Harding University

University Student Launch Initiative

Final Report

May 25, 2007

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I. Introduction

The Harding University "Flying Bison" USLI team deems its first year of competition to be a "qualified success." While not all mission success criteria were fully met, much was learned through the competition, and the team is well-prepared for future rocketry endeavors. Only one member of the team had previous high power rocketry experience, so the process of designing, building, and flying a rocket with a scientific payload was highly educational.

The Flying Bison set for itself five mission success criteria. Three of these goals were successfully met, one was not, and one was partially met. Each of the five goals is stated below, along with the ways in which the goal was or was not met and the reasons why. Following this introductory section, the various areas of difficulty during the construction and launch process are detailed, and the science package is examined in detail.

Criterion One: Successful completion of USLI design process (Proposal, PDR, CDR, Final Report).

Outcome: Success. The Flying Bison completed all reports and designed a rocket vehicle that performed admirably.

Criterion Two: Constructing and testing vehicle airframe, recovery system and payload.

Outcome: Success. The Flying Bison worked together as a group to construct and finish the launch vehicle and to mount and test various electronics components.

Criterion Three: Safe ascent of vehicle and recovery of all components in reusable condition.

Outcome: Success. The vehicle flew and recovered safely. The only damage sustained was cosmetic and easily repairable.

Criterion Four: Achievement of 5280 feet altitude within 5%.

Outcome: Failure. The final altitude achieved was 1088 feet. The proximal cause of this failure was insufficient nitrous oxide in the hybrid motor at the time of launch, which was in turn caused by poorly prepared launch equipment and flight procedures and various delays that had prevented full flight testing.

Criterion Five: Return, via telemetry and post-flight downlink, of the following data: altitude, 3-axis acceleration, GPS, temperature, pressure, color video with sound, and spectroscopic analysis of exhaust plume (to be compared with results from ground tests).

Outcome: Partial success. The telemetry and GPS units associated with the R-DAS failed on the day of the launch and were not flown. The R-DAS recorded altitude, acceleration, and velocity data, but the spectroscopic analysis of the exhaust plume did not yield useful data. The team's conclusions regarding the science package are detailed in Section III.

Color video with sound was received via a separate telemetry link during flight. Ground-based video of the flight is available at http://www.youtube.com/watch?v=OXBZHFIWG14, while the onboard video is available at http://www.youtube.com/watch?v=kcGDtewdv34.

II. Failures and Outcomes

II.A. Flight operations

Because of a scheduling conflict with finals week, the Flying Bison USLI team attended the high school SLI launch in Huntsville, Alabama. The general assembly and preparation work on the launch vehicle went as planned on the launch day. However, attending the launch at Redstone Arsenal under Army supervision introduced a few unexpected rules. First, there were long delays between final preparation to fly (which occurred by 1:00 p.m.) and the actual flight (which occurred well after 4:00 p.m.). While switches were provided on most of the in-flight electronics to allow activation on the launch pad, a switch had not been wired into the video camera assembly, so the Boostervision camera had to be turned prior to full airframe assembly and left running for several hours. While the Boostervision assembly performed remarkably well, in the future the Flying Bison will plan on the possibility of several hours wait time between prep and flying.

Also, Army personnel would not allow teams to retrieve their own rockets. The 10-foot diameter main of the Flying Bison launch vehicle remained inflated for some time after landing, dragging the rocket along the ground and causing additional cosmetic damage. Recovering data from the electronics post-flight would not have been a concern had the telemetry worked as planned, but without telemetry, recovering the rocket as soon as possible was a concern.

The design of the electronics bays could be improved for future flight vehicles. While having a design with an electronics board mounted on a central plate on threaded rods between two bulkheads proved to be durable, the assembly process at the field was complex and did not allow for easy access to the electronics. A design with built-in hatches might be preferable.

II.B. Timeline and testing

A combination of weather conditions and scheduling difficulties prevented the Flying Bison from attending two planned test launches in Memphis. Because of these problems an in-flight test of a Contrail Rocketry hybrid K motor or a full-up test flight of the launch vehicle was not possible. The G-Wiz recovery electronics package was tested in flight, and a Contrail Rocketry I hybrid was static tested. These tests gave the team sufficient confidence in the ignition procedures for Contrail Rocketry hybrid motors and the efficacy of the recovery electronics to proceed with the launch.

II.C. Altitude

Due to the use of a hybrid motor, The Flying Bison team provided its own ignition system (a RATTWorks and Contrail Rocketry compatible hybrid system from Pratt Hobbies) with a 100 foot cord. However, because a full-scale test flight on the K motor had not been possible, the team overlooked that K motors require a minimal safe distance of 200 feet to launch. If this problem had been foreseen, a simple extension to the Pratt Hobbies system could have been purchased. During flight procedures the hybrid motor was filled via the Pratt Hobbies system from 100 feet. The Safety Officer and a NASA representative then evacuated the launch area to a distance of 200 feet, after which a brief countdown was commenced. Approximately 30 seconds passed between the completion of nitrous filling (as indicated by venting from the rocket) and actual firing of the rocket, allowing an unknown yet significant amount of nitrous to vent.

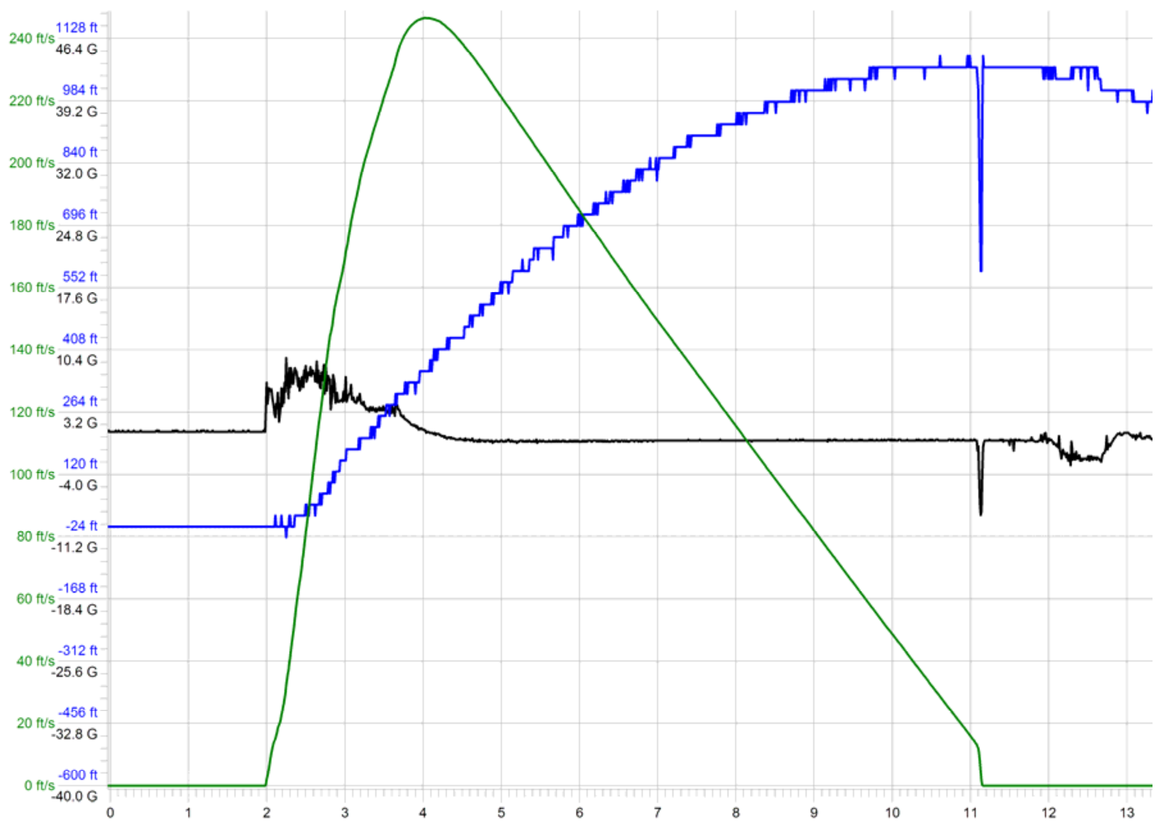
This decrease in nitrous oxide caused the rocket to be underpowered and only achieve an altitude of 1088 feet. The decrease in velocity coming off the 10 foot rail was also the likely cause of the deviation from a vertical path observed directly after launch (viewable in the launch video at http://www.youtube.com/watch?v=OXBZHFIWG14). The integrity and stability of the launch vehicle allowed it to remain intact and resume an upward trajectory after this deviation.

II.D. Recovery

The R-DAS deployed its ejection charge (for apogee deployment of the 3-foot diameter drogue) at apogee as planned. The G-Wiz unit fired both main and drogue ejection charges at apogee. The main charge was programmed to fire at 800 feet. No second charge was visible or audible after main deployment, but both ejection charges connected to the G-Wiz were determined to have fired after recovery, so it assumed the main charge fired at the same time as the drogue charge. Again, full flight-testing of the vehicle may have enabled the team to determine the cause of premature main deployment. More testing is required to determine the cause of this failure.

II.E. Recovered data

The R-DAS unit provided a reported altitude of 1088 feet. The velocity, acceleration, and altitude were all obtained and graphed as follows, with green being velocity, blue being altitude, and black being acceleration:



II.F. Summary of successes and failures

Successes:
- •Successful ignition of hybrid motor
- •Structural integrity during flight
- •Stability during flight
- •Successful drogue deployment
- •Successful main deployment
- •Recovery without significant damage
- •Reporting of basic flight data (altitude, etc.)
- •Onboard video transmitted during flight
- •Completion of USLI paperwork
- •Safety during construction, test, and flight operations

Failures:
- •Nitrous fueling/venting procedures
- •Insufficient total altitude
- •Main deployment at apogee
- •GPS and telemetry unit failure
- •Scientific package failure

III. Science Package

III.A. Introduction

The science package flown with Harding's rocket was a plume sensor designed to measure the total illuminance of the rocket plume as a function of time. Initial on-site measurements indicated that a successful data collection had taken place. However, once the data was more carefully analyzed back at the laboratory, we were forced to conclude that the data recovered from the RDAS flight computer was not valid data, and our sensor collection process failed.

The failure of any critical flight component requires a careful examination of the possible failure modes to determine where the failure occurred and what steps can be taken to insure that such a failure doesn't occur on subsequent flights. The most likely failure modes identified pre-flight for the sensor package were as follows (in descending order of estimated likelihood):

1. Physical damage to the sensor package during flight
2. Failure of the onboard computer recording sensor data
3. Failure of the power package during flight
4. Failure of wiring connections during flight
5. Inadequate sensor design
6. Mechanical failure of the physical mounting of the onboard electronics.

A careful inspection of the (long-delayed) recovered rocket revealed no obvious mechanical failure of the airframe, nor any signs of physical damage to the sensor or its external wiring. This was further confirmed by inspection of the electronics package inside the airframe which showed no signs of physical damage.

The onboard RDAS computer did not completely fail since good data was recovered from the altimeter, accelerometer, and the velocity measurement. The likelihood of a failure in part of the RDAS system and not others was considered, while certainly possible, to be a very low probability occurrence.

The power package apparently also functioned properly since the power required for the RDAS and deployment systems clearly did not fail since as these functions worked properly during the flight.

A retest of the sensor assembly, in situ on the rocket, showed that it was functioning correctly and could be properly calibrated, as can be seen on the graphs attached to the next section of this report.

Based on these lines of evidence, we are forced to conclude that the most likely failure mode for our science package was a defective or broken connection between the sensor and the RDAS computer. Failure of two subsystems on launch day (GPS tracking, and Telemetry) required emergency repositioning of the electronics package and some mechanical modifications of the mounting assembly. It seems most likely that during this process a connection between the sensor and the RDAS was either weakened or broken and failed during the reassembly process. The analysis of the data supports this conclusion, since identical data was recovered from 3 of the 5 A/D inputs even though inputs AD1 and AD2 were open and not being used. The sensor was (supposedly) connected to AD0, but identical readings on these 3 inputs would seem to imply that AD0 was an open input during the flight.

This failure will require a careful study of the electronics connections for subsequent flight as well as the actual mounting of the electronics packages for our airframe.

III.B. Sensor Calibration

The sensor used as our science package was a UDT-455HS diode with a built-in amplifier as shown in Figure 1.

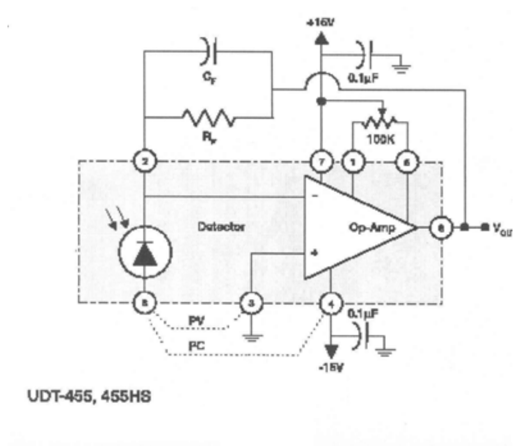


Figure 1. UDT-455HS Diode.

The diode was calibrated by use of a Stellarnet 2000 Spectrometer used in the calibrated illuminance mode. The spectrometer gives the integrated illuminance in w/m^2 from 300 to 860 nm. A precision tungsten pin lamp was used as a source with a variable power input. The detector and the spectrometer probe were positioned as close together physically as possible for the 0.3m calibration, however it was necessary to reposition the spectrometer probe during subsequent calibrations to allow insertion of a calibrated neutral density filter between the spectrometer probe and the source to prevent saturation of the detector. Care was taken to ensure that the probe and sensor were at equal distances from the source and in as nearly equal physical orientation as possible. Figs. 2 – 4 all show that the sensor reading tracked very closely with the spectrometer data. Based on the onboard calibration, a calibration curve was determined for the Illuminance as a function of sensor voltage for the sensor being used. This curve was

$$I = 0.0675\ V^2 + 0.2514\ V - 0.005$$

The calibration plots are given below: Figure 2 at 0.3 m (onboard distance), Figure 3 at 0.15m,
Figure 4 at 0.45m, and Figure 5 showing the sensor calibration curve.

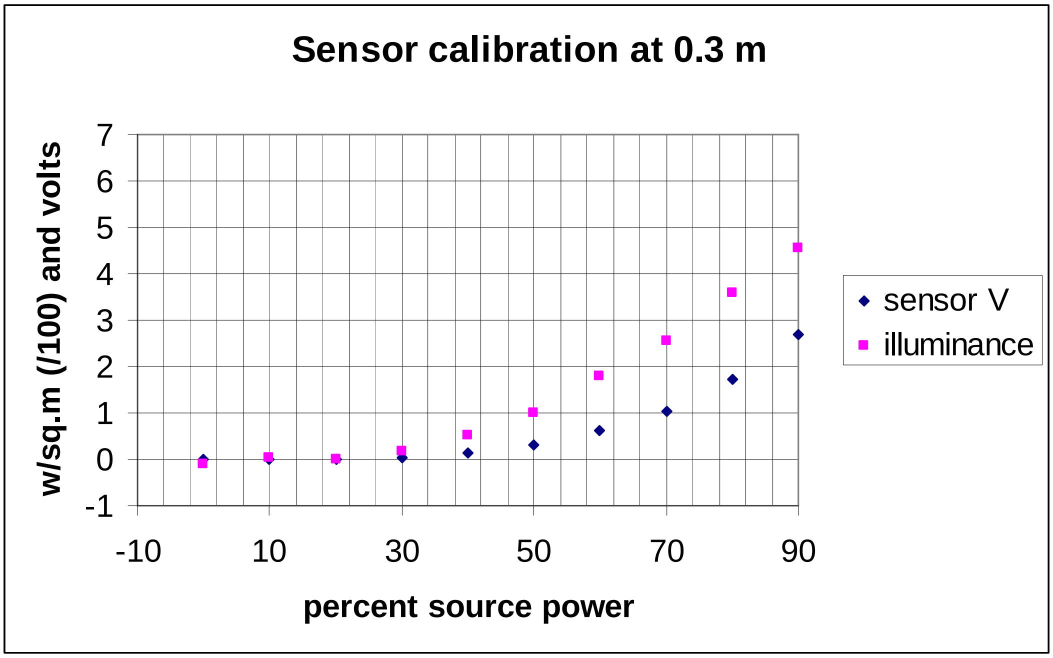


Figure 2. Sensor Calibration onboard rocket at 0.3m.

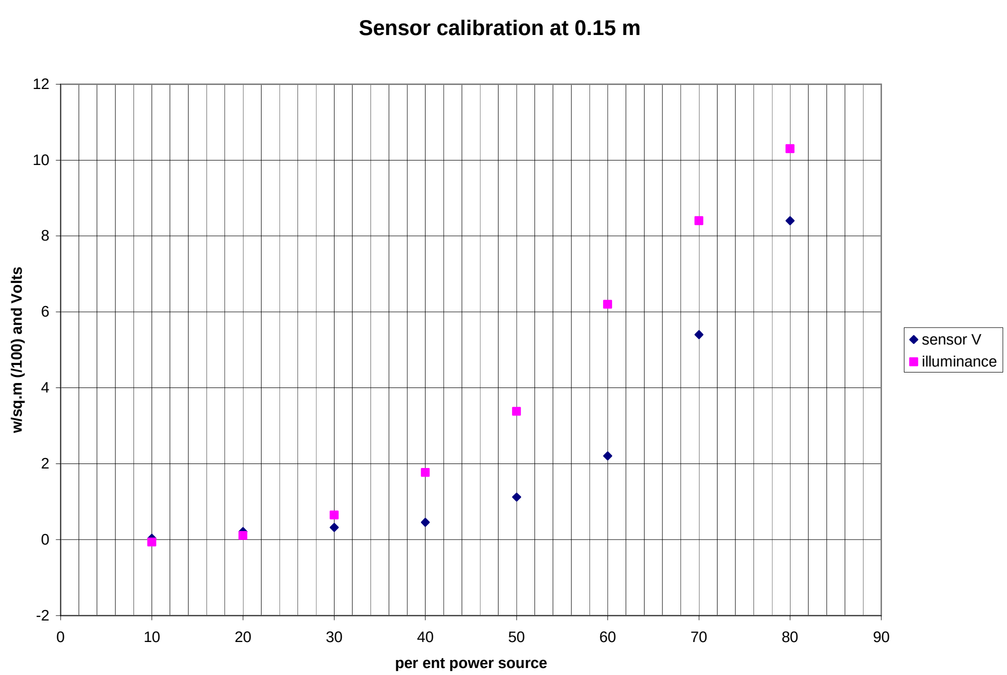


Figure 3. Sensor calibration at 0.15m.

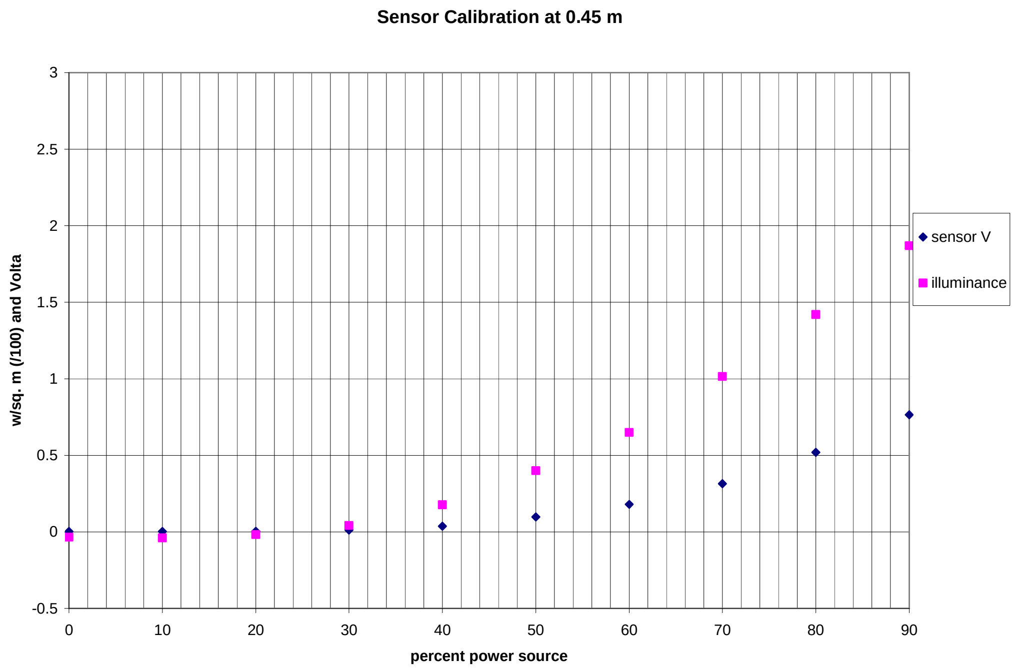


Figure 4. Sensor Calibration at 0.45m.

The sensor calibration curve was determined from the data plotted in Figure 5

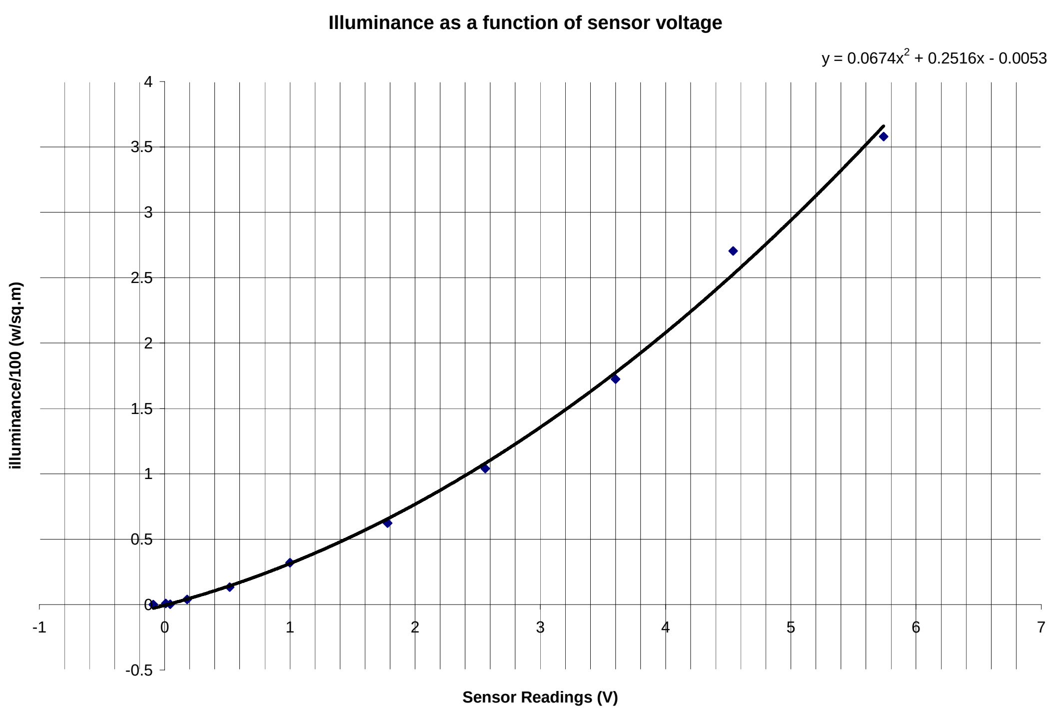


Figure 5. Sensor calibration curve.

III.C. Science Package Conclusions:

Analysis of science package data indicated that the data collection for the science package had failed probably as a result of broken wiring in the electronics package connecting the sensor to the RDAS flight computer. The sensor package successfully survived the flight and was capable of producing the desired data. The analysis also shows several areas of improvement needed in electronic interconnections, mounting of the electronics assembly, and launch day procedures. The successful launch and recovery of our hybrid rocket demonstrates a capability to successfully instrument and fly the hybrid with modifications of assembly and mounting procedures.

IV. Conclusion

After a full academic year of teamwork, including outreach activities, designing a rocket launch vehicle and scientific payload, constructing the rocket, and traveling to the high school SLI launch in Huntsville, Alabama, The Flying Bison team has learned much. We consider our project this year to be a “qualified success,” in that we were able to complete paperwork, design the rocket, launch and recover successfully, and recover some flight data and video, but were unable to reach the target altitude of one mile or recover usable data from our scientific payload. The experience we gained in communication skills, teamwork, knowledge of rocketry design, and know-how at the launch range will unable us to compete even more strongly next year. Group cohesion and planning a timeline of activity with plenty of time for testing and other considerations will be at the front of our thoughts in planning for USLI in 2007-2008.