Rocket Team at UCSC

NASA Student Launch 2018-2019
FRR Addendum
March 25th, 2019

1 Summary

1.1 Team Summary

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1.2 Purpose of Flight

The purpose of the flight detailed below was to fulfill the requirements for both the vehicle demonstration re-flight and payload demonstration flight. During our first flight of our full-scale vehicle, payload securement and recovery failed, resulting in a failed mission. This, in conjunction with the inability to launch due to launch site cancellations, lead the team to request for a re-flight which was granted and conducted on March 16th, 2019. This flight was a vehicle success, but payload failure. The vehicle and recovery systems functioned nominally, while the payload was not deployed upon landing. The payload securement method, however, functioned nominally. The Adaptive Aerobraking System (ADAS) did not deploy the aerobraking fins and as such, was not successful.

1.3 Flight Summary Information

Table 1.1 outlines the major specifications of the final full-scale vehicle design.

Length (inches)	**Diameter (inches)**		**Mass (lbs, dry)**	**Final Motor Selection**	**Rail Size**	**Recovery System (inches)**		**Target Altitude (feet)**	**Vehicle Material**	**CG (in, nose)**	**CP (in, nose)**
	Outer	*Inner*				*Drogue*	*Main*				
106	5.52	5.34	20.5	L1000	8ft 10-10	18	60	5280	Carbon Fiber	67.66	81.73

Table 1.1 Full-scale Rocket Parameters

Flight Information Item	**Information**
Date of flight	March 16th, 2019

Flight location	FAR Launch Site, Cantil CA
Launch conditions	No cloud cover and 10MPH winds
Motor flown	AeroTech L1000
Ballast flown (lbs)	0
Final payload flown	Y, with some systems non-operational. Discussed in section 2, Payload Demonstration Flight
Aerobraking system status during flight	No deployment
Target altitude (ft)	5280
Projected altitude (ft)	5022
Measured altitude (ft)	5012
Off-nominal events during flight	No off-nominal events occurred during the mission execution

1.4 Changes Made Since FRR

Sections 1.4.1 to 1.4.3 document vehicle changes, payload changes, and various other changes made since the FRR submission.

1.4.1 Vehicle Changes

Change	Rationale
Changed recovery section from 22 inches to 18 inches	Increasing the length of the section maximizes the space for parachutes, decreasing risk of tangled parachutes, and therefore decreasing the risk of a failed flight.
Added 3 inch carbon fiber ring to avionics bay coupler	When the recovery section length was increased, we needed another 3 inch ring to be added to a coupler to maximize recovery parachute space.
Changed fin material for two fins	The new fin material added sturdiness to fins and decreased chances of fin breakage

	mid-flight. The change to only two of the four fins was due to a material shortage, and because two fins broke during the first fullscale flight.
Drilled and tapped additional holes for semi-permanent attachments	The length change and carbon fiber ring required new semi-permanents and accompanied holes.
Created housing for receiver for payload	A housing for payload's receiver was created and placed in the nosecone. The receiver was required to be in the nosecone as the carbon fiber sections inhibited signal to be transmitted through the body of the rocket. The housing was 3D printed and held all required components for receiving signal to activate the payload.

1.4.2 Payload Changes

Change	Rationale
Magnetic switch for powering on systems flowing deployment instead of a mechanical kill switch	The mechanical kill switch proved too difficult to activate and include in the rover design. The new magnetic switch is simpler, and allows for more freedom when designing the payload system.
All batteries have been changed from LiPo to Duracell 9Vs	Duracell 9Vs proved to be more reliable and readily available than the previous batteries.
Removed additional RaspberryPi and camera	Due to design constraints, the additional RaspberryPi and camera have been removed. All systems are still functional with this change.
Arming screw switch installed to allow for on-pad arming of the deployment system	An exterior accessible arming switch was installed below the nosecone to power on the deployment system. This was implemented to follow NASA and safety guidelines.

1.4.3 Miscellaneous Changes

Change	Rationale
Using a 24 inch nomex blanket instead of 13 inch	A bigger blanket would adequately cover the recovery hardware so that it would be protected from the black powder charges.

2 Payload Demonstration Flight

2.1 Payload Retention System

2.1.1 Summary of Design

The rover retention system experienced a catastrophic failure in the February 16th flight. Therefore, the entire system was redesigned for structural integrity and simplification. The new design was flown on March 16th and tested to be fully functional.

The main point of failure in the February flight was in the load bearing servo of the ALC system and the primary and secondary retention system. To combat these failures the ALC has been redesigned into a passive component that utilizes a bearing that takes advantage of the natural righting ability of gravity to stabilize the rover. A inner ring secures the sled to the coupler, which is screwed into the airframe.

The securement system was also changed: It features a locking pin that secures the ALC system to the rocket body in flight in order to prevent the component from moving within it and throwing the rocket off course due to weight oscillations. Finally, the separation point was moved to just behind the nose cone. The securement shear screws have been upgraded to a higher force tolerance as well to combat premature separation. The redundant securement method was kept as is with the addendum that securement will be done with a proper bowline self-clinching knot.

2.1.2 Functional Systems

On the March 16th flight, all subsystems of the Payload Retention System were fully functional and safely fastened all parts of the rover and housing to the rest of the rocket.

2.1.2.1 Rover-sled securement

The Rover-sled securement utilizes a servo bit on the bottom of the sled that locks a circular piece on the bottom of the rover to the sled. This is to prevent any movement of the rover in any direction, in the event that separation occurs mid-flight.

After the March flight, by an inspection test, the rover remained completely secured to the sled.

2.1.2.2 Sled-coupler securement

The sled is secured to the coupler by a ring epoxied to the coupler that prevents upward movement, in addition to a cap on the bottom of the coupler, preventing downward movement. After the flight, the ring and sled were fully intact, proving that it was effective and secure.

2.1.2.3 Locking bit/Anti-swivel securement

Anti-swivel securement in the cap at the end of the payload section ensures that the bearing in the ALC will not move around during flight and affect the rocket's projection. The stable flight of the rocket proved that the payload was not affecting its projection, and additional ground testing showed that the rover sled did not rotate prior to separation.

2.1.2.4 Secondary retention system (rope)

In the unlikely event that the black powder charges between the payload section and the nose cone activate mid-flight, there is a rope connecting the nose cone and the payload section. This rope is secured by a semi-permanent bolt by way of a knot and a nut, screwed on following the knot. The rope used will be nylon ripcord, the same rope used for the recovery harness. This rope has been chosen due to its strength, durability, availability, and ability to withstand black powder charges. During disassembly of the full-scale vehicle following this flight, the strength of the cord was verified through pull tests and a visual inspection. It was deemed strong and secure, and will be used in all future launches.

In the February launch, this knot was not tied properly, and was not nylon ripcord. This resulted in the rope fraying and coming undone, allowing the nose cone and payload section to freefall, untethered to the rest of the vehicle. In the March launch and future launches, a proper bowline self-clinching knot will be fastened using nylon ripcord.

2.1.3 Failed Systems

Due to the payload retention system being fully operational, no systems or items of the retention failed.

2.1.4 Plan of Action for Failed Systems

The payload retention system did not undergo any failures and therefore, require no plan of action. However, the retention system may be modified in order to add more redundancy and safety features. This includes stronger rope, more semi-permanent bolts and stronger knots and materials.

2.1.5 Retention System Lessons

At the last failed launch, the team was made aware of the utmost importance of a payload retention system and directed all focus to redesigning and rebuilding the securement system. As evident from this flight, this redesigned retention system is much stronger and more successful. The team learned many things from the previous launch. These included stronger shear pins, and more reliable connections at stress points. The redesign featured stronger servo motors, larger plates to distribute forces, and a nylon cord to secure the nose cone.

2.2 Payload Mission Successes and Failures

2.2.1 Summary of Mission Sequence

Due to the failure to test the payload deployment, all actions following the deployment were unable to occur. However, a detailed timeline has been developed to outline the events that occur post-deployment. During deployment, a magnetic switch is pulled, powering on the rover locking mechanism and allowing the actuated landing correction system to passively rotate the rover and sled to the upright position. After approximately two minutes, the rover locking mechanism unlocks, allowing the rover to drive out. The rover then drives out, turns 90 degrees and continues forward for a minimum of 10 feet. Once the rover travels the necessary 10 feet, the scoop is lowered and the rover drives forward, filling up the scoop with soil. After a few feet of travel, the scoop is closed and the rover remains stationary until retrieved by team members.

2.2.2 Functional Systems

During the flight, it was proven that the payload securement system was functional and in working order. The securement system successfully contained the payload and rover within the payload bay during ascent, descent and landing. Upon disassembly of the vehicle, no parts of the payload or rover were damaged, deeming the mission a success. Along with the securement system, the rover's drive system was functional, however this was only tested prior to launch since deployment of the payload did not occur after the vehicle's flight.

2.2.3 Failed Systems

2.2.3.1 Radio

Due to electrical issues (specifically, the n-channel MOSFET being over sensitive to the radio signals), it was deemed unsafe for payload to be deployed during the March launch. The rocket was launched with the radio and deployment electronics powered off.

2.2.4 Plan of Action for Failed Systems

2.2.4.1 Radio

Further research will be done on transistors and electronic systems to get the radio/deployment circuit in full working order. The team will ensure, with extensive tests using e-matches, that the deployment circuit will not detonate prematurely and will function properly when the radio signal is received (after landing and given permission by the RSO).

2.2.5 Payload Lessons

Through the numerous tests and flights, a number of lessons have been learned regarding the payload systems. Firstly, the team learned that making and following detailed checklists will allow for a less stressful, complicated and sporadic launch day, and prevent many mistakes from occurring. Secondly, the team learned that conducting more tests helps to point out problems in designs early enough to allow for redesigns and tests in order to make sure the launches go smoothly. Finally, the team learned that redundancy is an important factor when designing deployment and securement systems. With adequate redundancy, the failure during the February launch would have been avoided. Also, with redundancy, the payload system as a whole would be more reliable and safe.

2.3 Payload Deployment Test

2.3.1 Summary of Design

Three tests were completed on March 23 to ensure sufficient size of charges to separate the nosecone and payload sections, and to test the radio circuit and communication. It was determined that the deployment charges were sufficient, radio communication is strong, but radio circuit electronics are still in progress.

Test Description	**Success Criteria**	**Results**
Detonate a 2g deployment charge remotely via a disconnected screw switch to determine whether charge size is sufficient for separation	• The nose cone separates off of the top of the payload section, giving the rover sufficient space to exit	Successful: 2g is sufficient and will be used for future launches
Test voltage and current while arming switch is on, radio is off/on	• Radio is off: Current reads 0A (+- minor noise), voltage is 0V (+- minor noise) • Radio is on: Current reads 0.5-2A, voltage reads 8-9.6V	Successful: Wires going to charges are reading expected values
Keep radio connected for an hour and attempt to communicate	• Radio receiver and transmitter stays connected	Successful: radios were communicating after an hour and withstood detonation of charges
Screw in screw switch and deploy charges via radio to e-match (at a distance of 2 feet away, while matches are in a box)	• The e-match is not lit until the radio signal is sent • E-match is lit immediately following radio signal receival	Failed: E-match lit prematurely following activation of screw switch

2.3.2 Reasons for Test

Electrical issues in the radio circuit prevented the team from initiating deployment safely during regular launch. These issues were resolved on the ground but deemed too unreliable to fly. Further testing on the ground and slight rework to remove electrical signal integrity issues means that the team is now confident that payload deployment can be executed safely and reliably. To ensure that this is the case, additional ground testing of the deployment system is required.

2.3.3 Test Results

A deployment test has shown that 2 gram black powder charges are sufficient enough to separate the payload section from the nose cone. Securement tests, conducted pre-flight, during flight, and post-flight deemed that securement is fully functional, even in subnominal events. Further work on electronics needs to be completed to ensure that all systems function adequately and no failures occur.

3 Vehicle Demonstration Re-Flight

3.1 Functional Systems

Recovery systems were fully operational in the duration of the launch. Redundant features were verified working upon motor ejection. The main parachute deployed at the predicted lower altitude of 600 feet, 100 feet above the minimum requirement. The drogue parachute deployed apogee, 5012 feet.

The semi-permanent securement bolts used were proven to be strong and reliable during the previous full scale flight. The same bolts were used on this demonstration flight and safely secured all internal payloads and avionics bays. The removable fin system came in beneficial when two of the four fins broke during the previous flight. Two new fins were manufactured and were flown during this flight. None of the fins were damaged upon landing, deeming this flight a success.

3.2 Failed Systems

While the flight did not experience any system failures, several of the systems did not properly function or were tested; it is not reasonable to describe the flight as having had two failed systems. Firstly, the payload was not deployed upon landing due to software and hardware issues. While this is not an explicit failure, it was a failure in the eyes of the team. This failure and the steps taken because of it is detailed in section 2. The second system was the Adaptive Aerobraking System (ADAS). ADAS was assembled correctly and proved to be in working condition prior to launch. However, as detailed below, an oversight led to ADAS being non-functioning and therefore failing to collect data and deploy the air brakes.

3.2.1 Adaptive Aerobraking System (ADAS)

The Adaptive Aerobraking System (ADAS) was assembled and fully tested prior to launch. All systems were functioning, including launch detection and a predetermined airbrake deployment process. However, due to an oversight on behalf of the team, the SD card containing all necessary software was not inserted to the flight computer prior to launch. This meant that the system would not function, and resulted in zero airbrake deployment and data collection. This cause of failure was determined after the flight and after the vehicle was returned to the workstation, when the vehicle was disassembled and the SD card was found to be not inserted into the flight computer. This failure means that ADAS will not fly during the competition.

3.3 Flight Data and Analysis

The full-scale vehicle re-flight was carried out on March 16th, 2019 at the Friends of Amateur Rocketry (FAR) launch site in Cantil, CA. This was the only available launch site for the team to launch at due to our normal launch site Snow Ranch being rained out, along with another local launch site Tripoli Central California (TCC). The team was joined by our mentor, David Raimondi, who facilitated all ejection charge and motor assembly.

3.3.1 Launch Day Conditions

The launch day conditions were nominal and friendly. The winds were low, with very small occasional gusts. Cloud cover was non-existent, allowing the team to launch at a moments notice. Once assembled, the team took the vehicle to the launch pad and prepared to launch.

Time	Wind Speed	Wind Gusts	Direction	Temperature	Pressure	Conditions
16:52 PST	10 MPH	15 MPH	80° West	70° F	29.99 Hg	No cloud cover, low winds.

Table 3.1 Weather conditions at time of launch

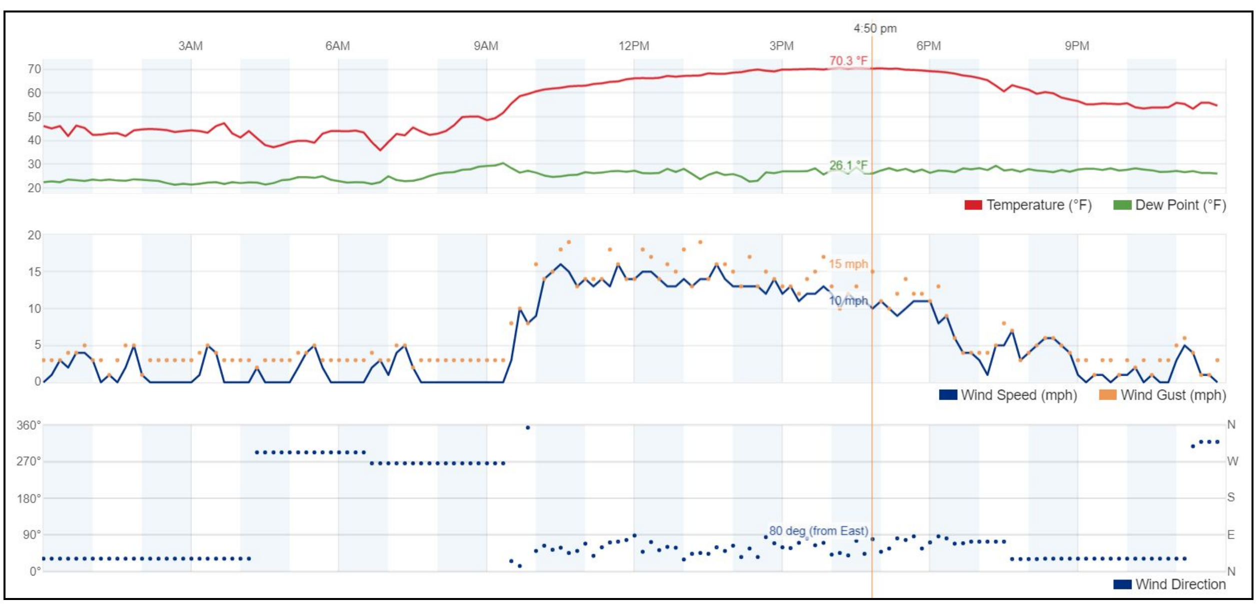

Figure 3.1 Launch day conditions from a nearby weather station

3.3.2 Flight Data

Figure 3.2 details the vehicles various characteristics during its flight. During this flight however, only the Stratologger Altimeter recorded data. This was due to the EasyMini's on board storage being full and ADAS not recording data. Despite this, we were able to recover a large amount of data to properly model the vehicle's flight. The drogue parachute was successfully deployed at apogee and the main at 600ft during descent.

Compared to the OpenRocket simulations, the vehicle reached a maximum altitude of 5012ft, 10ft less than predicted. The vehicle reached a maximum velocity of 673ft/s, and a maximum acceleration of 456ft/s^2. With the detailed and clear data recovered, the team was able to determine the descent rates for the vehicle under the drogue and main which were 60ft/s and 20ft/s respectively. It should be noted however, that after apogee, the OpenRocket and flight data drift apart. This is believed to be due to the OpenRocket model not having the correct drogue, or the drag of the drogue is much higher under flight conditions. Despite this, the OpenRocket model has proved to be very accurate for apogee estimations.

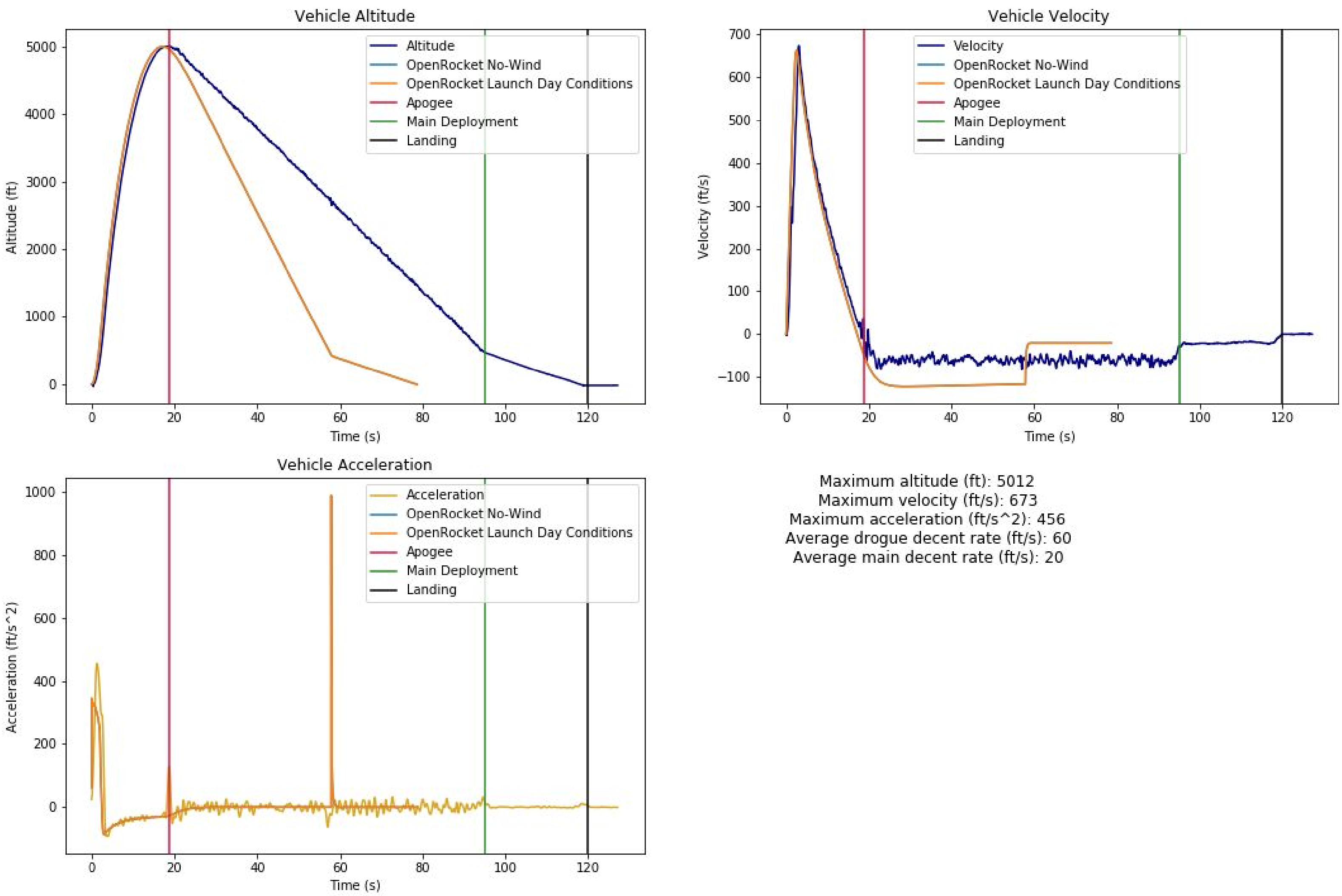

Figure 3.2 Vehicle flight data and OpenRocket model data

3.3.3 Drag Calculation

Despite having only one source of flight data, the team was able to recover an estimated coefficient of drag of .34. This was calculated using the force on the vehicle during the coast phase, between motor burnout and approximately 100ft/s. The reason for the lower velocity is bound is due to the inaccurate coefficient of drag during lower velocities. The process of determining the coefficient of drag went as follows. First, a function of the drag force was derived using the vehicles mass and measured acceleration. Second, the force of gravity of subtracted out in order to isolate the force on the rocket from drag. Finally, using the drag equation, the coefficient of drag was calculated and then averaged out of the above interval. There were steps in between these involving smoothing data, and fitting functions, but the main idea remained the same.

3.4 Plan of Action for Failed Systems

3.4.1 ADAS

Due to the oversight on behalf of the team, we are looking to implement stricter pre-launch checklists and plans for all future launches. This oversight could have been avoided had a detailed checklist been made and followed. Because of this, ADAS will have a checklist detailing all necessary steps required to assemble the system. The failure is not believed to be from software or hardware since all tests proved the system was fully functional. The team plans to further refine the software and fly *Oh Yeah* in the upcoming few months with ADAS active. This will allow the team to complete real-world tests of the system to verify functionality. These tests and experience will prove extremely beneficial and helpful for future iterations of the system and for future competitions.

3.5 Lessons Learned

This flight has demonstrated a number of things to the team that is required to be well functioning and successful in all future launches. While this launch was, in large part, a success, there were a number of places where basic improvements could be made to have a 100% successful mission.

The first item the team will address is making checklists. The team, up until now, has made poor checklists and failed to follow them. From now on, a detailed checklist outlining all necessary steps will required for each system prior to launch. The safety officer will then verify the checklist was followed and allow the system to fly. With this change, we hope to minimize launch day stresses, complications, and system failures.

The second item is to conduct more, and more detailed tests. A greater number of tests, both detailed and simple, would help the team to prevent launch day stresses, and complications. Tests would allow the team to thoroughly analyze all failure modes and plan for them prior to launch. While the lack of tests did not result in a mission failure, they would have allowed the team to have an even more successful flight and project.