DEVELOPMENT OF A COMPOSITE PAYLOAD FAIRING ROCKET

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High Powered Amateur Rocketry is an established medium that student groups across the country use to compete in many different engineering competitions. This paper will explore the background, design, flights, and lessons learned from the University in Alabama in Huntsville's Space Hardware Club Planetary Rover Rocket. The project provided university freshmen a chance to learn about rocketry and compete in a national AIAA competition. Through the student engineering project environment, the team also learned about active communication, testing, and flight hardware delivery. This paper will also act serve as research material for future students interesting in pursuing rocketry.

Nomenclature

UAH = The University of Alabama in Huntsville
MAE = Mechanical and Aerospace Engineering

SHC = Space Hardware Club

ASGC = Alabama Space Grant Consortium

TRA =Tripoli Rocketry Association

PMW = Phoenix Missile Works, Tripoli Chapter #83, our launch field in Childersburg, AL

NAR = National Association of Rocketry

I. Introduction

The Space Hardware Club (SHC) was formed in 2006 with the mission to design, build, test, and fly student engineering and space hardware projects. This has included High Altitude Ballooning payloads, Cansats (mock satellites), and the ChargerSat CubeSat program. In 2012, the club brought on a competition rocketry team.

II. Team Background

As the club grew, it decided to take on another project. This was done to keep the individual team rosters at reasonable levels. The UAH SHC Mars Rover team was formed in September, 2011 as a freshmen team to compete in the AIAA Planetary Rover competition in Culpepper, Virginia in April, 2012. The team was made up of 9 freshmen, made up of 8 aerospace engineering undergraduate students and 1 electrical engineering undergraduate student, and 3 team mentors, consisting of 2 aerospace engineering graduate students and 1 electrical engineering undergraduate student. Most of the freshmen team had no experience with rocketry or robots, though a few had programming and robot experience from high school. This was a learning experience for all of us.

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III. Competition Overview

The AIAA Planetary Rover Competition is held near Culpepper, VA annually in early April. Each student team is tasked with building a rover capable of being launch by rocket to 1,000feet above ground level, descending by parachute, upon landing deploy a marker, move 10 feet, drop a second marker, make a 90deg turn, and roll another 10 feet. This paper will focus on the rocket we made to get the rover to the IP (initial point, rover deployment from the rocket).

IV. Rocket Beginnings

This was the first competition rocket team from SHC, but the club had some prior experience with high powered amateur rocketry. Several members were already Level One certified through NAR and TRA, which meant that they had gone through the certification process, had successful flights and recoveries, and were certified to fly the kinds of rockets we would need for this competition. They highly recommended that the members of the rocket team get Level 1 certified as this would allow us to fly bigger motors, which would be needed to get the payload (the rover) to altitude. With this in mind, we set about designing the rocket we would use to get Level One certified. It needed to be strong enough to take punishment from rookies, but also be simple enough and cheap enough that we could build it on our budget and with our skills.

V. The Certification Rockets

We were had just finished the proposal for the project, an entirely new experience for everyone. The next step was to get certified with the bigger rocket motors. We chose to go with a 3 inch airframe diameter, as we already had fins and centering rings for this size from previous rockets. The rocket was designed using a java app that does many of the calculations and simulations needed for high powered rocketry. We ordered components from an online rocket component supply and information website. The fins were rapid prototyped using the 3D printer at the UAH MAE student shop. After a bright neon green and yellow paint job, it was off to the launch fields at PMW. We chose to name the rocket "Parker".

The first launch weekend after rocket fabrication was complete was in December, right after final exams. Due to a SI/English units conversion error, the nose cone had too much mass and separated from the shock cord at

apogee. We had read material from several different sources, but actually being at a launch is difficult to convey in a magazine article. We learned more that day by not getting certified than if we had.

Over the next month we were able to practice launch preparations and continue to learn more about rocketry. The next launch window came. This time, the rocket 'zippered' upon parachute deployment. 'Zippering' occurs when the shock cord breaks through the airframe due to the extreme forces exerted on the parachute, shock cord, and airframe at separation. The shock cord is pulled through the airframe several inches, leaving a 'zipper' like crack in the airframe. This is significant damage and the rocket cannot be flown till it is repaired. The launch was not a total loss, however, as the team successfully completed all the prelaunch preparations successfully and on time.



Figure 1: Zippered Body Tube

We made modifications to Parker over the next few weeks. A wet layup fiberglass collar was added to the top of the airframe to patch the zipper and strengthen the 'mouth' of the airframe. The shock cord was also lengthened from 15 feet to 45 feet. This additional length gives the nose cone time to slow down after pulling the

parachute of the airframe, thereby reducing the loads on the airframe. These modifications proved successful on the next launch. The author successfully launched and recovered Parker on an H160 motor, thereby achieving Level One certification. The modifications made to strength the rocket have proved successfully on subsequent launch, providing a valuable platform with which to practice new techniques and test new hardware. With some training and certification accomplished, energy could now be devoted to the competition rocket.



Figure 2: Successful Certification Launch

VI. **The Competition Rocket**

The mission of the competition rocket was to get the payload, the rover, up to its staring altitude of 1,000 feet. This is the IP for the rover's mission. The competition rules dictated that the rover be less than 1 kilogram. Rough designs were started over winter break, using a 1 kilogram mass simulator. Back when the proposal was written, we didn't have any experience with rocketry or fabrication. We went with the best option at the time, which was to purchase carbon fiber body tubes from an online vendor. In the intervening months, some members of the rocket team had discovered that the UAH student shop had the facilities necessary to fabricate our own carbon fiber and fiberglass rocket components in house. This would later prove to be a huge benefit in keeping the project on track because we didn't have to wait for shipping time.

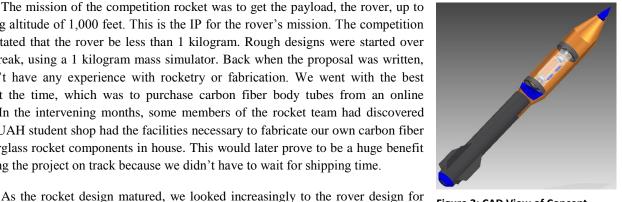


Figure 3: CAD View of Concept

guidance on how much room they needed for the payload. The rover design was about 3 weeks behind the rocket, which meant that the payload dimensions kept changing. It did not make sense to redesign the rocket for each design change, so a payload fairing concept was adopted. We could accommodate the payload

requirement changes by adjusting only the size of the rocket where the payload would be, and keep most of the rocket the same.

We chose to make the airframe carbon fiber tubes 4inches in diameter because that gave us a good size from which the fairing could be expanded to many different sizes. Carbon Fiber Pre-Preg was used in fabrication. This allowed us to produce many very strong body tubes very quickly. One advantage of pre-preg is that the fibers and the epoxy are already at the optimal mix rates, and we don't have to bother with applying epoxy. This allows for a more consistent part. The final 'stack', all the components put together included two carbon fiber airframes. The bottom one served as the mounting point for

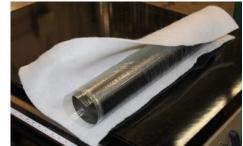


Figure 4: Carbon Fiber Lay-up

the fins and the boat tail. We chose to secure the boat tail with a series of screws, instead of epoxy, to allow us access to the fin mounts in case we needed to change a fin on the launch field. This flexibility was greatly appreciated at competition. The 5-grain CTI 38mm motor casing also fit in the lower body tube. The upper body tube contained the parachute and shock cord for the rocket, the deployment charge controller, and served as the mounting point for the fairings.

The fairings had a pyramidal nose cone with polycarbonate blast tip, 6 inch diameter, 16 inch long payload section, transition section for 6inch diameter to 4in diameter, and the coupler for the airframe. Two fairings enclose the payload until it is released. The fairings were fabricated from fiberglass to allow radio transparency in case the payload needed to add that capability late in the project lifetime. A wood mold was machined using a cnc mill in order to



Figure 5: Composite **Payload Fairing Mold**

make the precise shape needed for the composite part. The mold block was big enough that it could be remilled for a bigger fairing, in case that contingency was reached. Figure 2, to the right, shows the mold in the vertical position. Note the pencil at the base for scale. In the future, the author would recommend the use of male molds when the part has inside curves, as this is difficult to layup on a female mold. Each fairing had half of the rover mount, where the rover sat during ascent. At the tip of the nose of each fairing was a polycarbonate nose cone, which held a black powder charge used to separate the fairings on descent and release the rover. The method for connecting the fairings with the airframe was never completely finalized and has continued to plague the design team. Methods tested included small clips, block inserts that matched the inside volume of the top of the airframe, and polycarbonate funnels that align themselves with the top of the airframe.

The rocket's final version of the mission profile starts on the launch pad. After liftoff, the rocket climbs to approximately 1,500 feet at apogee, where the external drogue pod deploys a 16 inch drogue parachute to stabilize descent. At 13,000 feet, the two airframes are separated by a blast charge and the main parachute is deployed. The deceleration from main parachute deployment also forces the fairings off the upper airframe, where they hang from individual shock cords. At 1,100 feet, the nose cone blast charge separates the fairings, allowing the rocket to be deployed and begin its mission.



Figure 6: Rocket on the **Launch Pad**

The first test flight was in early February. The entire team had worked hard for several days to get the rocket out the door for this test flight. At the launch field, it was discovered that the drogue, at this time a internally stored streamer, was much too big for its allotted compartment. The rocket flew as the last launch of the day. Liftoff was beautiful, very rewarding for the team to watch. As it arched over at apogee, we began to sense something was amiss when neither the drogue nor the main parachute deployed. The rocket crashed into the field, burying the mass simulator underground and snapping the fairings into pieces. Interestingly enough, the carbon fiber airframe survived relatively unscathed. During post flight analysis, it was discovered that the airflow around the rocket had

kept the drogue in its compartment, and that the ejection charge for the main parachute was too small. While it is unfortunate to have lost the first test vehicle, the launch team learned a great deal that day.

Over the next few weeks modifications were made to the parachute systems and fairing attach method. The design adjusted to allow the parachutes to move to the middle of the airframe, easily deployed by a proper black powder charge. A second test was conducted early in March. Again, the recovery systems did not deploy and the rocket crashed into the ground. Post Flight analysis showed that the carbon fiber honeycomb bulkhead had been compromised, reducing the effectiveness of the separation charge.

Figure 7: Flight Test Results

VII. **Solutions for Competition**

With a little less than three weeks to competition, there would be no more test flights. The rocket team looked over the post flight analysis from each of the test flights, and made modifications to the final competition vehicle. The blast powder charge sizes were increased by a gram to 3 grams from 2 grams, as we were

confident the carbon fiber could take the increase in force. Previously, it had been difficult to integrate the fairings onto the airframe at the launch site, so polycarbonate funnels were installed, where the fairing would automatically center itself over the airframe.

An external drogue pod was also invented by a team mate. This pod was completely removed from the ejection charge system for the



Figure 8: Redundant Drogue Pod

main parachute, thereby adding an additional level of redundancy to the system. The idea was that this pod would fire even if the main failed, there by bringing in the rocket at a slow enough speed that the rocket would not be destroyed and could be flown again. This was heavily tested on rapid ascents and descents on the side of a local mountain. With these changes, we felt confident that we were ready for competition.

VIII. Competition

Upon arriving at competition, we discovered that we were the only team to have fabricated the rocket ourselves, and the only ones to use composites or fairings of any kind. The standard rocket was a large diameter rocket that ejected the rover at apogee. We set about preparing for our first flight.

First flight prep went well. After several test flights, the ground crew was well rehearsed in the tasks of parachute folding, black powder charge preparation, ejection altimeter programming, and rocket stack integration. The night before competition, it was discovered that circular wheels did not provide the rover with enough traction to move, so square foam wheels were fashioned. The corners provided traction, while the foam compressed enough to allow the wheel to rotate. The additional size of the wheels proved to be an issue as we tried to fit the rover into the payload fairings. Liftoff was beautiful. Shortly after motor burnout, the fairings separated and released the rover, much too low. After all the parts were recovered, it was determined that the failure had come from a combination of drag separation (where the payload fairing rides forward of its location of the rocket, as the motor cuts out and the fins' drag begins to be significant, but then the momentum of the rocket brings it up through the fairings, which have less momentum), and the new larger wheels pushing the fairings apart. Upon landing, one of the fins had been compromised. We were very happy that we had



Figure 9: Competition Liftoff

gone with a removable boat tail, as we could now service the fin mounts and replace the broken fin.

We prepped the rocket for its second flight soon after recovery had finished. The payload team secured the wheels, so they would fit within the 6in fairings. The top of the airframe was built up, so as to provide more friction with the fairing and hopefully prevent drag separation. Unfortunately, the fairings separated on the final competition flight also. The rover wheels deployed successfully, and the rover performed its function perfectly.



Figure 10: Square Wheeled Rover

IX. Lessons Learned

As an all freshmen team, it is quite impressive that we successfully field a competition ready product with little or no starting experience. The rocket team learned a great deal through the project life cycle. From rocket

certifications to composite fabrication to flight line trouble shooting, the skills and experience gained by the team cannot be easily learned in the classroom.

Testing is a very important part of any project, and should have been incorporated into this project sooner. The flight tests we did have provided valuable results, but more testing was needed to



Figure 11: Ejection Charge Testing

prove the rocket ready for competition.

Team communication is crucial to the survival and success of the team. We learned this the hard way, as design decisions were not communicated effectively as they were happening. We are very glad we produced design review documents to reference during our work though. These documents provided us some solid discussion points and are a valuable record of decisions. Any student engineering project should produce design reviews.

We never perfected the fairing-airframe integration technique before competition. After everything was finished and we went home for the summer, some of the rocket team got together and have come up with several viable solutions that deserve a test flight to potentially prove their worth.

X. Conclusion

We learned more from this project than we ever thought possible. Many long days and late nights produced camaraderie among the team that continues to this day. We should have started earlier on the project, which would have allowed more time for testing and final tweaking, but that is a lesson that can only be learned the hard way. We successfully learned about high powered amateur rocketry safely, supplemented our classroom education with valuable flight line experience, and learned skills that we can take with us to future jobs. We are very thankful for the opportunities available to us at UAH.

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AIAA Planetary Rover Competiton

The 2012 Mars Rover Rocket Team

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About the Author

Markus Murdy is an aerospace engineering undergrad interested in rockets, aeronautics, and transportation system design. He has very much enjoyed the opportunities Space Hardware Club has provided above and beyond his classroom education to provide a transformational experience, and hopes the administration sees the benefit in continued support of the club. He will graduate from UAH in May of 2015.