The UAH Space Hardware Club Sounding Rocket Program

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The purpose of the Space Hardware Club at the University of Alabama in Huntsville is to develop a new generation of engineers and scientists who gain real-world experience by developing space-related hardware and performing outreach. With this goal in mind, The Club has founded the Sounding Rocket Program. Building on four years of competition-based high-power rocketry projects, the focus of the Sounding Rocket Program is to expand the students' knowledge, experience, and capabilities. This is being accomplished primarily through The Supersonic Challenge, which splits the incoming freshmen into two teams, competing against each other in order to inspire the teams to push themselves and their designs. Incorporating both training and research engineering teams, the preservation of knowledge and laying the foundation for future projects after the current members have moved on are the hub of the Sounding Rocket Program.

Nomenclature

UAH = University of Alabama in Huntsville
SHC = Space Hardware Club
PDR = Preliminary Design Review
CDR = Critical Design Review
FRR = Flight Readiness Review
PFR = Post Flight Review
CAD = Computer Aided Design

I. Introduction

THE Sounding Rocket Program was created to facilitate high-power rocketry projects within the UAH Space Hardware Club. The program promotes the advancement of rocketry skills and capabilities to be used in upcoming projects. L1 Month gives members an introduction to the basics of rocketry that allows them to advance to upper-level projects. After completing L1 Month, students move on to The Supersonic Challenge, a friendly competition that provides an advanced challenge and promotes a desire to gain skills that will benefit them in a team environment. This project is the largest and most advanced training program seen by the Space Hardware Club.

II. Space Hardware Club

The Space Hardware Club at The University of Alabama in Huntsville is a student run organization which focuses on the development of flight hardware used in satellites, high altitude balloons, and rockets. The aim is to have members gain real-world experience by working on numerous projects and performing outreach to inspire others.

Figure 1. The Space Hardware Club logo *The SHC logo features SHC's main four programs: rocketry, BalloonSat, CubeSat, and CanSat.*

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A. Organization

SHC is a completely student run organization with elected leadership and a constitution written by the students. The Club represents a diverse range of academic majors, including Aerospace, Industrial Systems, and Optical Engineering as well as Physics, Mathematics, and Computer Science. Other than a weekly meeting with the faculty advisor, all activities are conducted completely autonomously, only requiring approval from the officer board.

The Club has a consistent base of at least 40 members, with an influx of about 120 every year through the One Month Program. Recruiting and outreach efforts persist in order to build new generations of membership and inspire even younger students to enter the STEM field and contribute to SHC.

B. Real-World Experience

During students' time in The Club, they participate in various projects to acquire skills that will frequently be used in their professional careers. Similar to the NASA standard, all teams must go through the design review process including PDR, CDR, FRR, and PFR. This process provides a chance for seasoned club members to impart their knowledge to the younger generation through valuable feedback on their projects and ensure the teams' success. By manufacturing and assembling flight hardware in house, members gain hands-on experience. Additionally, by working together on team projects, they learn the leadership skills necessary to thrive in the engineering industry.

C. Programs

The Sounding Rocket Program is an entirely new program established in 2016, which focuses solely on high-power rocketry. In order to give new members the knowledge and experience necessary to move on to projects bigger than previously possible, the Sounding Rocket Program emphasizes training and expanding capabilities, rather than winning competitions.

From The Club's inception in 2006, BalloonSat has been a wide-use platform that utilizes high-altitude balloons for experimentation with new technologies, outreach, and helping other club projects with testing. The BalloonSat program strives to be a tool for validating new hardware while being available to help others inside and outside of The Club. In 2017, the Space Hardware Club completed its 57th BalloonSat mission.

Figure 2. BalloonSat 001 April 22nd, 2006
This picture was taken on the first launch of the SHC BalloonSat Program.

The CanSat competition has been a Space Hardware Club staple since 2008. Around 45 international teams compete every year in this design-build-fly competition. The majority of teams are senior-design teams challenged by the complex integration of electrical, software, and mechanical systems. Every year, The Club fields 2 or 3 teams, comprised almost completely of freshmen as a training project before moving on to bigger projects like CubeSat or Rockoon.

Figure 3. ChargerSat 1 rendering
This image features the final design of the ChargerSat 1 CubeSat.

In 2012, the Space Hardware Club ChargerSat 1 team built a 10 cm^3, 1 kg orbital satellite as part of the CubeSat program. The objectives were to improve communications for pico-satellite operations, demonstrate passive nadir axis stabilization for attitude control, and improve solar power collection for pico-satellite operations. Currently, the ChargerSat Azure team is developing a similar, slightly larger satellite with active attitude determination and control abilities.

Outreach is a program that works with a younger generation of students to interest them in STEM fields. Members of Outreach and other members from The Club have participated in two outreach balloon flights last year in addition to a community outreach flight. When members travel to schools, they teach the students the importance of STEM by offering events like balloon launches where they can learn about ballooning. Students work hands-on during flight operations to contribute to flying the

balloon. After the flight, The Club presents any data recovered and shares a video from the flight so the students can reflect on their accomplishments to gain an understanding of the importance of balloon flights for experimentation and research purposes.

III. Past Rocketry in Space Hardware Club

Like the aerospace industry, rocketry forms a large portion of the Space Hardware Club's activities and research. Additionally, its main purpose is to serve as a vehicle for science payloads. However, in order to provide the needed testbed for these payloads, the focus must be on expanding capabilities, rather than meeting competition requirements.

Figure 4. Mars Rover 2016 *The team preparing for the final competition flight in Fruitland, MD.*

A. Battle of the Rockets: Mars Rover

In 2012, a team of 9 students began Space Hardware rocketry by competing in the Battle of the Rockets: Mars Rover. The rocket for this competition was required to take an autonomous roving payload up to 1,000 ft before deploying it and descending safely. Being the first scratch-built rocket made by Space Hardware Club, there were many flaws in the design, including the payload fairing. Fairings are not a common design component in high-power rocketry, and in 2012, the team was disqualified in both competition flights due to a failure in this part of the system.

The team returned in 2014 with the experience necessary to build a functioning rocket. The rocket, Magnum, had a brand new reliable composite fairing design. All teams competing in 2014 technically failed the challenge because none of the rovers actually travelled, but with a successful rocket and design reviews, the UAH SHC team took home 1st place.

In 2016, The Club fielded an entirely new team with an even more efficient and reliable rocket. However, for the 2016 team, the competition requirements were a constraint, rather than a challenge and necessitated a new program to expand rocketry capabilities. The rocket, Spitfire, utilized new manufacturing capabilities and built off of previous successful rockets to become the most reliable in Space Hardware history. After 5 successful test flights, the team flew 3 times for competition scoring, but a circuitry problem in the rover caused a failure, so scores once again boiled down to design reviews and the team took 2nd place.

B. CanSat

Another Space Hardware Club staple is the CanSat competition, which requires students to design and build a mock satellite, to be deployed at 2,000 ft from a high-power rocket. Although rockets are provided for competition flights, The Club requires flight testing prior to competition, so a rocket is built every year for this purpose. All 4 of the CanSat rockets made over the years have been destroyed during flights, which has provided an excellent opportunity to gain experience building larger diameter rockets, but the rockets have all been very similar in design and not pushed the capabilities of The Club.

C. Midwest High-Power Rocketry

In 2015, the Midwest High-Power Rocketry Competition was opened to include teams from across the United States. The challenge was to construct a boosted dart to reach maximum apogee on a given motor. This was the first SHC rocket to fly with multiple stages, even though the second stage was not powered. Many of the technologies developed for this competition were built upon in the subsequent Rover team, and continued development through Project URSA, SHC's current multistage rocket project.

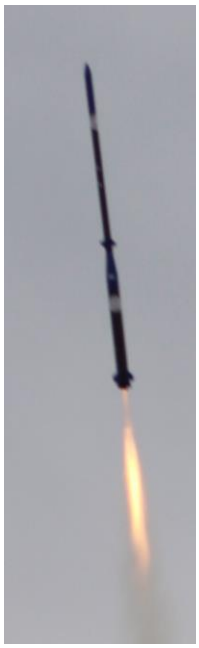

Figure 5. Midwest High-Power Rocketry *The rocket, Going Postal during its Competition*

IV. The Sounding Rocket Program

Space Hardware Club is currently running 12 projects, 4 of which are rocketry based. The Sounding Rocket Program brings all the rocketry projects together under one roof and holds the overall goal of laying the foundation for future projects after the members have moved on. The program defines a pathway for continual learning in order to move forward with more advanced projects than previously possible.

Figure 6. L1 Month, 2016 *The project participants doing a fiberglass layup in the UAH Engineering Design and Prototyping Facility.*

A. L1 Month

New members who are interested in high-power rocketry typically join L1 Month after completing the One Month project. L1 Month is an opportunity that allows members to earn their Tripoli Rocketry Association Level 1 certification. A Level 1 certification allows for the purchase and flight of rocket motors with an impulse in the H and I range, meaning an impulse between 160 and 640 Ns (newton-seconds), regardless of the propellant. Project members must design and build a rocket from scratch that comes down safely and is recovered in flyable condition.

During the design process, members learn how to simulate rocket flights using the Open Rocket software. They also gained extremely valuable hands-on experience with composites. Almost all components are manufactured by hand by the new members with the guidance of older members, excluding a few prohibitively difficult parts. This involved spending tens of hours doing wet fiberglass layups for body tubes, motor tubes, and fins. Additionally, they learned CAD skills in Siemens Solid Edge.

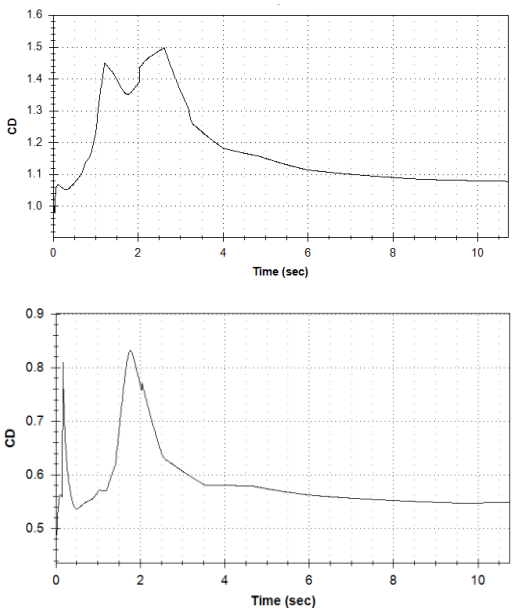

Figure 7. CD vs Time *Data for Mach 6 (top) and Gold Team (bottom) during flight from RASAero II*

B. Supersonic Challenge

Members typically advance to a rocketry project after L1 Month where they can apply their newly acquired skills. The Supersonic Challenge requires 2 teams to design, build, and fly a rocket that travels at a speed exceeding Mach 1 with a projected altitude between 5,000 and 10,000 ft. The 2 teams compete in a friendly competition within The Club based on a point system established by experienced club members: 40% Design Reviews, 50% Flight Performance, and 10% PFR. Project members must pass PDR and learn how to create CDR, FRR, and PFR.

Supersonic teams apply their designing skills learned from L1 Month to their PDRs. Teams utilize their CAD and Open Rocket Software skills to create designs and run flight simulations. Both teams must test their rockets before they reach their competition flight. A test flight allows for the teams to discover potential faults in their design or assembly that can be fixed before the competition day. Team members have learned important information about supersonic flight including the highest risk failure points such as fin flutter and the increase in drag at transonic speeds. During this project, members gain the skills necessary to advance to more difficult projects like Project URSA and Rockoon, an ongoing project launching a rocket from a high-altitude balloon.

The 2 Supersonic teams are named Mach 6 and Gold Team. Mach 6 is designing their rocket to reach 9,700 ft with a maximum velocity 1500 ft/s (Mach 1.33). They are doing a test flight and competition flight with a K1275 motor, "K" denotes that it has an impulse in the 1,280–2,560 Ns range and an average thrust of 1275 N. Gold Team is designing their rocket to reach 9,400 ft and 1172 ft/s (Mach 1.04) also flying a K1275 motor for their competition flight. The difference in performance between the 2 rockets is primarily due to the fact that Mach 6 is using a minimum diameter design, meaning the inner diameter of the rocket's aiframe is equal to the outer diameter of the motor, 54 mm or roughly 2.125 in. Gold team, on the other hand, is using a body tube diameter of 3 in, but they are also using wedged fins. By using a minimum diameter, Mach 6 is greatly reducing mass, allowing for greater acceleration and a greater maximum velocity. However, the reduction in drag that comes with a minimum diameter design must be balanced out in the fin shape in order to stay within the required apogee range. So, Mach 6 is taking much greater total drag forces (90 lb vs. 70 lb), but it has a much lower mass.

C. Project URSA

Project URSA is a team developing a multistage rocket that must reach 30,000 ft and have 2 powered stages with a combined impulse of at least 5,120 Ns. The rocket is 11.7 ft in length and has a predicted apogee of over 31,000 ft. Additionally, this project is the first in SHC history to fire a rocket motor during ascent, and the rocket has a total installed impulse of 8,454 Ns, which is well into the Tripoli Level 3 range, another first for The Club. Going through the standard design review process including PDR, CDR, FRR, and PFR, the URSA team hopes to mitigate any risks associated with flying an experimental design with a massive total installed impulse. However, the experience gained through this project will be vital to future rocketry projects, including Rockoon.

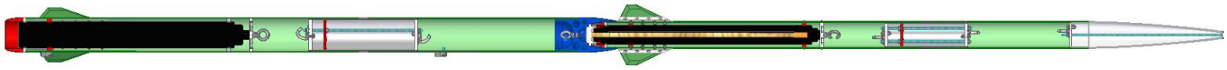

Figure 8. Cross-sectional view of Ursa *CAD made in Siemens Solid Edge ST8 by Project URSA for PDR.*

D. Rockoon

Project Rockoon is developing a mission concept for a suborbital launch vehicle that will employ a balloon assisted rocket to bypass significant atmospheric density. This project is conducted to provide cheap high-altitude experimentation to small companies. The rocket will ignite at balloon apogee and boost the payload higher than possible on a high-power rocket or balloon alone. The current background development will be used to set up timelines and funding considerations for the mission before moving on to the design review process in late 2017 and continuing through 2018.

VI. Conclusion

The Sounding Rocket Program was developed as a platform for rocketry based projects for active SHC members. The training acquired advances members from one team to the next, expanding their capabilities to move on to cutting edge projects. Additionally, their experience both in an engineering atmosphere and working together to finish projects is beneficial to life outside the academic and professional realms. Graduating members of The Club are accustomed to holding leadership positions, learning in a fast paced environment, and supporting peers, which are all invaluable components of a successful career.

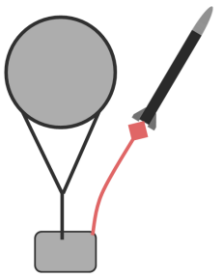

Figure 9. Rockoon diagram *Basic concept of operations for a rocket launching from a high-altitude balloon.*

Acknowledgments

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