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DEVELOPMENT OF A REUSABLE PARACHUTE TEST SYSTEM

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Abstract

A unique, reusable instrumented drop body has been designed for flight qualification testing of new, larger capacity parachute recovery systems for the Black Brant family of sounding rockets. Project duration and costs have been greatly diminished by utilizing a deployable ballast section. This ballast section, which is jettisoned after completion of the main parachute test phase, allows the remaining instrumented drop body to become buoyant in water and to be recovered by surface vessel. This enables economical testing using existing local NASA tracking facilities and personnel. The drop body, which is deployed from a NASA aircraft, contains an on-board video camera; self-contained and programmable triaxial acceleration sensors; and an on-board telemetry system for transmitting acceleration and housekeeping data to a ground station.

Introduction

A specially configured 17.26-inch (0.438-meter) diameter test body has been designed and developed for flight qualification testing of parachute systems used to recover NASA scientific payloads that are launched on unguided sounding rockets. Design requirements include a 13.0-inch (0.330-meter) diameter variable length parabay; on-board instrumentation to measure flight parameters; a minimum and maximum weight capability of 325 and 1500 pounds (147.4 and 680.4 kilograms), respectively; reusability; and deployability from existing NASA aircraft. Local NASA facilities track the drop body from aircraft ejection to impact in the Atlantic Ocean near Wallops Island.

The test body, designated Modified ORSA Recovery Test Instrument (MORTI), has been flown and recovered successfully three times. The MORTI test vehicle consists of a standard Black Brant Ogive Recovery System Assembly (ORSA), retrofitted to have a parabay length of 26.0 inches (0.660 meters); a sealed, watertight instrumentation and logic section; an externally mounted, watertight video camera housing; a 51-inch (1.295-meter) long flotation compartment; and a deployable ballast section. The overall length of the recoverable portion of the MORTI is 96 inches (2.438 meters).

The watertight instrumentation compartment contains (1) a self-contained and programmable triaxial acceleration recorder; (2) accelerometers and other housekeeping components that transmit data to a ground station through an on-board telemetry system; and (3) system logic. Ground based optical and radar tracking devices provide additional data.

The system is armed as it exits the aircraft. When passing through 11,000 feet (3.35 kilometers), the drogue plate (which extracts the reefed drogue parachute) is pyrotechnically deployed by a pressure sensing switch. The drogue disreefs 6 seconds later. The reefed main is extracted 14 seconds after initial drogue deployment.

The ballast section is dropped by a timer-activated pyrotechnic at approximately 2,000 feet (610 meters) above the water. The remaining portion of the drop body descends on the parachute until it impacts and

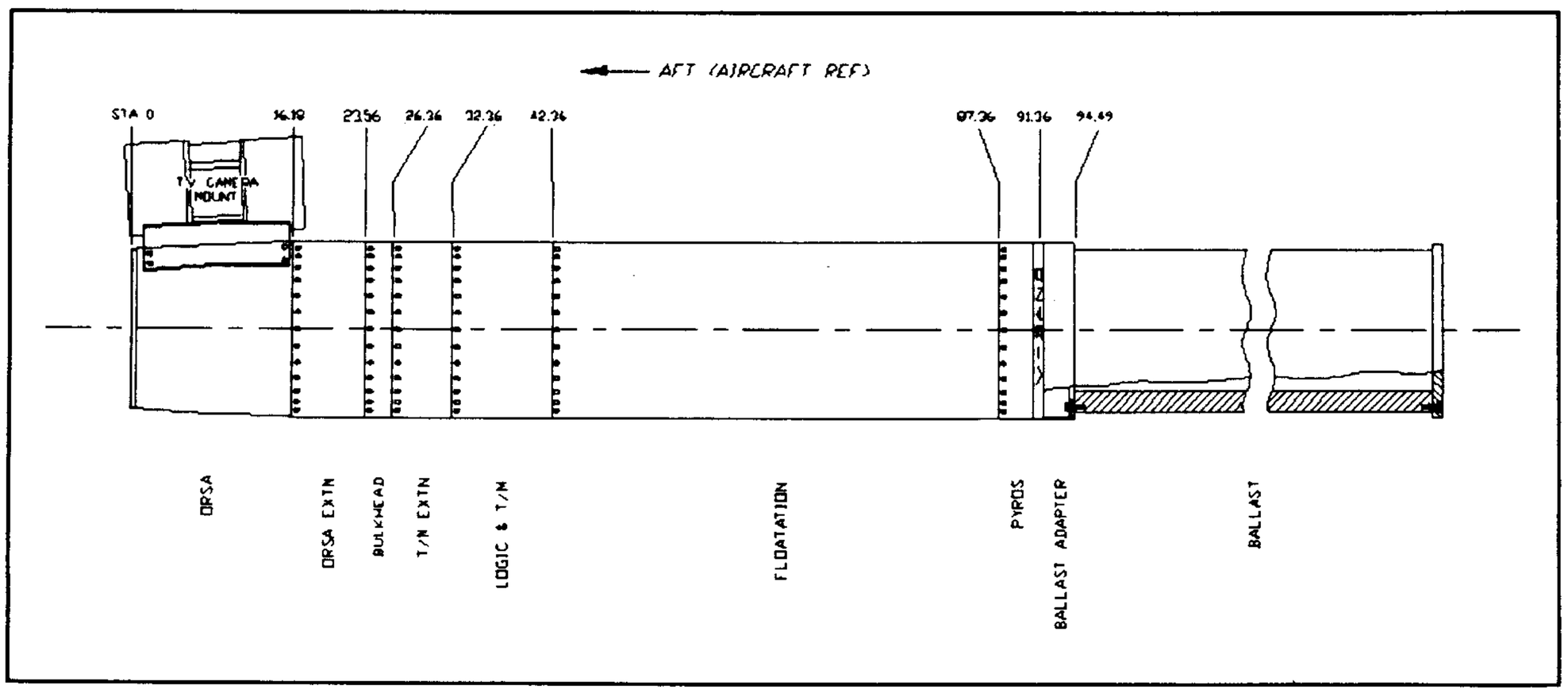


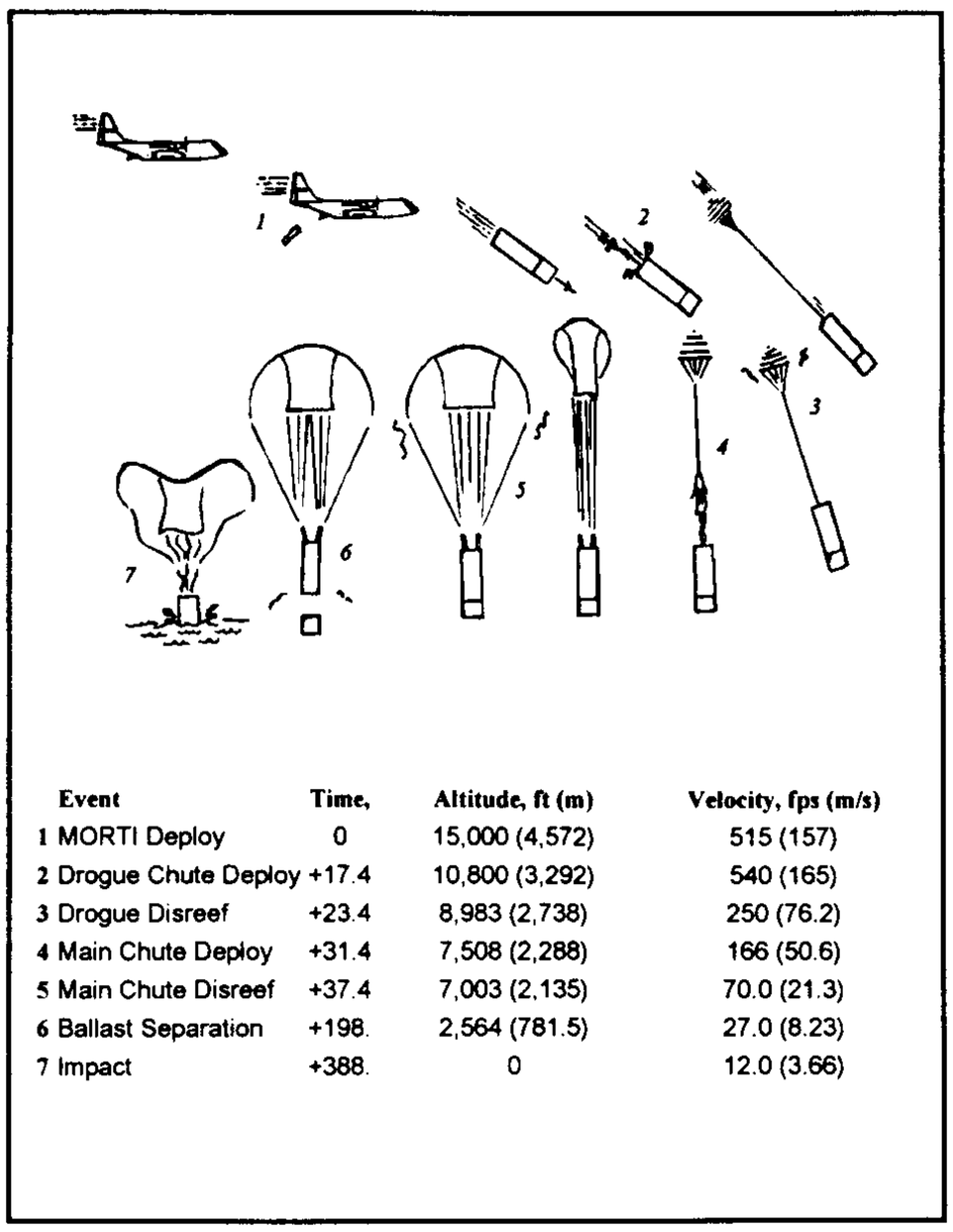
Fig. 1. MORTI Assembly Drawing

floats in the ocean. The MORTI test body, as described, has been successfully flown, recovered, refurbished, and reused three times.

Design and Development

Sounding rocket payloads have grown larger, heavier, more complex and more expensive. The maximum payload weight carried by the Black Brant family of sounding rockets has historically been 1000 pounds (454 kilograms). New parachute recovery systems are needed to accommodate payloads surpassing this limit. Flight qualification testing of these larger parachute recovery systems required a reusable, instrumented drop test vehicle. Economic factors dictated using existing local NASA tracking facilities and personnel. This required the test vehicle to be recovered after impacting in the Atlantic Ocean in the proximity of Wallops Island. The main design element that would enable test vehicle recovery was a deployable ballast section which could be jettisoned after completing the main parachute test phase. The remaining instrumented payload and expended parachute were designed with positive buoyancy so that they could float until recovery by surface vessel.

The test parachute system, which included both a drogue and main parachute, each reefed for 6 seconds, was carried to the point of parachute deployment by means of the MORTI drop test vehicle. The MORTI test body was carried aloft and deployed from a NASA P-3 or C-130 aircraft to an altitude which allowed the test vehicle to reach dynamic pressures ("q") of 250 pounds per square foot (11.97 kilonewtons per square meter) for drogue deployment in the altitude region of 11,000 feet (3.35 kilometers). Computer simulations which used the measured physical properties of each drop body (Figure 1) and aircraft limitations were used to determine the drop altitude required to achieve the desired test conditions. A typical sequence of events is given in Figure 2, while Figure 3 shows the drop altitude required to give the test conditions required for a drogue deployment in the altitude region of 11,000 feet (3.35 kilometers).



Event	Time,	Altitude, ft (m)	Velocity, fps (m/s)
1 MORTI Deploy	0	15,000 (4,572)	515 (157)
2 Drogue Chute Deploy	+17.4	10,800 (3,292)	540 (165)
3 Drogue Disreef	+23.4	8,983 (2,738)	250 (76.2)
4 Main Chute Deploy	+31.4	7,508 (2,288)	166 (50.6)
5 Main Chute Disreef	+37.4	7,003 (2,135)	70.0 (21.3)
6 Ballast Separation	+198.	2,564 (781.5)	27.0 (8.23)
7 Impact	+388.	0	12.0 (3.66)

Fig. 2. Sequence of Events, 1250 lb. Drop Test

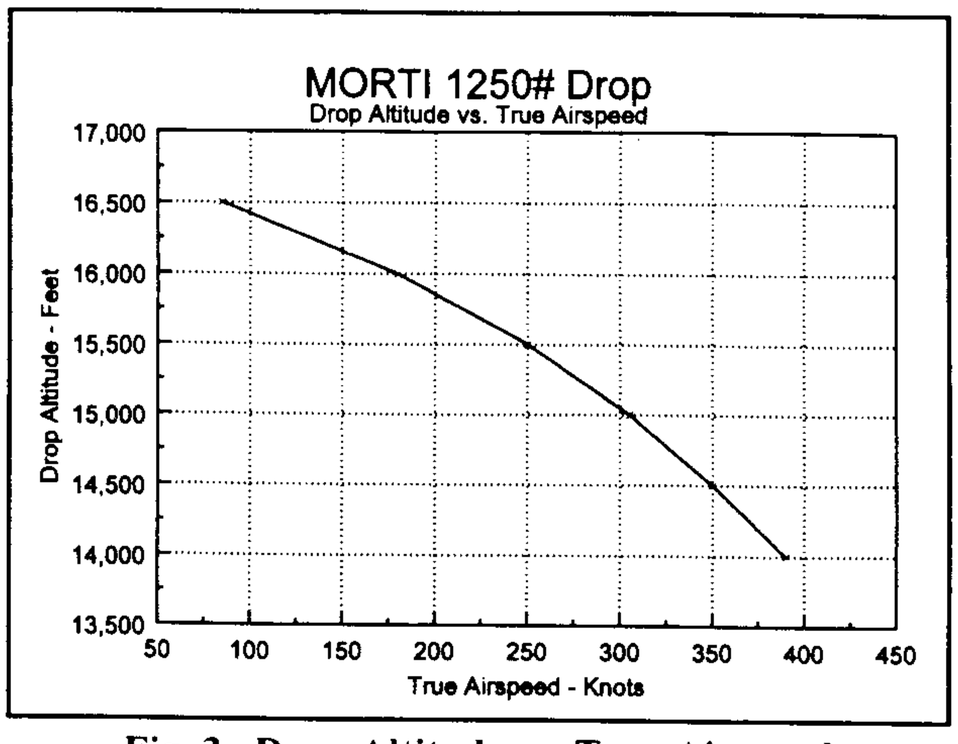


Fig. 3. Drop Altitude vs. True Airspeed

Figure 4 depicts the recoverable portion of the MORTI test vehicle. The payload sections, from top to bottom, are (1) a watertight compartment containing a HiRes 8 video camera, mounted to the exterior radius of (2) the ORSA; (3) a sealed logic and instrumentation section with an externally mounted wraparound telemetry antenna; and (4) a floatation compartment. A ballast section designed to provide specific physical properties for specific test conditions would be attached to the end of the flotation section with an adapter and a manacle ring. Detailed descriptions of each section follow.

The ORSA contains a 13-inch (0.330-meter) diameter parabay having a length of 26 inches (0.660 meters). During a drop test, a drogue deployment plate at the end of the ORSA is pyrotechnically ejected by pressure-sensing switches in the altitude region of 11,000 feet (3.35 kilometers). This drogue plate pulls the drogue bag away, allowing the reefed ribbon drogue parachute to deploy. The 14-second-delay, dual-cutter staging is activated when the drogue bag is stripped away. The main bag is stripped away by the unreefed drogue and allows the reefed main parachute to deploy. All parachutes tested were packed using the techniques developed by Sandia National Laboratory for sounding rocket payloads in 1974.[1]

The logic system is activated by a lanyard that is pulled as the MORTI test vehicle exits the drop aircraft. When the test vehicle passes through the altitude region of 11,000 feet (3.35 kilometers), pressure-sensing switches are closed, the drogue extraction plate is pyrotechnically ejected, and the parachute deployment sequence is initiated.

Instrumentation contained in the sealed logic section include an S-band telemetry transmitter; triaxial accelerometers; a C-band radar transponder; power components; and required housekeeping electronic components.

The flotation compartment has a calculated buoyancy force of 380 pounds (1690 newtons), giving a margin of safety greater than 1.23 to float the test vehicle after ballast drop. Ballast drop occurs approximately 200 seconds after the test body has been deployed from the drop aircraft.

The ballast section is secured to the floatation section with a deployable manacle ring, or V-band. The manacle ring comes in two pieces which are connected, once installed around mating joints on the end of the floatation and ballast sections, by two #6-32 UNF retention screws on each side. Each of the two pieces has mid-span mounted links which allows some rotation of the two manacle ring sections. This allowable rotation simplifies installation and reduces tip-off during separation. Deployment is initiated by two pyrotechnic devices triggered by a timer. Each of these two pyrotechnic devices, which are mounted 180 degrees apart on the manacle ring, shear two of the

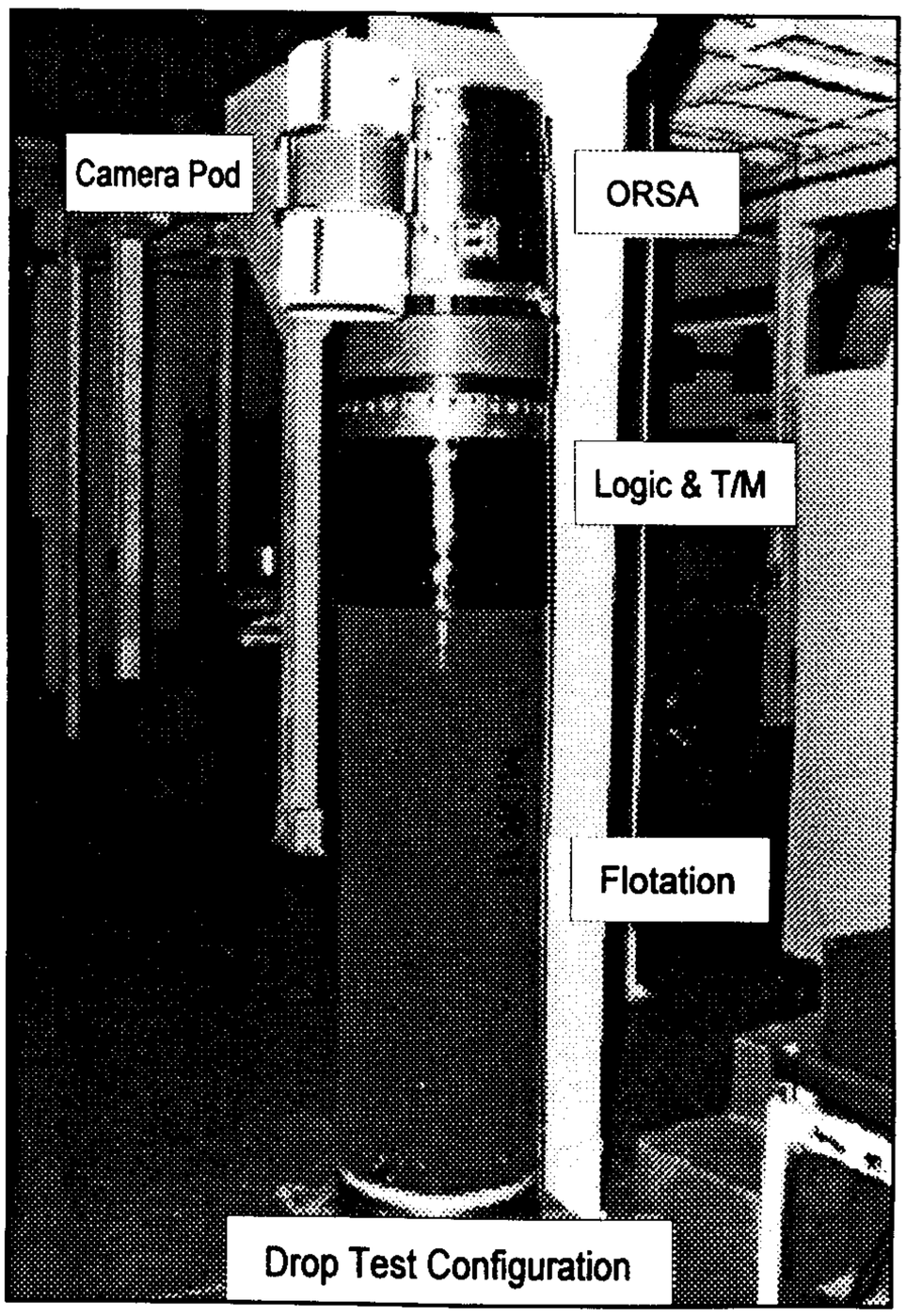


Fig. 4. Recoverable MORTI Assembly

Test Number	1	2	3
Aircraft	P-3	P-3	C-130
Date of Test	6 Dec 91	30 Nov 92	25 Feb 93
Test Weight (pounds)	1500	1250	1500
"q" at Drogue Deployment (lb/in^2)	240	188	205
Recovered Weight (pounds)	271	303	308
Test Parachute (cross chute panel length, ft.)	64.4	56.6	64.4

Table 1. MORTI Flight History

#6-32 UNF retention screws. The ballast section is then gravity deployed from the descending test vehicle and impacts approximately 2 minutes before the now lightly loaded canopy. A schematic of the separation event is shown in Figure 5. This manacle ring and deployment system design has been used since the early 1970's for separating sounding rocket components. No separation failures have occurred in more than 1,000 separations.

Project costs were minimized using existing, obsolete and/or previously flown sounding rocket components. Ballast weights were custom designed to accommodate specific test requirements and were fabricated using readily available and inexpensive high-density materials such as steel tubing and concrete.

Prior to each drop test, preflight testing included mass properties measurements, floatation verification, and vibration testing. The measured weight and center of gravity were coupled with aerodynamic properties and used in the final performance analysis. The floatation section was immersed in water to verify the integrity of the sealed section while the sealed instrumentation and camera housing were pressurized to assure watertightness. The instrumentation and recovery sections were vibrated in the longitudinal axis to confirm mechanical and electrical integrity. The components were then integrated to form the MORTI test vehicle, and safety devices were installed.

Test Description and Results

A 12-foot (3.66-meter) diameter, 20-degree conical ribbon parachute was selected for drogue deployment of cross or paraform main parachutes. The design of the existing 1000-pound (454-kilogram) Black Brant parachute recovery system was modified for suspended weights of 1250 pounds (567.0 kilograms) and 1500 pounds (680.4 kilograms). The parachutes were flight qualified after MORTI deployment from either a NASA P-3 (NA 428) or C-130 (NA 427) aircraft. Figure 6 shows the MORTI test vehicle after final integration has been completed. Table 1 presents a summary of MORTI flight qualification tests.

When deployed from the P-3 aircraft, the MORTI test vehicle was attached to an Aero Model 7A-3 ejector rack located in the bomb bay of the aircraft. This ejector rack provides a vertically downward acceleration to the center of gravity of the drop body. The drogue plate (which extracts the reefed drogue parachute) is pyrotechnically deployed by a pressure-sensing switch as the drop body free falls through

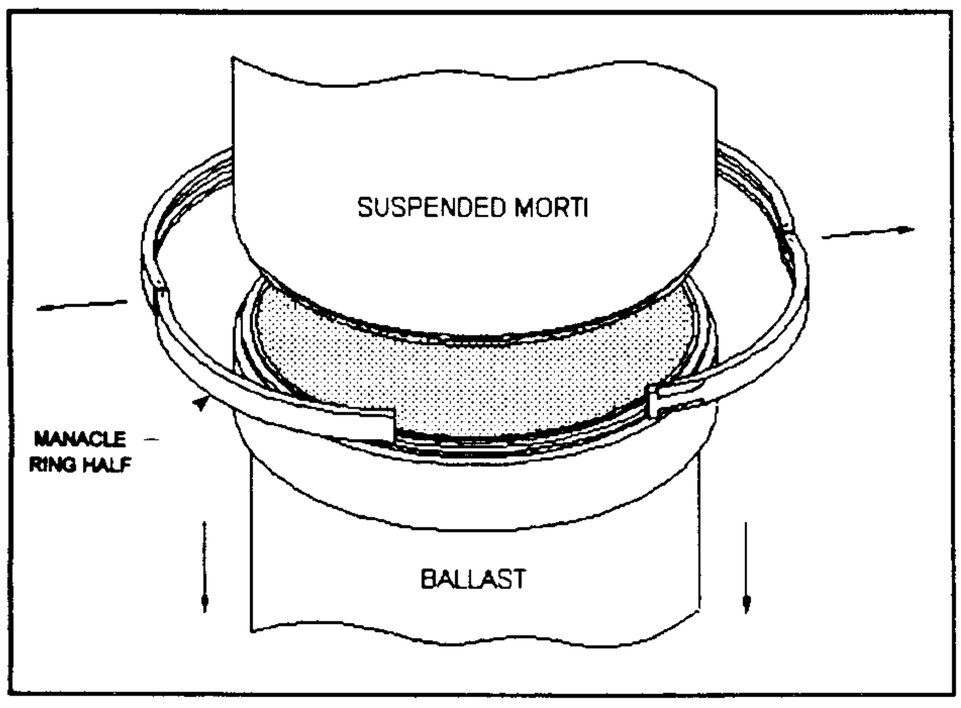


Fig. 5. Schematic of Ballast Separation

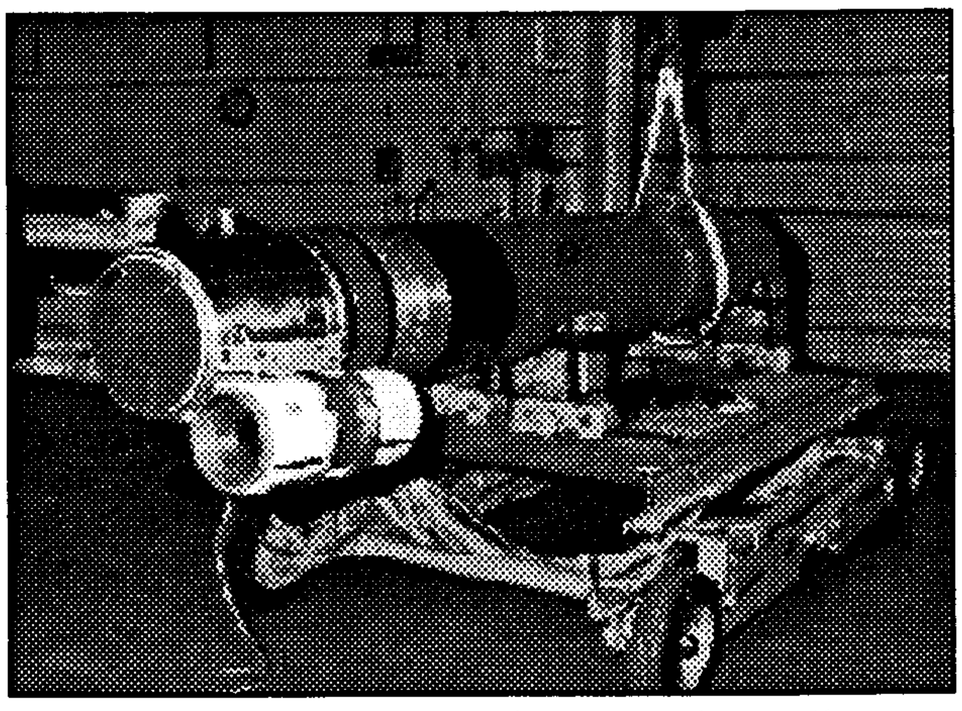


Fig. 6. MORTI Ready for Aircraft Loading

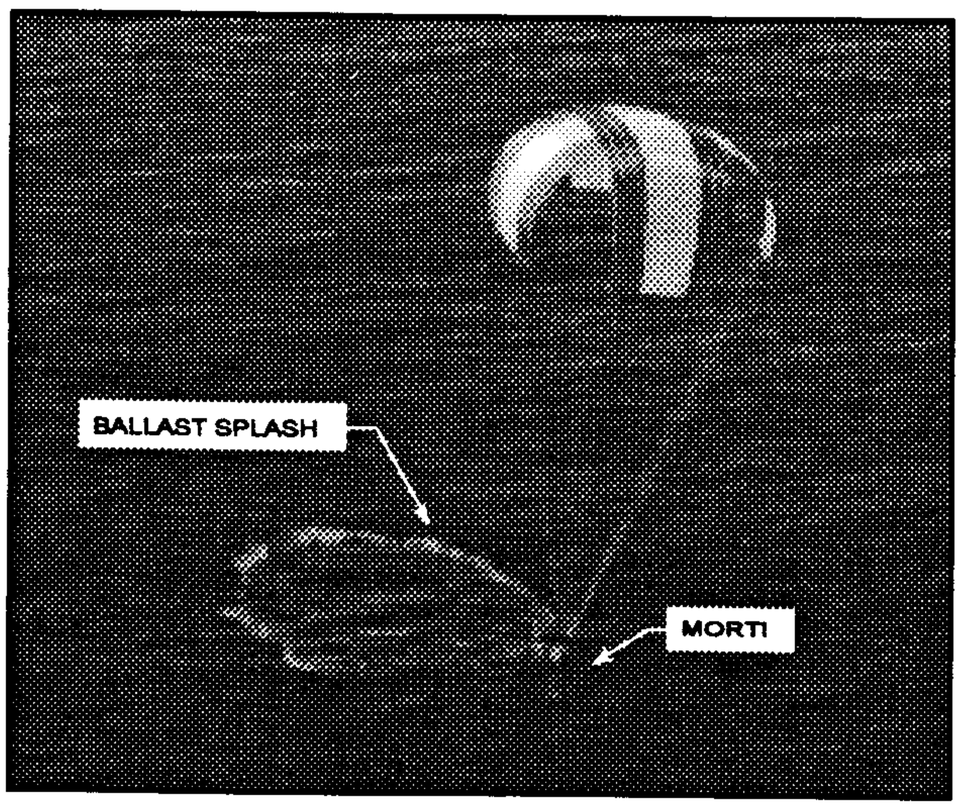


Fig. 7. MORTI Descent

11,000 feet (3.35 kilometers). The drogue disreefs 6 seconds later. The reefed main is deployed 14 seconds after drogue plate deployment. The main disreefs 6 seconds later and the fully deployed test parachute descends until ballast drop. The manacle ring which secures the ballast weight to the MORTI drop body is released by timer-activated pyrotechnics. The ballast section then falls away from the descending MORTI test vehicle, which impacts in the ocean approximately 60 seconds later. Figure 7 shows the unballasted MORTI, suspended from a cross chute, at an approximate altitude of 1,000 feet (305 meters), with the splash created by the deployed ballast weight visible in the background.

When using the C-130 aircraft, the MORTI test vehicle is attached to a specially fabricated conveyor trough mounted to the floor of the aircraft's cargo bay. The MORTI test body is manually deployed from this conveyor trough. The remaining sequence of events is the same as discussed in the previous paragraph.

Flight data is obtained from on-board video and instrumentation. This instrumentation data is transmitted to a ground-based telemetry receiving station. Ground-based radar and tracking cameras provide additional data.

Conclusions

The MORTI test vehicle has been successfully flown, recovered, refurbished, and reused three times. It has proven to be a cost-effective and reliable test system, having flight qualified 1250-pound (567.0-kilogram) and 1500-pound (680.4-kilogram) parachute recovery systems for use within the NASA sounding rocket program.

References

[1]Widdows, H. E., "Packing and Installation Instructions for Sandia National Laboratories/ NASA/DFVLR Rocket Payload Parachute Recovery System (P/N T19328-000)," Sandia National Laboratory document SLA-73-0997, April 1974.