LOW DENSITY SUPERSONIC DECELERATOR

Kolby Javinar
Department of Electrical Engineering
University of Hawai‘i at Mānoa
Honolulu, HI 96822

ABSTRACT

During the summer of 2014, NASA planned on testing two new decelerators for their Low Density Supersonic Decelerator (LDSD) Project. The “Low Density” refers to the thin atmosphere of Mars. The National Aeronautics and Space Administration (NASA) want to advance the technology of delivering larger payloads to Mars. The two new decelerators will help slow down the speed of the entry vehicle to subsonic speeds for safe water landings. The device that was tested during the summer was the Supersonic Inflatable Aerodynamic Decelerator Robotic Class (SIAD-R). The SIAD is equipped to a Test Vehicle that will be launched from a balloon. The balloon will carry the TV to an altitude of 120,000 feet. The TV will use a rocket-fueled motor to bring it to the top of the stratosphere and drop down to the Earth at Mach 4 speed. The SIAD will inflate to slow down the TV. A supersonic parachute is also attached to the TV to slow it down for a safe landing. The test is the first steps on a path to potentially landing humans on Mars.

INTRODUCTION

The Low Density Supersonic Decelerator (LDSD) Project is a technology development effort in the Technology Demonstration Missions portion of NASA’s Space Technology Mission Directorate (STMD) [1]. The project’s objective is to develop full-scale supersonic decelerators for application in low-density atmospheres, such as on Mars, by demonstrating their capability in relevant to the environments on Earth [1].

The LDSD Project is currently being tested on Kaua‘i at the Pacific Missile Range Facility (PMRF). Shown in Figure 1, the test vehicle (TV) is a launch mechanism that's in the shape of a capsule with one side shaved off to store electrical devices to implement autonomous actions along with a motor for propulsion.

Figure 1: The Test Vehicle equipped with the Star-48 motor and SIAD-R [2]
The TV will be used to implement two decelerators that are known as Supersonic Inflatable Aerodynamic Decelerators (SIADs). These are very large, durable, balloon-like pressure devices. The technologies being tested are the SIAD-R (20ft in diameter) and the, still in development, SIAD-E (26ft in diameter). Another device that's being tested is the Supersonic Disk Sail (SSDS) parachute. The supersonic parachute will be the largest of its kind ever flown.

The task that I was given was to create a Launch Day Operations book that would include information on the different roles of the mission. The LDSD is a huge project made up of three different NASA groups. There are the Jet Propulsion Lab (JPL), the Wallops Flight Facility (WFF), and also the Columbia Scientific Balloon Facility (CSBF). The Launch Book will have a list of different procedures and checklists that will be crucial information to the launch process. I was also given the task of creating a visitor information booklet that will contain a water-down version of the project and its goals.

The first flight is an experimental flight test, to see if it can accurately achieve the speeds and altitudes required for the demonstration of the technologies in a Mars-like environment. Two more tests are scheduled next year to collect the required data on the decelerator technologies. The two decelerators (the SIAD-R and the SSDS Parachute) are on-board this first shakeout flight, and will be deployed if the proper conditions are met.

The launch of the flight test will be implemented with the use of a balloon instead of rocket. The reason for this is due to an earlier program conducted by NASA. The Viking program was an earlier attempt at developing and testing decelerators for the same purpose [1]. A balloon was used to launch decelerators for testing rather than a rocket because of cost [1]. It was more efficient to use a balloon than it was to launch an expensive jet-fueled rocket to the attended height. However, the TV itself is equipped with a Star-48 booster rocket. The balloon is incapable of lifting the TV up to the attended height, so a rocket is used to fill the gap. Four spin-up and four de-spin motors are used to provide stability during powered flight [3]. The SIAD attached to the outer rim of the TV will inflate when the test vehicle is flying at Mach 3.8 and decelerate the vehicle to Mach 2.5, where it becomes safe to deploy a supersonic parachute [3]. The SIAD-R is intended for extended performance of Mars Lander class entry systems and to enable more precise landings for heavier payloads [1].

Key Points

Early forms of decelerators date back to NASA's Viking program. This program put two Landers on Mars in 1976 and its parachute design is still being used in recent missions such as the Mars Curiosity rover in 2012 to land in Mars [3]. To safely land heavier payloads on Mars, larger parachutes and other decelerators that at supersonic speeds are needed. The LDSD project's aim is to solve the complicated problem of slowing down Martian entry vehicles enough to safely deliver large payloads to the surface of Mars [3]. These are the first steps on the path to potentially landing humans and there return rockets safely on Mars [3]. The new designs borrow from the same technique used by the Hawaiian puffer fish – the ‘o’opu hue – to increase its size without adding mass: rapid inflation [4]. The first flight is a shakeout test of the TV at speeds up to Mach 4. There will be two more flights next summer to test the technologies.
Dimensions

**Test Vehicle (TV):**
- Weigh w/fuel: 6,878 lbs. (3,120 kg.)
- Diameter (pre-inflation): 15 ft, 5 in. (4.7 meters)
- Post inflation: 20 ft (6 meters)
- Maximum Speed Traveled: Mach 4
- Duration of flight test from balloon launch to vehicle splashdown: approximately 3 hours

**Parachute:**
- 100 ft (30.5 meters) in diameter; longest supersonic parachute ever deployed.

**Launch Balloon:**
- Width: 460 ft (140 meters)
- Height: 396 ft (120 meters)
- About the size of a football stadium

**METHODS**

The day of the launch starts off with the transfer of the TV to the launch pad. Launch pad activities will be conducted in preparation for pre-lift operations. There are electrical checkouts and arming activities that need to be established such as positioning of the TV on the launch tower and connecting to the tower and TV. This leads into lifting the TV to the height of the tower and conducting post-lift electrical checkouts. These checkouts include checking the balloon's and TV's telecom systems and verifying console displays from B560 (TOC/BOC) and B105 (ROCC). The balloon is then laid out and inflated with helium. The internal power of the TV is turned on at this time. All of these checks and balances that need to be done to the TV and balloon take's about 6-7 hours to complete prior to launch.

The balloon and vehicle are released from the tower at L-minus 0. The balloon carries the vehicle to an altitude of 120,000 feet. Then, the balloon will release the TV and the Star-48 booster rocket will kick in and take it to an altitude of around 180,000 feet (top of the stratosphere). There are also small rocket motors attached to the side of the SIAD that spin the vehicle ahead of the main motor ignition. Spinning the test vehicle while in flight keeps it stable. Having the vehicle stable is important for deploying the decelerators; if the vehicle wobbles too much, it could get the parachute tangled during its deploy. The TV will be dropped at a maximum altitude of 180,000 feet and travel at approximately Mach 4 speeds. The TV will then deploy the SIAD to decelerate the vehicle to approximately Mach 2.5 speeds. The SSDS parachute will deploy to slow it down to subsonic speeds and carry it safely to the surface for a controlled water impact. Figure 2 shows a brief explanation on how this launch plays out.

There are two recovery boats called the Kahana and the Honua that are going to recover a few items from the water. The balloon envelope and TV will be recovered after impact. The duration of the recovery phase will be driven by how quickly boats are able to locate the items to be recovered, address any safety hazards and assess the article, pick up the article on-board the boat, and head back to port. It is required, due to the environmental sensitivity of the region, for all floating objects be recovered from the ocean following launch. Recovery off of the waters of Kaua‘i consists of the Balloon, test vehicle, SSDS Parachute, Flight Imagery Recorder (FIR),...
and other floating debris. The balloon, the TV, and FIR is expected to remain buoyant after impact. The FIR, located on the TV, is an on-board memory module for the storage of all high speed and high resolution data. It has been designed to separate itself from the TC on ocean impact if submersed in saltwater for a given period.

![Figure 2: Flight overview of the Supersonic Flight Dynamics Test (SFDT)](image)

**RESULTS**

The launch for the LDSD project was scheduled for the first two weeks of June. During those two weeks, the weather was not favorable for the launch. The biggest problem for the launch was the wind. There are many restricted areas that were in place by either the Federal Flight Administration (FAA) or PMRF. The team conducted many balloon trajectory simulations prior to and up until the launch day to predict where the balloon will go. Simulations weren’t very reliable due to imprecise data up until the day of launch; so, they also released smaller balloons the morning of the launch days to see where the wind would take the balloon when launched. During the first two weeks of June, the predictions always had the balloon hovering in restricted areas. These counted as going over populated areas or entering flight restricted areas. To get the balloon to fly over water, the winds must be at near perfect conditions. In Hawai‘i, the trade winds needed to be present with minimum clouds and showers. It wasn’t till the ending of June that these conditions were present.

The launch for the LDSD project happened on June 28, 2014. The day started off just as planned. The TV was setup on the launch tower and adjusted according to the wind direction. The Launch Operations Book was finished and ready for use by the Range Operations Team. The camera displays in both Building 560 and 102 were working along with the streaming devices for video feed of the operations. NASA’s website had a live feed of the entire operation. The launch of the balloon was delayed a bit due to extra checks that needed to be done to ensure
that nothing terrible happens during launch. The balloon was launched around 8:40am HST. Figure 3 shows the balloon launch in action.

![Image of a balloon filled with helium and released into the air to lift the TV off a launch tower](image1)

**Figure 3:** The balloon is filled with helium and released into the air to lift the TV off of a launch tower

The launch went off without a hitch. The balloon and the TV’s Star 48 rocket-fueled motor worked perfectly. Figure 4 shows the view of one of the GoPro Cameras attached to the TV. The balloon hovered over the water north of Ni‘ihau at an altitude of about 120,000 feet when it detached from the TV. The TV propelled itself to an altitude of about 180,000 feet; then, the TV activated the spin motors to stabilize itself for the fall to Earth. The TV fell at Mach 4 speeds and successfully deployed the SIAD. The SIAD was able to slow the TV down to about Mach 2.1 speeds. From there, the TV deployed the SSDS parachute to slow down the TV for landing. When the parachute was deployed, it immediately ripped apart (Shown in Figure 5). The parachute did slow down the TV a bit, but it never did reach subsonic speeds. The impact that the TV made with the water was like hitting concrete. The TV was significantly damaged when it landed in the water.

![Image of the Star-48 rocket motor propelling the TV up to the top of the stratosphere](image2)

**Figure 4:** The Star-48 rocket motor propels the TV up to the top of the stratosphere
The TV was recovered from the ocean just north of Ni‘ihau. The TV suffered major damage to the top of the structure, creating a huge hole in the TV. However, the electronic devices of the TV didn’t suffer too much damage. The TV was in the water for a few hours before the recovery boat fished it out of the ocean (Shown in Figure 6). Within that amount of time, the electronics did sustain a lot of corrosion from the salt water. Most of what’s left from the TV’s electronic system is salvageable.
CONCLUSION

Despite the parachute being torn apart when it deployed, the other aspects of the test went according to plan. The LDSD team would call this a huge success on their part. The parachute problem is a minor fix; although, they’re not quite sure why the parachute ripped apart so vigorously. The LDSD team is very excited for their return to Kaua‘i for the next phase of operation. They will probably test the SIAD-R a couple more times before moving on to the SIAD-E. Next summer (around the same time as this launch) will be their next scheduled launch opportunity at PMRF.

ACKNOWLEDGEMENTS

I would like to express our biggest thank you to the Hawai‘i Space Grant Consortium for fronting the stipends for this internship along with Mr. Burley who helped me apply for this opportunity. I would also like to thank everyone involved with the LDSD project and the people that I worked with at PMRF after the conclusion with the LDSD project. I am very grateful for the opportunity to be part of this project and being a part of this history in the making.

REFERENCES


