AIAA Balloon Systems Conference
21 - 24 May 2007, Williamsburg, VA

AIAA 2007-2629

An Inexpensive Guided Recovery System for Stratospheric Balloons

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Safety has always been a major concern in the stratospheric ballooning industry. This is especially true during the launch and recovery phases of a balloon flight. A growing concern, and too often a reason for aborting a launch, is the possibility of a payload descending over a populated area. This can result from a catastrophic balloon failure, slow leak, or an unexpected change in the wind direction that could direct a balloon or a descending payload on a course toward a highly populated area. A guided parachute payload recovery system can provide an extra margin of safety for these situations. There are many guided parachute systems on the market today. These systems however are designed to deploy at 40,000 ft or below, and are required to make precision landings. Due to the low air density in the stratosphere, modern high glide ratio ram air parachutes may not work for this application. Ram air parachutes have difficulty staying pressurized and would have unreliable deployments in the stratosphere. They would also require more elaborate control and guidance systems. For these reasons modified flat circular parachutes can be used. Flat circular parachutes have been used since the beginning of stratospheric ballooning. They are very reliable, deployable in the stratosphere, have low manufacturing costs, and provide a simple configuration for suspending payloads on balloons. Through the use of various slots and openings in the parachute's gores, moderate glide speeds can be obtained. Using very simple steering techniques, it is possible to direct a descending parachute many miles from the nominal trajectory of a standard circular parachute. These systems are designed for population avoidance, not precise landings. This concept is scalable from a 5 lb payload up to a 10,000 lb payload. This paper will present the design and performance calculations for a family of parachutes suitable for any scientific balloon mission. Results of the development and testing of this concept will also be presented.

I. Introduction

PAYLOAD recovery, regardless of mission outcome, is a requirement of the end of every flight. Once released from the balloon the payload is now at the mercy of the wind. Using wind data and educated predictions, one can only estimate the general area a scientific payload will land. Most balloon flights are carried out in remote areas of the country for this reason. Even in the most remote places there are still small towns, cities, property and large bodies of water. Weather conditions and winds change frequently; this is why inexpensive and reliable modified flat circular parachutes can be an asset to the ballooning industry. These parachutes will add an extra margin of safety to balloon missions. These systems would be designed to avoid the proverbial bull's-eye rather than precisely land on it. Initial drop tests with a modified flat circular parachute have been performed at lower altitudes with promising results. These tests were performed as a proof of concept for further exploration of guided payload recovery during stratospheric balloon missions.

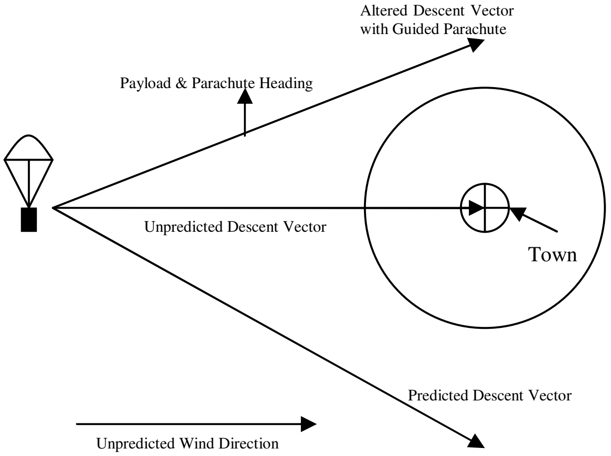

Figure 1 – Descent Diagram

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II. The Test Parachute

A flat circular parachute used for scientific payload recovery was chosen primarily for its extremely high reliability of deployment at high altitudes. Aerostar International's standard 12 foot diameter-14 gore parachute was used for initial testing. This parachute is designed for a 23 ft/s descent rate at sea level for payloads up to 50 lbs. A "T-U" modification was chosen because research[1] on various types of modifications indicated this would produce the best forward speeds on a flat circular parachute design. The total amount of canopy fabric removed was 15.2 ft^2 over 5 gores. Large diameter netting was sewn in place of the removed gore sections in order to retain the shape of the deployed canopy and prevent any malfunctions due to canopy fabric passing through the modifications. Figure 2 illustrates the modification that was used.

Figure 2 – Test parachute with "T-U" modifications

III. The Test Payload

The test payload was a very simple configuration. It consisted of a 12 inch x 12 inch x 7 inch plastic container with ½ inch thick foam surrounding all sides. An additional 4 inches of foam was placed on the bottom of the payload for extra cushion for ground impact. Attachment to the parachute was achieved with a custom sewn pouch and harness system. The pouch allowed ballast weight to be added to the underside of the payload to properly load the parachute. Attached to the parachute were four risers. The two front risers had four lines each attached, and the two rear risers had three lines each. The right rear riser was used for control via deformation of the canopy. This enabled the parachute to rotate to the right only. It was left free for movement through a ring on the front riser. A thick section of webbing material was used as a stopper during deployment and during neutral flight mode so the control motor was only loaded when it was activated. This riser was attached to an aluminum spool inside the payload. A high torque direct current motor was used to retract the riser onto the spool which pulled the right rear three suspension lines and deformed the canopy causing a right turn. The motor was controlled with a simple on/off switch activated via remote control by a servo. Also installed inside the payload was a Global Positioning System (GPS) that provided real time speed, heading, and altitude. A static line deployment system, consisting of a spring loaded pilot parachute attached to a deployment bag and to the apex of the parachute, was used for testing. All was packed into a container sewn to the harness system. Only the static line held the container closed. Figures 3-5 illustrate the payload setup.

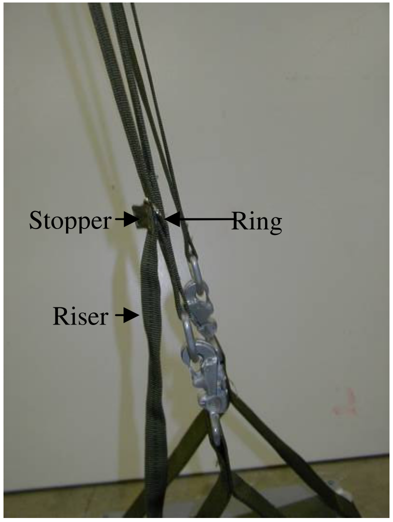

Figure 3 – Control Riser

Figure 4 – Test Payload

Figure 5 – Deployment Bag with Lines Stowed

IV. Drop Tests

Both drop tests were conducted at a sport parachuting drop zone. The drop aircraft was a Cessna 182 that was set up for carrying parachutists. The wind speed during the first test was approximately 5 knots from the north northeast direction. The wind speed during the second test was approximately 0-5 knots. Line of flight for the aircraft during both tests was directly into the wind. The previously discussed static line system was used instead of a direct bag deployment due to the pilots concerns with a deployment malfunction and the payload and parachute being towed behind the plane. Therefore once the static line opened the parachute container the payload and parachute system were completely separated from the plane. This system worked flawlessly for both tests. Complete parachute inflation was achieved two seconds from payload release. The aircrafts speed during both drops was approximately 80 knots. The first tests drop was from an altitude of 1,000 feet above ground level. The payload was released too far upwind and the receiving station for the GPS data was obstructed by a hanger. This resulted in poor GPS data. The second drop tests produced better results. The altitude that the payload and parachute achieved a vertical position was approximately 1,738 feet above ground level. The position was almost directly over the controller's position, but far enough away from personnel and property in the event of a malfunction. The GPS unit retained a solid lock during the entire test. Figure 6 is the GPS track recorded for the second test.

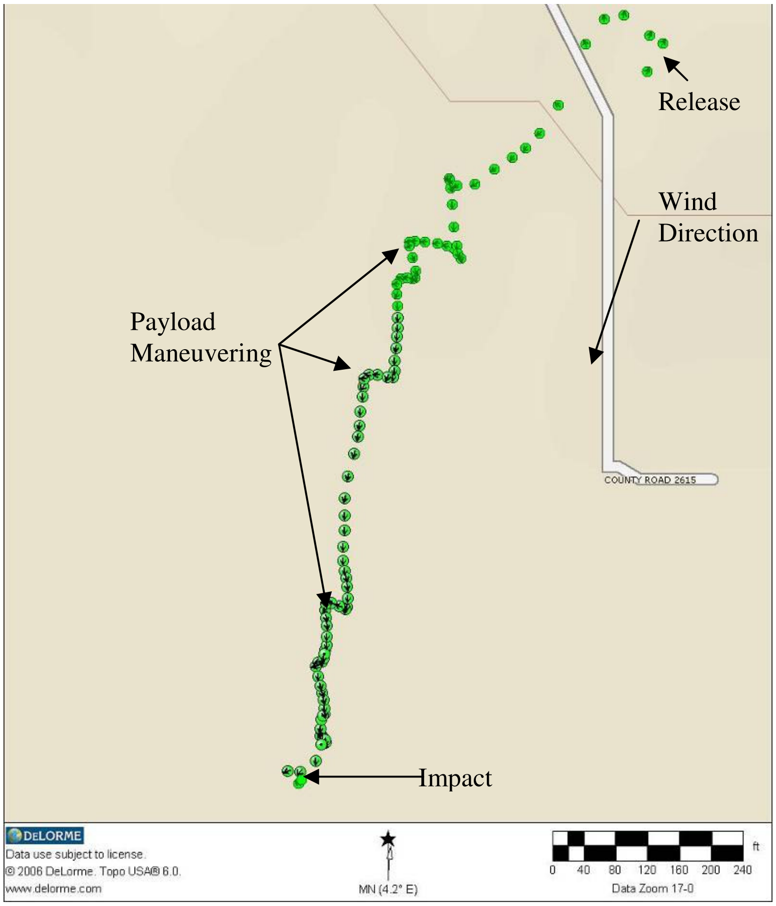

Figure 6 – GPS Track of Second Drop Test

V. Results

Results from the first test were purely visual. It was observed from both the air and ground that the canopy and control method produced very responsive turns. The payload would swing out from under the canopy when turned to the desired direction. During the second test the controller was able to rapidly turn the payload perpendicular to the wind, into the wind, and downwind several times before impact with the ground. Flight time from the point where the payload and parachute achieved a vertical position to touchdown was 93 seconds, this gave an average descent rate of 18.7 ft/s. A 19.6 ft/s nominal descent rate was calculated for the flat circular canopy without modifications, with the atmospheric conditions of the test day, and using the 45 lb payload. Estimates from GPS data demonstrated that the parachute produced a forward speed of approximately 5-8 knots.

VI. Conclusions

A simple guidance system for flat circular parachutes has been demonstrated. This system allows considerable cross range control of descending balloon payloads for avoidance of towns or large bodies of water. By incorporating the most reliable parachute canopy design with a robust control system, flight safety can be greatly enhanced for minimal cost.

VII. Future Testing

Future testing will consist of test drops from both low and high altitudes. Polyethylene research balloons will be used for the high altitude tests. These tests will take place in the stratosphere with light payloads and then gradually increasing the payload weight and parachute size. Parachutes will not be controlled with the suspension lines due to the amount of force that is required to cause canopy deformation. Instead lightly loaded control lines will be added to either deform the canopy or close slots that will cause the canopy to rotate. The canopy rotation time will be reduced but a high rotation speed is not needed for this application. This will require less expensive actuators or motors to be used since less force is required to control the canopy.

References

Books

[1] Knacke, T. W., *Parachute Recovery Systems Design Manual*, 1st ed., Para Publishing, California, 1992.