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BALLUTES: LAUNCHING AEROBOTS WITHOUT COMPROMISES

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ABSTRACT

There is great interest in exploring Solar System destinations, particularly Titan, using aerobots, robotic balloons and blimps. But how will they be launched? If they are filled under a parachute there is a vertical slipstream. If they are filled on the surface, the terrain may be unsuitable and there may be surface wind.

This paper proposes to avoid all these problems with a ballute, a "BALLoon parachUTE". The ballute fills like a parachute and is then heated, becoming a hot air balloon. Once floating it is an ideal launch platform: there is no wind and it is away from the surface.

The following notes focus on Titan but ballutes also appear useful for Venus and Mars.

NOTE This ballute is quite different way from those for aerobraking which are inflated in space.

1. THE PROBLEM - LAUNCHING AEROBOTS

There is great interest in flying aerobots, robotic balloons and blimps, over several Solar System bodies, particularly Titan [1]. The aerobot would arrive from space in an aeroshell. But how will it be launched?

The aerobot could be extracted from the aeroshell at altitude and inflated while descending under a parachute. This is problematic because:

- Time is limited.
- The fabric will flap in the slipstream, risking damage. Fabrics may be more vulnerable at Titan's low temperatures.
- There may be damage as large or heavy components move at random.
- As the aerobot become buoyant, the parachute will continue down and might collapse over the aerobot.

Alternatively inflating on the surface is problematic:

- The surface may be rough at the landing place.
- It may be windy.

While inflation on the surface might be possible at the Huygens landing location, it appears impossible on the steep slopes in the "highlands region" about 5 km to the North. Even if average winds are light, it might be windy at landing time. The craft would have to wait on the surface for calm, risking further uncertainty.

Although inflation and launch take little time, it is a crucial period. Inflating balloons in anything other than calm conditions is always precarious and to date blimps have invariably been inflated inside hangars.

2. THE SOLUTION – UTILIZE A BALLUTE

Using a ballute "BALLoon parachUTE" eliminates all of these problems. The kind of ballute proposed here is a cross between a parachute and a hot air balloon. As it falls through the atmosphere it fills like a parachute. It is then heated and floats like a hot air balloon.

At the destination the system enters the atmosphere and decelerates in an aeroshell. At an appropriate altitude a drogue extends the ballute from the aeroshell, Fig. 1:

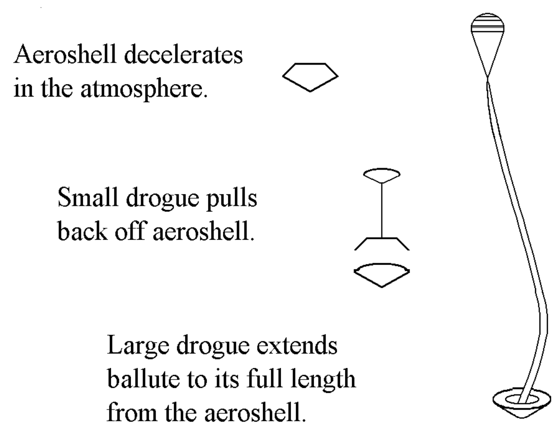

Fig. 1. Atmospheric entry and initial deployment.

Once clear of the aeroshell and pulled down by the payload, dynamic pressure is greatest at the bottom of the ballute, the mouth, which is forced open, forcing the ballute to inflate. When it is full, heat is supplied by burning a few kilograms of solid propellant and it flies level as a hot air balloon, Fig. 2. Conditions are now extraordinarily tranquil, hard to appreciate without firsthand experience of hot air balloons, Fig 3.

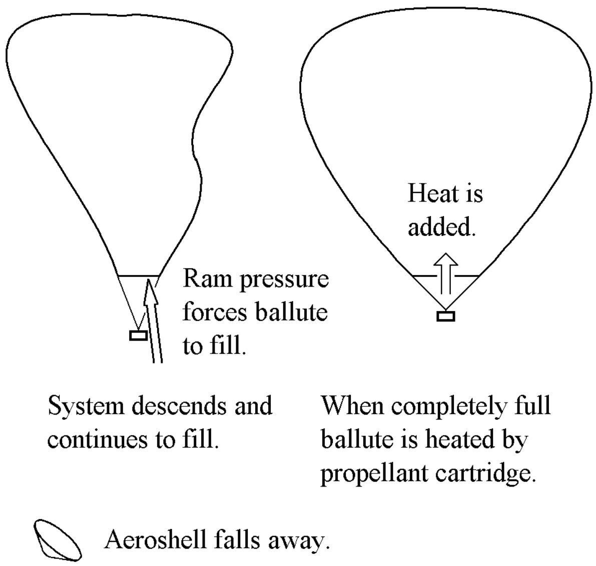

Fig. 2. Ballute fills and is heated.

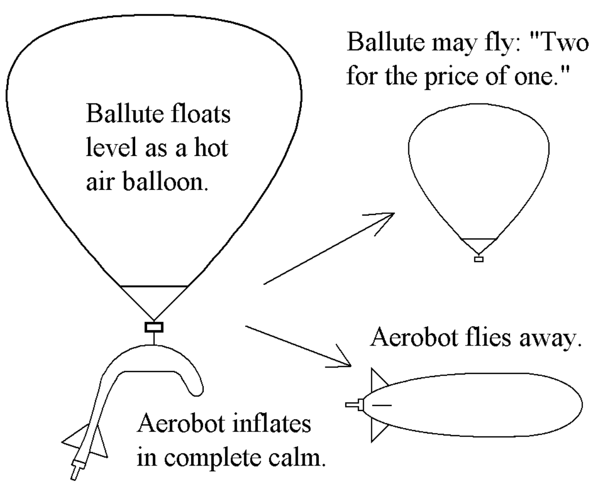

Fig. 3. After heating, the ballute flies level. A blimp or balloon can be inflated in perfect calm.

Helium now flows into the aerobot, which fills in perfectly calm conditions. As the ballute cools hot air lift is lost but helium lift increases. The gas flow is regulated to keep perfect equilibrium. In Titan's conditions the time constants are tens of minutes or longer.

This method completely avoids surface hazards.

During filling, flexing may cause fabric pinholes, but hot air balloons are highly tolerant of pinholes.

Because the heat required in Titan conditions is low, a solid propellant cartridge could support a ballute for long periods. Vertical motion can be detected with a pressure transducer and easily regulated. With only one axis of control, hot air balloon autopilots are simple. Many examples have been successfully flown.

A ballutes has other advantages. It usually deploys much slower than a parachute because it fills through the small mouth. This reduces opening shock. If correctly proportioned, a ballute is extremely stable without the swinging common with many parachute types.

3. EXISTING EXPERIENCE

Wide experience shows every aspect is practical.

Ballutes are very widely used in personal parachutes and to decelerate weapons dropped from high-speed aircraft. Fig. 4

Fig. 4. Ballute inflation during munition release at high speed. Photo Irvin Aerospace.

The Huygens parachutes were fully effective. The numerical methods used to design them have advance greatly in the years since. These methods are equally applicable to the inflation of a ballute.

Aerostar [Raven] completed practical demonstrations deploying several types of systems in which ballutes were launched at altitude, filled and then heated to float level. Fig. 5 to 7 shows a typical sequence, in this case to float an airborne electronics jammer.

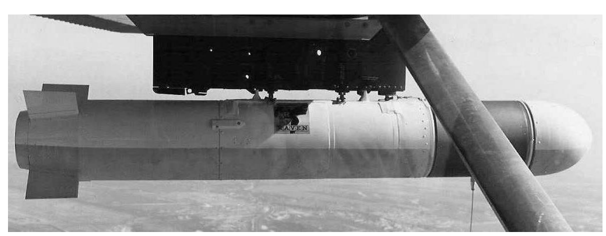

Fig. 5. System canister at altitude below aircraft wing before drop. A ballute can be packed in any shape, for instance an aeroshell. Photo Rekwin Achieve.

Fig. 6. Falling and inflating. Note systems canister below mouth of ballute. Photo Rekwin Achieve.

Fig. 7. Ballute fully inflated, heated & flying level. Photo Rekwin Achieve.

The author easily stopped a 15,000 meter terminal [burner off] descent in a hot air balloon in 200 meters, Fig. 8. Indeed stopping a descent is so easy that every student is now required to make a terminal descent in training to receiving a balloon pilot license.

4. MAJOR DESIGN ADVANTAGE

If an aerobot is inflated under a parachute it must be designed to survive this dynamic situation as well as normal flight. But if a ballute is used, the aerobot need only be designed for normal flight. This simplification is a major benefit.

5. SIMPLIFIED TERRESTRIAL TESTING

The calm conditions under a ballute mean the actual inflation will be easier. In addition testing on Earth is much simpler. Physically simulating inflation falling under a parachute is difficult. A vertical wind tunnel cooled to 90K is conceivable, but would be a major facility. By contrast a simple static chamber cooled to near the boiling point of nitrogen provides an excellent facility to simulate static inflation under a ballute.

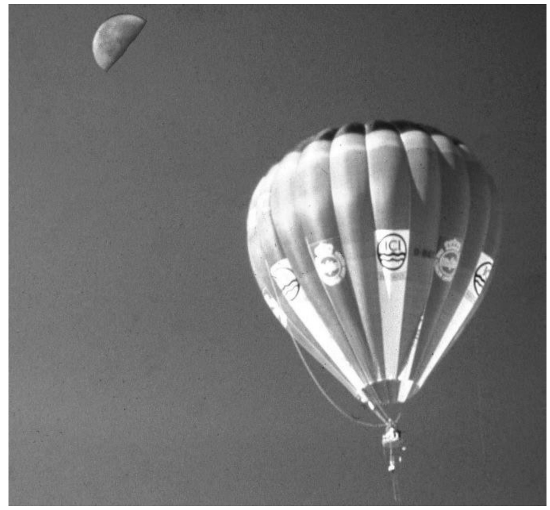

Fig. 8. The author easily stopped the terminal descent of this balloon after falling 15,000 meters.

6. TWO FOR THE PRICE OF ONE

An attractive possibility is that the ballute would not be discarded but would itself fly away as a hot air balloon heated by a radioisotope heat source. This launches two complementary craft with a single entry vehicle.

7. OTHER SOLAR SYSTEM DESTINATIONS

A ballute would be ideal at altitude above Venus and may be applicable over Mars.

REFERENCES AND ACKNOWLEDGEMENTS

1. Hall, J. L. et al, "An aerobot for global in situ exploration of Titan" 35th COSPAR Scientific Assembly, Paris, France, July 18-25, 2004.

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