UC Berkeley Space Technologies and Rocketry
Post Launch Assessment Review
Project U.R.S.A.[1]

April 24, 2017

[1]Upright Recovery and Sight Acquisition

Contents

1 Flight Results

1.1 Motor Used

We used an Aerotech L1150 motor.

1.2 Altitude Reached

The altitude reached during our Huntsville flight was 4530 feet.

1.3 Vehicle Summary

The rocket was primarily constructed from Blue Tube. The fins were constructed from G10 fiberglass and were attached through the wall to the phenolic motor mount and connected to the booster outer tube with carbon fiber and epoxy fillets. The nosecone was constructed from fiberglass, and the nosecone tip was replaced by a a vacuum formed clear PET-G tip for the target detection payload experiment.

The primary recovery system utilized a same-side dual-deployment mechanism initiated with two 4-gram black powder charges between the Avionics Bay and Booster+ sections of the rocket. The 24" elliptical drogue chute was deployed at apogee while the 72" toroidal main chute was deployed at 1000 ft. AGL. Altitudes were determined with two altimeters: one Perfectflite Stratologger CF and one Missileworks RRC3. The dual deployment was made possible with two L2 Tender Descenders connected series to ensure redundancy.

1.4 Data Analysis & Results of Vehicle

1.4.1 GPS Data

We present below the tracking data from the payload GPS. Note: we were not using the altitude data from the GPS for any purpose.
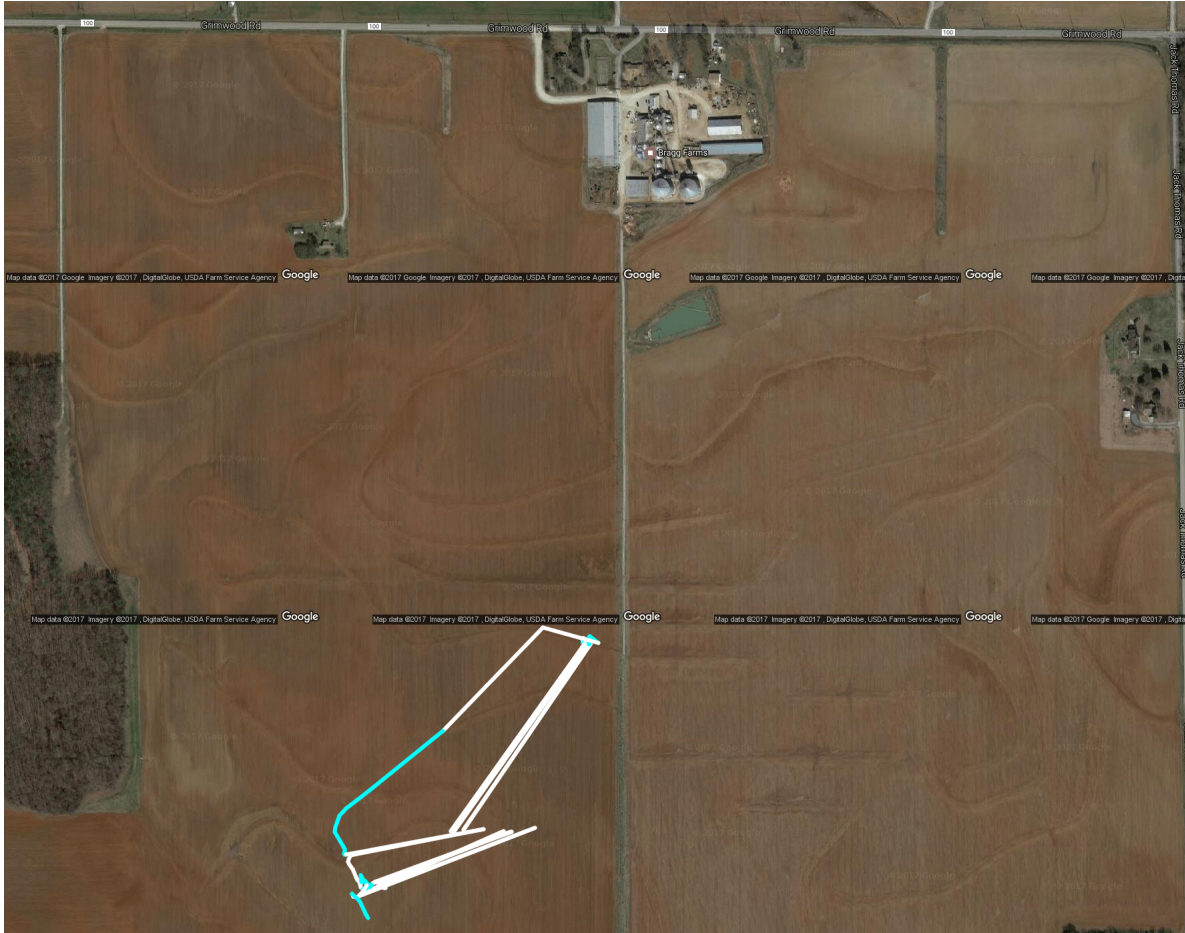
GPS data do not indicate any in-flight anomalies. The tracking was accurate for the wind drift encountered on launch day. The altitude as recorded by our official scoring flight altimeter was 4530 feet. The resulting altitude was lower than calculated in our models, which can probably be attributed to wind, the launch angle required by the launch provider and launch safety at the range, and an excess of weight due to unforeseen manufacturing discrepancies between the computer model and Ursa Major.

1.5 Payload Summary

We attempted the target detection and upright landing payload challenge. During descent, a camera located inside the transparent nose cone tip would identify and track the ground targets. Our payload bay and nose cone were designed to then separate from the main body of the rocket entirely via a black powder charge, deploying a set of landing legs and parachutes with onboard servo motors and landing upright under the drag of those chutes.

At the time we first got our rocket onto the launch rail, around 11 am, electronics appeared to be functioning perfectly. We did an on-rail test of the landing legs′ servo motors, which had been known to fail during previous tests, but there were no such issues and the motors worked flawlessly. However, we had to delay our launch due to a mechanical issue on the payload.

That problem took around two hours to fix; however, at that point, attempting to boot up the Raspberry Pi caused it to loop endlessly. A further two hours were spent attempting to fix the error, including rewriting sections of the code and swapping our Raspberry Pi out for the backup we had, but nothing seemed to work.

1.6 Data Analysis & Results of Payload

A major electronics failure prevented us from successfully launching our payload, but we gleaned meaningful information from the failure. Our best guess at this point was that running multiple Python programs (target detection and upright landing) in parallel caused the Pi to crash on boot, although we remain unsure why this happened only about half the time.

The failure did serve to demonstrate the limitations of the Raspberry Pi a high-level computer system with its own Linux-based OS, programmed mostly in Python, was not the right tool for a system in which robustness and speed are top priorities. Going forward, we intend to use an Arduino, which is more minimalistic and therefore less prone to black box errors, as an interim solution. As a long-term solution, we hope to transition to a custom ARM-based processor to provide memory and processing power better than those achievable by an Arduino.

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2   Payload Description

The objective of our vehicle's payload experiment is to fulfill the Target Detection and Upright Landing challenge, which an onboard camera system identifies ground targets, and the section housing the cameras lands upright. Our payload, SAGITTA-VL, uses an onboard camera mounted inside the nose cone viewing through a clear tip. A custom software package, operated using a Raspberry Pi camera, is used to view the ground during descent, and identify the three ground targets by color. This sequence of operations constitutes **"Target Detection"**. After Target Detection has been completed, or after an altitude threshold has been reached, the payload section will be ejected from the vehicle to be recovered independently. The payload deploys three parachutes via the deployment of three landing legs. The positioning of the payload center of gravity below the parachutes causes the section to turn upright during its descent, allowing the payload to land upright. This sequence of operations constitutes **"Upright Landing"**. The payload section consists of an 18" section of tubing and a 21" nose cone. This acts as the upper section of the main vehicle airframe. A camera is mounted in the top of the nose cone, and views through a clear PETG tip. The tubing section contains three landing legs, which deploy out in order to assist Upright Landing. During "launch configuration," the legs are folded in so as to be flush against the airframe. During "landing configuration," the legs are extended, and the inner assembly is exposed. The payload parachutes are deployed via springs that push the parachutes out when they are exposed (i.e. when the legs are deployed). The legs are held in place using a latch 3d-printed into the landing leg, which are released by a servo motor that controls an arm with an attached roller bearing.

3   Vehicle Dimensions

Figure 1: OpenRocket Model of URSA Major
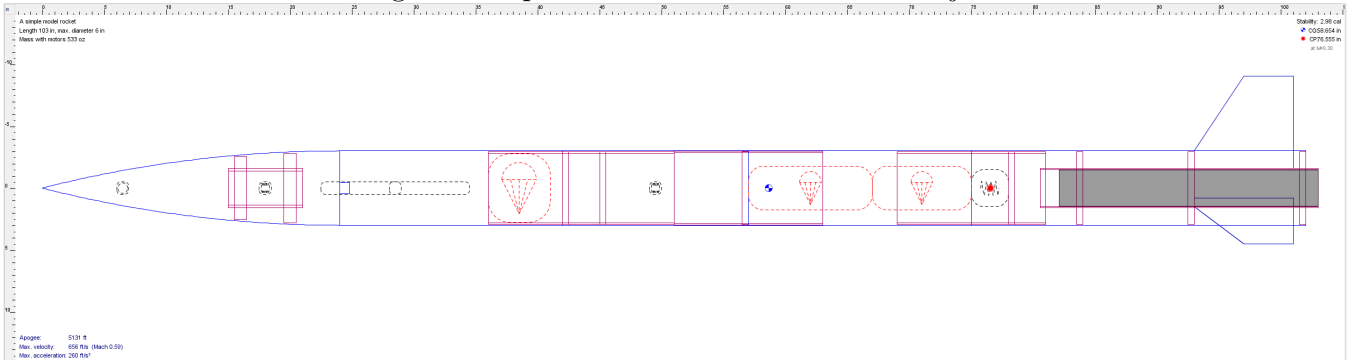
The vehicle airframe was 103 inches long, 6 inches in diameter, and weighed 33 pounds with the motor, an Aerotech L1150. Without the motor, the airframe weighed approximately 25 pounds. The CG was 58.7 inches from the nosecone, and the CP was 76.6 inches from the nosecone, giving the rocket a stability of 2.98 calibers.

4   Scientific Value

There is currently significant interest in upright landing rockets, obviously in large part due to SpaceXs Falcon 9 rockets. For large scale, orbital, rockets, the ability to land sections upright

allows for reusable sections, and large monetary savings. For rockets like those we flew this year and hope to in the near future, upright landing sections allow for more controlled, gentle landings, and thus, the possibility of implementing designs that may otherwise be problematic and have the potential for damage. Vision during flight, and the ability to track targets on the ground, holds significant value as well. For large scale rockets, this allows for the surveying of Earth, and other astronomical bodies. The ability to both detect ground targets and land the detecting section of the rocket leads to numerous possibilities for rockets of immediate interest to STAR. The next logical progression would be to land on targets, and following that, to locate ideal areas of the ground on which to land in flight.

5   Visual Data Observed

We observed slight weathercocking during the first second of flight, but there were no observable irregularities for the rest of flight. Upon recovery of the vehicle, we observed a small scorch mark on the drogue parachute, but there was no structural damage to the chute or any other part of the vehicle.

6   Lessons Learned

6.1   Electronics

Failure mitigation and redundancy, with particular regard to the electronics component of our payload, has proved to be a design consideration that we will need to improve upon on future missions. Having our upright landing legs controlled by the same computer that performed target detection prevent us from attempting either experiment whenever that computer failed. Additionally, electrostatic discharge analysis of the materials surrounding our electronic components as well as mitigative measures (like a case around our Raspberry Pi) should be conducted in future projects.

6.2   Payload

With regards to manufacturing, we discovered that reducing the number of hand-measured cuts and joins during our manufacturing processes and increasing the amount of parts manufactured by computer-controlled processes (like 3D-printing and laser cutting) drastically improves the aerodynamic profile of the payload without many added build-hours. In fact, after iterating on the 3D-printed parts, we managed to also improve the structural integrity of the payload by improving tolerancing and adding material in places that we noted experienced large stresses during our unexpected launch failure prior to FRR.

Throughout the design and build process, scheduling was a persistent issue. The prototyping stage needs begin as soon as possible to allow for a fully flushed out design. Many of the design issues that ultimately pushed payload to be behind schedule were discovered during the build process—particularly surrounding tolerancing and hand-manufacturing, in addition to forces exerted on parts that were not accounted for, often resulting in surface-to-surface binding/friction issues. These issues could have been avoided if more time had been dedicated to prototyping different designs. Then, more time should always be alloted for the build process so that issues can be properly dealt with as they arise. This includes participating in early launches so that any external problems such as weather don't delay the schedule.

6.3 Recovery

When reviewing the recovery system right before launch, many details should be looked over, and with an appropriate checklist the system can be made as robust and consistent as possible. There is a necessity to constantly update the checklist in order to foolproof the system against all the issues that can be thought of. Oversights such as shock cord tangling or wires failing to break apart lead to solutions like shock cord arrangement and wire disconnects being added to the checklist, effectively preventing the issue from future launches. The checklist allowed for a 100% success rate regarding the recovery system in all flights.

In terms of the avionics bay itself, several important lessons were learned. First, a more robust design is needed for the switches that activate the altimeters. The switches experienced a higher rate of failure after prolonged use. The door on the avionics bay made preparation before flight extremely efficient, as well as allowed for easy access to all electronics needed for successful deployment. However, the door limited the minimum size that the avionics bay could be and increased drag. Counterboring the holes for the screws used to hold down the door did prevent the increase in drag from becoming too large. Future designs would consider a more compact arrangement that still allows for easy access before flight, as the current avionics bay had a large amount of wasted space. The 3D printed sled used to hold the altimeters worked extremely well, and allowed for better organization within the avionics bay. A more reliable way to maintain alignment is also important, as shear pin holes had to be re-drilled several times. Alternatives to shear pins will be considered in future designs.

One of the most surprising lessons learned was the reliability and consistency of the dual-deployment system, which utilized a unique orientation of two L2 Tender Descenders attached in series. The design was fabricated in a fashion that would ensure main chute deployment after drogue deployment if any, or both, of the two Tender Descenders were ignited. This led to extremely successful recoveries in every launch, except for the Full Scale re-flight, where the trajectory of the rocket was severely impaired with the launch rail. In the end, the decision to choose this method of employing Tender Descenders in the deployment system over other deployment systems, such as Jolly Logic, provided a creative, redundant, and most importantly, safe method of recovering the rocket. In the future, it can be possible to manufacture the Tender Descender components in house, allowing for more control and ownership in the design and implementation process.

In the future, more effort can be made in creating a more durable and robust method of protecting the main and drogue parachutes. In the final full-scale launch, the drogue chute was slightly charred, which was most likely due to the lack of complete protection during the black powder ejection charge ignition. This lack of protection could have been a result of having the rocket jostled around during transportation of the rocket from the prep station to the field. As a result, designing a more sturdy and reliable parachute bag/compartment would prevent future impairments to the parachutes.

6.4 Airframe

The summation of smaller issues can have a big effect on the rocket as a whole. Our altitude suffered due to inconsistencies in the airframe as well as sub-standard attention to detail in regards to the finish of the rocket.

Also, it is imperative that the execution of putting pieces together be as close to the intended design as possible. For example, when attaching the fins to the airframe during the subscale, they were not exactly 120° apart which caused unintended roll. For the fullscale, a fin jig was used to ensure that they were spaced as close to 120° as possible.

In addition to taking into account proper construction, it is vital that proper weight estimations are made. Without proper weight estimations, the team cannot come up with a design that satisfies the altitude requirement. After the build process, the rocket was 3 lbs. heavier. This makes hundreds of ft. of difference in altitude.

There were also some logistical parts throughout this year that caused some issues. The most prevalent was the rush shipping orders that had to be made consistently. Due to a naive design schedule, many parts were being ordered a couple days before they were needed. Unfortunately, model rocketry companies are very slow if ordered with regular shipping. This led to a constant need for extra money for rush shipping. For airframe, rush shipping was $\frac{1}{3}$ of the total cost. This is unacceptable and needs to be something that is improved as the club goes forward.

Finally, the build process documentation needs to be better. When something breaks, it is critical that the piece be replaced with specifications as close to the original as possible. This process can be streamlined through the use of proper documentation of how each part was built. Going forward, this process needs to be implemented with full detail so that anyone can take over and build the piece if it is necessary.

6.5 Safety

The most significant safety problem this year was the repeated obsolescence of various parts of the checklists at each launch. Due to different mechanical and electrical problems at launches, there was a significant amount of on-site construction, which immediately makes the relevant checklist sections out-of-date and useless. Next year we therefore should have more troubleshooting steps in our checklists, which ideally will obviate some amount of this launch-day rocket improvement: if some item does not work as intended, troubleshooting may fix the issue, and make one-off repairs unnecessary.

There were not other significant safety issues, and as such we will focus primarily on producing more accurate and detailed checklists next year.

7 Competition Summary

7.1 Overall Experience

This was not only STARs first year competing in the NASA Student Launch Competition, but its first year competing in any competition and designing a rocket. Along the way we faced a multitude of challenges and obstacles. STAR consists largely of members who, at the beginning of this competition, had no experience designing, manufacturing, constructing, or flying a rocket. The design challenge we took part in this year of landing the upper part of the rocket, led to much scientific value for the team and team members. In order to design and build our payload, we not only had to consider the mechanical and electrical components, but also, how to ensure no loss of safety, how to mitigate the hindrance to the aerodynamics of the vehicle, the optimal sequence of target identification, leg deployment, and ejection. This was not simply an engineering design challenge, but *blank* challenge. As a result, the value from the process extended much past the knowledge in rocket design and construction which we engaged in.

The sub-scale flight took place on December 3rd, and was the first high powered launch many team members had experienced. The payload was only simulated with sand ballast for this flight. The sub-scale flight and recovery was a complete success. Following winter break, manufacturing and construction of the full scale rocket began. The full scale flight was initially planned for February

4th. However, due to rain cancelations and payload design modifications, our first full scale flight did not take place until March 4th. While launch and recovery was sucessful, the payload, due to electrical issues discussed in length in previous reports, was not tested. At a March 15th launch with the goal of testing payload, a launch rail failure caused or rocket to crash and become severly damaged. This was the point were STAR faced its largest challenge. In order to be able to launch our rocket in Huntsville, we had 13 days to rebuild large portions of our rocket and relaunch it sucessfully. After much hard work and design modifications, not to mention a long drive to Mojave Desert to launch, the final test launch was sucessful.

18 team members were able to travel to Huntsville and take part in launch week activities. The experiences there were extremely valuable and provided team members with many ideas and asperations for things to explore in the following year.

7.2 Educational Engagement

7.2.1 Summary of Events and Counts

Habitat for Humanity Campus Visit

- Date: November 19, 2016
- Location: UC Berkeley Campus
- Total Count: 62
- Description: Local elementary schools visited campus. We held multiple demonstrations and presentations of bottle rockets and how rockets work in general.

Calapalooza

- Date: January 26, 2017
- Location: UC Berkeley Campus
- Total Count: 71
- Description: A Berkeley-wide event where clubs and programs show off their activities to new students.

Arcadia High School Visit

- Date: November 28, 2016
- Location: Arcadia High School
- Total Count: 30
- Description: A team member visited his high school and gave a talk on rocketry, Nasa Student Launch, and held a small rocket demonstration.

Engineering 4 Kids

- Date: March 11, 2017

- Location: UC Berkeley Campus

- Total Count: 109

- Description: Kids from the Bay Area visited campus and we held multiple egg drop classes/competitions throughout the day.

CalDay

- Date: April 22, 2017

- Location: UC Berkeley Campus

- Total Count: 337

- Description: A Berkeley-wide event to show off school activities to all people interested (current students, alumni, local families)

CubCon

- Date: April 23, 2017

- Location: UC Berkeley Campus

- Total Count: 12

- Description: A small hackathon with a few clubs demonstrating the electronics and computer science skills used in their projects.

7.2.2 Closing Remarks

As a first year team, we focused a lot of our effort in establishing a name for ourselves, participating in relatively small events nearby. As time progressed, we were invited to larger and larger events, like Engineering 4 Kids, where we reached the most students all year. We closed of the year with more recruitment events. We need more members in the future years if we want to continue to make high powered rockets and perform supplementary research.

7.3   Budget

Total Materials' Costs	$5,450.45
Individual Travel Costs Subtotal	$6,761.01
Shared Travel Costs Subtotal	$6,023.45
Total Travel Costs	$12,784.46
Total Costs	$18,234.91
ESC Travel Reimbursement	-$2500.00
Prior Funding	-$8255.33
Total	**$7479.58**

A crowd funding campaign is currently underway for with the goal of $5000 dollars to further reimburse members for travel costs and for next year. More funding opportunities are also underway as we hope to explore a much wider range of projects next year.