mex., March 7–9, 1973; submitted March 29, 1973; revision received January 17, 1974. This work was supported by the U.S. Atomic Energy Commission.
Index categories: Sounding Rocket Systems; Entry Deceleration Systems and Flight Mechanics (e.g., Parachutes).

* Member of Technical Staff, Deceleration and Recovery Systems Div., Aerodynamics Projects. Associate Fellow AIAA.

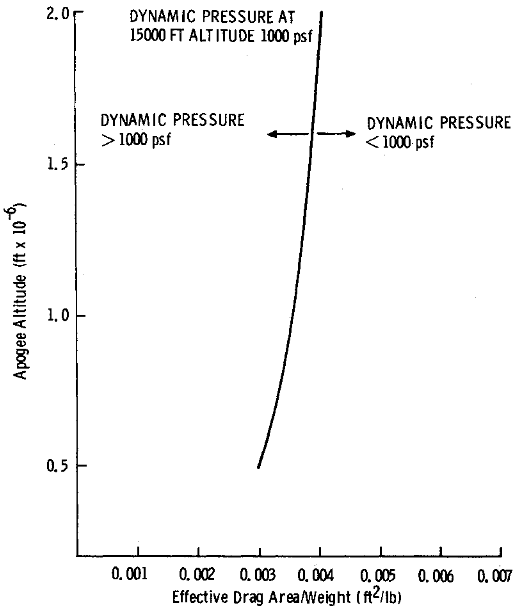

Fig. 2 Effective drag area required to obtain recovery system deployment conditions.

altitude. This curve indicates that the required $C_D A_{eff}$ should not be very restrictive on payload design.

To avoid imposing high acceleration on the payload during recovery, 10,000 lb (44.5 kN) was chosen as the maximum load to be developed by the recovery system. Consideration of payload kinetic energy to be absorbed by the recovery system at water entry led to a design impact velocity of 50 fps (15 mps) for a 1000-lb (454-kg) payload. From these criteria, a trajectory analysis was conducted which resulted in the drag-area time schedule shown in Fig. 3. The resulting velocity and dynamic pressure vs time curves are shown in Fig. 4.

An 8-ft (2.4-m)-diam conical ribbon parachute was chosen as the first-stage decelerator. To control the maximum load developed, the parachute is reefed to 35% of the full open drag area for 10 sec. Main chute deployment occurs 24 sec after the initiation of the recovery system at a dynamic pressure of 41 psf (1963 N/m^2).

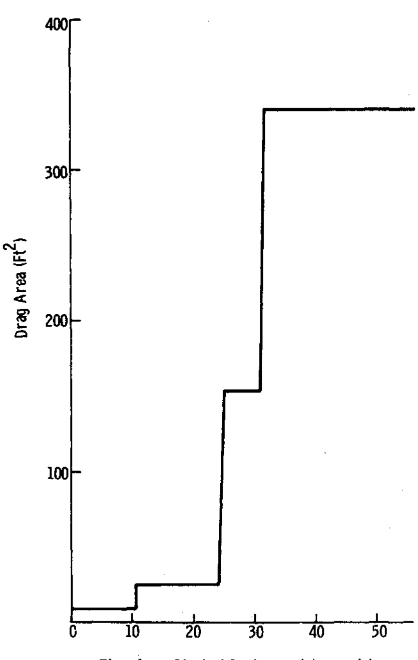

Fig. 3 Drag area schedule—Sandia Mod 7 recovery system.

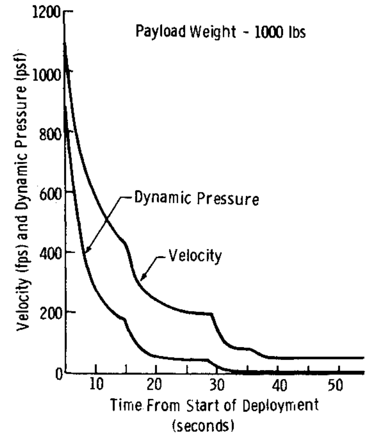

Fig. 4 Theoretical velocity and dynamic pressure vs time for Mod 7 recovery system.

Previously designed recovery systems have used stable ribless guide surface parachutes in conjunction with ram air-inflated flotation devices. In that ribless guide surface parachutes of the size required for this system are expensive and difficult to make, a personnel guide surface was selected as the second-stage decelerator. This parachute has reasonable stability ($\pm$10 to 15°) and still maintains the solid canopy necessary to inflate ram air flotation devices at low canopy loadings. The parachute has a nominal diameter of 24 ft (7.3 m) and is reefed to 45% of the full open drag area for 6 sec to control the load.

Because a 750-lb (3336-N) minimum buoyant force is required, a 35-ft^3 (1-m^3) ram air-inflated flotation bag with a divider and a one-way inlet valve is attached to the vent of the 24-ft (7.3-m)-diam parachute. Location aids are attached to the top of the flotation bag.

Four drop tests of the recovery system were conducted: two on the AEC range at Tonopah, Nev., and two into water off Wallops Island, Va. The first test used a stable vehicle to obtain a dynamic pressure of 440 psf (21 kN/m^2) at start of deployment. The dynamic pressure at deployment of the 24-ft (7.3 m) parachute was 42 psf (2011 N/m^2). The other three tests were conducted with an 18-in. (0.46-m) diam ogive-cylinder representative of a typical payload. The center-of-gravity of the test vehicle was varied between 52% and 68%. On one test at Wallops Island, the deceleration of the simulated payload at water entry was measured. These data indicate a maximum deceleration of 7 g's with a 150-msec rise time. Further testing is required to qualify the 8-ft (2.4-m)-diam parachute for deployment at a dynamic pressure of 1000 psf (47.9 kN/m^2). The system was also successfully tested on a ballistic flight launched from the AEC Kauai Test Facility in Hawaii on Oct. 25, 1972.

Conclusions

This Note outlines recent developments in sounding rocket payload recovery systems used at Sandia Labs. The systems, which have been used successfully on 96 rocket flights, permit reliable recovery of camera or other on-board data and recovery of expensive instruments, attitude control systems, and telemetry.

References

[1] Johnson, D. W., "A Recovery System for the Sandia Hawk Series of Sounding Rockets," SC-RR-65-470, Nov. 1965, Sandia Labs., Albuquerque, N. Mex.

[2] Johnson, D. W., "Evolution of the Recovery System for High Altitude Sounding Rockets," AIAA Paper 68-959, El Centro, Calif., 1968.

[3] Johnson, D. W., "Development of Recovery Systems for High-Altitude Sounding Rockets," *Journal of Spacecraft and Rockets*, Vol. 6, No. 4, April 1969, pp. 489–491.