Deployment of a Spin Parachute in the Altitude Region of 260,000 Ft

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The mounting of four electric field sensors on the shroud lines of a rotating parachute deployed in the altitude region of 260,000 ft (80 km) from a Super Arcas sounding rocket was the objective of this series of flight tests. Four deflector vanes were fitted to the gap area of a 16.6 ft (5.1 m) Disk Gap Band parachute to cause it to rotate similar to a turbine as it descended through the atmosphere. The successful deployment of this system was the first known high-altitude deployment of a rotating parachute.

Introduction

A SPECIALLY configured 16.6 ft (5.1 m) Disk Gap Band (DGB) spin parachute has been designed, developed, integrated with a sounding rocket, and qualified by flight testing. Design requirements include: 1) a stable parachute that should successfully deploy in the altitude region of 260,000 ft (80 km) from a Super Arcas launch vehicle; 2) after deployment, parachute and payload spin rate should be greater than 3 rpm; 3) four electric field sensors should be mounted on the parachute shroud lines and have provisions to be electrically connected to the suspended payload; and 4) time above 100,000 ft (30 km) should exceed 5 min. The successful meeting of these requirements provided the first known high-altitude deployment of a spin parachute.

A literature search was conducted and revealed that there was nothing readily available to satisfy the spin requirements. Prior to a test program, various parachute configurations were eliminated due to the packing, stability, and high-altitude deployment requirements.

A serious problem in some parachute applications arises when the inflated parachute tends to rotate about its axis at such a rate as to twist the suspension lines causing the collapse of the parachute canopy. Results from wind tunnel and actual flight tests have indicated that this spin is caused by: 1) asymmetries in the parachute canopy and/or shroud lines; 2) cloth permeability; and 3) torque or spin-producing devices.[1,2]

The spin effects due to asymmetries in manufacturing tolerances and technique were dropped from further consideration.

Parachute spin rate and drag coefficient increases as cloth permeability decreases.[1] This indicated that a high permeability canopy be considered in further testing.

Torque or spin-producing devices have been investigated in wind tunnel testing.[2] These wind tunnel tests were not carried to actual flight testing at high altitudes. Due to the lack of high-altitude deployment reliability, it was decided to concentrate efforts on causing a parachute with good high-altitude deployment reliability to spin. This narrowed the parachute selection to the Cross and DGB parachutes, both having demonstrated abilities to deploy and open in the altitude region of 260,000 ft (80 km).[3,4] These two parachute configurations also satisfied stability and packing requirements.[3,5] Low-altitude drop tests indicated that the Cross parachute was very sensitive to asymmetries in shroud line length. Wind tunnel tests indicate that as the velocity increased, the rotation rate increased.[1] Since velocities up to 1000 ft/s (300 m/s) could be expected, the Cross parachute would spin so fast when the swivel was removed that the canopy would collapse. The Cross parachute was not considered for high altitudes because of this anticipated high spin rate. It was successfully used in aircraft drop tests to achieve the anticipated spin rate of the DGB at higher altitudes. This was to test the method of using four confluence points to prevent canopy "wrap up." The spin of the Cross parachute was effected by shortening one shroud line 7 in. out of a total line length of 15 ft. These Cross parachutes had a canopy area of 58 ft^2 and a descent velocity of 12 ft/s (3.7 m/s) when deployed from 7000 ft (2 km) with a total suspended weight of 7.0 lb (3.2 kg). These Cross parachutes achieved an average spin rate of 16 rpm when deployed from 7000 ft (2 km).

Test Description

The DGB parachute was chosen for testing as a spin parachute using aircraft-, balloon-, and rocket-borne test platforms.

The spin of the DGB parachute was effected by two different methods. These included canted fins mounted on the band portion of the parachute, and deflector vanes mounted in the gap area between the disk and band. These two configurations were deployed from a helicopter at 7000 ft (2 km) and spin rates and descent velocities were measured. The canted fin configuration was not considered for further high-altitude test because it was considered impractical to pack this configuration. The DGB parachute with deflector vanes was considered for further high-altitude testing and is shown in Fig. 1 when deployed from a helicopter at 8000 ft (2.5 km). Table 1 presents the properties of the 16.6 ft (5.1 m) DGB spin parachute system. The effects of the number of vanes were investigated when three configurations having 2, 4, and 10 vanes, respectively, were deployed in succession within a 2-h period and were all deployed from 8000 ft (2.5 km). The results of these tests are shown in Fig. 2. This test showed that the 2-, 4-, and 10-vane DGB parachutes had an average spin rate of 1.66, 2.66, and 5.4 rpm, respectively, and that the higher spinning, 10-vane DGB parachute took more than 2 min longer to impact than the other two configurations. This would indicate that the higher spin rate gives a somewhat higher drag coefficient.[6,7] The phenomenon was not investigated further. The spin rates for all helicopter drop tests were determined optically from long-range tracking cameras (80-in. focal length). These data were time-correlated with radar and other tracking data.

The effects of significantly changing altitude and descent velocities were investigated by deploying a 4-vane DGB spin parachute from an altitude of 75,000 ft (23 km) in three

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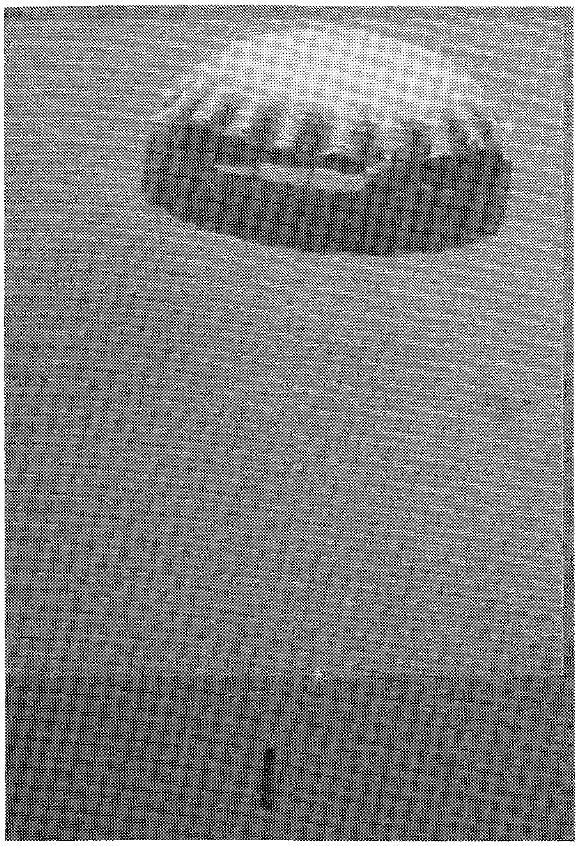

Fig. 1 16.6 ft DGB spin parachute with four deflector vanes.

Table 1 Properties of 16.6 ft DGB spin parachute system

Weight of parachute, lb	2.56
Weight of payload, lb	12.08
Total suspended weight, lb	14.64
Canopy area,[a] ft^2	216
Nominal diameter, ft	16.6
Length of shroud lines,[b] ft	18
Length of shroud lines	20
Number of confluence points	4
Number of deflector vanes[c]	4
Vane area, per vane, in.^2	276

[a] Laminate of 0.30 mil Mylar × 220 Denier Dacron yarn. [b] 100 lb test braided nylon. [c] Type I rip stop nylon.

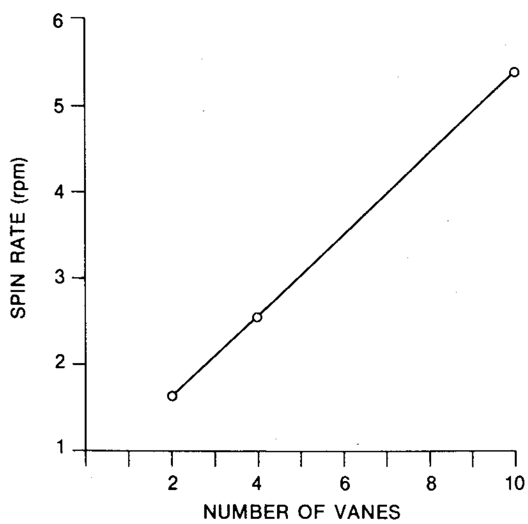

Fig. 2 Spin rate vs number of deflector vanes.

separate flight tests utilizing a balloon-borne drop platform. The packed parachute and telemetry payload were released by altitude sensing switches at an altitude of 75,000 ft (23 km) and tracked by radar and telemetry ground stations at Wallops. The onboard sensors included two axis magnetometers, accelerometers, and the antenna pattern. The stability effects were determined from the magnetometers, clinometers, and accelerometers. The results of these three separate flight tests were in good agreement.

The 16.6 ft (5.1 m) DGB parachute with four deflector vanes was integrated with a scientific payload for flight testing on a Super Arcas launch vehicle.[8] The rocket payload is shown in Fig. 3, while Fig. 4 graphically depicts the descending spin parachute and scientific payload. The 15.106 UI (NASA identification number) configuration (Fig. 5) included a Super Arcas rocket motor and a payload consisting of a parachute section, despin section, and a 4:1 tangent ogive. The total payload weight, which included the 4-vane 16.6 ft (5.1 m) DGB spin parachute and the scientific payload, was 17.6 lb (7.99 kg). The total liftoff weight was 100.3 lb (45.53 kg).

To insure proper parachute deployment, the 15.106 UI Super Arcas vehicle was despun from 18.4 cycles/s to less

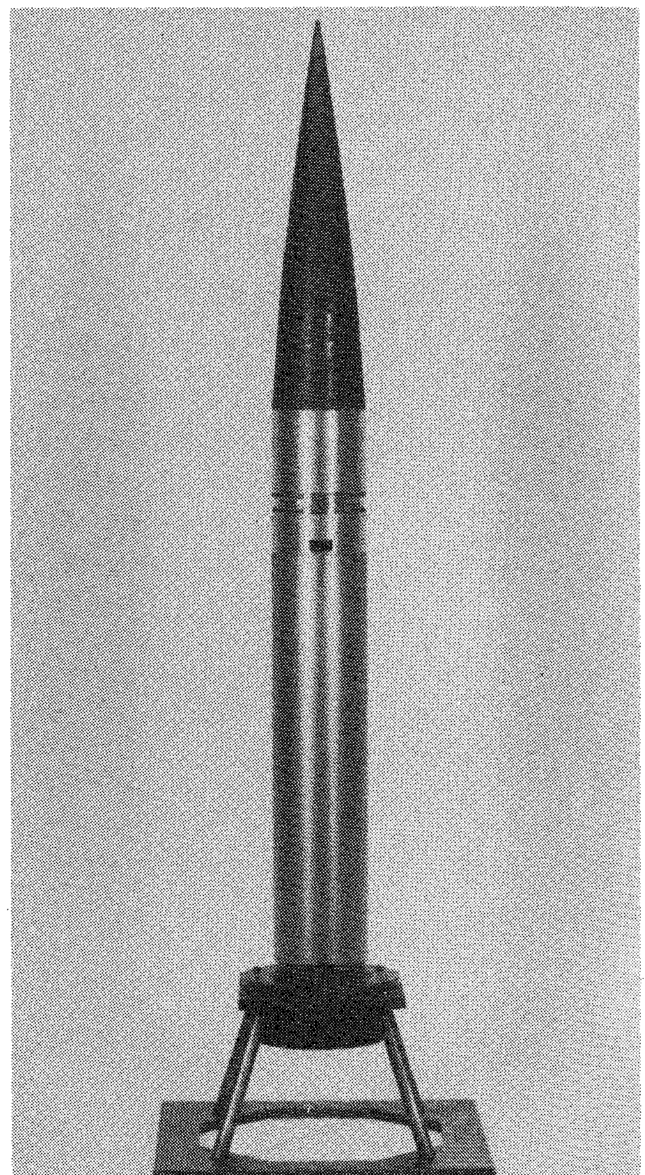

Fig. 3 15.106 UI Super Arcas payload containing 16.6 ft DGB spin parachute.

than 0.5 cycles/s 127.3 s after launch (Fig. 6). Payload separation occurred 1 s later at an altitude of 244,170 ft (74.4 km) and a velocity of 909 ft/s (227 m/s). The spin parachute and payload attained a maximum spin rate of 2.4 cycles/s (144 rpm) approximately 97 s after payload separation. The total suspended weight of the spin parachute and payload was 14.64 lb (6.54 kg).

A trajectory analysis was performed for the Super Arcas rocket and the DGB spin parachute using the GE-625 digital computer using a three-dimensional particle trajectory analysis on a rotating spheroidal Earth. Initial conditions for this trajectory analysis were taken from the nominal separation conditions for the Super Arcas vehicle at 128 sec after launch. The drag coefficients for the 16.6 ft DGB parachute were obtained from wind tunnel and actual flight data.[3] The actual canopy layout area and measured weights were used to complete the input data for this trajectory analysis. Figure 7 shows the predicted and flight profiles for the rocket and expended booster and the beginning of the parachute flight trajectory.

Performance characteristics of the 16.6 ft (5.1 m) DGB spin parachute were investigated for ejection in the altitude region of 75 km using the previously discussed trajectory analysis. Figure 8 shows altitude as a function of velocity, while Fig. 9 presents altitude as a function of descent time. Figure 10 presents the flight roll time history for the 15.106 UI spin parachute. The effects of spin are not known, and therefore, were not used in the predicted portion of this analysis. The 15.106 UI parachute and payload were recovered successfully.

A correlation of altitude, descent velocity, and spin rate obtained from the 15.106 UI rocket flight and one of the balloon test flights is given in Fig. 11. It is noted that the total suspended weight was 14.65 lb (6.65 kg) for the rocket test and 13.78 lb (6.26 kg) for the balloon test.

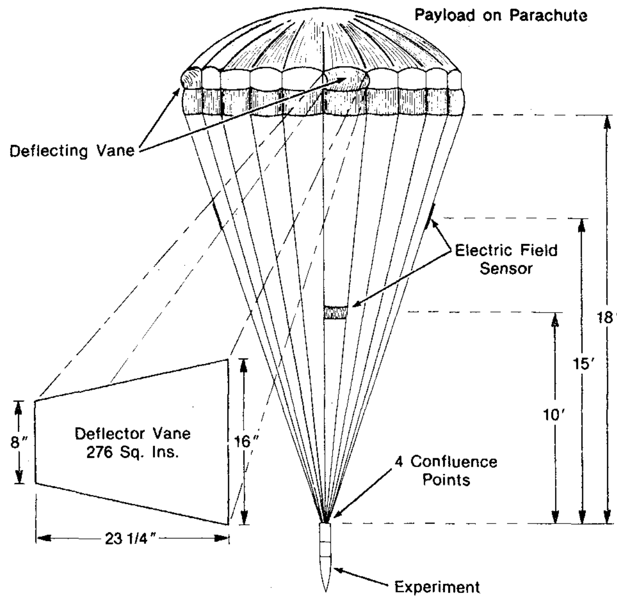

Fig. 4 16.6 ft DGB spin parachute with four deflector vanes.

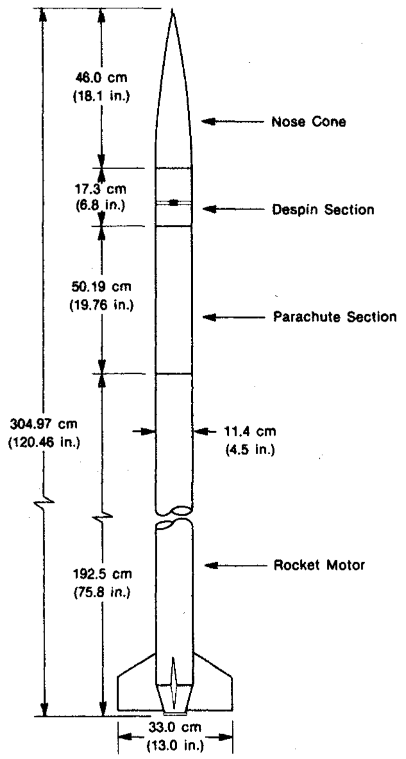

Fig. 5 Super Arcas 15.106 UI Super Arcas configuration.

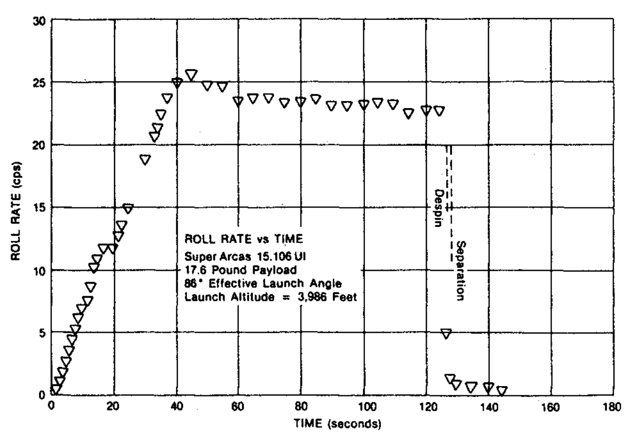

Fig. 6 Roll rate vs time for 15.106 UI Super Arcas.

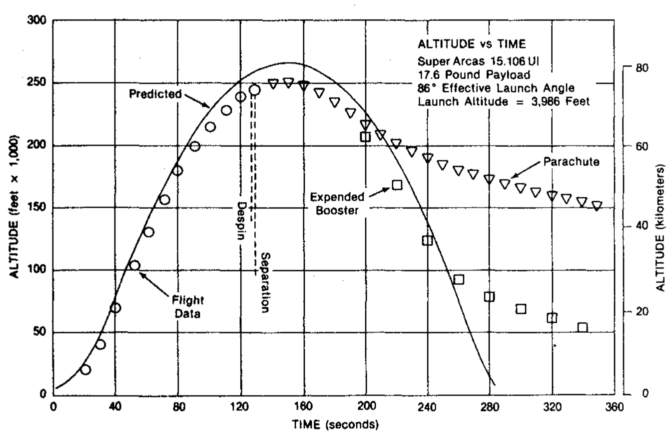

Fig. 7 Altitude vs time for 15.106 UI configuration.

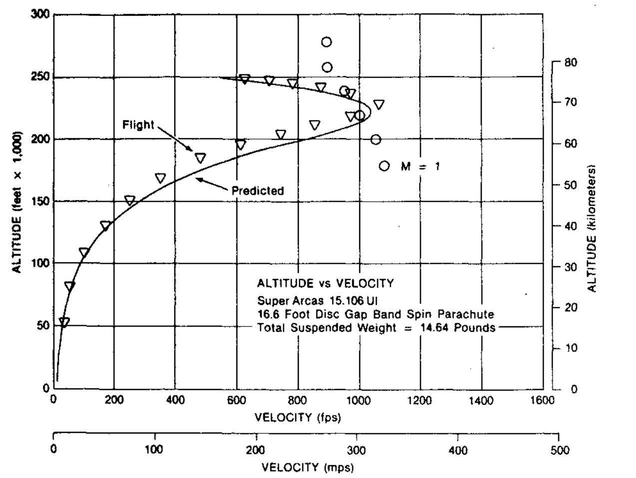

Fig. 8 Altitude vs descent velocity for 16.6 ft DGB spin parachute.

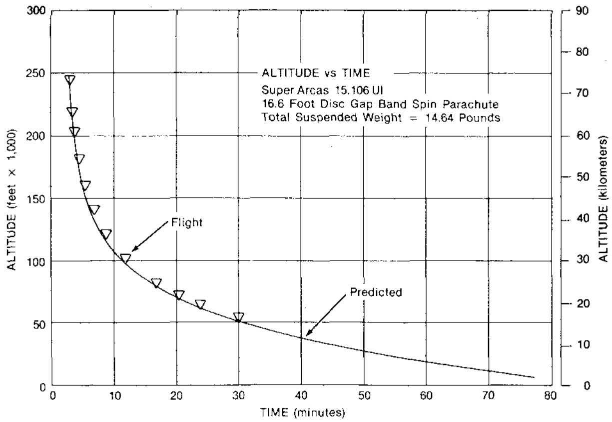

Fig. 9 Altitude vs time for 16.6 ft DGB spin parachute.

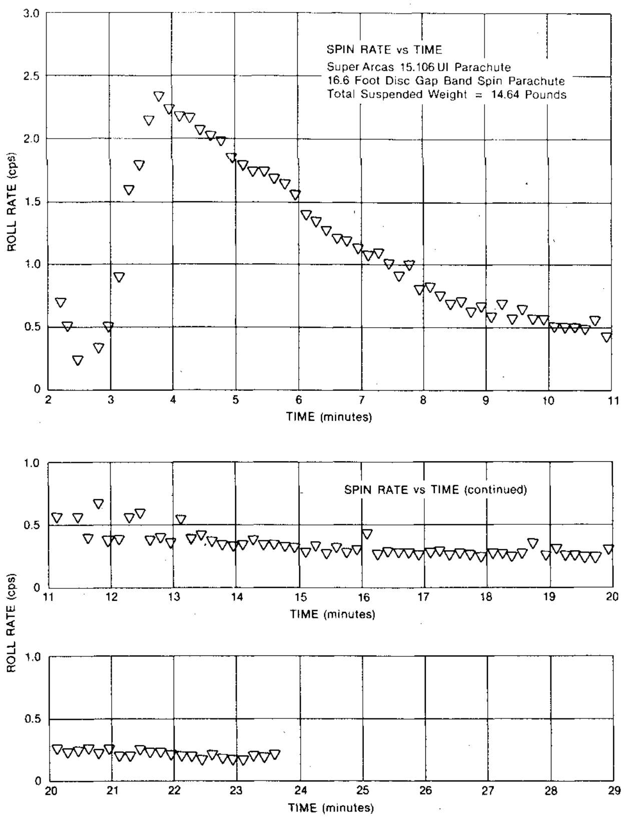

Fig. 10 Spin rate vs time for 16.6 ft DGB spin parachute.

Conclusion

The 16.6 ft (5.1 m) DGB spin parachute has been successfully deployed in the altitude region of 246,000 ft (75 km), recovered, and successfully flown again. This represents the first successful high-altitude deployment of a spin parachute.

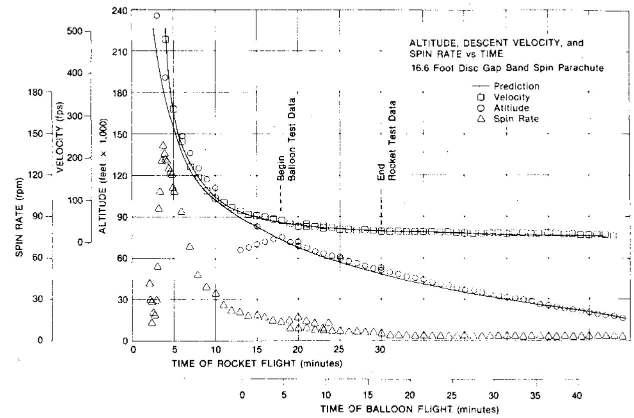

Fig. 11 Correlation of altitude, descent velocity, and spin rate as a function of time for rocket and balloon test flights.

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