NASA Student Launch

2014-2015 PLAR

April 29, 2014

Table of Contents

SUMMARY OF PLAR REPORT

TEAM SUMMARY

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LAUNCH VEHICLE

OVERVIEW

The focus of the team's launch vehicle was to simulate a versatile payload delivery system to the Martian surface while maintaining safety and design efficiency through all systems. The rocket hosted an adjustable ballast system, a fairing deployment system, and a removable fin system. Together, these unique systems allowed for a truly versatile launch vehicle that was capable of launching, deploying and recovering all payloads and vehicle subsystems.

VEHICLE SPECIFICATIONS

The requested vehicle specification are as follows:

- Competition Motor: Cesaroni Technologies L935-IM
- Height: 143" from tip to motor retainer
- Diameter: 6.17" diameter body tube airframe
- Mass: 42.9 lb_m (wet) and 37.3 lb_m (dry)
- CG: 88.37" from tip
- CP: 99.79" from tip

Figure 1. Full scale competition rocket and team ready for launch in Alabama.

PAYLOAD

PAYLOAD DESCRIPTION

The payload and integration was a key part of this year's competition launch vehicle. The payload, itself, was a weighted generic section of PVC tubing. The payload became an integral part of the launch vehicle once it was inserted into the launch vehicle and introduced to the cache capsule. The system recognized payload insertion, where a servo closed a door containing the fully assembly. The cache containment was encapsulated within the launch vehicles fairing. The goal was to safely house the cache payload, and then safely deploy it at a predetermined altitude during descent.

PAYLOAD SUMMARY

The fairing deployment system was the primary actuating system on the launch vehicle. The main goal of the launch was to be able to safely deploy the payload at a precise altitude. This required the fairing to safely integrate the payload into the launch vehicle. The cache containment assembly securely accepted the payload, and sealed itself from the outside environments. It was constrained in place by machine foam inserts. Attached to it was a cruciform parachute.

The fairing statically wants to stay open. Being constrained by a pyro cap at the bottom of, the system secures the cache capsule until the point where the on board electronics deploy the pyro cap from the fairing. At this point the fairing opens up, the cache capsule falls out of the fairing, and the payload recovery parachute inflates and carries the payload to the surface at a safe descent velocity for retrieval. All events from launch day occurred as planned, and the payload and cache containment were safely recovered.

Requirement	Requirement Satisfied	Analysis
Integrate cache payload into the launch vehicle	Partially	The payload arm picked up the payload and loaded the cache into the retaining clips inside the cache capsule. With the capsule door closed upon arm retraction, the payload was fully integrated into the launch vehicle. This was no accomplished autonomously however.
Secure the cache capsule during flight	Yes	Foam inserts were machined to a tight fitment inside the fairing airframe and around the cache capsule. The foam acted as a damper to vibrations seen throughout flight. The capsule showed no signs of damage upon recovery
Close door upon payload insertion.	Yes	The flex sensor detected the payload being inserted into the launch cache capsule. The onboard Arduino detected the change in voltage, and when the nominal voltage was read again (when the arm had retracted) the cache capsule doors closed.
Deploy cache capsule from launch vehicle	Yes	The fairing contained the cache capsule throughout flight. After the onboard altimeter detected the appropriate altitude, the pyro cap was jettisoned from the fairing, and the fairing opened. The cache capsule slipped out of the foam inserts and fell under parachute.
Be recovered with no physical damage	Yes	Using mass analysis to design the cruciform parachute, the cache capsule descended at a safe velocity. Upon inspection after landing, there was no physical damage to the cache capsule.

Table 1. Analysis of payload integration.

AGSE

Overview

The focus of the AGSE was to design a system that would be robust enough to perform all task on a Mars exploratory mission. The system featured an automated platform leveling system (APLS), a payload arm, a vehicle erection system (VES), and automated ignitor insertion system.

AGSE Results

The AGSE was transported to the launch site via a trailer. Upon arrival, the full assembly was carried to its position on the launch field. The payload arm was installed into position and testing began. Prior to the launch, the team noticed various programming issues that was causing a discontinuity in the autonomous portion of the AGSE. All process functioned as intended, however, there was a communication disconnect when the payload arm was added into sequence. After a multitude of reiterations of code, the team opted to manually override all systems. This allowed for each system function as designed, and accomplish each task. Each system was initiated by a dedicated switch on the main control box.

Figure 2. VES raising the launch vehicle for launch.

The functionality of the APLS system was shown to launch site viewers. The AGSE outrigger arms lifted the assembly to the appropriate height to allow for the VES to fully articulate. Upon vehicle insertion, the VES was manual actuated, as seen in Figure 2, via the switch on the main control box. The guide tower was raised to within 5 degrees of true 90 degrees with respect to the AGSE. This occurred when the carriage contacted a mechanical reed switch that shut power to the VES. For launch, an ignitor was manually fed into the motor to ensure proper seating for the competition launch. The RSO sent the signal for launch, and the AGSE remained stable as the launch vehicle raced out of the guide tower.

SCIENTIFIC VALUE

The team spent the competition year evaluating the feasibility of designing a fully autonomous ground station that would supply the launch vehicle with a payload sample before erecting it and preparing it for launch. By incorporating a system, such as this, the team was able to contemplate various design challenges to bring this to fruition.

There were many scientific challenges brought out through the development and manufacturing of the AGSE and launch vehicle. Designing the ground station to be capable of survival on the Martian surface proved to be both challenging, and rewarding. No air breathing systems were incorporated into the AGSE. First and foremost, the team chose to build a robust system that would survive the elements. This meant designing a system out materials that would last. Weighing in just under 400 lbs, the mechanical engineering students were forced into designing robust articulating and actuating systems that could resist the high loads seen by the system. Knowing that a Martian exploratory mission would require a truly reliable system for launch vehicle integration, the team was tasked with applying true design safety factors and criteria on a global assembly scale to ensure a rigid design.

The electrical team, including programming, dealt with various new challenges. When integrating complex wiring into a system such as this, a thought out plan for addressing electrical noise had to be addressed. Designing electrical systems on paper, and wiring them up on a small-scale desktop setup, and then applying them to a full scale model proved to be a challenge in of itself. New and rigorous methods of electrical integration had to be addressed to ensure that all systems function as planned.

The launch vehicle saw its own unique challenges. The aim was to push for a design for real life applications. With each Martian sample having a good chance of consisting of different materials, soil samples, and masses, the launch vehicle needed to address the issue of a fluctuating center of gravity. By incorporating a ballast system in the nosecone of the launch vehicle, the team's rocket would be capable of adjusting its own center of gravity to ensure it was stable for flight. Having a payload within the confinement of the launch vehicle meant that the team needed to design a way to deploy said payload. In a real world application, a deployment of the payload and a safe recovery is crucial. The team looked at all facets of possible deployment methodologies. Using a fairing ejection system proved robust and reliable. Some may overlook it, but vehicle transportation, storage, and modularity plays a huge role in the use of said launch vehicle. Addressing all physical launch vehicle constraints, integrating a means for removable fins seemed important. Custom machining this subsystem allowed for the launch vehicle to safely, and reliably be transported. Furthermore, this allowed the fins, one of the most crucial components on the launch vehicle, to be quickly replaced in the event of breakage.

VISUAL DATA OBSERVED

VEHICLE

This flight functioned nominally. The launch vehicle components functioned as planned prior to launch. The removable fin system allowed for a quick fin installation upon arrival to the launch sight. The vehicle, upon being fully erected into launch position, was lifted a foot to feel how tight or loose the vehicle rested in the guide tower. The talcum powder and fitment allowed for an acceptably low friction of the launch vehicle against the guide tower rails.

The launch vehicle's motor ignited and the vehicle left the guide tower quickly. From the ground, the vehicle appeared to fly straight and true. All sections remained intact throughout the launch vehicle's flight to apogee.

RECOVERY

The recovery sequence was entirely successful during the competition flight. At apogee, the main parachute, a custom made vortex ring, opened, acting like a drogue. The vortex ring parachute was selected for the following reasons: efficiency, low oscillation, and low opening force. Each of these features of the parachute were proven during the flight. The parachute operated with a coefficient of drag of approximately 1.2. The parachute also had minimal oscillation during decent, allowing for the remainder of the recovery scheme to operate as planned. Finally, the low opening shock prevented the lower section of airframe from prematurely separating.

At 1700 ft, the second black powder charges were fired, ejecting the lower airframe from the rocket. This section of the airframe fell under a custom made cruciform parachute. At 1000 ft, the pyro cap was fired, allowing for the faring to be opened. This allowed for the cache capsule to be ejected and recovered under an independent recovery device at the desired altitude. The recovery of the nosecone and fairing falling under the vortex ring, and the lower airframe falling under the cruciform parachute are shown in Figure 3.

Figure 3: Custom vortex ring and cruciform parachute safely recovering rocket at competition.

All recovery operated as expected and landed within the maximum drift requirement of a half a mile. Upon retrieval of the rocket, all aspects were carefully examined before being moved. This allowed for the team to carefully analyze the scene and to determine that all recovery devices appeared to have operate without tangling from ejection until landing. A closer inspection was then performed which revealed that the recovery devices had survived the course of the launch without any burns, cuts, or tears. Through inspection of the rocket itself, it was concluded that the vehicle did not incur any damage during the course of the flight or recovery.

AGSE

Individually all systems functioned as intended. This ignores the aforementioned programming issue. The APLS was able to raise the ground station to a height that would allow for the VES to fully articulate. While the payload arm functioned nominally mechanically, certain components were noticed to begin to show signs of wear. A 3D printed alignment feature ended up cracking on launch day. This was fixed by use of epoxy. However, this brought to question the life cycle of other 3D printed components.

The rocket was loaded into the lowered guide tower, and fitment checked. Upon payload insertion, the VES raised the rocket. The outrigger arms showed no signs of flexing, vibration, or movement during this time. Once erected, the ignitor was pushed into the launch vehicle. The wrapping of the piano wire to the launch day ignitor proved to be too rigid. The servo motors actuating the ignitor system spun freely as the ignitor wheels spun freely over the ignitor. A stand-in ignitor was then inserted for launch to ensure a successful motor ignition. The ground station, itself, stayed stable and did not flex or shift as the launch vehicle launched from the guide tower.

Flight Analysis

StratoLogger Altimeters

The altimeter used as the designated "competition" was a Perfectflite Stratologger altimiter that was mounted in the nose cone. The altimeter recorded a maximum altitude of 2,282 feet above ground level. The altitude and velocities are shown for the various sections of airframe in the following figures. In Figure 4, the altimeter data from the nosecone is shown. The vortex ring was attached to the nosecone and it can be easily identifies where the parachute fully inflated approximately 16 seconds into the flight. The decent velocity stabalized until the lower airframe was dropped off at an altitude of 1700 ft or approximantely 30 seconds into the flight. The nosecone then stabalized and decended at a constant and safe velocity.

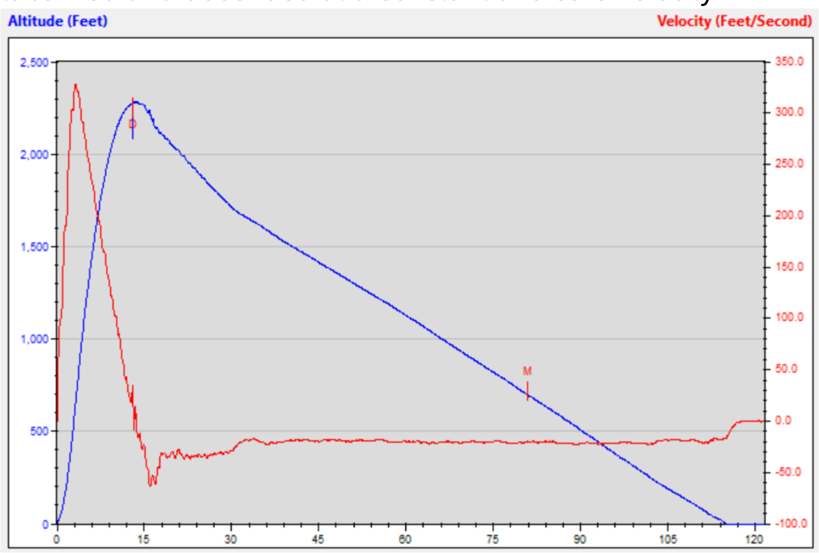

Figure 4: Nosecone altimeter data.

The data collected by the primary altimeter in the propulsion bay is shown in Figure 5.

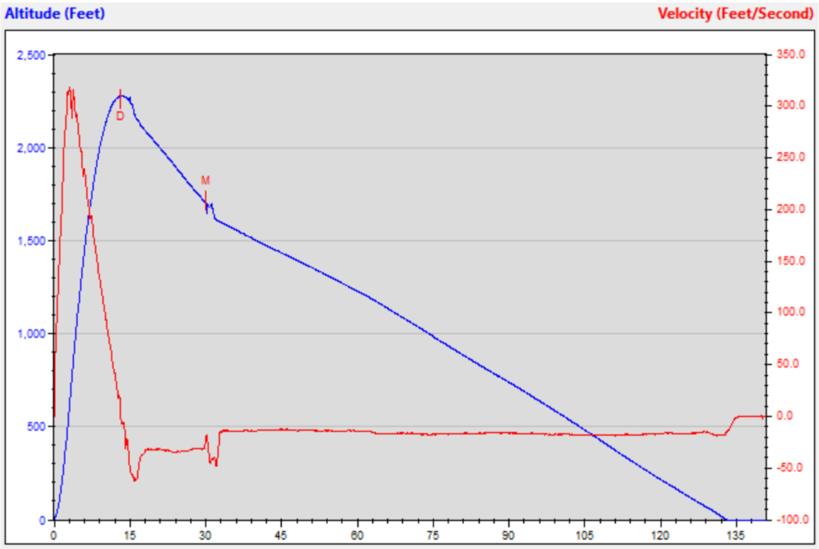

Figure 5: Propulsion bay altimeter data.

The data collected by the primary altimeter in the fairing is shown in Figure 6. The large spike in the data is the result from the ejection charge firing at that instant in the recovery.

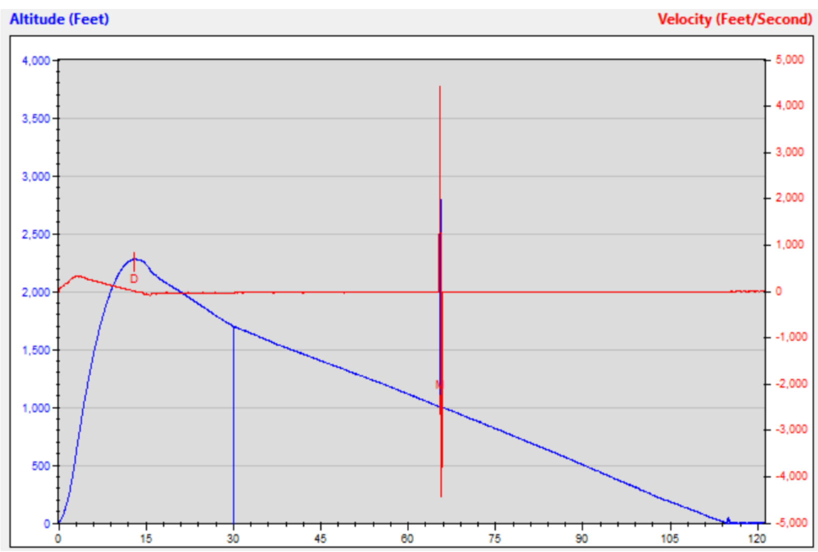

Figure 6: Fairing altimeter data.

LANDING VELOCITY AND ENERGY

Using the altimeter data given above, the descent rates of each section of airframe was determined. Using this data and the known mass of each section of airframe, the landing kinetic energy of each section was calculated. The calculated kinetic energy of each section is shown in Table 2 below.

Section of airframe	KE (ft-lb$_f$)
Propulsion bay	52.01
Fairing	39.44
Nosecone	54.48

Table 2: Kinetic energy calculations.

The kinetic energy requirement for each section is 75 ft-lbs, therefore, each of the sections of airframe met the requirement.

EDUCATIONAL ENGAGEMENT

The team has already been extremely active throughout the season with regards to educational outreach. While we have not yet reached our goal of 1000 students engaged due to the cancelation of E-expo, we are pleased with the quality of programs and the number of students we have been able to reach.

Participant's Grade Level	Education		Outreach	
	Direct Interactions	**Indirect** Interactions	**Direct** Interactions	**Indirect** Interactions
K-4	42	0	0	0
5-9	367	0	392	0
10-12	0	0	50	0
12+	0	0	0	0
Educators (5-9)	25	10	44	0
Educators (other)	5	0	24	0
Total Outreach	**959**			

Table 3: Educational outreach totals for the season.

We continuously strive to inspire students across our community to discover a passion for STEM and to pursue lifelong learning. The community has supported our school team tremendously and we understand the importance of giving back to the community. Just because our season is coming to a close, doesn't mean that we stop working with the youth of our community. We continue to offer programs throughout the summer in an effort to encourage as many students as possible.

BUDGET

OVERVIEW

The team set a large goal for this competition year. To meet all requirements the team had to find ways to ensure they had the proper funding, and then apply a healthy budget to all sub-teams. This year the team focused on keeping track of the team's inflow and outflow of money. This included both monetary donations and material donations. Figure 7, below, shows the overall inflow budget and how the outflow budget corresponds to it.

Overall Inflow Budget	
Supporter/Sponsor	**Total Investment**
Raytheon	$1,000.00
Samtec Material Donations	$1,500.00
FirstBuild Material Donations	$1,500.00
UofL ECE Department	$2,000.00
UofL ME Department	$2,000.00
UofL CECS Department	$1,000.00
UofL's Speed Dean's Office	$6,000.00
KSGC Grant	$10,000.00
Bagel	$2,000.00
Overall Cost	**$27,000.00**

Overall Outflow Budget	
Budget	**Total Cost**
Full Scale Vehicle	$3,175.09
Recovery	$1,322.21
Subscale Vehicle	$946.08
Payload "Arm" Budget	$243.99
Educational Engagement	$778.79
Travel Expenses	$5,750.00
Promotional Materials	$975.00
Safety Materials / Miscellaneous	$1,739.75
Ground Station	$3,742.03
Overall Cost	**$18,672.94**

Figure 7. River City Rocketry's inflow and outflow budget.

The team was extremely fortunate to have so much material donated to it this year. Due to the team's success over the past few years, the university has really jumped behind the team as well. This correlated to donations from all departments that had students on the team. One of the largest backers, however, was the generous donation from the NASA Kentucky Space Grant Consortium. Raising $5,000 and having it matched 2:1, the team received a generous grant.

While the outflow does not meet the total inflow, the reasoning behind this stands on its own. Every two years the team is capable of applying for the KSGC grant, and the team needs to make sure it can stay funded during the "off year". The team cannot always guarantee certain donations from various people and departments. This is why each year the team focusing on building a strong base that they know the team can live off of to get the ball rolling, so to speak, for the future competition year.

Figure 8, below, shows the distribution of the budget throughout the various sub-teams and subsystems. The development of the full-scale launch vehicle and AGSE proved to be the heaviest, budget-wise in terms of design work. As anticipated, the traveling and lodging was the overall biggest portion of the team's budget this year.

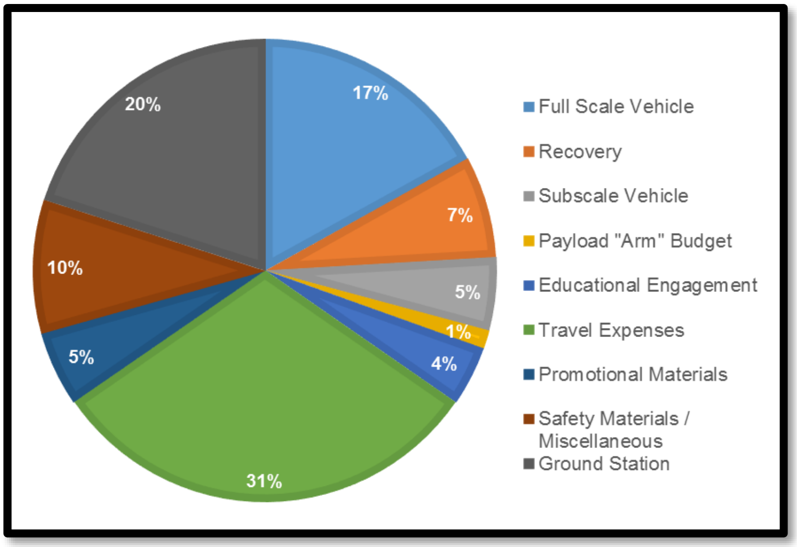

Figure 8. River City Rocketry 2014-2015 budget distribution.

LESSONS LEARNED

Each year the team seems to grow stronger in terms of applicable knowledge and passion towards the project. One of the biggest struggles is figuring out a way to top the year prior. That's what forces the team to truly push itself to the limits to put out a product that is truly awesome. This has its own inherent challenges. This means that each new design will have its own new challenges.

Having two complete systems, the launch vehicle and the AGSE, integrate together seamlessly was the principal challenge of the competition year. Typically in years past, the electrical and programmable payloads were standalone from the launch vehicle. This means that if, for whatever reason, the electronics were not functioning as planned the launch vehicle could still perform its task. However, by moving to an automated ground station that is supposed to control the steps leading up to vehicle launch the electronics and programming now played an integral role in the success of the launch vehicle. They were no longer independent.

This posed challenges, for all parties involved. Designing circuits and motor controllers on a small scale, or for desktop applications can appear good on paper. However, when integrating them into a robust system, such as our AGSE, things can start acting up. We noticed a lot of electrical interference when moving through all of the wiring, motors, and controllers. The team definitely learned multiple lessons on how to set up systems for full scale testing. The need to address possible electrical issues prior to installation was apparent. The team felt that this project gave them a real working experience on how to prepare themselves for systems they may meet in their future careers.

Summary

All good things must come to an end, including this competition season. There are always feelings of relief and accomplishment at the end of each competition year. However, there will continue to be questions raised as the team moves through the post-competition time of the year. What did we do wrong? What could have been designed better? And where is that crescent wrench that I know I set down right over there?

The competition year has been a challenging one. A compressed schedule and rigorous agenda ensured the team knew that when they accepted this challenge, everything would have to be earned and nothing would be handed to them. Pushing through the late nights, the design challenges, and the multitude of reports, the team was able to submit a final product that they were proud of. The launch vehicle and ground station designed by the University of Louisville for the 2014-2015 competition year represented the engineering knowledge that the university had bestowed upon its students.

There is something special about working with a group of your peers on a project that everyone is personally passionate about. Throughout the teammate's academic careers, they have worked on countless team projects. Nevertheless, the true ability of each member truly shines through when they are given the opportunity to pursue questions and design challenges specific to their interests. By coming together, the University of Louisville's River City Rocketry team was able to apply their individual talents to not only overcome challenges but to exceed personal expectations to make something that everyone was able to call their own. On top of that, the team was extremely grateful to be recognized with the Vehicle Design Award, Project Review Award, and Safety Award for this competition year.

The NASA Student Launch competition is a great program that reaches out to those who want to grab a piece of what it's like to work on something spectacular. While the challenges may seem enormous throughout the year, the opportunities and applicable lessons learned proved priceless to the students involved. These students are the future; and it is great to see so many people come together to – not only compete – but to share thoughts and ideas with one another. It is true, after all, that in the end we are all in this one together.