High Altitude Test Program For A Mars Subsonic Parachute

R. Mitcheltree[*] , R. Bruno[†], E. Slimko[‡], C. Baffes[§], and E. Konefat.[**]
The Jet Propulsion laboratory, California Institute of Technology, Pasadena, Ca, 91109

A. Witkowski[††]
Pioneer Aerospace, Hartford, Ct.

Three high altitude drop tests of a 33.5 m Ringsail Canopy were conducted in the Fall of 2004 from Ft. Sumner, New Mexico. The deployment conditions were consistent with those expected on Mars when using this parachute in conjunction with the Viking 16.1 m supersonic parachute as part of a two-stage system. A 0.34 million cubic meter helium balloon was used to hoist the test article to 36 km altitude. When the instrumented test article was released, a drogue parachute was static-line deployed. The main deployment was triggered 21 seconds later at Mach 0.54 and 148 Pa. This test series was the first in a program of three test series designed to develop this new parachute system for Mars exploration. This paper describes one method by which an Earth qualification test program for a Mars parachute can be conducted.

I. Introduction

NASA is currently developing the next generation of spacecraft for Mars robotic exploration. Many of the landed missions under consideration include payloads that are five times more massive than those of previous missions. The current Viking-heritage parachute system – qualified in, and used since 1972 - is not sufficiently large for these payloads.

There are two paths available for developing a more mass-capable Mars parachute system. The first path is to develop and qualify of a new, larger supersonic parachute. The design effort is substantial, but the cost burden for this path lies in the qualification testing at high altitude and supersonic speeds. The second and less expensive path is to develop a large subsonic parachute to be used in conjunction with the existing Viking parachute as part of a two-stage system. The Viking-qualified parachute would be deployed as usual, but after it has decelerated the payload to subsonic speeds, the new large main would be staged.

The cost reduction for the second path results from the difference between supersonic and subsonic qualification testing. Both require high altitude Earth testing to recreate the low densities near Mars surface. The desired subsonic test conditions can, however, be achieved by a simple drop test procedure from standard Helium balloons. Removing the need to obtain supersonic deployment conditions removes costly propulsion and guidance systems, thus greatly reducing the associated test costs.

The addition of the subsonic parachute nearly doubles the Entry, Descent, and Landing (EDL) systems mass capability. For mission that require larger landed masses, a new, larger supersonic parachute must be considered.

NASA has conducted several high altitude parachute test programs towards the development of planetary entry system decelerators. The SPED[1] (Supersonic Parachute Experiment Development), SHAPE[2] (Supersonic High Altitude Parachute Experiment), and PEPP (Planetary Exploration Parachute Program)[3] were conducted in the

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[*] Principle Engineer, Flight Systems Section, MS 301-440A, 4800 Oak Grove Ave, Senior Member AIAA
[†] Deputy Section Head, Instrumentation Section, 4800 Oak Grove Ave, Pasadena, Ca.
[‡] Mechanical Engineer, Mechanical Engineering Section, 4800 Oak Grove Ave, Pasadena, Ca.
[§] Mechanical Engineer, Mechanical Engineering Section, 4800 Oak Grove Ave., Pasadena, Ca
[**]Senior Engineer, GN&C Section 343, 4800 Oak Grove Ave., Pasadena, Ca.
[††]Deputy Director For Engineering, Pioneer Aerospacce, AIAA Member

1960's and included examination of Disk-Gap-Band, Cruciform and Ringsail Canopies. The Mars Viking Program conducted the BLDT[4] qualification test series on a 16.1 m Disk-Gap-Band canopy in 1972.

Since the 1960 and 70's, helium ballooning has become more reliable. The National Scientific Balloon Facility (NSBF) routinely conducts high altitude testing of science payloads. These tests typically include ascent followed by hours or days of float duration that permits scientific sensing outside the bulk of Earth's atmosphere. NSBF launches different sized balloons for this purpose. The largest in the "standard" category of balloons is a 1.1 million cubic meter (39 million cubic foot) balloon that can hoist a 1134 kg payload to 42 km MSL. A test article released into the thin atmosphere at this altitude will free fall to Mach 0.8 deployment conditions while still in the correct dynamic pressure range associated with a Mars entry. Though the test article must be capable of sustaining the near space environments at this altitude, its functions are no more complex than most low altitude test articles.

This test series was the first in a program of three test series designed to develop this high altitude test methodology as well as the new parachute system for Mars exploration. The program recognized the empirical nature of parachute development and includes sufficient time and resources to redesign both the test set-up and the parachute prior to a second test series. A final qualification test series would then be conducted to qualify this system for Mars operation. The first test series utilized a smaller 0.34 million cubic meter balloon to hoist the test article to 36 km altitude. When the instrumented test article was released, a drogue parachute was static-line deployed. The main deployment was triggered 21 seconds later at Mach 0.54 and 148 Pa.

The objective of this paper is to summarize the simple methodology and hardware employed to prepare for and conduct the first test series with a 33.5 m diameter ringsail parachute. Three drop tests were conducted in Fall of 2004 in Ft. Sumner, NM, USA.. Reference 5 presents more details on the parachute development. Reference 6 presents more details on the results of this first test series.

II. Parachute Development

The Ringsail canopy design was selected as a promising candidate for a Mars Subsonic parachute since it provides good flexibility and balance between drag, stability, and opening characteristics. This high performance canopy design evolved from the ringslot canopy in the 1950's and derivatives were flown as part of the Mercury, Gemini, and Apollo programs[7]. Ringsail canopies have continued in use in recent years[8] as part of the Boeing Evolved Extended Launch Vehicle studies, ESA's Beagle 2 probe, and the Kistler Launch system. Its construction allows for significant control of the amount, and distribution. of porosity throughout the canopy[9]. This benefit is particularly useful for Mars applications where most fabrics appear nearly impermeable and porosity must be achieved primarily by geometric means.

The development of the Mars subsonic parachute system for these tests is described in Ref. 5. The philosophy of this design was to utilize nearly impermeable fabric such that total porosity was determined solely from geometric means. The distribution of this porosity was designed to recreate the total (fabric plus geometric) of successful low altitude terrestrial designs. The 33.5 m (110 ft.) diameter was chosen to provide Mars descent velocities of approximately 50 m/s for suspended mass around 2500 kg.

In addition to the subsonic ringsail canopy developed for this test, a "programmer" drogue parachute was required as described in section IV *Drop Test Set up* below. Ideally, a Viking Disk-Gap-Band (DGB) parachute would have been useful to provide this drogue parachute capability to better recreate the Mars two-stage combination. Unfortunately, this large parachute would limit the deployment conditions obtainable in a simple drop test. Conversely, if the drogue size were too small, the canopy extraction velocities during staging would be much slower than expected on Mars. A 6 m D_p guide surface canopy was selected as an appropriate compromise between these constraints. This canopy design provided good inflation and stability characteristics and represented the largest drogue that could be used and still obtain the desired deployment conditions. Details of the design of this canopy are presented in Ref. 5.

The two-stage parachute system must be designed with Mars entry capsule packaging in mind. The supersonic Viking disk-gap-band parachute will be mortar deployed. The most symmetric packaging of the subsonic main is then an annular stowage surrounding the Viking mortar. The present tests did not include a mortar deployment of the drogue, a simpler static line deployment was utilized. The present test did store and deploy the main ringsail canopy from a representative annular configuration.

III. Mars and Earth Operating Conditions

The exact deployment and operating conditions for a subsonic parachute on Mars are a function of many mission specific variables. Representative conditions were selected for these tests based on a 2500 kg entry mass, 4.5m diameter entry capsule and a 16.1 m Viking DGB supersonic decelerator. This combination results in deployments in the Mach range between 0.4 and 0.8 at dynamic pressures between 65 and 150 Pa. The associated velocities are 155 to 185 m/s. While these conditions are a function of many variables, they are representative of a class of similar missions.

In general, the atmospheric density near Mars surface is equivalent to Earth densities at altitudes between 30 and 35 km. However, the speed of sound near the Mars surface is about 35% lower than at these Earth Altitudes. It is, therefore, not possible to simultaneously match Mars Mach, dynamic pressure, and velocity conditions in a high altitude Earth test. This was true for the PEPP and BLDT high altitude tests also, but is more relevant to this subsonic parachute deployment, since inflation times are more sensitive to velocity. This first test series focused on obtaining deployment at Mach 0.6, dynamic pressure of 150 Pa, and velocities of 180 m/s. A second series of tests covering a range of conditions will be required to develop a parametric inflation model for the canopy - as well as its qualification.

Earth's gravity is 2.6 times greater than Mars. This presents another problem for test design. A decision must be made to match Mars mass or Mars weight. Recreating the deployment, inflation, and associated deceleration of the payload dictates use of the same mass to recreate inertial effects. This is particularly important for this subsonic parachute since the associated inflation is not quite an infinite mass inflation. However, recreating parachute performance during terminal descent requires scaling that mass by gravity to obtain the same weight and canopy loading. This first test series specified the latter as the dominant factor and chose to reduce the Mars mass by a factor of 2.6 to mach Mars weight. While this will alter the decelerations following inflation, the eventual approach is to test both Mars mass and weight over the range of conditions and create a parametric inflation model for the canopy. The gondola plus canopy mass flown in these tests were 980kg which corresponds to a Mars system mass of ~2500 kg.

IV. High Altitude Balloon Drop Test Set-up

The High Altitude test involves five phases: Launch, Ascent, Float, Test, and Recovery. The Launch setup is shown in Figure 1. The Gondola containing the drogue and main parachute system is suspended from the ground launch vehicle (right side of image). This is connected via a gondola release mechanism to an extended safety parachute (red) whose function is to decelerate the gondola if the balloon bursts. At the top of the recovery parachute is the terminate release mechanism which is then connected to the balloon.

Figure 1: Balloon Launch Set-up

When the Gondola avionics and instrumentation checks are complete, the required amount of helium is injected into the top portion of the balloon though the two fill tubes shown. The upper portion of the balloon is secured via a second specialized launch vehicle (image left). Launch is initiated when that second vehicle releases the upper portion of the balloon. The balloon ascends until it is above the launch vehicle. The launch vehicle operator maneuvers until he is precisely beneath the balloon then releases the gondola for ascent. Large balloon launches are constrained to specific wind speeds and direction. The ascent train just after launch is shown in Figure 2.

The present Parachute test set-up differs from the standard high altitude balloon science test set-up. The standard method for high altitude balloon science tests utilizes a simpler ascent train comprised of the gondola, the extended recovery parachute, a single terminate-release mechanism, and the balloon. Science payloads desire to float at altitude for extended periods and then are brought down under the recovery parachute. The change was required to release the test gondola entirely from the ascent train for a static line deployment of the programmer parachute. Initially, the drogue was considered as a replacement for the safety parachute, but it was too small to bring the Gondola down at reasonable velocities in the advent of an ascent balloon burst.

Figure 2: Ascent

It takes two to three hours for the balloon to reach float altitudes. When the desired altitude is obtained, the gondola release mechanism is activated. As the gondola falls free, a static line deploys the packed drogue and the gondola falls toward the desired main deployment conditions. For the present test program, 21 seconds of descent were required to obtain Mach 0.6 deployment conditions. Timers on the gondola count down and trigger main deployment via simultaneous activation of pyrotechnic cutters.

Once the gondola has been released, the hardware remaining above the gondola and the balloon must also be recovered. Since the remaining hardware mass is small, a smaller recovery parachute is needed. The size of this parachute is a trade between small enough to allow a reasonable descent (and drift) of the remaining hardware, and large enough to safely bring the entire gondola down in the event of a balloon burst during ascent. A small amount of ballast was added to the remaining hardware and a 49 ft recovery parachute was selected as the appropriate balance between these factors. After the gondola is released, the remaining hardware is released. This second release pulls a seam out of the balloon which then also descends to the ground.

The National Scientific Balloon Facility routinely launches four different sized balloons: 0.1, 0.34, 0.79, and 1.1 million cubic meters. Larger balloons that can lift larger gondolas to higher altitudes are available. Cost for each test is proportional to the volume of the balloon. The present test made use of the 0.34 million cubic meter balloons, since this size could lift 1134 kg to approximately 36.6 km. Descent under drogue from this altitude would allow the gondola to obtain the Mach 0.6, and dynamic pressure 150 Pa conditions with a 21 second free-fall. Additional tests are planned with the larger balloons to obtain Mach 0.8 conditions without exceeding the dynamic pressures associated with Mars deployments.

V. Gondola and Instrumentation

The gondola is shown in Figure 3. It is a simple truss structure that includes a faceted aerodynamic fairing to produce an aerodynamic wake similar to that expected from a hypersonic entry capsule of diameter 3.5m. The fairing assures the parachute inflates and operates in wake conditions similar to those expected on Mars.

The structural base of the gondola is a 2.54 cm thick steel regular nonagon (nine sided polygon with equal sides). Beneath this base plate 0.4 m of crushable paper honeycomb is mounted for ground impact energy absorption. The strength of this crush pad was sized to limit loads to about 20-g's during impact, and its thickness was set for impact velocities up to about 12 m/s (Nominal impact speeds were expected to be 4.5 m/s). On top of this base plate the batteries, instrumentation, pyrotechnics, and NSBF telecommunications equipment were mounted. Bipod trusses connected the base plate to three structural nodes at the parachute deck above. Both the drogue triple risers and the main triple risers were attached to these structural nodes. The nodes were designed for loads up to 267 kN each. The main ringsail canopy was stowed in an annular deployment bag on the parachute deck and the smaller drogue deployment bag was stored on top of the main.

Figure 3: Gondola Test Article with Stowed Main and Drogue parachutes.

Staging of the main parachute was commanded by a pyrotechnics system on the Gondola. Cut wires in the gondola release cutters activated timers in the on-board pyrotechnics system. When these timers expired, they commanded cutters at each structural node that simultaneously severed the three drogue triple risers. A lazy leg off the drogue confluence fitting then pulled the main deployment bag off the parachute deck.

The gondola carried four cameras: three up-looking cameras to observe the deployment and operation of the drogue and main canopies, one horizon looking camera, and one down-looking camera. Two of the up-looking cameras were mini-Digital-Video camcorders mounted in heated enclosures off the parachute deck. The 30 frames per second imagery from these two cameras were stored onboard for retrieval at recovery. These cameras only possessed 1 hour of standard video record capability so required activation just prior to release from the balloon. Activation was accomplished by mounting infrared transmitters to the cameras which were controlled by ground command through the NSBF telecom system. The third uplook camera was connected directly to the telecom system for real-time observation and storage on the ground. This real-time camera was mounted on the gondola centerline and viewed through the center hole in the main canopy. The final camera was a down-looking camera which was part of a separate experiment dedicated towards obtaining visual imagery for optical navigation of a pin-point landing technology task. Additional imagery was collected via a ground-based telescope fitted with a video camera and another video camera in the chase airplane.

The instrumentation suite included numerous sensors to record the deployment, inflation, and inflated performance of the parachute. Analog channels were converted to digital signals, multiplexed and then combined with digital sensors through a Virtex TM, Field Programmable Gate Array. All data was stored by an on-board, low power CPU with flash memory storage at 100 Hz. A nominal test required activation of the instrumentation 2.5 hours prior to launch (last access), a 2 hour ascent, then a 1 hour descent. The memory capacity (and Lithium-ion battery power supply) was sized for a 10 hour duration. This time accounted for potential delays in launch, or extended period at float while an acceptable descent corridor was found.

A Northrop Grumman LN-200 Inertial Measurement Unit (IMU) included 3-axis accelerometers and 3-axis rate gyros. This combination would describe the detailed dynamics of the gondola. Load cells were mounted in-line on each of the main parachute triple risers. In addition to providing a direct measurement of inflation loads, the load cells could describe the motion of the parachute relative to the gondola. A Global Positioning System (GPS) receiver and antennae were included to provide rough trajectory and altitude information. Five pressure transducers were also included. Three of these were static pressure sensors to record the range of static pressure from low to high altitude at a location behind the aerodynamic fairing. The two remaining pressure sensors were differential transducers connected between a total pressure probe in front of the vehicle and a static pressure port behind the aerodynamic fairing. Finally, numerous temperature transducers were included to examine temperatures of the load cells, the pressure transducers, and the electronics to assure they were within calibrated or acceptable operating ranges.

VI. Ground Tests Prior to High Altitude Tests

The past 30 years of high altitude ballooning have greatly increased the reliability of launch, ascent, and operations. The cost, however, remains high relative to helicopter or aircraft-based drop tests. When costs per test are high, it is advantageous to conduct low altitude, and ground-based testing prior to high altitude tests in order to mitigate risk areas.

For the main and drogue parachute canopy, Pioneer Aerospace conducted low altitude aircraft drop. While these tests do not recreate the correct deployment conditions, they were useful in verifying many functional aspects of the parachute system. The low altitude drop tests are described in References 5 and 6. Ground tests were also conducted on energy modulator systems for the canopy.

One particular inadequacy of the low altitude aircraft tests was the canopy extraction speeds were limited to about 30 m/s while the high altitude tests expected values closer to 60 m/s. A ground test was desired that would extract the canopy from its deployment bag at representative speeds as an inexpensive means of verifying that the canopy was not damaged during this event. In addition, since a smaller drogue canopy was used in the high altitude tests, extraction speeds would be slightly lower than expected on Mars. A ground extraction test capability would be useful in qualifying the deployment to the higher Mars conditions.

Numerous approaches were examined including pneumatic cannons, rocket sleds, and low altitude drop tests. One real challenge with designing this test was that any set-up that extracted the canopy from its bag at the right speeds also subjected the canopy to unacceptably high dynamic pressures due to the low altitude (high density) test conditions. A tethered balloon approach was finally identified as the most favorable cost to benefit compromise. The test set-up is shown in Figure 4. The stowed main parachute was held just inside the mouth of a truncated cone then hoisted via tethered helium balloon to 300 m above the test surface. A 180 kg steel ingot was then released. This ingot unwrapped a 245 m cable from the cone during its free-fall. The end of the cable was attached to the parachute risers that then extracted the canopy at the desired speeds. Shortly after the canopy was extracted, the steel mass struck the ground removing the motive force from the parachute prior to its inflation, thus avoiding large inflation loads. After numerous drops to refine aspects of the set-up, the test was conducted in May of 2004. Extraction speeds in excess of 50 m/s were attained and no damage to the canopy was observed.

Figure 4: Ground Extraction Test Set Up

A subsonic windtunnel test of a scaled model of the Gondola was conducted.in the Vigiyan subsonic windunnel in Hampton, Virginia. The purpose of this test was to determine the drag coefficient for the gondola to permit isolation of the main parachute drag characteristics. The windtunnel tests were also used to establish calibration factors for the static and total pressure probes.

High altitude testing subjects the test article and its avionics to near space environmental conditions. Design considerations must be made for the low pressures, high incident solar radiation, and very low ambient temperatures expected at high altitude. In addition, the system must operate in low altitude conditions prior to launch and after ground impact without overheating. The low power camera systems presented no problem at low altitude, but required heated thermal enclosures for high altitude. The gondola instrumentation consumed about 50 watts of power but still required thermal insulation to maintain operating temperatures. This same thermal enclosure would produce overheating for ground operation so the thermal enclosure was fitted with a thermostatically controlled fan.
A series of thermal-vacuum tests were conducted to verify the operation of the electronics. In addition, an ambient pressure hot-sun test was conducted to verify post ground impact operation.

VII. Four Drop Tests

A series of four launches were conducted at Ft. Sumner New Mexico in the fall of 2004. The first two experienced parachute anomalies, the third suffered a balloon failure and the fourth was successful. A description of each follows.

The first test was conducted on August 15th, 2004. Launch preparations, launch, and ascent went as expected. The payload was released from 36.6 km altitude. The static line deployment of the drogue was characterized by a large rebound in that canopy. The guide surface drogue still inflated properly and provided the expected drag area for the 21-second acceleration to deployment conditions. The main parachute deployed from the gondola correctly, but suffered a pre-inflation anomaly that resulted in a tangled canopy. The parachute never achieved the proper reefed inflation state. At disreef. the parachute suffered structural damage and remained tangled (Figure 5). The damaged canopy still provided sufficient drag area to safely descend the payload. Ground impact was estimated at 12 m/s and no damage to the hardware was experienced. Inspection of the recovered elements of the parachute system revealed that the vent control leash had malfunctioned and broke after stroking only one third of its length. Examination of the uplook video in conjunction with side video collected via ground telescope revealed that a significant apex rebound followed the leash failure. This rebound led to the entanglement and improper reefed state.

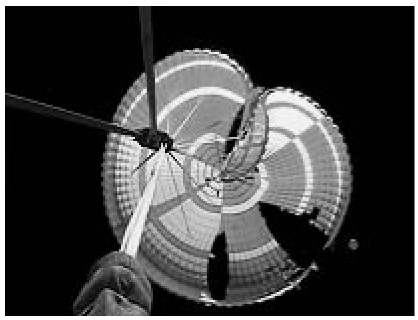

Figure 5: Attempt 1 Parachute damage

An examination of the vent control leash design and stowage identified potential weaknesses in that design. In particular, the leash design in conjunction with its stowage could combined to result in the leash tangling on itself which led to its failure and the ensuing canopy deployment anomaly. These inadequacies were not revealed in either the low altitude tests or the tethered balloon ground extraction tests. A new design and stowage concept were incorporated that would prevent that deployment anomaly. In addition, a new design for the drogue vent control leash was incorporated to reduce the observed rebound in that canopy.

The second high altitude test was conducted on September 11, 2004. Launch preparations, launch, and ascent went as expected. The payload was released from 36.3 km. Drogue deployment was significantly improved from test 1. Main deployment occurred at the correct conditions, however, canopy entanglement and improper reefed state again resulted. At disreef, the canopy suffered substantial structural failure (Figure 6). Review of the telescope video revealed another apex rebound during deployment indicating inadequate vent control. Inspection of the recovered pieces revealed that the redesigned vent control leash deployed and performed as designed, but the strength was inadequate. The apex rebound drove the vent region of the canopy into the lower inflating portion of the canopy at speeds around 40 m/s. This produced another entanglement and led to the ensuing canopy damage. The significantly reduced drag area of the parachute provided some deceleration to the payload. Ground impact was estimated at 18 m/s. The honeycomb crush pad provided significant impact energy absorption, but the gondola suffered some structural deformation and several electrical cables were damaged.

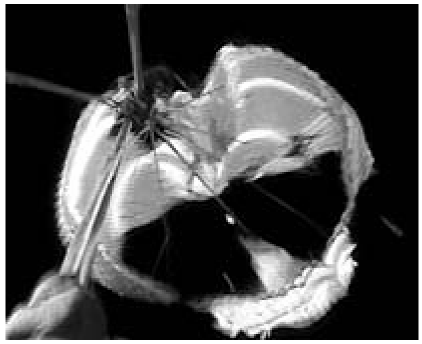

Figure 6: Attempt 2 Parachute damage

Additional investigation into the Vent Control Leash design was undertaken and revealed that the redesign from test 1 solved the stowage and deployment problems experienced there, but now revealed that the strength was inadequate for the high altitude conditions. Inadequate strength decreased the time which the leash controlled the vent and allowed the vent to attain significant out-of-column attitudes. The strength and length of the vent control leash were increased.

The third high altitude test was conducted on October 21, 2005. Again launch preparations and launch proceeded as expected. However, as the balloon ascended through 18.3 km altitude it burst. The NSBF recovery parachute inflated as designed and the gondola was brought safely to the ground. The test canopies were not deployed, however, they were on board the Gondola during the ensuing 18 m/s ground impact which subjected the packed canopies to ~20 g impact loads. This impact raised concerns over potential damage to the packed canopy. Unfortunately, the test window for Ft. Sumner New Mexico was over and no time was available to allow an unpack, inspection, and repack.

The fourth attempt was conducted October 25th, 2004. Float altitudes winds were approximately 50 m/s to the East. The balloon achieved the desired float altitude in a location unsuitable for test conduct. The balloon drifted for 2 hours until it was east of Amarillo Texas and which time the test could be conducted with a safe landing in South Western Oklahoma. The test went as expected and the parachute inflated without damage (Figure 7).

Examination of the drogue's performance reveals an average drag area of 22.5 m^2. At 20.95 seconds the gondola pyrotechnics circuit triggered main parachute deployment. Integration of this period indicates main deployment occurred at 167 m/s, Mach 0.54, and dynamic pressure of 148 Pa. Line stretch occurred 1.82 seconds later, with the canopy extraction marked by accelerations near 30 m/s^2. The peak acceleration of 158.7 m/s2 (148.9 m/s2 applied acceleration) occurred 2.66 seconds after line stretch and indicated a peak inflation load of 144.5 kN (32,486 lbf) (for the 977 kg gondola plus main when the 1272 N Gondola aerodynamic drag is removed). Descent took just over 60 minutes and ended with a ground impact around 5 m/s.

However, the uplook cameras revealed the reefing system did not work as expected. The reefing system is designed to constrict the canopy mouth to 15% of the parachute diameter for the first 6 seconds of inflation. This assists in producing an orderly inflation and decreases the peak loads on the canopy. The video reveals that the reefing system was in place, and did hold the skirt in its proper configuration but there was no apparent pause in the inflation and the canopy went directly to its full inflation state. Fortunately, the canopy was designed with positive margin against a safety factor of two so that it possessed sufficient strength to handle the associated loads.

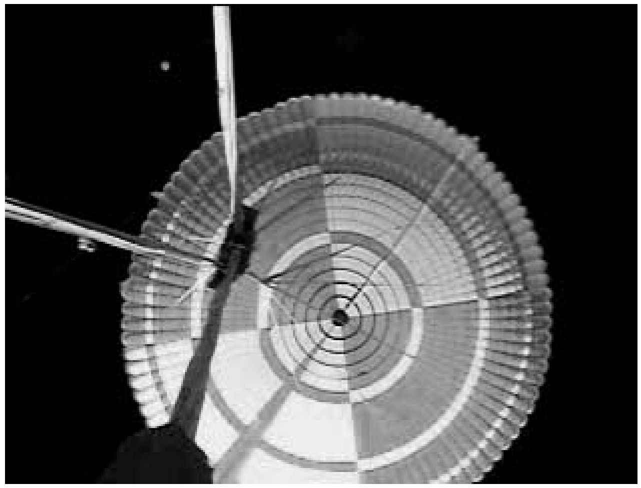

Figure 7: Full inflation image from uplook video.

An investigation into the cause of the reefing system anomaly was conducted. Inspection of the recovered canopy revealed that all but two of the reefing rings and one reefing cutter were torn from the skirt of the canopy. This suggests that when the canopy had ingested sufficient gas to begin loading the reefing line, the reefing rings were stripped from their attachment to the canopy. Uplook video reveals this stripping occurred first on one side of the canopy then followed by the opposite side leaving the reefing line only connected through the two cutters. The two cutters held only briefly before one was also stripped from the skirt.

This canopy was the same flown in attempt 3 on October 22nd. That flight suffered the balloon failure and descent under the NSBF recovery parachute. The ground impact of the stowed canopy subjected that packed assembly to ~20g's. Numerous risks were identified associated with reflight of the canopy without inspection and repack. The primary risk discussed was friction damage to the canopy structure, but other risks identified included the possibility that the reefing cutters had been triggered (Lanyard pull) and fired following impact. This risk was judged to be unlikely given the orientation and dense packing of the cutter regions. The repack option would have delayed the test some two weeks and probably prevented a fourth test in this Ft. Sumner Fall 2004 campaign. The program made the decision to accept the risks and re-fly the canopy with only an inspection of its attachment to the Gondola.

It appears evident that the Test 3 impact may have damaged the connection of an unknown quantity of the reefing rings to the canopy, their failure started an unzipping phenomena that removed the remainder.

Summary

Three high altitude drop tests of a 33.5 m Ringsail Canopy were conducted in the Fall of 2004 from Ft. Sumner, New Mexico. The deployment conditions were consistent with those expected on Mars when using this parachute in conjunction with the Viking 16.1 m supersonic parachute as part of a two-stage system. A 0.34 million cubic meter helium balloon was used to hoist the test article to 36 km altitude. When the instrumented test article was released, a drogue parachute was static-line deployed. The main deployment was triggered 21 seconds later at Mach 0.54 and 148 Pa.

This was the first test series of a technology task that planed two additional test series to complete the development of this parachute system. The second test series will incorporate design changes to correct the anomalies observed in these tests and expand the test matrix to explore the remaining range of Mach and dynamic pressures. The third test series is envisioned as a flight qualification test series.

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