NASA Student Launch
2016-2017

Post Launch Assessment Review

Citrus College

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Project Aegis

Fragile Material Protection

April 24, 2017

Table of Contents

I. Team Name

Citrus College Rocket Owls

II. Motor

- Aerotech L1420R
- RMS-75/5120 4 grain hardware
- Red line APCP propellant
- Thrust-to-weight: 7.02

III. Payload Description

The fragile material protection payload was constructed to house and protect an unknown sample(s) prior, during, and post flight. This is done by inserting solid samples into their own inner rack compartment. The silicone disks of the inner rack are adjusted manually by threading the metal nuts holding the silicone disks in place, up or down over the metal rods until the desired number of compartments are created. The silicone disk compartments can be manually adjusted to fit 1-8 samples. The objects are placed into their individual compartments one at a time, a team member then manually screws the metal nuts on the threaded rods, both above and below the silicone disks, until the silicone disks are taut around the sample(s). After the samples are secured into the inner rack, the rack is inserted into the inner chamber of the container and sealed closed with threaded fitted cap. Liquid samples are carefully poured into the liquid compartment, then the cover is secured.

The payload is composed of an outer shell, inner chamber, lid adapter, and inner rack. The outer shell is a polycarbonate cylinder 13” in length with an outer diameter of 5.5” and an inner diameter of 5.25”. There is a polycarbonate disk secured onto the inner diameter of the outer shell. Silicone sheets 0.125” in thickness are attached to the inner walls of outer shell. The inner chamber is a 12.75” long polycarbonate tube with an outer diameter of 4.5” and an inner diameter of 4.25”. There is a polycarbonate disk secured onto the inner diameter of the inner chamber tube. The inner chamber is secured onto the inner base of the outer shell. A 0.125” thick layer of aerogel is in the cavity between the outer shell and the inner chamber. The lid adapter is fixed onto the top of the outer shell. The inner rack is inside of the inner chamber, its function is to house up to 8 samples and prevent their motion or interaction with the rest of the container. The base of the inner rack is comprised of a wooden disk 4.25” in diameter, the disk has three steel rods attached through its surface via nuts. The 8 inner rack compartments are made of 16 separate silicone disks 4.25” in diameter. The zinc plated rods run through all the silicone disks and are separated by springs over the rods. Each disk is secured into position using nuts. A silicone disk was placed over the top wooden disk to create the sealing disk. The sealing disk incorporated a wooden disk 4.25” in diameter and a wooden handle. The sealing disk was secured to the steel rods by placing a nut on top of the disk and another nut at the bottom of the wooden disk.

IV. Vehicle Dimensions and Summary

- Length: 119”
- Diameter: 6.08”
- Gross Lift-Off Mass: 45.61 lbs
- Airframe Material: Blue Tube 2.0 and Fiberglass
- Fin Material: 0.25” Aircraft Grade Plywood and Fiberglass
- Static Stability Margin: 3.33

- Drogue Parachute: 24” Elliptical
- Main Parachute: 120” Compact Toroidal (deployed at 800 ft)
- Rail Size: 12ft-1515
- Recovery: Two (2) Missile Works RRC2+ Altimeters (Black Powder Redundant System)

V. Altitude Reached

The designated competition RRC2+ altimeter reported a maximum altitude of 5358 ft on launch day.

VI. Data Analysis and Results of Vehicle

The LSM9DS1 accelerometer was used to gather the flight data for the full-scale launch. Upon launch vehicle recovery, the SD card storing the data gathered throughout flight was utilized in conjunction with Microsoft Excel to create the following graphs.

Figure 1: Launch Vehicle Gyroscope Data

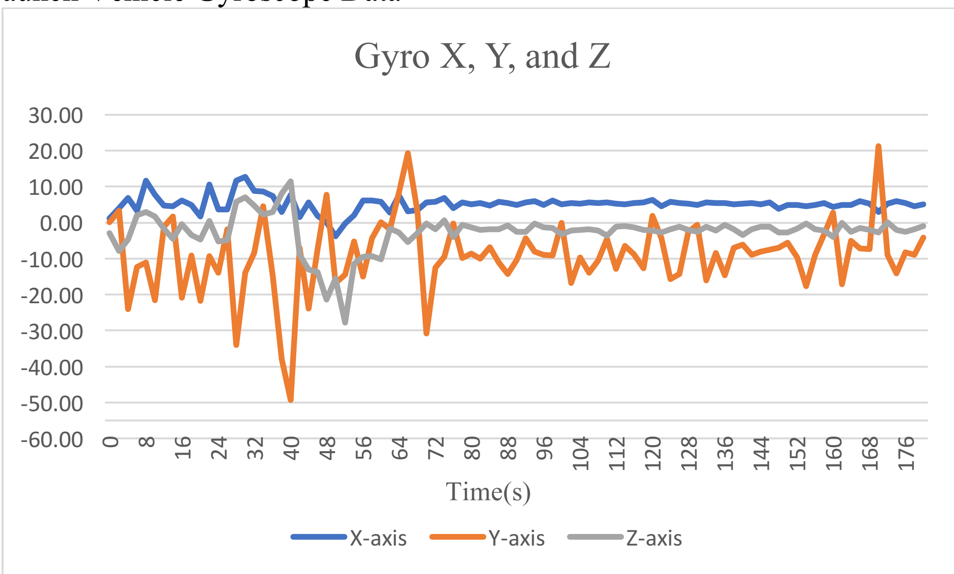

Figure 1 shows the data in the X, Y and Z direction of the gyroscope. The overall rotations do not exceed -50 or +25.

The data from the gyroscope show the angular velocity experienced by the launch vehicle during flight. The graph indicates that the launch vehicle did not experience angular velocities that exceeded 50 degrees per second. This suggests a steady straight flight.

Figure 2: Launch Vehicle Accelerometer Data

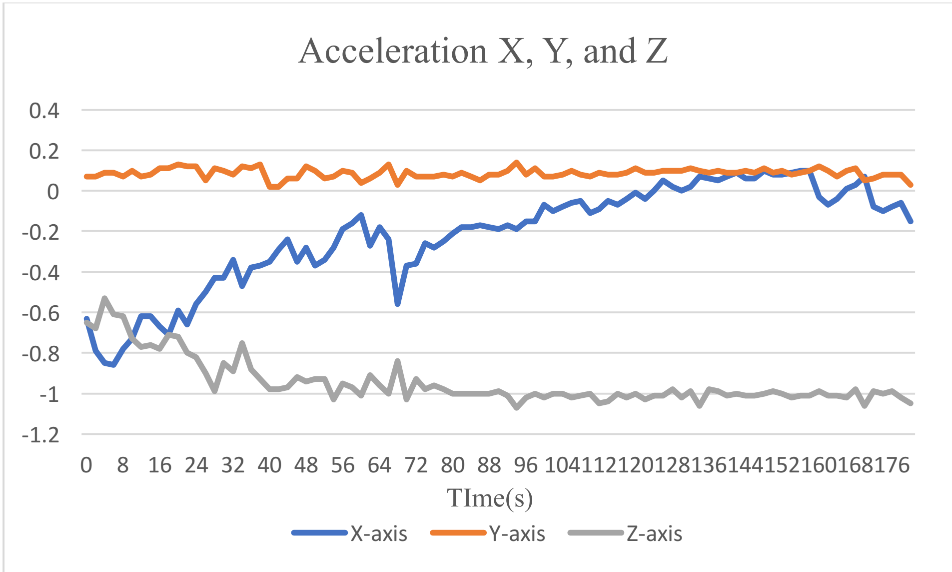

Figure 2 shows the acceleration of the launch vehicle in the X, Y and Z axis. The acceleration of the launch vehicle did not exceed -2 or +2 G's. These values did not exceed -1.2 or +0.2 indicating a safe and steady flight

Figure 3: Launch Vehicle Pitch Data

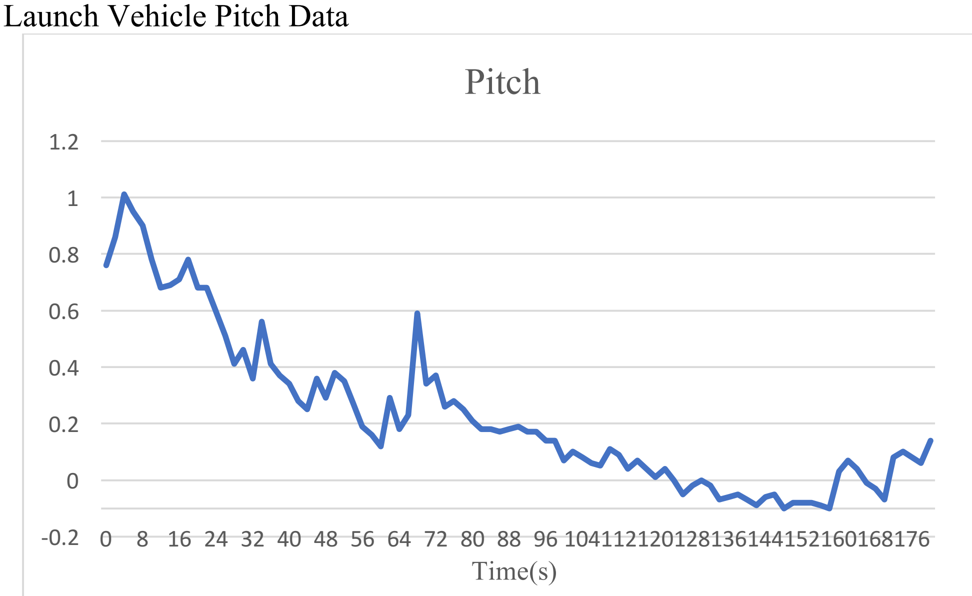

Figure 3 shows the pitch data of the launch vehicle. The data illustrates that the launch vehicle did not experience a pitch greater than -0.2 or +1.2 indicating a stable flight with little rotation in respect to the y-axis.

Figure 4: Launch Vehicle Roll Data

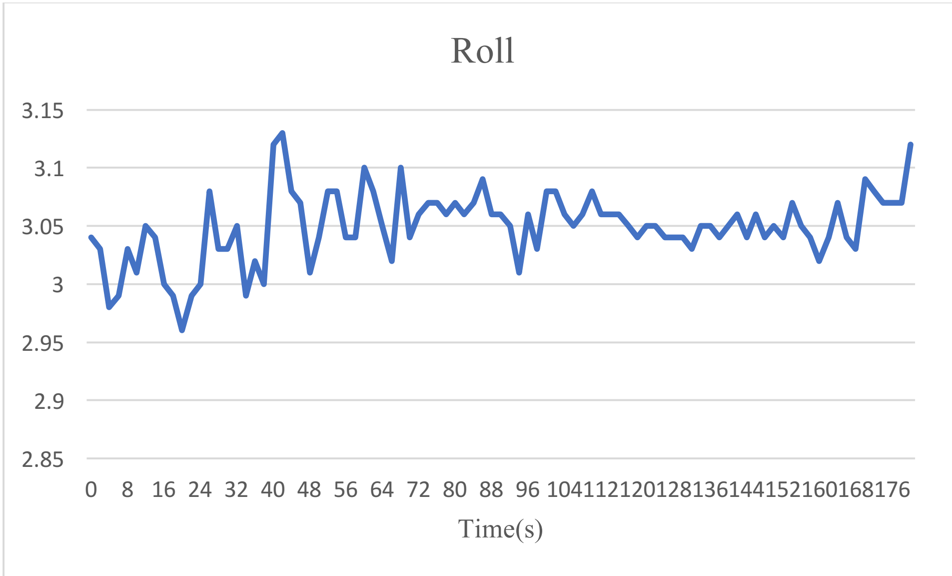

Figure 4 shows the roll data of the launch vehicle. The data indicates that the roll felt by the launch vehicle did not exceed -2.95 or +3.15.

As indicated by the data from Figure 3 and 4, the launch vehicle fully rotates about the z-axis with little rotation about the y-axis during flight. The rotation becomes faster where the data lines are closer together.

VII. Payload Summary

- Fullly mechanical
- Dimensions:
    - Maximum height: 17.0”
    - Maximum diameter: 5.8”
- Mass: 8.50 lbs
- Materials:
    - Polycarbonate (outer shell and inner chamber)
    - PVC (threaded cap and fitting)
    - Metal springs
    - Metal threaded rods and nuts
    - Sillicone (disks and radiation shield)
    - Aerogel
    - 10-ply aircraft grade plywood (top disk, handle, and bottom disk)
- Contructed to protect against:
    - Impact/Shock
    - Cross contamination
    - Raditaion
    - Temperature change
    - Flammability

VIII. Data Analysis and Results of Payload

The payload did not include electronics, and thus only visual data analysis is described in this section

The team-constructed payload protected the five shatter blast clay disks, fragile material, successfully prior, during, and post launch. The silicone disks of the inner rack were adjusted manually to secure the fragile materials. Post launch, the payload was removed from the launch vehicle and opened. Upon inner rack removal, the fragile materials remained in their designated compartments and were removed from the payload without damage as shown in figure 15. All components of the payload remained intact after flight declaring the team-constructed payload as reusable.

Figure 5: Fragile Material Condition

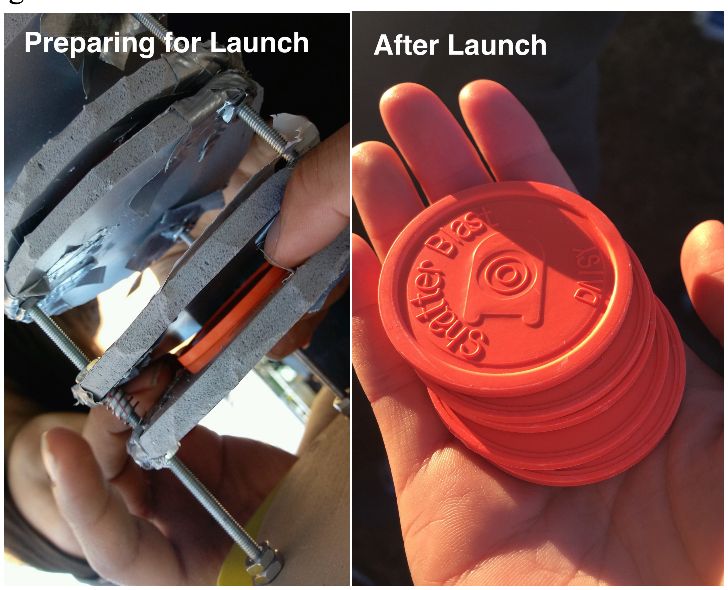

Figure 5 displays an independent fragile material incorporated into a compartment within the payload inner rack prior to launch (left) as well as the mint condition of the fragile material post launch (right).

IX. Scientific Value

As participants of the NASA Student Launch, teams were given the opportunity to select a challenge based on multiple experiment, such as target identification and landing control, launch vehicle roll maneuvers, and fragile material protection. The Citrus Rocket Owls' chose to tackle the fragile material protection challenge. The payload container was designed to store and protect unknown sample(s) from Mars and keep said sample(s) in optimal condition during its descent back to Earth. Thus, when designing the payload, various aspects and variables were taken into consideration, such as insuring the sample would be well protected against any impact or shock that occurs during the flight and landing of the launch vehicle. Another important aspect taken into consideration when designing the payload was protecting the sample against changes in temperature that may occur during the trip to Earth. Protection against changes in temperature was essential, considering Mars is significantly colder than Earth. Hence, the temperature difference could damage the integrity of the sample(s) by causing phase changes in molecular bonds or altered chemical structures. The payload container was designed and constructed to reduce flammability, preventing damages from occurring to the sample(s). A key aspect when designing the payload, was keeping the sample(s) from Mars separated to prevent cross contamination. Objects of the same material can still cross contaminate each other which could potentially alter accuracy and/or the validity of any observational or experiments data obtained using the sample(s). Another especially important feature was protecting the sample(s) from space radiation. As radiation might cause changes to the samples chemical composition or alter it molecularly, compromising the validity of any experiments conducted on the sample. Thus, the designed, construction, and material selection for the fragile material protection payload was based with the intent of receiving a sample from Mars.

X. Visual Data Observed

The launch vehicle exited the launch rail in a stable upright position. The flight was stable and the drogue parachute was successfully deployed at apogee. A second cloud of ejection charge was visible after drogue deployment, indicating that the redundant recovery system was functioning correctly. The launch vehicle continued its decent until it reached an altitude of 800ft and the main parachute was successfully ejected, but unfortunately the main parachute did not fully deploy. The main parachute got tangled in its own shroud lines and thus, the launch vehicle landed with only the slow down created by the drogue. The team walked approximately a quarter of a mile for the recovery of the launch vehicle. The launch vehicle was completely tethered and as each individual section of the vehicle was examined it was verified that no damage had been inflicted onto the launch vehicle. The fins, as well as the rest of the launch vehicle and payload, were intact with no cracks or deformations and the launch vehicle was found to be reuasble. Figures 5-8 display the visual data from the competition launch.

Figure 6: Launch Vehicle at Landing

Figure 6 shows a side view of the launch vehicle after landing. The nose cone pierced the ground but sustained no damaged. All connections between the sections of the rocket remained secured and the vehicle showed no signs of damage.

Figure 7: Launch Vehicle Fins (Post-Launch)

Figure 7 shows the condition in which the fins were found after landing. Fins did not show any evidence of cracking or slpintering and all connections were intact.

Figure 8: Avionics Bay (Post-Launch)

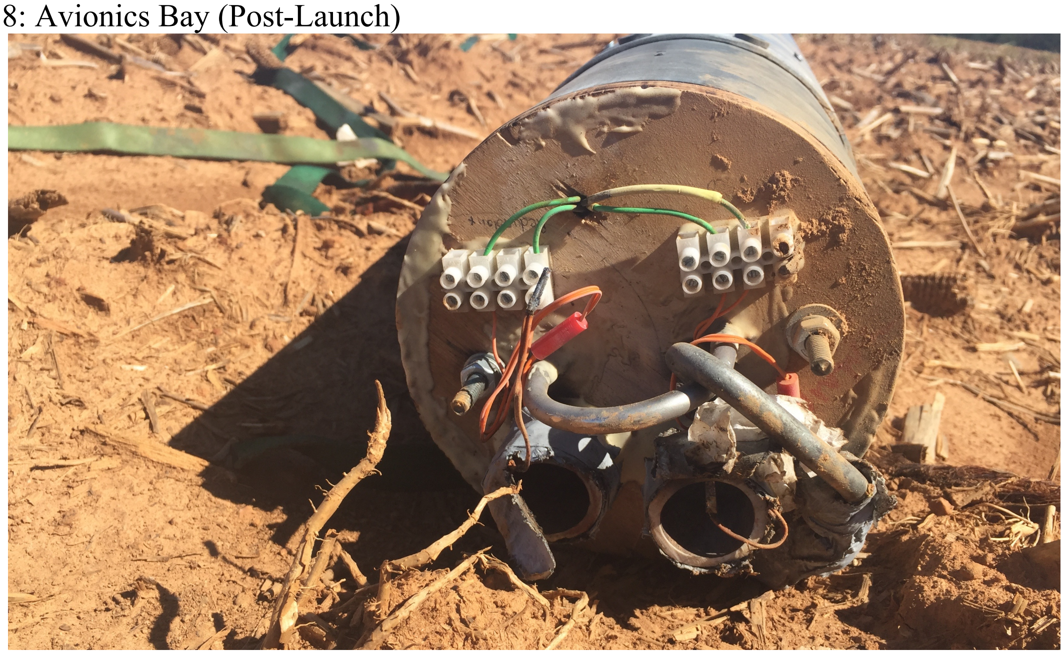

Figure 8 displays the condition in which the avionics bay was found after landing. All wires remained intact and connected. The ejection charge canisters or the avionics bay did not substanced any damage. Both ejection canisters displayed clear indications that the main and redundant charged occurred during launch.

Figure 9: Launch Vehicle (Post-Launch)

Figure 9 shows the booster section of launch vehicle after landing, it sustained no damage during or after flight.

All airframes were checked for chipping or zippering and shock cords were inspected for burns or tears. No damage was found on the vehicle.

XI. Lessons Learned

- If cost permits, have everything in duplicate.
- Purchase your motor well in advance.
- Communication is important.
- Time management is of utmost importance, especially in a small team.
- Finish a basic design first, and if time permits improve it.
- Safety is paramount in engineering.
- Multiple launches are a great way to learn about engineering principles.
- Network with local launch organizations, because they provide useful help.
- Do no underestimate the time necessary to format a technical paper.
- Check motor hardware inventory prior to leaving for launch, as motor ignitors and forward seal disks can be sold seperately.
- Attach aft rail button prior to secruing flushed aft centering ring.

- Do not neglect the length of the forward threading protusion when measuring the space for the motor mount.
- Bring enough food and water for launch days.

XII. Summary of Overall Experience

Prior to the team's trip to Huntsville, Alabama, the team was confident about the functionality of the constructed launch vehicle, payload, and subsystems. We have learned the importance of creating and conducting test plans to remove doubts and enhance data accuracy and durability of the project. The feedback provided during presentations was helpful and helped us to see why we were doing not just what.

Launch week was exciting. The team felt pleasure gathering with people from diverse backgrounds that carry the same passion in the field of engineering. We were inspired by participating teams during the Rocket Fair and their innovative thinking; their approaches to problem solving are ones to consider for future projects.

The NASA University Student Launch Initiative, NASA USLI, has been a unique project for the members in the Citrus College Rocket Owls. The project has provided insight of what it takes to work in tandem with team mates to complete an engineering project. Each member has improved their skills in technical writing, data analysis, formal presentation, problem-solving, team work, and budget planning. Through eight months of dedication, the team members have increased their curiosity and fascination towards rocketry and STEM careers. We have learned to appreciate the principle of learning-by-doing as well as research and analysis of results to improve and finalize designs. The team members displayed perseverance throughout the project and could balance school work with NASA SL successfully. The NASA USLI has been a truly rewarding experience that has challenged us to discover our limitless potential.

XIII. Educational Engagement Summary

This section summarizes the different outreaches conducted by the team, their span, and overall outcome. The Rocket Owls have conducted outreaches since the start of the Nasa Student Launch Project and have reached many children teaching them about physics and showing them that STEM topics are interesting and understandable.

Junior Rocket Owls (JRO)

This project spanned a total of nine months and begun with 28 5th grade students. Twenty five of these children went on to complete the project and will be presenting their work May 13, 2017 at a Citrus College hosted Symposium. Over the course of the project the students learned about basic physics and rocketry principles. They constructed and launched two model rockets, a small Estes Alpha model and a Loadstar model. The Loadstar model, held a scientific payload with a student designed experiment. This rocket was launched with the purpose of obtaining results for their experiments and determining whether or not their hypothesis was correct. Altimeters were utilized during flight to determine the apogee of their launch vehicles. Each student wrote and designed a research poster including their predicted and actual apogee for their rockets, the results of their experiment and flight. The students really displayed an eagerness to learn and a developed an understanding of physics and rocketry. The Junior Rocket Owls learned many different aspects of rocket building, physics, and team work. They showed excitement for the lessons taught to them and enjoyed spending time with each other and the Rocket Owls. Many of them developed a friendship with the Rocket Owls giving them drawings, crocheted gifts, or paper crafts. The team served as role models to these young children and hopefully inspired a lifelong interest of an enjoyment in STEM related topics.

It's Rocket Math

This outreach was conducted over the course of four months and included six 7th grade children. It covered topics ranging from the physics of motion to rocketry and had an emphasis on the mathematical aspect of rocketry. These children succesfully built and launched their own Loadstar model rocket which contained payloads designed to answer a scientific question. With the assitance of the Rocket Owls they also wrote and designed scientific posters and will be presenting their findings at the Symposium on May 13 along with the JRO. These children were intially more shy and quite than the Junior Rocket Owls but they became more comfortable and outspoken with each session. They showed enthusiasm and understanding for each lesson and exhibited an eagerness to learn new concepts.

Rocketry Classes

The Rocketry classes are Glendora Unified School District GATE workshops taught at Sellers Elementary by two of the Rocket Owls. These classes consisted of two three class sessions with a total of 40 children registered. During the first session the participants launched air rockets and learned basic physics related to rocketry and in the second session they will be constructing and launching Estes Alpha model rockets. The children range from 3rd-5th grade and are eager to learn about rockets, motors, parachute designs, and physics.

Additional Outreaches

In addition to *Its Rocket Math!* and the Junior Rocket Owls Program the Rocket Owls also conducted single day outreaches. One such outreach was at the Azusa Career Fair. The Rocket Owls set up a table displaying a large rocket and discussed physics and rocketry with middle school students. The team explained the Nasa Student Launch project and answered any questions the students had, encouraging them to pursue their interest in STEM related fields. Another additional outreach was the Science and Technology Day outreach. For this event the Rocket Owls taught young children about kinetic and potential energy as well as velocity, acceleration, and solar power.The participants built solar powered cars and raced them outside as a way to illustrate these concepts.

XIV. Budget Summary

This section overviews the budget of the project including expenses in the following: full-scale and sub-scale launch vehicle construction, payload, food and travel. The total price includes the shipping, taxes, and cost per item purchased.

Table 1 lists all expenses of the project and the calculated total.

Table 1: Project Expenses				
Item	**Quantity**	**Unit price**	**Total price**	**Vendor**
Full-scale Construction Expenses				
6" diameter blue tube	4	$66.95	$396.17	Apogee Rockets
6" diameter coupler tubes	1	$19.95	$21.75	Apogee Rockets

6” Ogive 4:1 nose cone	1	$129.00	$141.90	Mad Cow Rocketry
1” Tubular webbing	40	$0.45	$25.61	REI
18” Nomex blanket	2	$10.49	$26.07	Apogee Rockets
24” Nomex blanket	2	$13.99	$33.83	Apogee Rockets
24” Drogue Parachute	1	$68.36	$74.51	Fruity Chutes
120” Main Parachute	1	$414.92	$452.26	Fruity Chutes
U-bolt	3	$1.56	$5.10	Home Depot
Elastic cord	5	$1.19	$6.50	99 Cent Mart
RRC2+ Altimeter	4	$44.95	$186.80	Missile Works
Terminal blocks	1	$9.05	$15.08	Apogee Rockets
22-gauge stranded wire pack	1	$19.95	$29.19	Home Depot
Heat shrink tubing	1	$10.99	$17.02	Amazon
9V Duracell battery	2	$3.20	$6.97	Amazon
Key switch	4	$4.62	$25.75	Amazon
6” E-bay	1	$71.95	$89.06	Apogee Rockets
¼” Aircraft plywood	1	$112.75	$122.90	Aircraft Spruce
½” Baltic birch plywood	1	$112.75	$122.90	Home Depot
1515 Rail button	2	$4.65	$9.98	Apogee Rockets
Shear pins	5	$3.10	$20.38	Apogee Rockets
Machine screws (1 pack)	3	$1.98	$6.00	Home Depot
Mega foam	1 qrt.	$39.48	$43.03	Giant Leap Rocketry
Rocket epoxy (pt)	2	$38.25	$100.14	Apogee Rockets
Fiberglass cloth 3 oz. satin weave	3 yrds	$9.96	$42.51	Sher-Fab Unlimited
Fiberglass resin	1	$42.99	$58.81	Sher-Fab Unlimited
Fiberglass hardener	1	$21.99	$34.78	Sher-Fab Unlimited
Motor retainer	1	$53.50	$63.79	Apogee Rockets
L1420 Motor	1	$540.91	$654.99	MotoJoe
Engine casing	1	$235.40	$248.27	Apogee
Forward closure	1	$101.65	$110.80	Apogee
Aft closure	1	$80.25	$87.47	Apogee
Forward sealing disk	1	$32.00	$49.88	Apogee
Shipping expenses	1	$157.49	$157.49	FedEx
Rocket stand	1	$37.41	$37.41	Home Depot
Spray paint	4	$9.22	$36.89	Home Depot
Construction Expenses Total:	$3561.99			
Sub-scale Construction Expenses				
4” diameter blue tube	2	$38.95	$104.79	Apogee Rockets
98 mm E-bay	1	$42.95	$51.78	Apogee Rockets

4" Ogive 4:1 nose cone	1	$65.00	$73.95	Apogee Rockets
Tube coupler	1	$10.95	$19.30	Apogee Rockets
Motor	1	$159.99	$221.43	Bay Area Rocketry
Sub-scale Construction Expenses Total:	$471.25			
Payload Expenses				
Polycarbonate tubing	1	$215.25	$246.62	Eplastics
Silicone sheet	4	$156.55	$178.65	Amazon
Zinc threaded rails	3	$5.11	$16.71	Home Depot
Epoxy plastic bonder	2	$4.26	$9.28	Amazon
Polycarbonate tubing	2	$75.00	$43.14	Eplastics
Payload Expenses Total:	$494.40			
Tools and Safety Expenses				
Miter saw	1	$215.49	$234.88	Home Depot
Jigsaw	1	$59.01	$64.32	Home Depot
Blades	2	$8.97	$19.55	Home Depot
Palm sander	2	$29.99	$80.62	Home Depot
Nitrile gloves	4	$8.16	$36.91	Amazon
Respirators	20	$2.10	$45.71	Home Depot
Sand paper 80 grit	1	$15.38	$22.75	Home Depot
Sandpaper 5" 120 grit	1	$14.40	$21.69	Home Depot
Synthetic grease	1	$5.89	$12.95	
Tools and Safety Expenses Total:	$539.38			
Food and Travel Expenses				
Airfare	5	$570.60	$2,853.00	American Airlines
Luggage	2	$100.00	$200.00	American Airlines
Hotel expenses	2	$519.15	$1,038.30	Embassy Suites
Food expenses	5	$100.00	$500.00	-
Launch day supplies	-	-	$54.13	Walmart
Food and Travel Expenses Total:	$4,635.43			
Grand Total:	$9699.58			

Figure 10: Rocket Owls' Budget

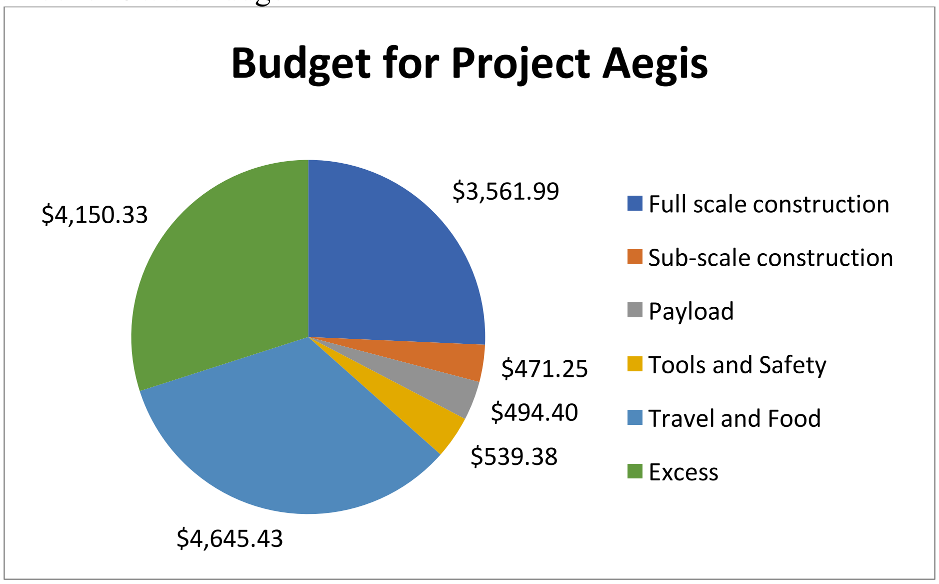

Figure 10 displays the money expenditure throughout Project Aegis. The pie chart demonstartes that the majority of the money was spent on travel and food, second on the construction of the full-scale, and thirdly on the construction of the payload. The remaining funds are also shown above.

The majority of the budget went to travel and food expenses, $4,645.43, which is 34% of the total budget. Five tickets were purchased from American Airlines for a total of $2,853.00 and two hotel rooms were booked for five nights for a total of $1,038.30. Support from donors and sponsors made it possible for the team to participate in this project. The team received a total of $13,850 from grants, foundations money, and private donations. Donations from friends and family members also helped fund the team, allowing for a food budget of $500. The total expense for the project was $9,699.58, which includes expenses for construction of a full-scale and sub-scale launch vehicle, payload, tools and safety equipment, travel expenses, and food expenses. The total is well within this $13,850 budget, leaving $4,150.33 excess funds. The remaining funds will go to next year's Citrus College Rocket Owls team who are already beginning to prepare for the upcoming project