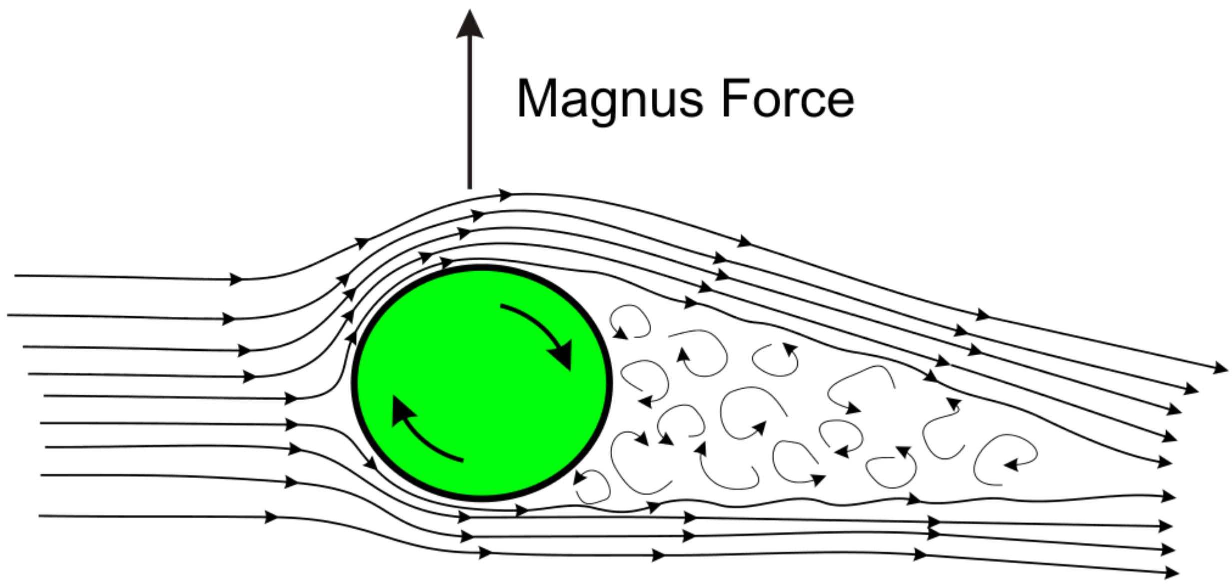
Request for Proposal (RFP)

Unmanned Aerial Vehicle with Experimental Magnus Force Lift



Mailing Address:

15 Wyoming
Irvine, CA 92606

AIAA OC Section
9/20/17

Albert (team leader)
Allison; Annabel; Brenda; Kushagra; Sahil

Table of Contents

1 General Information

The American Institute of Aeronautics and Astronautics is the professional society for the field of Aerospace Engineering. Our Student Launch (SL) team is sponsored by the Orange County section in
California. The board meets on the first Tuesday of every month. In their educational outreach, they provide professional guidance and assistance to youth who wish to pursue projects related to aerospace. The organization of the board of the Orange County section is as follows: Chair Kimberly Castro, Chair Elect Jeff Norton, Treasurer Philip Ridout, Secretary Ronald Freeman, Technical Dino Roman; Honors & Awards Bob Davey, Programs Scott Roland, Membership Bob Welge, Young Professionals Lee Cheng, Communications Enrique Castro, At Large Justin Joseph, At Large John Rose, At Large Toby Holtz, Public Policy Kemal Shweyk, Education Jann Koepke (Mentor to SL), TARC and SLI Bob Koepke (Mentor to SLI), Past Chair James Martin.

Since we are attached to the American Institute of Aeronautics and Astronautics, we can reach out to the hundreds of aerospace professionals in Southern California for help in designing airplanes, rockets, and construction with composite materials.

1.1 AIAA OC Section, Project Information

AIAA OC Section is the official name of this SL team. It will launch a payload that uses the Magnus Effect to generate lift and descend safely to a specific location using GPS.

1.2 Adult Educators

1.2.1 Robert Koepke (Electrical Engineer, Programmer, Level 2 NAR)

Robert has been co-leading TARC teams for eight years and 4H rocketry projects for 13 years. He has a BS degree in Electrical Engineering from USC and has worked as an electronics designer, programmer, and now a director of the software department doing embedded programming for thermal printers. Robert worked on the F-20 Tigershark while at Northrop. Robert launched his first rockets shortly after Sputnik in 1957 and has continued in rocketry with his own children and grandchildren, Indian Princesses and Indian Guides, and 4H.

Robert can be contacted via rkoepke@socal.rr.com. His phone number is (714)-504-3591.

1.2.2 Jann Koepke (Artist, Mom, Level 2 NAR)

Jann has been co-leading TARC teams for eight years and 4-H rocketry projects for 11 years. She has a bachelor’s degree in Fine Arts from Cal State University Los Angeles in 1979. She has worked in electronic business as an assembler and in the accounting office. Now she is retired. She has been doing Rocketry for 25 years with her husband children and grandchildren. Jann is the AIAA OC Section Council member in charge of education. She has been in 4-H for 11 years and has been doing rocketry in 4-H for 11 years. She has also led 4-H projects in livestock including lambs, goats, and beef.

Jann can be contacted at jkoepke@socal.rr.com. Her phone number is (714)-504-3591.

1.3 Range Safety Officer

Sahil is identified as the Student Range Safety Officer.

1.4 Student Team Leader (Albert)

Albert is the student team leader. He can be contacted at verticalprojectile.rocket@gmail.com.

1.5 Student Participants in Project

There will be a total of four students committed to the project for the entirety of the Student Launch 2018 project cycle.

Name	Duties
Albert (Student Team Leader)	• Maintain regular meetings • Ensure deliverables are submitted on time • Organize project timeline • Full Scale Vehicle Design • Payload and Launch Vehicle Management • Kinetic Energy Calculations
Brenda	• Budget Maintenance • Outreach Management • Subscale Vehicle Design • Radio Frequency • Funding Management • Payload Coding • Black Powder Calculations
Kushagra	• Recovery and Avionics • Avionics Testing

	• GPS Management • Payload Coding • Kinetic Energy Calculations

Sahil	• Student Range Safety Officer
	    ○ Ensure safety overall
	    ○ Ensure all tests performed
	• Air Brakes Maintenance
	• Payload Coding

1.6 NAR/TRA Section Collaboration

The AIAA OC Section rocketry is NAR Section #718. Launches will be held at Lucerne Dry Lake in the Mojave Desert near Lucerne Valley, California. NAR section #538, the Rocketry Organization of California (ROC) holds launches on the weekends around the second Saturday of each month. Mentors Robert and Jann Koepke have been members of ROC for several years and team members have attended many ROC launches over the past 5 years. Many ROC members hold level 1 – 3 certifications and have always provided mentoring and review assistance to anyone asking. ROC currently has an FAA waiver allowing flights to 7,000' AGL, with call-in windows available to 19,000' AGL (http://www.rocstock.org) at their monthly launches.

2 Facilities/Equipment

2.1. Description of facilities

The two facilities we had for building our rockets and do research was at the Koepke's home and IvyMax , where we have also built all of our TARC rockets. IvyMax provided classrooms and whiteboards for us to plan our designs and efficiently make our rockets. Using the prize money from TARC Nationals, our team has bought a toolbox along with all the necessary equipment for building our rocket. The list of equipment is shown below.

- Tape measure
- Smart weigh scale
- Superior Mini Digital Platform Scale
- Drill
- Band Saw
- Angled Ruler
- Epoxy Bag
- Drill Bit Box
- Adjustable Crescent Wrench
- Curvy Spring Pliers
- Assorted Screws Box
- Screwdriver
- Hobby Knife
- Monkey Wrench
- Scissors
- Pliers
- Electrical Hinge Tape
- Hack Saw
- Blue Masking Tape
- Epoxy Clay
- Washers
- Benchtop Sanders and Grinders
- Table Saw
- Vacuum pump
- Vacuum Bagging Supplies

2.2. Necessary personnel

Our mentors Bob and Jann Koepke are also present at IvyMax and the Koepke's workshop to offer advice and answer any of the team members' questions.

2.3. Computer equipment

2.3.1. Hardware

- Two PC laptops to take to launches to check design and calculations and to record flight data
- Each team member has at least one laptop computer.
- Webcam and speakers as required for the WebEx sessions

2.3.2. Software

2.3.2.1. Microsoft Office

A suite of applications that we will use to write proposals as well as the design reviews. The suite includes Word, a word processor used to create written documents, PowerPoint used to create presentations, and Excel used to track budgets and schedules/timelines.

2.3.2.2. Adobe Acrobat

A program used to create .pdf files which is a universal method to distribute documents since a .pdf reader is free and on most PCs.

2.3.2.3. Adobe Photoshop

A program used to manipulate and edit photographs and drawings

2.3.2.4. RockSim 9

A CAD program used to help design the rocket. This program also calculates the center of pressure and center of gravity to determine the stability of the vehicle. It allows flight simulation for tracking the stability and safety of the rocket.

2.3.3 Web Presence

The Vertical Projectile website at http://verticalprojectile.org has a tab under “NASA SL” where we have our proposals under “DOCUMENTS” and our personal information under “TEAM BIO”.

2.3.4. WebEx Facilities

We will use the Honeywell Executive Conference Room in Irvine. Several of the mentors work at this location. Conferences and WebEx’s are held frequently there and it is permanently equipped with:

- PC computer
- 80 inch large screen TV

- 2 T1 lines connected to the Internet
- Audio system with speakers
- Conference phone

We provide a Logitech C910 webcam. In case of problems, all mentors from Honeywell are familiar with the WebEx and network.

2.4. Implementation of the Architectural and Transportation Barriers Compliance Board for Electronic and Information Technology

The Rehabilitation Act of 1973 prohibits the discrimination of the disabled in programs run by federal agencies. Any person with disabilities have the same access to the information as anyone without disabilities when Federal Agencies use electronic and information technology. Therefore, teams part of SL fall under the same restrictions as the Federal Agency, as these teams participate in a NASA project, which is a Federal Agency program. This applies to three subparts:

- 1194.21 Software applications and operating systems: No delivery of software applications or operating systems.
- 1194.22 Web-based intranet and internet information and applications: Documents posted on the Internet are accessible to everyone, with or without disabilities. Any documents developed in Microsoft Office have built in features that allows for speech recognition, keyboard shortcuts, and customization of layout and toolbars. Any documents posted through Adobe Acrobat permits the customization of colors, contrast, layout, and other keyboard options.
- 1194.26 Desktop and portable computers: Although no teams in the AIAA OC Section currently have disabled members, all tools and PCs are designed in a way that allow for easy access for the disabled.

3 Safety

3.1 Safety Plan

The SL team has developed a series of risk mitigation plans to reduce the risk of this project.

3.1.1 Material Safety

Appendix E includes Material Safety Data Sheets for fiberglass, 4F Black Powder, and APCP.

Handling, risks and mitigations, and protective equipment are listed under section 3.2.2.

3.1.2 Facility Safety

In an emergency, dial 911
California Poison Control Center: 1-800-222-1222

While completing the launch vehicle, team members will frequently come into contact with hazardous materials. These substances will not be dangerous to the team members as long as these rules are followed when handling. Concerning materials include adhesives, paints, and the actual materials used to build the vehicle. The manufacturer of those materials knows best about the posed hazards. Each manufacturer and safety organizations publish MSDS for each product.

Handling these materials will require the use of Personal Protective Equipment (PPE).

An MSDS (Material Safety Data Sheet) is available to provide an overview explaining how to work safely with and handle specific chemicals or materials. It is compiled by the manufacturer of the particular chemical. Although MSDS do not have a particular format, they are required to have certain information per OSHA (Occupational Safety and Health Administration) 29 CFR 1910.1200. A list of the required information can be found here on this website;

<http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10099>.

We will also use this as a reference for facility safety:

<u>AIAA OC Section Shop Safety Rules</u>
<u>For all rocketry activities (Youth – TARC – modified for SLI)</u>

In an emergency, dial 911
California Poison Control Center: 1-800-222-1222

There is always a risk when someone is handling shop tools or is near another who is handling shop tools. Great precaution measures should always be taken. The following are the AIAA Orange County Section shop rules:

Generally:

- Keep work area orderly and clean; neatly arrange all equipment and material. Put all tools and materials back where they belong.
- Always think through an entire task before starting it, and never rush a process or take chances.
- If you are unsure about safety operation or process, ask for assistance from a program manager or mentor.
- At all times when using chemicals, X-Acto knives, electrical tools, or any tool that creates a danger of fumes or particles entering your eyes, wear safety glasses.
- Flammable liquids such as paints, solvents, and thinners must be stored in their original containers or in approved safety cans with flame arresters.
- If there are any unsafe conditions, report them to a program manager or mentor right away. Rely on the best of your own judgment and knowledge of safety to guide you.
- When lifting a heavy object, lift with your legs and not with your back; keep your back straight.
- Do not use an air hose for cleaning or dusting yourself off. Never point it towards anyone.
- If you have long hair, you must tie it back or keep it from falling down so it won't be caught in rotating tools.
- Horseplay of any kind is not allowed.
- Heavy glues and household chemicals should only be used in well ventilated areas; heavy sanding, painting, and use of chemicals are to be done outdoors.
- For documents that require work with potentially hazardous tools or operations, specific sections will be marked with the following: HAZARDOUS OPERATION – SEE SAFETY PLAN

Electrical Tools

- Do not work with power tools unless there is at least one other person in proximity.
- Before operating any machine or equipment, make sure that all safety guards are in place. The guards must be replaced as soon as repairs or servicing on a machine has been completed and put into operation.
- Never oil, remove guards, or attempt to repair machinery while it is on or in motion.
- Never use a rag near moving machinery.
- It is prohibited to tie down, block out, or otherwise make inoperative of any type of safety device, attachment method, or guard.
- Before energizing or operating any equipment, be sure to verify the safety of all personnel.
- When a machine is de-energizing for the purpose of changing the setup or making a minor adjustment, turn off the machine and pull the plug. Allow the machine to come to a complete stop before proceeding with your task.
- Do not handle electrical equipment while standing on damp or wet surfaces or when your hands are wet.

- Wear suitable clothing for the work that you are doing. Loose clothing, neckties, rings, watches, and even gloves can create a hazard when operating tools. Long sleeves or non-synthetic clothes should be worn when sparks or hot metal is present.

3.1.3 Range Safety Officer Duties

Sahil is identified as the Student Range Safety Officer. His duties are as follows, according to the Student Launch Handbook:

"The roles and responsibilities of each safety officer will include, but not limited to:

- Monitor team activities with an emphasis on Safety during:
- Design and vehicle payload
- Construction of vehicle and payload
- Assembly of vehicle and payload
- Ground-testing of vehicle and payload
- Sub-scale launch test(s)
- Full-scale launch test(s)
- Launch day
- Recovery activities
- Educational Engagement Activities
- Implement procedures developed by the team for construction, assembly, launch, and recovery activities
- Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures"

3.1.4 Risk Assessment and Mitigations

The following tables have been made to address potential catastrophes. All risks in the red columns are considerably dangerous, while risks in the green columns are not necessarily dangerous but warrant steady caution.

3.1.4.1 Vehicle Risk Mitigation

1. **Risk** - The engine does not ignite while conducting the launch of the rocket. **Mitigation** - Prior to launch, multiple team members will check to make sure the igniter is	4. **Risk** - The rocket body caves in, or collapses on itself. **Mitigation** - The team will use fiberglass for the body tube, a material capable of withstanding outside forces. Inside, flight boards, bulkheads, and centering	7. **Risk** - The electronic matches fall out of their designated place. **Mitigation** - Before placing the shear pins, the matches will be checked to ensure that they have been tightened down to remain in place. This

properly inserted in the engine to its full length, ensuring ignition of the motor.	rings will help to maintain the circular frame of the body tube.	task will be placed on a checklist that members will go through while preparing the rocket for launch.
2. **Risk** - The engine does not fit (too loose or tight) in the motor casing. **Mitigation** - The team will make sure the engine is inserted in the proper motor casing, and cannot be shaken or pulled out with ease. The team will also check when the motor casing is inserted into the motor mount.	5. **Risk** - The quick links are not attached properly. **Mitigation** - The team will double check all connections to ensure that the rocket is assembled completely before preparing the rocket for launch. These tasks will be written on a checklist, which members who checked the task will sign off to take responsibility.	8. **Risk**: Motor explodes **Mitigation**: Detailed instructions will be followed step by step when building the motor. Team members will be required to maintain focus and detail while putting together the motor. We will make sure the igniter is inserted without folding in on itself to prevent it from catching on its way out of the nozzle after ignition.
3. **Risk**: Airbrakes do not function while in flight. **Mitigation**: When electronics, are activated at ground level, a test for airbrake function will be performed. The airbrake motors will checked prior to assembling the whole rocket.	6. **Risk** - The shear pins do not shear due the ejection charge. **Mitigation** - When purchasing the pins, the team will note the force required to shear them. The team will perform black powder ground tests to make sure the ejection charges exert more force than the pins can withstand. To ensure shearing, the backup charge will have a greater amount of black powder.	9. **Risk** - Parachute was not packed correctly and does not deploy **Mitigation**: The team will check to make sure the parachuted is fitted correctly into the body of the rocket prior to launch. However, if the primary ejection charge does not separate the rocket, backup ejection charges with greater amounts of black powder will allow the parachute to deploy.

3.1.4.2 Payload Risks and Mitigations

1. **Risk**: The automation of the payload stops working **Mitigation**: Switch to RC	4. **Risk**: RC is still not safe in presence of crowd **Mitigation**: Deploy emergency parachute	7. **Risk**: Payload fails to have controlled descent. **Mitigation**: Immediately deploy parachute with autonomous sensor
2. **Risk**: Batteries are not fully charged **Mitigation**: Charge the batteries to max before the flight.	5. **Risk**: Steering rotor fails, resulting in loss of control of payload. **Mitigation**: Deploy parachute remotely	8. **Risk**: Payload ejects above 400 ft, which is illegal for RC aircraft **Mitigation**: Immediately deploy parachute, turn off auto and RC controls.
3. **Risk**: Payload does not eject **Mitigation**: Check if the supply wire is securely attached from the 5 volt pin of the teensy to the Sensor.	6. **Risk**: Batteries fail **Mitigation**: Use Voltmeter to check if the battery is fully charged before the flight.	9. **Risk**: Power fails entirely despite charging; power disconnect mid-flight **Mitigation**: Keep an independent power source and receiver for emergency parachute deployment for redundancy

3.1.4.3 Recovery Risks and Mitigations

1. **Risk**: Backup ejection charges do not ignite. **Mitigation**: Check to make sure the RRC3 is beeping in the specific sequence as denoted in the manual.	4. **Risk**: Drogue chute flies at wrong altitude **Mitigation**: Double check that the Stratologger and RRC3 both are beeping in their specific sequences.	7. **Risk**: Main chute doesn't deploy **Mitigation**: Backup Flight Computer and ejection charges should take care of this.
2. **Risk**: The Batteries of Backup Electronics Fall out **Mitigation**: Use battery holders and zip ties to ensure that the batteries do not fall out, and double check the sturdiness of these before every launch.	5. **Risk**: Airbrakes fail to close, interfering with recovery **Mitigation**: Double check that the LED light is blinking on the Arduino. Also, make sure the most recent code is uploaded in the Arduino.	8. **Risk**: Stratologger CF Flight Computer is not turned on **Mitigation**: The team will have three members check the Stratologger to see if it is beeping in its specific sequence, and they will affirm

		its status by signing their name in the checklist.
3. **Risk**: The Backup RRC3 Flight Computer is not turned on **Mitigation**: The team will have three members check the Flight Computer to see if it's beeping and affirm its status by signing their name in the checklist.	6. **Risk**: Drogue doesn't deploy **Mitigation**: Double check that the electronics are turned on and beeping, and have three people sign the checklist to affirm. Also, back up ejection charges will take care of this.	9. **Risk**: Main batteries fail **Mitigation**: Use fresh batteries and make sure the electronics will power up first in a test second before flight.

3.1.5 Risks to Project Completion

1. **Risk**: A team member is out sick or busy handling something else **Mitigation**: Keep calm, divide duties accordingly.	2. **Risk**: A launch severely damages a launch vehicle prior to PDR, CDR, or FRR submission. **Mitigation**: Follow all safety checklists, with a special emphasis on recovery and motor loading	3. **Risk**: Deliverables are not delivered on time **Mitigation**: Strictly follow a well-thought-out timeline and create documents accordingly.

3.2 Procedures for NAR/TRA Personnel

3.2.1 Compliance with NAR High Power Safety Code Requirements

A brief summary of the NAR safety rules is listed below; these rules are the ones that apply to SLI and SLI only. The actual NAR rules can be found here. The actual TRA rules can be found here.

Rule	AIAA SL Team Compliance

NAR: Person(s) will posses and fly only high power motors in their range of certification and required licensing TRA: The person who is a certified flyer shall operate and fly a high power rocket.	Only the team mentor with a minimum of Level 2 certification will purchase, possess, and load the high power motors (K).
NAR: Materials that are lightweight such as; paper, wood, rubber, plastic, and fiberglass will be used to construct the rocket. Only when required will ductile metal be used for the construction of the rocket. TRA: The high power rocket vehicle is intended to be propelled by one or more high power solid propellant rocket motor(s) shall be constructed using lightweight materials such as paper, wood, plastic, fiberglass, or when necessary ductile metal.	The vehicle will be made primarily of fiberglass, with some wood, paper, and plastic as required in the payload and recovery areas. Metals will be those commonly used in payload and recovery sections, and not present on on the exterior of the rocket.
NAR: The rocket motors that will be used will be certified and commercially made. They will not be tampered with or be used for anything except what is recommended by the manufacture. No smoking, open flame, or any heat source will be allowed within twenty five feet of these motors. TRA: The motors that are used will be certified commercially made rocket motors. They will not be dismantled, reloaded, or altered disposable or expendable high power rocket motors. Only use the rocket motor for only the purpose stated by the manufacturer.	A rocket motor manufactured by Aerotech has been chosen for use; Aerotech is a company that produces motors for recreational rocketry use. The motor will be K560. Team members will prevent unauthorized people to reach the loading area, restricting the ignition of an open flame. Team members will be looking for the possibility of an open flame or smoke at all times.
NAR: Rockets will be launched with an electrical launch system and with electrical motor igniters than will be installed in the motor after the rocket is at the launch pad or in the designated prepping area. The launch system that is used will have a safety interlock that works with the launch switch that is not installed until the rocket is ready for launch and the launch switch will return to the off position after the launch. If the rocket contains an onboard ignition systems for the motors or recovery devices,they will have safety	In the design process of the rocket, a locking mechanism that keeps all power off in the electronics will be included. This ensures a fail-safe for the rocket and keeps it inactive until the rocket is secured and ready on the loading area.

interlocks that will interrupt the current path until the rocket reaches the launch pad. TRA: The ignition system that is used is remotely controlled, electrically operated, and contains a launching switch that will return to "off" when released. The ignition system must contain a removable safety interlock device in series with the launch switch. The launch system and igniter combination must be designed, installed and operated so the liftoff of the rocket must occur within three seconds of actuation of the launch system. Ignition device must be installed in a high power rocket motor only at the launch site and at the last practical moment before the rocket is placed on the launcher.	
NAR: If the rocket doesn't launch after the button on the electrical launch system has been pressed, the launcher's safety interlock will be removed or the battery will be disconnected. Sixty seconds will be waited before anyone will be allowed to approach the rocket. TRA: You can launch the high power rocket if you have the immediate knowledge, permission and attention of the safety monitor. Everyone should be standing and facing the launcher during a countdown and launch. The countdown should be audible by everyone. Don't approach the high power rocket that has had a misfire until the safety interlock has been removed or the batter has been disconnected from the ignition system, one minute had passed and the safety monitor has given permission for a single person to approach the misfired rocket to inspect it.	While the rocket is on the launch pad, team members will be sure to get the public's attention and not beginning the launch sequence without it. Team members will make sure the range and sky is clear before proceeding with the countdown. With every misfire, team members will wait at least a minute before approaching the rocket. The rocket will first be deactivated, and the problem will be inspected.
NAR: Before a rocket is launched, there will be a five second countdown. No one will be any closer to the launch pad than allowed by the minimum distance table. In case of a problem, a means of communication will be	Once the rocket is secured on the launch pad, the Range Safety Officer will go through his checklist to make sure the rocket and its surroundings are ready for its flight. This includes warning the spectators and making

there to warn participants and spectators. Before the rocket is launched, it will not fly if stability cannot be determined. TRA: The person who fly's a high power rocket must first have it inspected and approved for flight by Safety Monitor for compliance with the applicable provisions of this code.	sure the rocket fits under the safe conditions described by these rules, which the Range Safety Officer will be aware of.
NAR: The rocket will be launched from stable device that provides rigid guidance until the rocket reaches the speed that guarantees a stable flight and is pointed within twenty degrees of vertical position. If wind exceeds five miles per hour, the launcher will be adjusted to the length that permits the rocket to attain a safe speed before leaving the launcher. A blast deflector will be in place to prevent the motors exhaust from hitting the ground. No dry grass will be around the launch pad, the minimum distance table will be referred to when determining this, and will increase the distance by a factor of one point five if the rocket motor being launched uses titanium sponge in the propellant. TRA: The high power rocket should be launched from a stable device that provides rigid guidance until the rocket has reached adequate speed to ensure a safe flight path. A jet deflector should be in place to prevent rocket motor exhaust from impinging directly on flammable materials. The launch pad should be at an angle less than twenty degrees off vertical. Make sure the end of the launch rail or rod is capped to prevent eye injury.	Stability of the launch pad will be guaranteed, as we are using a launch rail, which is more stable than a launch rod. This launch rail is established on a tripod-like metal base. In windy conditions, the Range Safety Officer will make sure what length the rail needs to be adjusted to. Team members might possibly tilt the rail in certain windy conditions a certain number of degrees to launch as straight as possible, but this tilt will be kept well below the max of 20 degrees. At our launch site, Lucerne Dry Lake, the lake bed has no burnable materials in its vicinity, so there is no chance of burning an item like dry grass.
NAR: The rocket will not contain a combination of motors that totals more than 40,960 N-sec of total impulse. The rocket will not weigh more at liftoff than one-third of the	The rocket will contain a K motor that has the maximum force of 2,560 N-sec of thrust and has the mass of 1,408.1 grams. Inside the rocket, black powder charges are placed

certified average thrust of the high power motors intended to be ignited at launch. TRA: Make sure the rocket weighs less than the rocket motor manufacturer's recommended maximum liftoff weight for the rocket motor(s) used for the flight. During the preflight inspection the safety monitory may or may not request documentary proof of compliance. Do not install a rocket motor or combination of rocket motors that will exceed 40,960 N-Seconds of total impulse.	inside the rocket for separation, and are well below the total impulse limit. The rocket is approximated to weigh 21.7 lbs and will be less than one-third of the average thrust of the K motor.
NAR: The rocket will not be launched at targets, clouds, near airplanes, or on trajectories over the heads of spectators or beyond boundaries of the launch site. The rocket will not have a flammable or explosive payload. The rocket will not be launched if the wind speeds exceed over twenty miles per hour. The people launching the rocket will comply with Federal Aviation Administration airspace regulations when flying and will ensure the rocket does not exceed any applicable altitude limited in effect at the launch site. TRA: The person(s) flying the rocket must comply with the "Airspace Control and Facilities", Federal Activation Act of 1958 and other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances TRA: Do not launch the high power rocket at a target, clouds or beyond the boundaries of the launch site. Do not launch a high power rocket if the wind exceeds twenty miles per hour. Do not launch the high power rocket if there is an aircraft in the window.	The rocket will not be tilted more than twenty degrees. Prior to launching, the team members will make sure the range and sky is clear to avoid airplanes or any other objects. Wind speed is noted every launch preparation, and if the speed is above twenty miles per hour, the team will not launch until conditions subside. ROC Association has obtained all permissions with state laws to launch at Lucerne Dry Lake.
NAR: The rocket will be launched outdoors, in an open area where trees, power lines, buildings, and people not involved in the	Lucerne Dry Lake is the designated launch site and is located in the Mojave Desert in Southern California. As a dry lake bed, there

launch do not present as a hazard. The area is at least as large as the smallest dimensions as one-half of the maximum altitude to which rockets are allowed to be flown at the site or 1500 feet, whichever is greater. TRA: The launch sight of high power rocketry should only be outdoor area, power lines, and building will not present a hazard to the safe flight operation of a high power rocket in the opinion of the safety monitor. Do not locate a launcher closer to the edge of the launch site than one-half the radius of the minimum launch site dimension. The launch site must be at least as large as the stated in the launch site dimension table.	is no structure within miles of the radius of the lakebed, such as trees, power lines, or buildings.
NAR: The launcher will be 1500 feet away from an inhabited building or from any public highway on which traffic flow exceed ten vehicles per hour, not including traffic flow related to the launch. It also won't be closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site. TRA: The launcher location must be more than 1,500 feet from any occupied building. Make sure that the ground for a radius of ten feet around the launcher is clear of brown grass, dry weeds, or other flammable substances. TRA: No person(s) can be closer to the launch pad of a high power rocket than the person actually launching the rocket and those with the title of safety monitor. All spectators must remain within the area determined by the safety monitor and behind the safety monitor and the person who Is launching the rocket.	The team members will make sure prior to launch that spectators are in the designated area and away a certain distance from the launch area. Occupied buildings are more than two miles away and the dry lake bed is clear of any flammable substances. The team members will make sure no one else is within the radius of the members and the rocket prior to launching.
NAR: The recovery system in the rocket will return all parts of the rocket safely and undamaged and can be flown again. The rocket will use only a flame-resistant or fireproof recovery system wadding in the rocket.	A drogue parachute and normal parachutes will safely bring down the rocket in multiple sections that will be tethered together.

TRA: The rocket must contain a recovery system that will return all parts of the rocket safely to the ground, and so the rocket may be flown again. Flame resistant recovery wadding should be installed if wadding is required by the design for the rocket.	Inside the rocket, blast cloth will shield the parachutes from heat or damage by the motor or ejection charges.
NAR: The people recovering the rocket will not attempt to recover the rocket from any power lines, tall trees, or other dangerous places. Therefore it will be flown under conditions where it is likely to recover in spectator areas or outside the launch site; no person(s) will attempt to catch the rocket as it approaches the ground. TRA: No person(s) should attempt to catch a high power rocket as it approaches the ground. No person(s) should retrieve a high power rocket from a place that is hazardous to people.	If the rocket happens to get stuck in a dangerous place, the team will not attempt to recover the device on their own, despite there being no trees or power lines within miles of the Lucerne Dry Lake launch site. All members are aware of the rule of not recovering the rocket in bad situations or catching the rocket prior to landing.
TRA: The high power rocket should be constructed to withstand the operating stresses and retain structural integrity under conditions expected or known to be encountered during the flight.	Fiberglass tubes will maintain the rigidity of the rocket during its flight. Flight boards that slide into the rocket will also maintain the circular structure of the tubing.
TRA: The person intending to operate the high power rocket will determine its stability before flight, providing documentation of the location of the center of pressure and center of gravity of the high power rocket to the safety monitor, if requested.	While designing the rocket on the software Rocksim, members were able to determine the stability margin and keep center of gravity one caliper ahead of center of pressure for the best flight possible.
TRA: The payload in the high power rocket should not be flammable, explosive, or cause harm. Don’t fly vertebrate animal in a high power rocket.	The scientific payload involves the detection of carbon dioxide at various altitudes, comprising of electronic components and not anything alive. These components are not flammable.

3.2.2 Hazardous materials handling and hazardous operations

3.3 Student Safety Briefing

3.3.1 Launch and Safety Checklist

"Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations."

3.4 Inclusion of Necessary Caution Statements

Listed are some threats to team members' safety that must be accounted for (see details below the table):

Risk	Mitigation
Impact to the body	Gloves, apron, goggles

Cut or puncture	Gloves and Apron
Chemicals – fumes and/or direct contact	Gloves, respirator, goggles
Heat/cold	Gloves

Harmful Dust and small particles	Mask and Goggles
Loud noises	Earplugs

The team will keep a copy of the MSDS for all materials used in the making of the vehicle when an MSDS exists for a certain material. The following items will be present and available for team member use whenever they are working, constructing the vehicle or payload, or launching.

- Safety goggles
- Rubber gloves
- Protective aprons

- Ear Plugs
- Leather gloves
- Respirators / Dust Masks

Eye protection must be worn whenever there is a danger of:

- Dust, dirt, metal, or wood chips entering the eye. This can happen when sawing, grinding, hammering, or using power tools.
- Strong winds during a launch (common at Lucerne Dry Lake)
- Chemical splashes when using paints, solvents, or adhesives
- Cutting fiberglass, which can produce damaging fine particles
- Objects thrown (intentionally or inadvertently) or swinging into a team member

These types of gloves must be worn to protect the team member's hands whenever there is danger of contact with a hazardous material:

- Latex or rubber gloves for possible contact with hazardous chemicals such as adhesive, paint, or thinners, or dangerous solid materials.
- Leather gloves to protect against impact, cuts, or abrasions (e.g. in the use of some power tools such as grinders)

Team members will always work in a clean, well-ventilated area. Protection for a team member's lungs (dust mask or respirator) must be used when:

- Working with chemicals emitting fumes (e.g. paints and solvents). In this case, the team member must wear a respirator.
- Working in an environment where there is dust (e.g. sanding and working with power tools). The team member must wear a dust mask.

Body protection, such as an apron must be worn whenever there is danger of:

- Splashes or spills from chemicals
- Possible impact from tools

Ear protection (plugs or ear muffs) must be worn whenever there are loud noises present, which include:

- Using loud power tools or hammers
- Launching larger rocket motors at launches

When creating documents that require work with potentially hazardous materials including chemicals, that section will be marked with the following:

"HAZARDOUS MATERIAL - SEE MSDS"

A sample MSDS is included in the next appendix to show what is included. As materials are identified during the research and design phases of this project, suitable MSDS for those materials used will be gathered and made available to all team members in hard copy form at the work area as well as on the web site.

3.5 Compliance with Federal, State, and Local Aerospace Laws

"Teams will abide by the rules set forth by the FAA."
"Each team shall provide a plan for complying with federal, state, and local laws regarding unmanned rocket launches and motor handling. Specifically, regarding the use of airspace, Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Amateur Rockets, Code of Federal Regulation 27 Part 55: Commerce in Explosives; and fire prevention, NFPA 1127 "Code for High Power Rocket Motors."

3.5.1 Federal Aviation Regulations 14 CFR

The team will comply with Federal Aviation Regulations 14 CFR by launch our rocket be unmanned, not launched across into the territory of another foreign country, and does not create a hazard to persons, property, or other aircraft. The motor our rocket will be using will be the Aerotech K560 which has a propellant mass of 1408.1g.
Our team launches in Lucerne Dry Lake in California, which is 72.5 kilometers away from the nearest airport and typically without clouds, and will launch at acute angles of attack. The rocket will also utilize a drogue and main parachute so that it will not pose a significant threat to people upon landing.
Our team will also notify the Federal Aviation Association (FAA) in the event that we are going to test a high power rocket. This will help avoid complications in air traffic.
Mr. Koepke, our mentor, will be present at these launches to observe the safety of them. He is 70 years old.

3.5.2 Amateur Rockets, Code of Federal Regulation 27 Part 55: Commerce in Explosives

The team will comply with these rules by keeping our pyrotechnic compositions and pyrotechnic devices will be sealed in antistatic bags and locked in ammo box.. All ammo boxes will have a fire apparatus nearby.

3.5.3 Fire prevention, NFPA 1127 Code for High Power Rocket Motors

All APCP motors for Student Launch will be purchased through Animal Motor Works, a certified retailer for pyrotechnic compositions and pyrotechnic devices, as requested by this particular law.

3.6 Purchase, Storage, Transport, and Use of Rocket Motors and Energetic Devices

3.6.1 Rocket Motors

Rocket motors will be purchased prior to flight, built in advance, and stored in antistatic, water-tight plastic boxes to lock out moisture.

3.6.2 Energetic Devices

Black powder will be kept in a locked ammo box in its original container. The container's lid will be locked tightly. The electric matches used for recovery will be stored in separate antistatic bags and will be stored inside their own ammo boxes.

3.7 Written Safety Statement

We, the team members of the Student Launch team of the AIAA OC Section, understand and will abide by the following safety regulations:

- Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or be removed from the program.
- The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
- Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

No.	Date	Name	Signature
1	9/20/17	Albert	AlbertW
2	9/20/17	Brenda	Brenda

3	9/19/17	Kushagra	
4	9/19/17	Sahil	

3.7.1 Range Safety Inspection

3.7.2 Prerogative of the Range Safety Officer

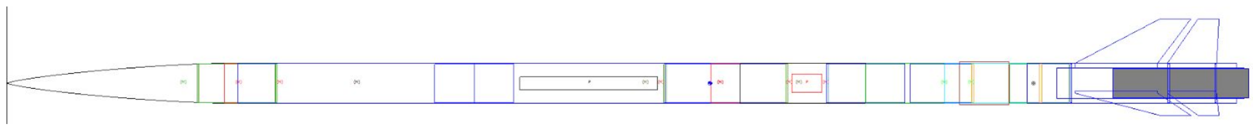
“During test flights, teams will abide by the rules and guidances of the local rocketry club’s RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch Initiative does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club’s President or Prefect and RSO before attending any NAR or TRA launch.”

3.7.3 Consequences of Failing to Meet Safety Requirements

Failing to meet safety requirements will result in the cancellation of the test flight and immediate review of design flaws.

4 Technical Design

4.1 Vehicle



4.1.1 General Vehicle Dimensions

The launch vehicle, which is a recoverable, reusable, and single-stage rocket, will be 125" long, have a 4" diameter, weigh 11.111 kg and will be made of fiberglass body tubes.

The diameter will be 4" to provide ample space for the payload and other electronics without adding too much drag to the overall design.

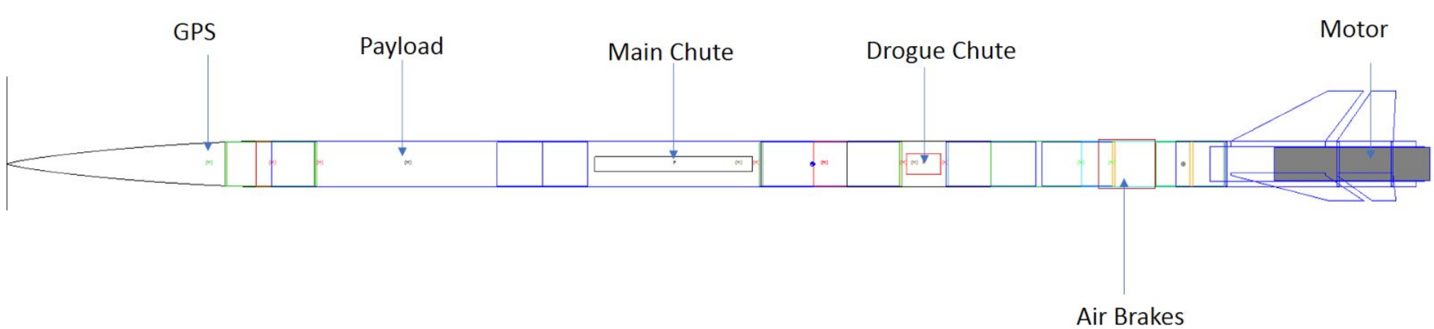
This launch vehicle will be a single stage modified Frenzy XL kit designed by Michael Stoop and purchased from Mad Cow Rocketry. Modifying a kit instead of designing an original flight vehicle would be a more efficient use of time and be less difficult.

The launch vehicle will also utilize an air brake system to meet the height requirement of exactly one mile.

There are four independent sections of this rocket, one of which stores the payload. This is called the payload bay.

The payload bay will open and push out the payload below 400 ft or lower, at the discretion of the RSO.

The center of gravity is at 80.9521" from the nose cone, and the center of pressure is 104.1570" from the nose cone.



4.1.2 Material Selection and Justification

4.1.2.1 Fiberglass

We will use G12 fiberglass tubes from madcowrocketry.com. This is filament-wound rocket tubing made with premium fiberglass and epoxy and is capable of withstanding high-powered flight.

4.1.2.2 Epoxy

The epoxy we will use for the launch vehicle is West Systems 105A Epoxy Resin. It bonds reliably to fiberglass.

- Flexural strength: 14,112 PSI
- Tensile strength: 7,846 PSI
- Heat deflection Temperature: 118°F

4.1.3 Construction Methods

4.1.3.1 Fiberglass Cutting

24-hour epoxy will be used to seal the fiberglass, and airbrakes will be included in this design to control the vehicle's altitude. If necessary, additional fiberglass can be layered onto the body tubes and vacuum-bagged to provide additional strength.

A hacksaw with a fine pitch blade will be used to cut the fiberglass body tubes. To cut the tube, we will gently cut a groove at the desired length of the body tube and rotate the tube as we cut. Fiberglass can dull the blade, so we may need to switch blades. After multiple rotations, we will be able to receive a fairly clean cut body tube. Alcohol will be used to remove fiberglass dust

Fiberglass is a hazardous material. The safety procedures for handling fiberglass can be found on page [what number?].

4.1.3.2 Epoxy

The epoxy we will use for the launch vehicle is West Systems 105A Epoxy Resin. It bonds reliably to fiberglass

4.1.3.3 Fiberglass Fillets

We will use fiberglass tape to secure the intersection between the fins and the main body tube. This is necessary because fins are known to break their original epoxy fillets without the tape as reinforcement.

4.1.4 Tracking Device

The GPS that we will be using is the Whistle GPS dog tracker, as seen below.

4.1.4.1 Tracking Device Alternatives

GPS system	Pros	Cons
Whistle GPS dog tracker	Easy to use because it requires knowledge of using a smartphone app. It can be recharged easily using the base station and is not dependent on any other external electronics. No additional telemetry required.	Only works where there is cellular coverage. Bigger than the other GPS options. More expensive because of money needed for cellular service.
EM-506 GPS Receiver	Really small, really accurate in rough geographical conditions like canyons, relatively cheap.	Relatively difficult to use compared to dog tracker. Also not as durable. Additional telemetry may be

		required.
Arduino GPS tracker	Small and easy to set up. It will be easy for us to use because of our experience with Arduino in TARC.	Additional space required for battery, really expensive, will require use to use a new and unfamiliar version of Arduino. Additional telemetry may be required, making it relatively harder to use.

4.1.4.2 Conclusions Drawn from GPS Subsystem

The Whistle GPS is the most affordable and reliable of the GPS alternatives.

4.2 Projected Altitude

Projected altitude: 5371.03 ft

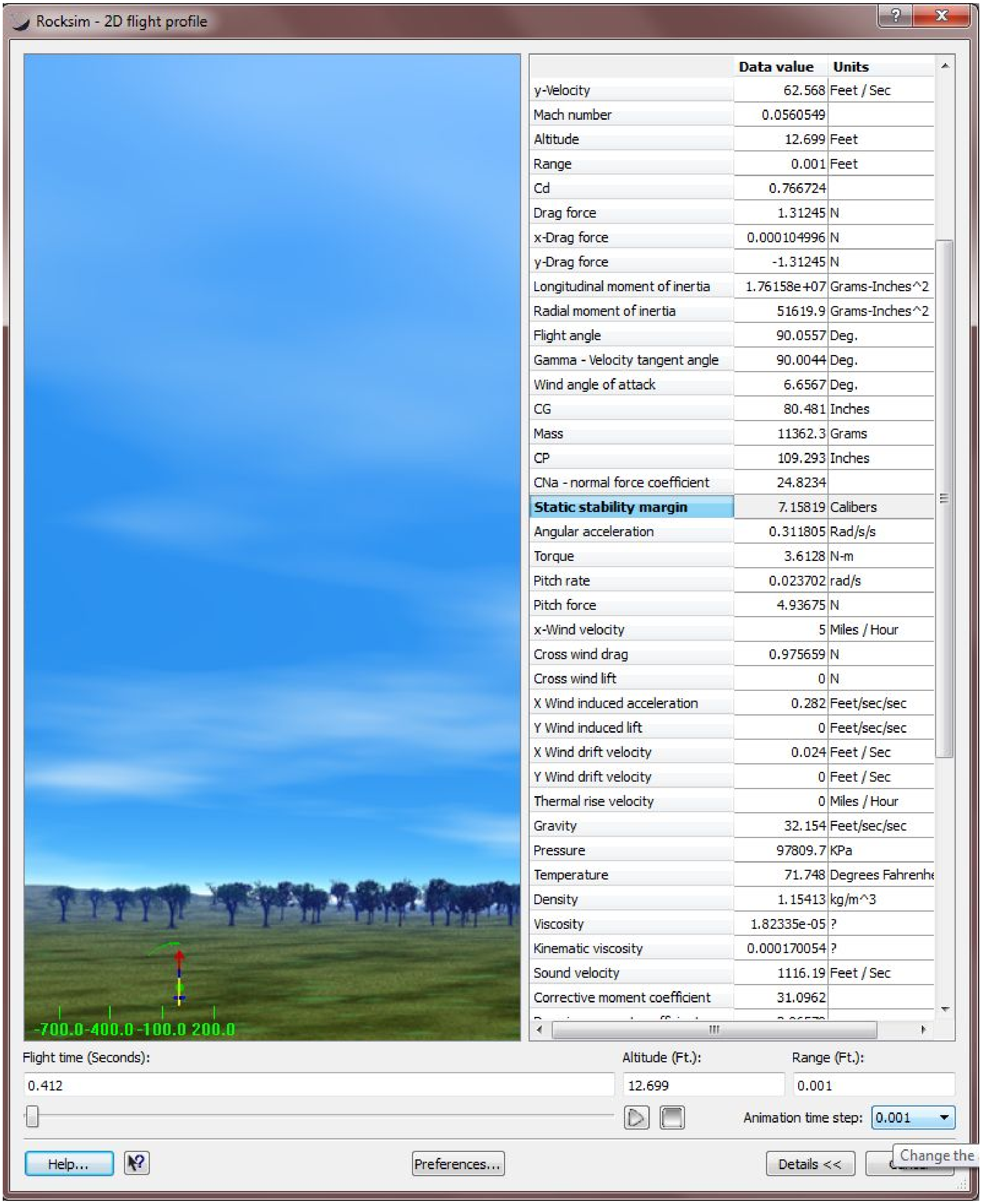
We must purposefully go over the target altitude so that the air brakes are able to perform and at the same time remain within a reasonable range for the air brakes to be effective. Holding the brakes for longer and opening more slowly can account for overshooting.

4.2.1 Projected Altitude Calculations

The altitude was projected using conditions at Lucerne Dry Lake, where our testing may take place, depending on weather.

4.2.2 Static Stability

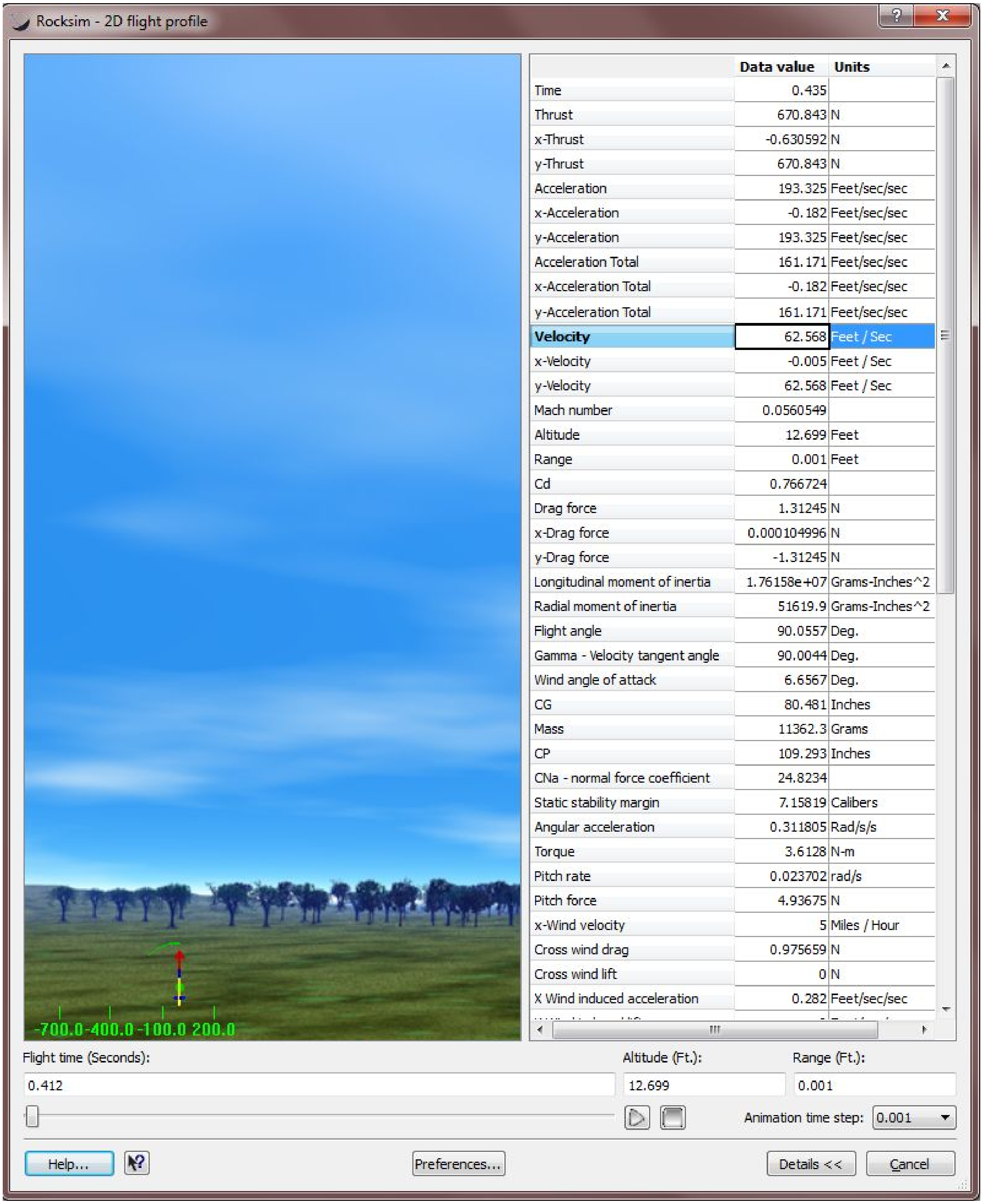
“The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit”



The static stability margin is clearly well over the minimum static stability margin.

4.2.3 Rail Exit Velocity

"The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit."



The rail exit velocity is well above 52 fps. It's at 62.568 fps.

4.2.4 Maximum Velocity

"The launch vehicle will not exceed Mach 1 at any point." - SL Handbook

The maximum velocity of this vehicle is simulated to be 585.98 fps. This is below Mach 1.

4.3 Projected Parachute System Design

Our main chute is 84" in diameter, deployed at an altitude of 500 ft.

84" Iris Ultra Standard Information	
Parachute Material	Rip-stop nylon
Shroud Line Material	400lb Flat tubular Nylon
Mass	539 g
OD	84"
ID	36"
Shroud line length	84"
Shape	Toroidal
Coefficient of drag	2.2
Colors	Red, White

Our drogue chute is 18" in diameter, deployed at apogee.

18" Classical Elliptical Information	
Parachute Material	1.1 oz rip-stop nylon
Shroud Line Material	220 lb tubular nylon
Mass	49 g

OD	18”
ID	6”
Shroud line length	24”
Shape	Elliptical
Coefficient of drag	1.5-1.6
Colors	Red, White

We will use a redundant avionics subsystem that uses 4F Black Powder to eject the two chutes, both wrapped in blast cloths, using 1” flat nylon from MadCow Rocketry, which withstands 3000 lbs of force.

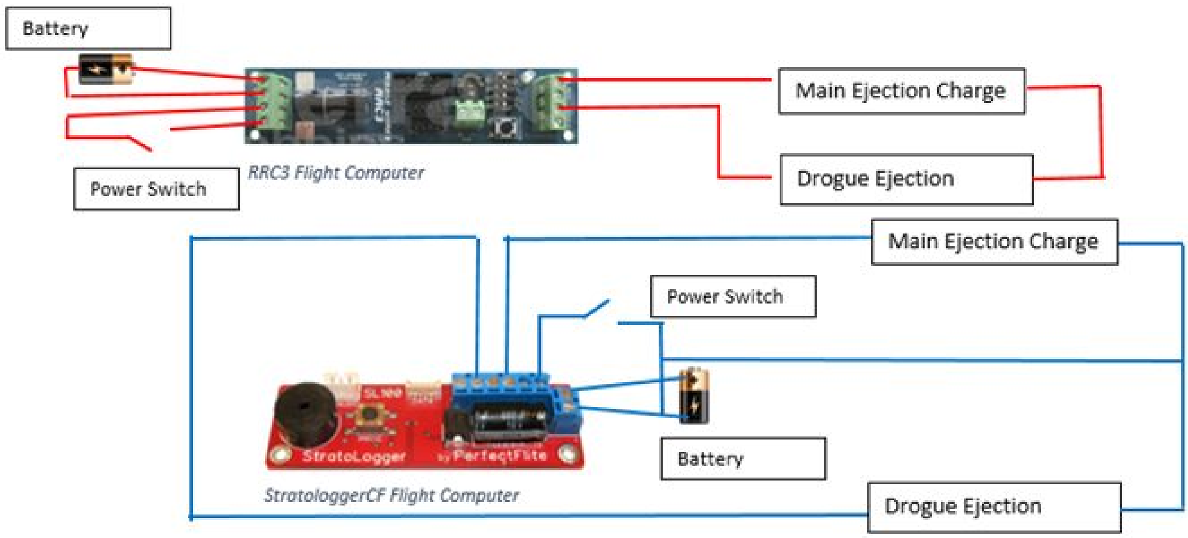
4.3.1 Altimeters

4.3.1.1 Altimeter Power

The vehicle will use redundant dual deployment for recovery. The top section will be connected to the parachutes via a nylon shock cord, and the avionics bay will also be connected via a nylon shock cord. Recovery will occur in three phases – near apogee a small drogue parachute will be deployed that is designed to slow the rocket for initial descent. Much later, at an altitude of 900 feet, the ejection charge will deploy the main, which is designated to drastically slow down ascent for the purpose of safety.

The primary set of recovery electronics will use a Stratologger CF Flight Computer, and the backup set will use an RRC3 Flight computer. In this way, if there is a bug in the design of either flight computer that would affect the recovery during our flight it will not be replicated in the other set of electronics. Each of the two recovery electronics has its own separate commercially available battery capable of powering the electronics for a minimum of 1 hour dwell time plus flight time. That battery is disconnected through an interlock key switch accessible on the outside of the rocket near the nose cone, and this is to ensure that the electronics are not powered on until it is safe to do so on the launch pad. They key can be removed only when the switch is locked ON. The recovery electronics will ignite a measured portion of gunpowder using an electric match.

4.3.1.2 Redundancy



The fact that the wires of the stratologger and RRC3 do not get mixed together proves the redundancy of the dual-deploy system

4.3.1.2 Shear Pins

The launch vehicle will use #2 shear pins to prevent the rocket from separating until the black powder charges are ignited, thus separating the rocket and propeling the parachutes outward

4.3.2 Arming Switch

There will be two key switches accessible from the outside of the rocket to arm the recovery electronics. One switch will be to turn on the Stratologger, and the other will be to turn on the RRC3.

4.3.3 Interference Protection

Recovery electronics are totally independent of the payload electronics and power. To assure that the radio frequency signals of other electronics do not interfere with recovery, use a MG Chemicals SuperShield. One to two mil coating provides 40dB - 50dB shielding across a frequency range of 5 to 1800MHz

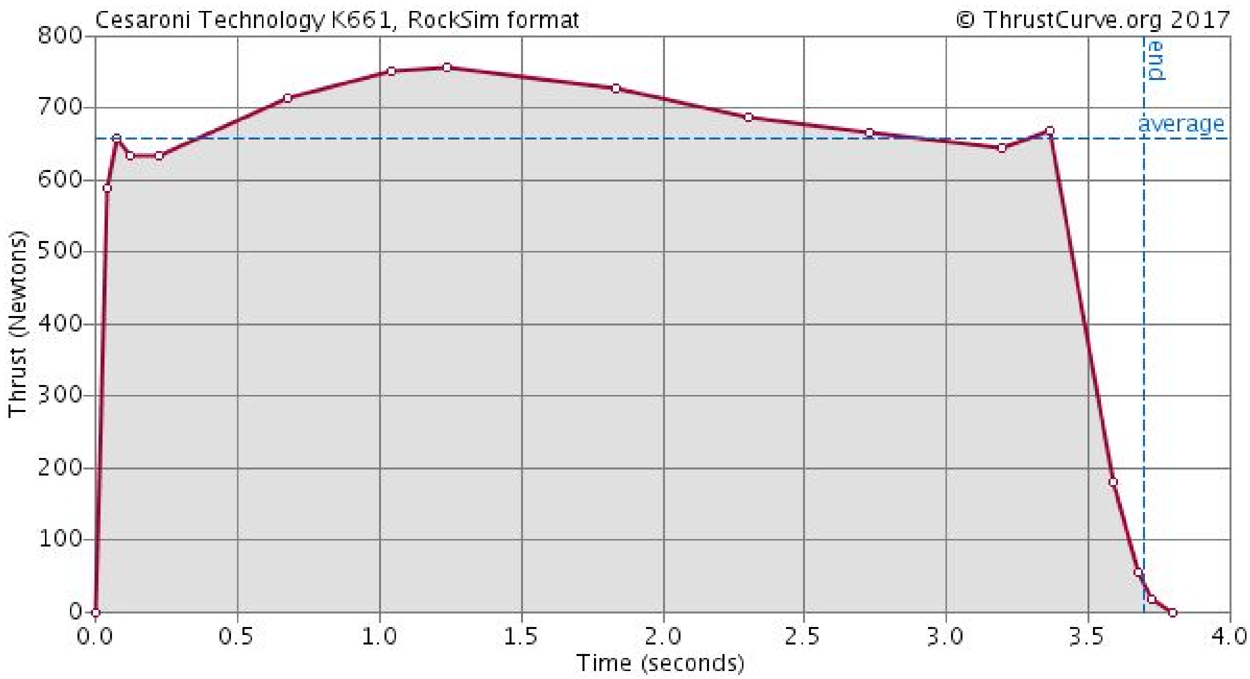
4.3.4 Predicted Kinetic Energy at Landing

"At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf."

4.3.5 Drift

Recovery area will be limited to a 2500 ft. radius from the launch pads.

4.4 Projected Motor, Brand Designation



The projected motor is a Cesaroni K661.

Engine Name	**Total Impulse (Ns)**	**Total Mass (g)**	**Max Altitude (ft)**	**Max Velocity (ft/s)**	**Max Accel (ft/s^2)**
K661 (75 mm)	2436.5	2527.8	609.50	645.60	616.43

4.4.1 Motor Retention

We will use AeroPack Fiberglass 75mm Motor Tube Retainers, purchased from Madcow Rocketry. This requires users to screw a cap onto the motor as positive motor retention.

Aero Pack 75mm Retainer (Fiberglass Motor Tubes) (RA75P)

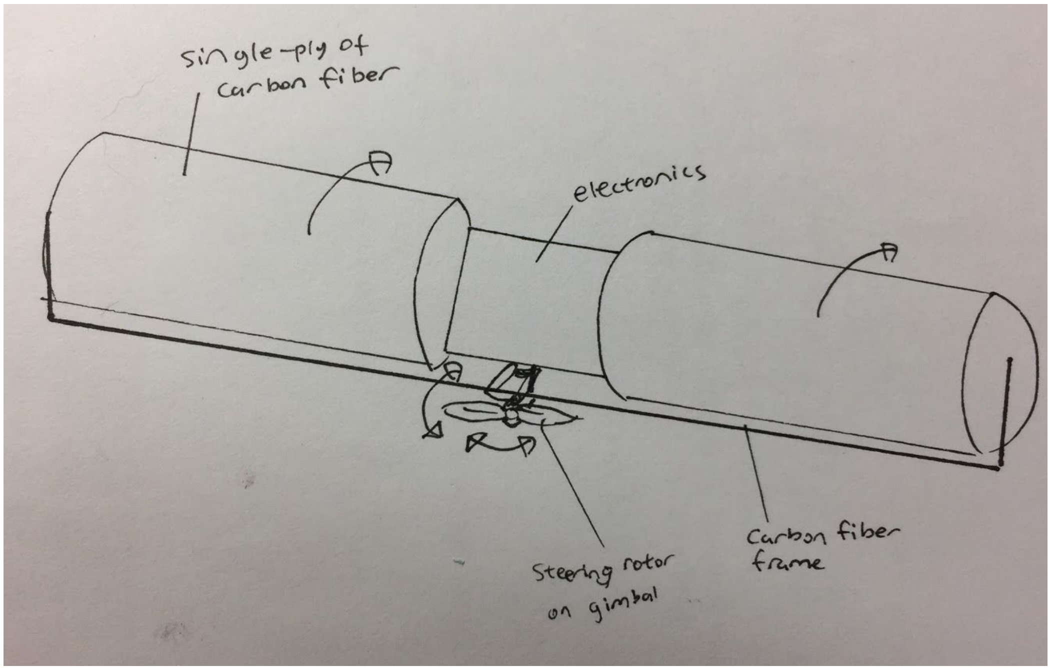
4.5 Payload Overview

“The launch vehicle will carry a science or engineering payload. The payload may be of the team’s discretion, but must be approved by NASA. NASA reserves the authority to require a team to modify or change a payload, as deemed necessary by the Review Panel, even after a proposal has been awarded.”
“Data from the science or engineering payload will be collected, analyzed, and reported by the team following the scientific method.”
“The payload must be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.”

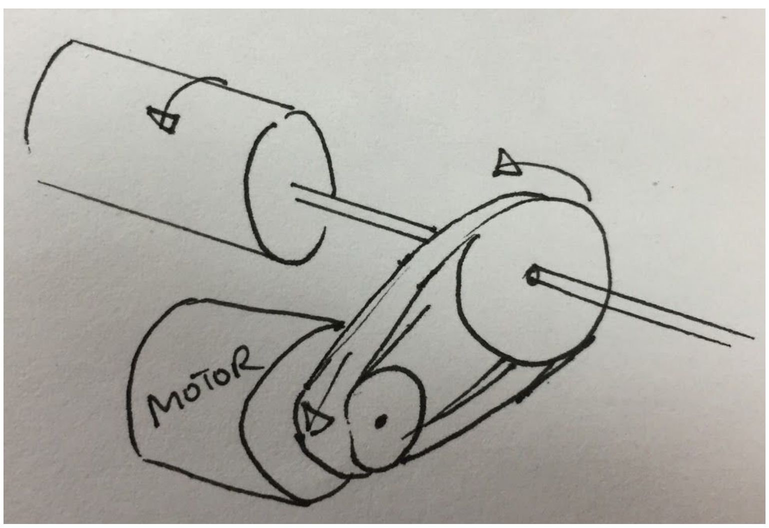
The engineering payload proposed by this team is a UAV that will utilize the Magnus Effect to generate lift and safely descend to a specified GPS coordinate. This operation should be autonomous, but RC control and an emergency parachute are installed for safety.

The Magnus Effect results from a rotating circular body entraining air around it, creating pressure differentials above and below the body and thus generating Magnus Force.

Magnus Force can be calculated using the Kutta-Joukowski Theorem for a Cylinder.



The inspiration for the above design can be found in this link.



The motor here will rotate both cylinders on a common axis to ensure both cylinders have identical angular velocities, thus generating equal Magnus Forces.

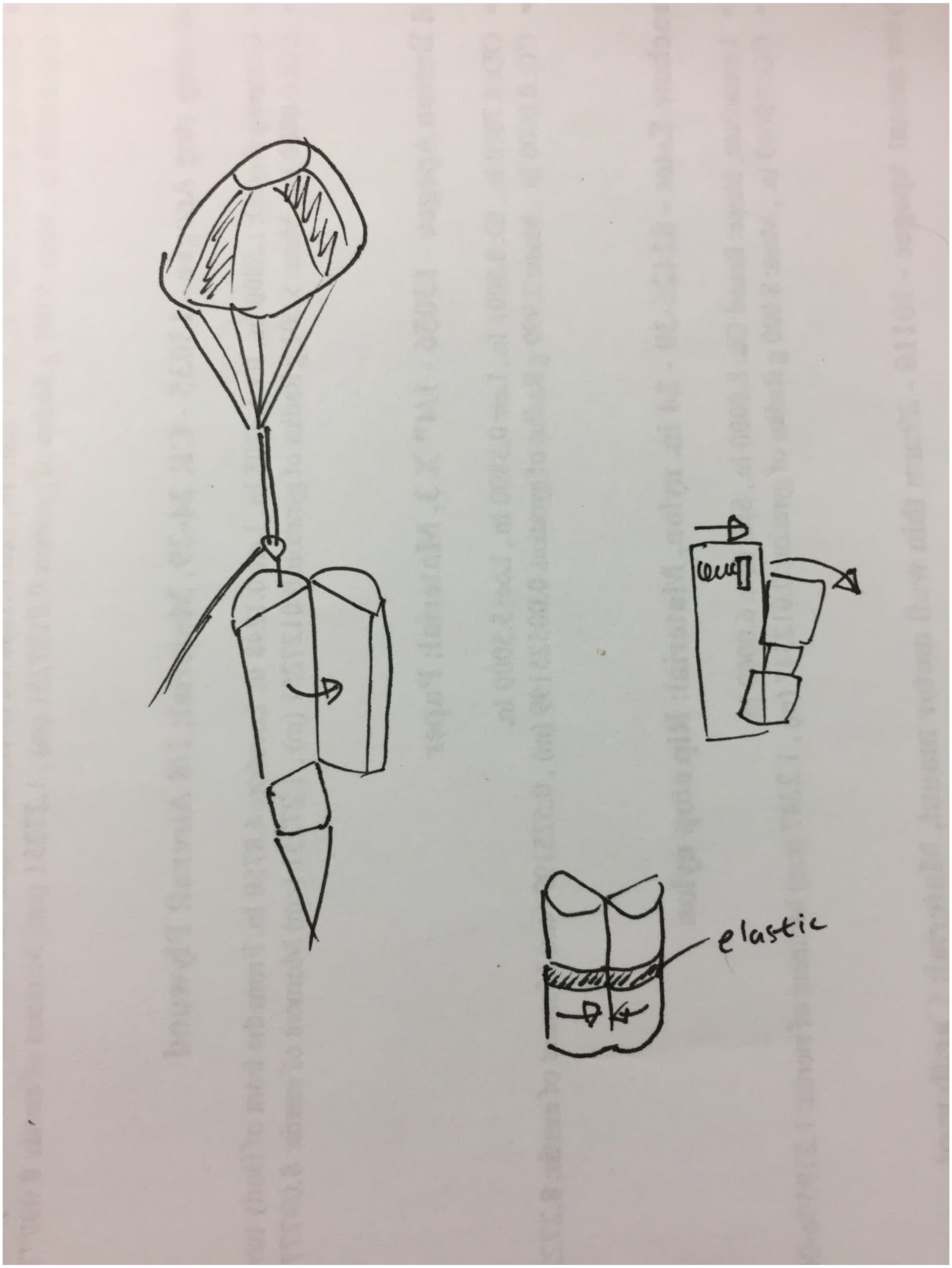
4.5.1 Tracking Device

The payload will be ejected from the main rocket. It will use an Adafruit Ultimate GPS Module, which has a 3.3 V operation.

4.5.2 UAV Release

“Unmanned aerial vehicle (UAV) payloads of any type will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given the authority to release the UAV.”
“Any payload element that is jettisoned during the recovery phase, or after the launch vehicle lands, will receive real-time RSO permission prior to initiating the jettison event.”

According to this criteria, then, the payload will be ejected remotely via RC.


elastic

The payload doors will be opened by a release mechanism, and an elastic band around the tube holding the payload will prevent the doors from snapping shut.

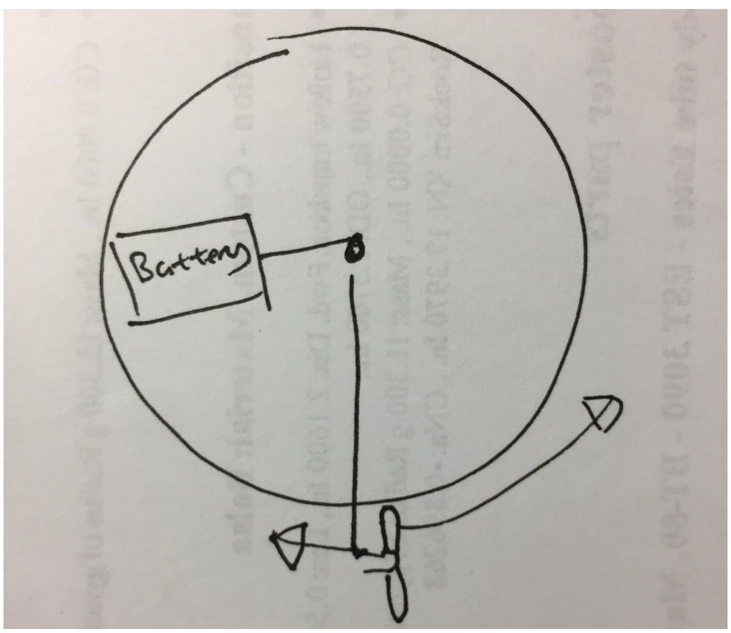
There will also be a spring-loaded mechanism to tip the payload out.

By the time the RSO has given the signal to release the UAV, the payload's cylinders should already have started rotating to give it some lift prior to commencing freefall.

4.5.3 Payload Parts (short list)

- GY-80 Multi-sensor board
  - Includes 3-Axis Gyro, 3-axis accelerometer, 3-axis magnetometer, barometer, and thermometer
- Adafruit Accessories Lithium Ion Polymer Battery 3.7V 500mAh
- Single-ply carbon fiber
- DC 12V 10000RPM Mini Magnetic Motor
  - 10000 RPM
- Propeller
- Teensy 2.0
- Plastic Casing to house electronics

4.5.4 Counterweights



To prevent the steering motor from exerting too much tangential force and subsequently disrupting the direction of Magnus Force upward, the batteries will be placed perpendicular to the propeller as a counterweight.

4.6 Addressing Vehicle, Recovery System, and Payload Requirements

Appendices A and B address the vehicle, recovery system, and payload requirements.

4.7 Addressing Major Technical Challenges and Solutions

4.8 Rocket Preparation

"The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens."
"The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components."

4.9 Rocket Launch

"The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider."
"The launch vehicles will require no external circuitry or special ground support equipment to initiate a launch (other than what is provided by Range Services)."

4.10 Air Brakes

We will continue using the same air brakes design from last year's Student Launch. Click here to see them in action.

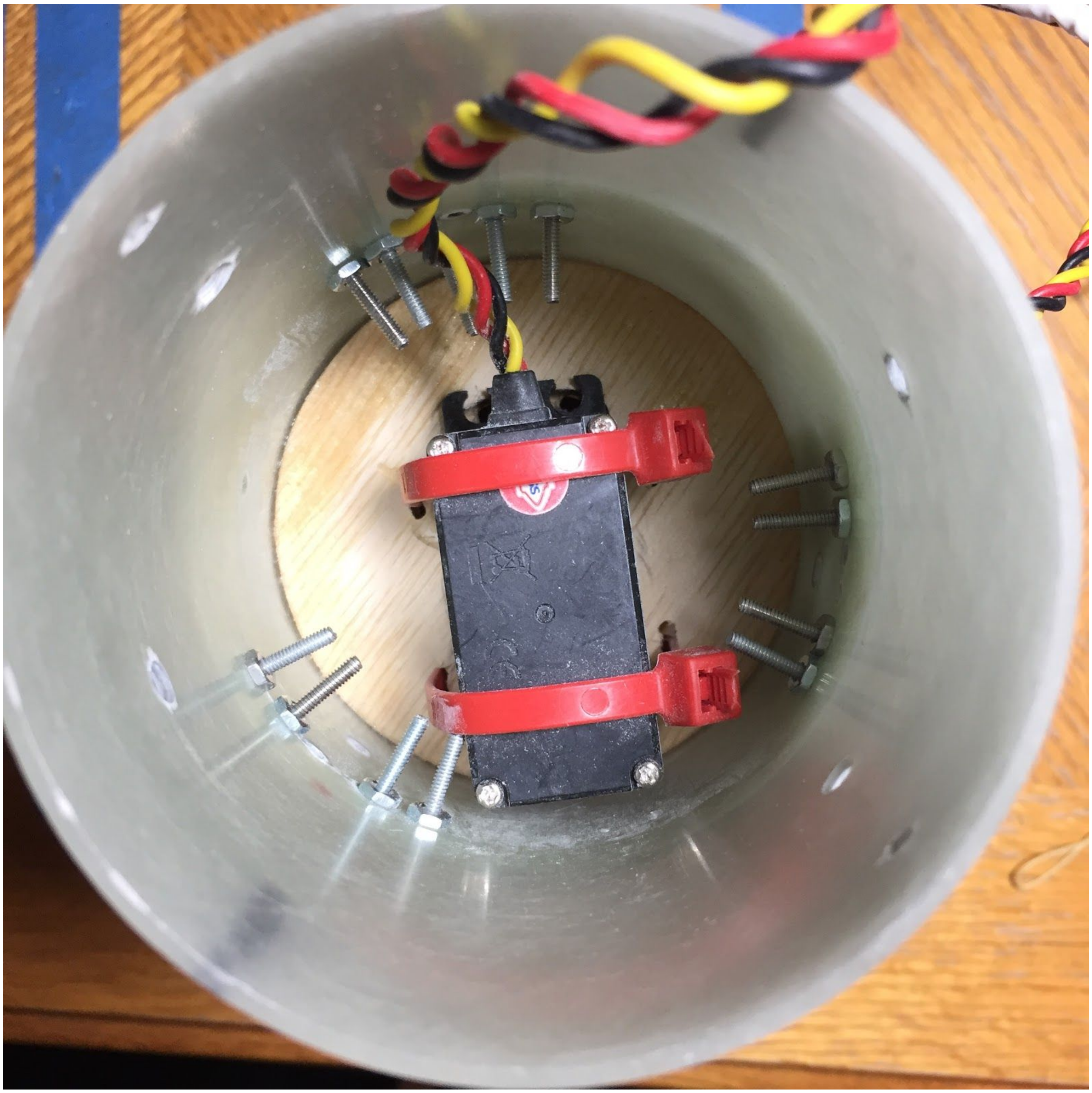
These air brakes will oscillate to adjust the rocket's overall drag and help the rocket meet its 5280 ft target altitude.

The air brakes will use a Hitec HS-7890T circular servo, which have the following statistics:

Dimensions	1.72" x 0.88" x 1.57" (43.8 x 22.4 x40 mm)
Product Weight	2.76 oz (78.2g)
No-Load Speed (6.0V)	0.21 sec/60°
No-Load Speed (7.4 V)	0.17 sec/60°

Stall Torque (6.0V)	500oz/in (26 kg.cm)
Stall Torque (7.4V)	611oz/in (44kg.cm)
Travel per µs (out ofbox)	.080°/µsec
Travel per µs (reprogrammed high res)	.132°/µsec

Servocity.com

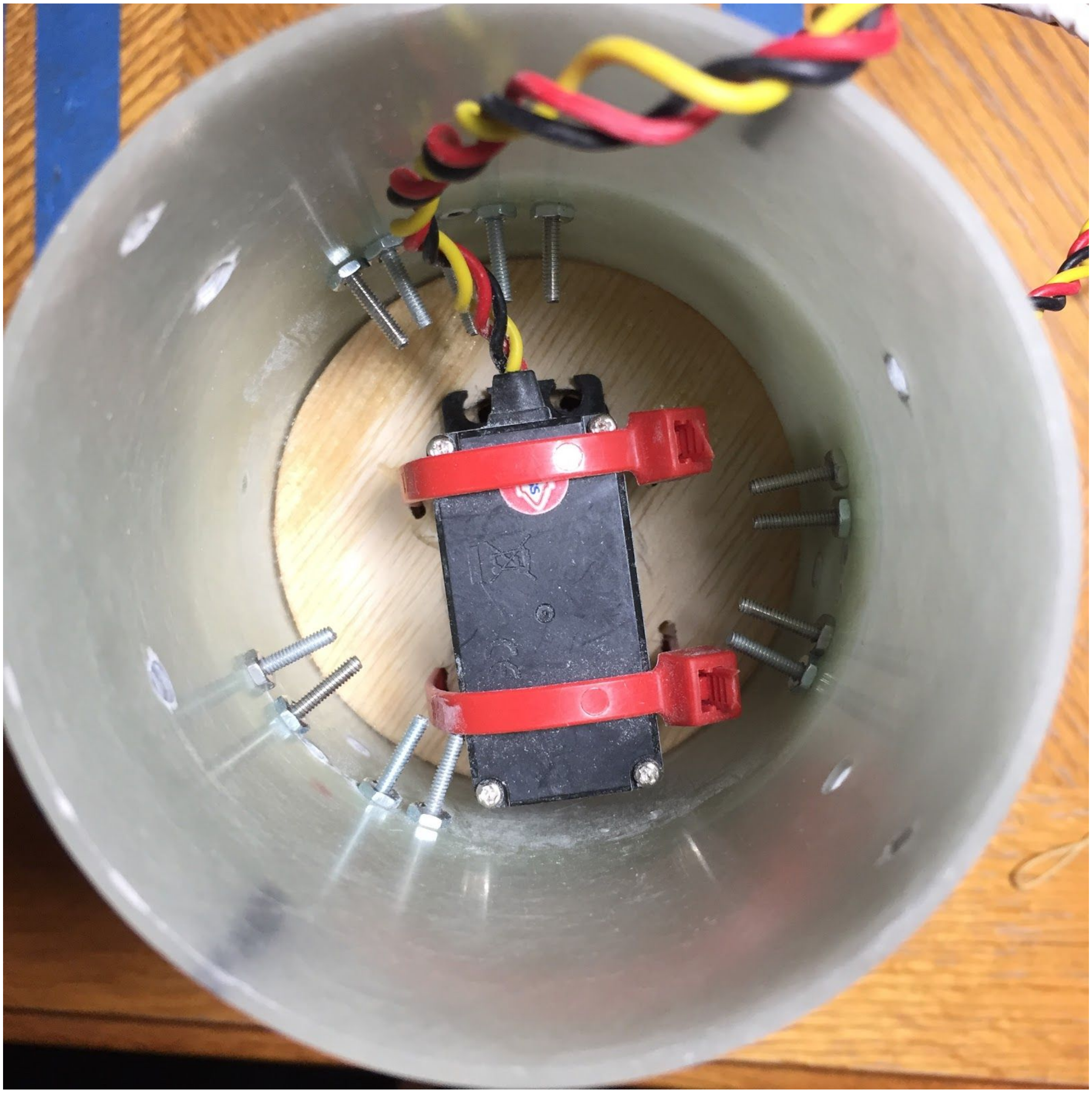


In the full-scale rocket, the air brake module will have an 8.25” long G10 fiberglass body tube, with a 6.5” long G10 fiberglass tube coupler, and. It will have a 4” diameter. It will be independently powered by a Lithium Polymer battery.

A small flight board run by Teensy 2.0 will use an algorithm to continuously adjust the rocket’s drag through oscillation and will immediately stop after apogee.

4.10.1 Mechanical Engineering

We will use ball-bearing swivels at a hobby store to add more flexibility to the rotational points. This swivel provides an additional hinge for the arm to turn on, so the air brake wing will come out.



5 Educational Engagement

We will engage the surrounding community by educating them about rocket science and SL.
We will:

- Use the AIAA network to reach out to AIAA members in Southern California so they can in turn reach out to the schools those members are involved with to make them aware of SL and TARC.
- Contact the Discovery Science Center in Santa Ana, CA, for a possible session with youth and rocketry.
- Raise awareness in the local population by holding presentations in Ivymax that will show current and future academy students what SL is all about. Fliers can also be handed out during the presentations to help increase the understanding of the audience.
- Put together flyers and distribute them around the community to bring to light rocketry and what we will be doing. This will also create interest locally and possibly bring in donations.
- Contact the Orange County Model Engineers, a 501c nonprofit organization, to see if it is possible to set up an event where we can talk about SL. The organization is located in Fairview Park in Costa Mesa, CA.

6 Project Plan

6.1 Development Timeline

The development timeline will be available on verticalprojectile.org under the NASA SL tab.

6.2 Budget

*Will be reusing last year's materials

Description	Unit Cost	Qty	Subtotal	
Scale Vehicles and Engines				
3" Fiberglass Frenzy XL	$200.00	1	$0.00*	
3" G12 Thin-Wall Airframe (12" length)	$20.00	1	$0.00*	
3" G12 Coupler (6" length)	$14.00	2	$0.00*	
3" G12 Coupler (9" length)	$21.00	1	$0.00*	
HS-7980TH	$190.00	1	$0.00*	
2-56 wire	$10.00	1	$0.00*	
1/4" Machine Closed Eye Bolt	$18.00	4	$0.00*	
Heavy unit easy connector	$5.00	1	$0.00*	
Iris Ultra 72" Compact parachute	$265.00	1	$0.00*	
12" Elliptical Parachute	$47.00	1	$0.00*	
Cesaroni J240RL	$85.00	1	$85.00*	
Total Scale Vehicle Cost				$85.00
Vehicle				
4" G12 Coupler (12" length)	$31.00	3	$0.00*	
4" G12 Coupler (8" length)	$21.00	2	$0.00*	
4" Fiberglass Frenzy XL	$300.00	1	$0.00*	
4" G12 Airframe (12" length)	$23.00	1	$0.00*	
2-56 wire	$10.00	1	$0.00*	
Heavy unit easy connector	$5.00	1	$0.00*	
Aero Pack 75mm Retainer (Fiberglass Motor Tubes)	$44.00	1	$0.00*	

Shock Cord Protector Sleeves of Kevlar	$10.00	3	$0.00*	
1 Inch Black Climbing Spec Tubular Nylon Webbing	$12.00	2	$0.00*	
3/8" Machine Closed Eye Bolt	$30.00	4	$0.00*	
4" G10 Airframe Plate	$6.00	8	$0.00*	
3" G10 Airframe Bulkplate	$5.00	8	$0.00*	
3" Aluminum Bulkplate	$15.00	4	$0.00*	
4" Aluminum Bulkplate	$20.00	4	$0.00*	
4" Coupler Bulkplate	$4.00	4	$0.00*	
3" Coupler Bulkplate	$3.50	4	$0.00*	
Electric Matches	$1.50	60	$90.00	
Aero Pack 54mm Retainer (Fiberglass Motor Tubes)	$29.00	1	$0.00*	
Cesaroni K661	$30.00	5	$150	
Total Vehicle Cost				$240
Recovery				
Iris Ultra 120" Compact Parachute	$504.00	1	$0.00*	
24" Elliptical Parachute	$60.00	1	$0.00*	
4F Black Powder	Kept by mentor			
Batteries (9v, 2 pack)	$7.00	3	$0.00*	
Battery Holder	$1.00	5	$0.00*	
Stratologger CF Flight Computer	$55.00	1	$0.00*	
RRC3 Flight Computer	$70.00	1	$0.00*	
PerfectFlite Pnut (2 units)	$55.00	2	$0.00*	
Total Recovery Cost				$0.00
Payload				
K30 CO2 Sensor	$85.00	1	$0.00*	
Arduino Uno kit (includes LED, resistors, regulators, etc)	$35.00	1	$0.00*	
SD card + Adapter	$10.00	1	$0.00*	
PerfectFlite Pnut Altimeter	$50.00	2	$0.00*	
Lithium Ion Battery (rechargeable)	$100.00	1	$0.00*	

DC 12v 10000RPM Mini Magnetic Motor	$5.53	2	$10.06	
16” Paper parachute	$4.00	2	$8.00	
Teensy				
Gimbal	$11.68	2	$23.36	
Adafruit Battery	$6.40 for 10	10	$6.40	
Total Payload Cost				$47.82
GPS System				
Whistle GPS Dog Tracker Kit	$75.00	1	$0.00*	
Cellular Service Fee (3 months free, 5 months to pay)	$40.00	1	$40.00	
Total Payload Cost				$40.00
Educational Outreach				
Color fliers (250 copies)	$170.00			
Total Educational Outreach Cost				$170.00
Travel (4 Members)				
Trips to Lucerne ($2.80/gal, 112mi; $21.00 per trip per car)				
Huntsville, Alabama (roundtrip plane ticket)	$332.00	4	$1328.00	
Food (2 meals a day, 6 days)	$10.00	48	$480.00	
Hotel (2 people per room, 6 days)	$120.00	12	$1440.00	
Total Travel Cost (Estimated)				$3248.00
Total Estimated Project Expenses				$3830.82

6.3 Funding Plan

The team will procure funds from various sources. Action plans include the following: go around the community to collect items for a garage sale and also ask for donations, explain to them what the team’s goal is, send letters to local businesses and aerospace companies requesting financial aid, and speak to vendors involved in rocketry and other supplies for discounts and donations.

Additionally, opportunities such as fundraising support from local restaurants and stores will be used to gain more funding for the team.

6.4 Project Sustainability

6.4.1 Providing for/Maintaining Established Partnerships

To provide and maintain established partnerships, the team will continue to contact and participate in events to encourage STEM as well as to maintain relationships with the community and other partnerships.

6.4.2 Educational Engagement

To provide educational engagement, the team has previously done a summer camp (over the summer of 2017) to help form and encourage involvement in rocketry, such as for TARC. The team will continue to take active roles in monthly outings and guide young rocketeers to learn about aerospace and build rockets.

6.4.3 Funding Sustainability

To maintain funds, the team will continually participate in fundraising opportunities and other forms of funding to support the expenses of the team.

6.4.4 Web Site

"The team will develop and host a Web site for project documentation" -SOW
"The team will post and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline." -SOW
"All deliverables must be in PDF format."

Refer to requirement 1.13 for accessibility standards.

Verticalprojectile.org is the site for project documentation under the NASA SL tab. All deliverables will be in PDF format.

Appendix A: Statement of Work Cross-Reference

Grayed out areas indicate requirements that are not mentioned/fulfilled in the RFP because they are larger in scope than is required for the RFP itself.

No.	Requirement in SOW	RFP Section
1. General Requirements		
1.1	Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor)	
1.2	The team will provide and maintain a project plan to include, but not limited to, the following items: project milestones, budget and community support, checklists, personnel assigned, educational engagement events, and risks and mitigations	6.1
1.3	Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from the team during these activities.	
1.4	The team must identify all team members attending launch week activities by the Critical Design Review (CDR). Team members will include:	
1.4.1	Students actively engaged in the project throughout the entire year	1.5
1.4.2	One mentor (see requirement 4.4.)	1.2
1.4.3	No more than two adult educators	1.2
1.5	The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Education Engagement Activity Report, by FRR. An educational engagement activity report will be completed	6.4.2

	and submitted within two weeks after completion of an event. A sample of the educational engagement activity report can be found on page 29 of the handbook.	
1.6	The team will develop and host a Web site for project documentation	6.4.4
1.7	Teams will post, and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline.	6.4.4
1.8	All deliverables must be in PDF format.	6.4.4
1.9	In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Table of Contents
1.10	In ever report, the team will include the page number at the bottom of the page.	Every page (except cover)
1.11	The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a broadband Internet connections. Cellular phones can be used for speakerphone capability as a last resort.	2
1.12	All teams must be required to use the launch pads provided by Student Launch's launch service provider. No custom pads will be permitted on the launch field. Launch services will have 8 ft. 1010 rails, and 8 and 12 ft 1515 rails available for use.	4.1.3
1.13	Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) and Accessibility Standards (36 CFR Part 1194) Subpart B-Technical Standards (http://www.section507.gov): ● 1194.21 Software applications and operating systems ● 1194.22 Web-based intranet and Internet information and applications	6.4.4
1.14	Each team must identify a "mentor." A mentor is defined as an adult who is included as a team member, who will	1.2

	be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor must maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of t2 flights in this or a higher impulse class, prior to the PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week. One travel stipend will only be provided if the team passes the FRR and the team and mentor attends launch week in April.	
2. Vehicle Requirements		
2.1	The vehicle will deliver the payload to an apogee altitude of 5, 280 feet above ground level (AGL).	4.2
2.2	The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the maximum number of altitude points if the official scoring altimeter reads a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude.	4.3
2.3	Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	4.3.2
2.4	Each altimeter will have a dedicated power supply.	4.3.1.1
2.5	Each arming switch will be capable of being locked in the ON position for the launch.	4.3.1.1
2.6	The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	4.3
2.7	The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or	4.3

	is recovered separately from the main vehicle using its own parachute.	
2.8	The launch vehicle will be limited to a single stage.	4.3
2.9	The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.	4.8
2.10	The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components.	4.8
2.11	The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider.	4.9
2.1.2	The launch vehicles will require no external circuitry or special ground support equipment to initiate a launch (other than what is provided by Range Services).	4.9
2.13	The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	4.4
2.13.1	Final motor choices must be made by the Critical Design Review (CDR).	
2.13.2	Any motor changes must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the changes is for the sole purpose of increasing the safety margin.	
2.14	Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:	
2.14.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be a 4:1 with supporting design documentation included in all milestone reviews.	

2.14.2	Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank.	
2.14.3	Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.	
2.15	The total impulse provided by a Middle and/or High School launch vehicle will not exceed 2560 Newton-seconds (K-class.)	4.4
2.16	The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit	4.2.2
2.17	The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	4.2.3
2.18	All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be a high power rockets.	
2.18.1	The subscale model should resemble and perform as similarly as possible to the full scale model, however, the full-scale will not be used as the subscale model.	
2.18.2	The subscale model will carry an altimeter capable of reporting the model's apogee altitude	
2.19	All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full scale demonstration flight:	
2.19.1	The vehicle and recovery system will have functioned as designed.	
2.19.2	The payload does not have to be flown during the	

	full-scale test flight. The following requirements still apply:	
2.19.2.1	If the payload is not flown, mass simulators will be used to simulate the payload mass.	
2.19.2.1.1	The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.	
2.19.3	If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale demonstration launch.	
2.19.4	The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulate, as closely as possible, the predicted maximum velocity and maximum acceleration of the launch day flight.	
2.19.5	The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight.	
2.19.6	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO)	
2.19.7	Full scale flights must be completed by the start of the FRRs (March 6th, 2018). If the Student Launch office determines that a re-flight is necessary, then an extension to March 28th, 2018 will be granted. This extension is only valid for re-flights; not first time flights.	
2.20	Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	
2.21	Vehicle Prohibitions	
2.21.1	The launch vehicle will not utilize forward canards.	4.1

2.21.2	The launch vehicle will not utilize forward firing motors.	4.1
2.21.3	The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.).	4.4
2.21.4	The launch vehicle will not utilize hybrid motors.	4.4
2.21.5	The launch vehicle will not utilize a cluster of motors.	4.4
2.21.6	The launch vehicle will not utilize friction fitting for motors.	4.4.1
2.21.7	The launch vehicle will not exceed Mach 1 at any point during the flight.	4.2.4
2.21.8	Vehicle ballast will not exceed 10% of the total weight of the rocket.	
3. Recovery System requirements		
3.1	The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.	4.3
3.2	Each team must perform a successful ground ejection test for both drogue and main parachutes. This must be done prior to the initial subscale and full scale launches	
3.3	At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.	4.3.4
3.4	The recovery system electrical circuits will be completely independent of any payload electrical circuits.	4.3
3.5	All recovery electronic will be powered by commercially available batteries.	4.3.1.1
3.6	The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	4.3.1.2

3.7	Motor ejection is not a permissible form of primary or secondary deployment	4.3
3.8	Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	4.3.1.2
3.9	Recovery area will be limited to a 2500 ft. radius from the launch pads.	4.3.5
3.10	An electronics tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.	4.1.4
3.10.1	Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device.	4.1.4, 4.5.1
3.10.2	The electronic tracking device will be fully functional during the official flight on launch day.	4.1.4, 4.5.1
3.11	The recovery system electronics will not be adversely affected by an other on-board electronic devices during flight (from launch until landing).	4.3.3
3.11.1	The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	4.1, 4.3.3
3.11.2	The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.	4.3.3
3.11.3	The recovery electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	4.3.3
3.11.4	The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	4.3.3
4. Payload requirements		
4.1	The launch vehicle will carry a science or engineering	4.5

	payload. The payload may be of the team's discretion, but must be approved by NASA. NASA reserves the authority to require a team to modify or change a payload, as deemed necessary by the Review Panel, even after a proposal has been awarded.	
4.2	Data from the science or engineering payload will be collected, analyzed, and reported by the team following the scientific method.	4.5
4.3	Unmanned aerial vehicle (UAV) payloads of any type will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given the authority to release the UAV.	4.5.2
4.4	Any payload element that is jettisoned during the recovery phase, or after the launch vehicle lands, will receive real-time RSO permission prior to initiating the jettison event.	4.5.2
4.5	The payload must be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	4.5
5. Safety Requirements		
5.1	Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	3.3.1
5.2	Each team must identify a student safety officer who will be responsible for all items in section 5.3	1.3
5.3	The roles and responsibilities of each safety officer will include, but not limited to:	1.3
5.3.1	Monitor team activities with an emphasis on Safety during:	1.3
5.3.1.1	Design and vehicle payload	1.3
5.3.1.2	Construction of vehicle and payload	1.3
5.3.1.3	Assembly of vehicle and payload	1.3

5.3.1.4	Ground-testing of vehicle and payload	1.3
5.3.1.5	Sub-scale launch test(s)	1.3
5.3.1.6	Full-scale launch test(s)	1.3
5.3.1.7	Launch day	1.3
5.1.3.8	Recovery activities	1.3
5.3.1.9	Educational Engagement Activities	1.3
5.3.2	Implement procedures developed by the team for construction, assembly, launch, and recovery activities	1.3
5.3.4	Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures	1.3
5.4	During test flights, teams will abide by the rules and guidances of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch Initiative does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	3.7.2
5.5	Teams will abide by the rules set forth by the FAA.	3.5

Appendix B: PDR Requirements Cross Reference

Summary of PDR		
1	Team Summary	Cover, 1.1
1.1	Team name and mailing address	
1.2	Name of mentor, NAR/TRA number and certification level, and contact information	
2	Launch Vehicle Summary	
2.1	Size and mass	
2.2	Motor Choice	
2.3	Recovery System	
2.4	Milestone Review Flysheet	
3	Payload Summary	
3.1	Payload Title	
3.2	Summarize Payload Experiment	
Changes made since Proposal (1-2 pages maximum)		
1	Highlight all changes made since the proposal and the reasons for those changes	
1.1	Changes made to vehicle criteria	
1.2	Changes made to payload criteria	
1.3	Changes made to project plan	
Vehicle Criteria		
1	Selection, Design and Rationale of Launch Vehicle	
1.1	Include unique mission statement, and mission success criteria	

1.2	Review the design at a system level, going through each system's alternative designs, and evaluating the pros and cons of each alternative	
1.3	For each alternative, present research on why that alternative should or should not be chosen	
1.4	After evaluating all alternatives, present a vehicle design with the current leading alternatives, and explain why they are leading choices	
1.4.1	Describe each subsystem, and the components within those subsystems	
1.4.2	Provide a dimensional drawing using the leading design	
1.4.3		
1.4.4		
Technical Design		
1.	A proposed and detailed approach to rocket and payload design.	4
1.a.	Include general vehicle dimensions, material selection and justification, and construction methods.	4.1
1.b.	Include projected altitude and describe how it was calculated.	4.2
1.c.	Include projected parachute system design.	4.3
1.d.	Include projected motor and brand designation	4.4
1.e.	Include detailed description of the team's projected payload	4.5
1.f.	Address the requirements for the vehicle, recovery system, and payload.	4.6
1.g.	Address major technical challenges and solutions.	4.7
Educational Engagement		
1.	Include plans and evaluation criteria for required educational engagement activities (see requirement 5.5).	5
Project Plan		

1.	Provide a detailed development schedule/timeline covering all aspects necessary to successfully complete the project.	6.1
2.	Provide a detailed budget to cover all aspects necessary to successfully complete the project including team travel to launch.	6.2
3.	Provide a detailed funding plan.	6.3
4.	Develop a clear plan for sustainability of the rocket project in the local area. This plan should include how to provide and maintain established partnerships and regularly engage successive classes of students in rocketry. It should also include partners (industry/community), recruitment of team members, funding sustainability, and educational engagement.	6.4

Appendix C: Testing

Appendix D: Material Safety Data Sheet (MSDS)

MSDS Outline

MSDS is an important document that states the health risks for an item in case an accident happens and the proper procedures that need to be undertaken just in case the health of the affected is at risk.

Appendix D.1 Fiberglass

Product Name(s): Woven Unidirectional Fiberglass Fabric (A-Style Warp Unidirectional), Stitchbonded Fiberglass Fabric, Woven Fiberglass Fabric
Manufacturer: Owens-Corning, World Headquarters, One Owens-Corning Parkway Attn. Product Stewardship, Toledo, OH, 43659, Telephone: 1-419-248-8234 (8am-5pm ET weekdays). OC Fabrics, 1851 S. Sequin Ave., New Braunfels, TX, 78130 Telephone: 1-210-629-4009 (8am-5pm CT weekdays).

Emergency Contacts: Emergencies ONLY (after 5pm ET and weekends): 1-419-248-5330, CHEMTREC (24 hours everyday): 1-800-424-9300, CANUTEC (Canada- 24 hours everyday): 1-613-996-6666. Health and Technical Contacts:
Health Issues Information: (8am-5pm ET):1-419-248-8234, Technical Product Information (8am-5pm ET): 1-800-GET-PINK.

Common Name	Chemical Name	CAS No.	Wt. %
Fiber Glass Continuous Filament (non respirable)	Fibrous Glass	65997-17-3	94-100
Size	Size	None	0-2
Polyester Yarn	Polyester Yarn	None	0-4

Appearance and Odor: White/off-white colored solid with no odor.
Primary Route(s) of Exposure: Inhalation, skin, eye
Potential Health Effects:

- **Acute (short term):** Fiber glass continuous filament is a mechanical irritant. Breathing dusts and fibers may cause short term irritation of the mouth, nose and throat. Skin contact with dust and fibers may cause itching and short term irritation. Eye contact with dust and fibers may cause short term mechanical irritation. Ingestion may cause short term mechanical irritation of the stomach and intestines. See Section 8 for exposure controls.
- **Chronic (long term):** There is no known health effects connected with long term use or contact with this product. See Section 11 of MSDS for more toxicological data.

Medical Conditions Aggravated by Exposure: Long term breathing or skin conditions that are aggravated by mechanical irritants may be at a higher risk for worsening from use or contact with this product.
Inhalation: Move person to fresh air. Seek medical attention if irritation persists.
Eye Contact: Flush eyes with running water for at least 15 minutes. Seek medical attention if irritation persists.
Skin Contact: Wash with mild soap and running water. Use a washcloth to help remove fibers. To avoid more irritation, do not rub or scratch affected areas. Rubbing or scratching may force fibers into skin. Seek medical attention if irritation persists.
Ingestion: Ingestion of this material is unlikely. If it does occur, watch the person for several days to make sure that intestinal blockage does not occur.
Flash Point and Method: None
Flammability Limits (%): None
Auto Ignition Temperature: Not Applicable
Extinguishing Media: Water, foam, CO_2 or dry chemical.
Unusual Fire and Explosion Hazards: None known
Fire Fighting Instructions: Use self contained breathing apparatus (SCBA) in a sustained fire.
Hazardous Combustion Products: Primary combustion products are carbon monoxide, carbon dioxide and water. Other undetermined compounds could be released in small quantities.

Land Spill: Scoop up material and put into suitable container for disposal as a nonhazardous waste.
Water Spill: This material will sink and disperse along the bottom of waterways and ponds. It can not easily be removed after it is waterborne; however, the material is non-hazardous in water. **Air Release:** This material will settle out of the air. If concentrated on land it can then be scooped up for disposal as a non-hazardous waste.
Storage Temperature: Not applicable
Storage Pressure: Not applicable
General: No special storage or handling procedures are required for this material.

Appendix D.2 Black Powder 4F

Hazardous Components

Material or Component	%	CAS no.	TLV	PEL
Potassium Nitrate	70-76	007757-79-1	NE	NE
Sodium Nitrate	70-74	007631-99-4	NE	NE
Charcoal	8-18	N/A	NE	NE
Sulfur	9-20	007704-34-9	NE	NE
Graphite	Trace	007782-42-5	15 mppct (TWA)	2.5 mg/m^3

Physical Data

Boiling Point: N/A
Vapor Pressure: N/A
Vapor Density: N/A
Solubility in Water: Good
Specific Gravity: 1.70 - 1.82 (mercury method) andŠ 1.92 - 2.08 (pycnometer)
pH: 6.0-8.0
Evaporation Rate: N/A
Appearance and Odor: Black granular powder. No odor detectable.

Hazardous Reactivity

Instability: Keep away from heat, sparks, and open flame. Avoid impact, friction, and static electricity.
Incompatibility: When dry, black powder is compatible with most metals; however, it is hygroscopic, and when wet, attracts all common metals except stainless steel. Black powder must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents,

adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials, and other similar materials, situations, and equipment.
Hazardous Decomposition: Detonation produces hazardous overpressures and fragments (if confined). Gases produced may be toxic if exposed in areas with inadequate ventilation.
Polymerization: Will not occur.

Fire and Explosion Data

Flashpoint: N/A
Auto Ignition Temperature: Approximately 464 C (867 F)
Explosive Temperature (5sec): Ignites at approximately 427 C (801 F)
Extinguishing Media: Water
Special Fire Fighting Procedures: ALL EXPLOSIVES: DO NOT FIGHT EXPLOSIVES FIRES. Try to keep fire from reaching explosives. Isolate area. Guard against intruders.

- Division 1.1 Explosives (heavily encased): Evacuate the area for 5000 feet (1 mile) if explosives are heavily encased.
- Division 1.1 Explosives (not heavily encased): Evacuate the area for 2500 feet (½ mile) if explosives are not heavily encased.
- Division 1.1 Explosives (all): Consult the 2000 Emergency Response Guidebook, Guide 112 for further details.

Unusual Fire and Explosion Hazards: Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

Health Hazards

General: Black powder is a Division 1.1 Explosive, and detonation may cause severe physical injury, including death. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced persons in accordance with all applicable federal, state, and local laws, regulations, and ordinances.
Carcinogenicity: None of the components of Black powder are listed as a carcinogen by NTP, IARC, or OSHA.

First Aid

Inhalation: Not a likely route of exposure. If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably by mouth-to-mouth. If breathing is difficult, give oxygen. Seek prompt medical attention.
Eye and Skin Contact: Not a likely route of exposure. Flush eyes with water. Wash skin with soap and water.
Ingestion: Not a likely route of exposure.. If ingested, induce vomiting immediately by giving two glasses of water and sticking finger down throat.
Injury from Detonation: Seek prompt medical attention.

Spill or Leak Procedures

Spill/Leak Response: Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in cleanup procedures. Carefully pick up spills with non-sparking and non-static producing tools.
Waste Disposal: Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with federal

regulations under the authority of the Resource Conservation and Recovery Act (40 CFR Parts 260-271).

Special Protection Information

Ventilation: Use only with adequate ventilation.
Respiratory: None
Eye: None
Gloves: Impervious rubber gloves
Other: Metal-free and non-static producing clothes

Appendix D.3 Ammonium Perchlorate Composite Propellant (APCP)

Product Name: Ammonium Perchlorate
Other/Generic Names: AP, ammonium salt of perchloric acid
Product Use: Analytical chemistry, oxidizer in various propellant or explosive mixtures, various industrial uses involving need for oxidizing or ionization in aqueous solution properties.
Manufacturer: American Pacific Corporation, Western Electrochemical Co. 10622 West 6400 North, Cedar City, UT 84721
For More Information Call: (435) 865-5000
In Case of Emergency Call: (435) 865-5044

Ingredient Name	CAS no.	Einecs no.	Wt. %
Ammonium Perchlorate	7790-98-9	232-235-1	100

OSHA Hazard Communication Standard: This product is considered hazardous under the OSHA Hazard Communication Standard. The stated hazards classifications are applicable to the ammonium perchlorate as manufactured by AMPAC and as delivered in the DOT/UN approved shipping containers. Any rework, modification, amending or additional processing of the ammonium perchlorate may change the hazards classification and may require further hazards classification testing to determine the appropriate classification. AMPAC will not be responsible for personnel or property damage caused by a failure to conduct or provide adequate safe measures needed due to any individual company’s production activities.
Emergency Overview: An odorless white crystal material. Perchlorate is an Oxidizing Agent; there is a risk of explosion if heated under confinement. As with any toxicant, dose and exposure are critically important variables to understand any potential treatment. Harmful if swallowed or inhaled in large doses.
Potential Health Effects:

- **Acute (short term):** Eye contact causes irritation, redness, and tearing. Skin contact causes irritation to mucous membranes and skin. Inhalation may cause respiratory tract irritation such as coughing, and shortness of breath; high concentrations may cause more significant respiratory effects. Ingestion: may cause gastrointestinal irritation; larger doses may cause nausea and vomiting.

- **Chronic (long term):** Perchlorates act to reversibly and competitively inhibit iodine uptake by the thyroid gland. Perchlorate is soluble in water, so exposure to ammonium perchlorate can be via water contaminated with ammonium perchlorate or inhalation in the workplace. With chronic exposure given sufficient dose (see NRC, 2005) and duration, ammonium perchlorate can cause thyroidal stores of iodine to be reduced, which may lead to hypothyroidism. For those individuals that live in areas of the world where endemic iodine deficiency occurs, it is important that these people receive adequate iodine in the diet or are supplemented with iodine.

May be explosive when mixed with combustible material. Risk of explosion if heated under confinement.

Routes of Exposure	Signs and Symptoms of Exposure:	Emergency and First Aid Procedures:
Skin:	May cause local irritation or stinging effect.	Wash exposed area immediately with plenty of water. Remove contaminated clothing and footwear.
Inhalation:	Airborne concentrations of ammonium perchlorate can aggravate pre-existing respiratory problems.	If experiencing breathing difficulties, move to fresh air. Administer oxygen if exposed person is unconscious such as mouth to mouth resuscitation. Never give anything by mouth to an unconscious person.
Ingestion:	Ingestion of large quantities has been reported to cause staggering in small mammals. Chronic ingestion of sufficient quantities may interfere with uptake of iodine by the thyroid.	Give water. Induce vomiting, keep airway clear. Seek medical attention.
Eyes:	Irritation of the eyes will cause stinging effect.	Flush eyes with fresh water for at least 15 minutes and move exposed person to a non-contaminated area.

Flash Point: Not flammable
Flash Point Method: Not applicable
Autoignition Temperature: Not applicable. Ammonium perchlorate decomposes spontaneously at 300o C in its pure state. Contaminants may cause decomposition at lower temperatures

typically down to 2700C but decomposition temperature has been listed as low as 240oC in one case
Upper Flammability Limit (volume % in air): Not applicable.
Lower Flammability Limit (volume % in air): Not applicable.
Extinguishing Media: Water - other extinguishing materials are ineffective
Unusual Fire and Explosion Hazards: Ammonium perchlorate is an oxidizing agent and may cause rapid combustion or explosions if mixed with fuels, including organic materials or powdered metals. This does not include DOT shipping containers if intimate mixtures are not present and the shipping container is not inordinately contaminated. Plastic containers have been observed to burn and leave standing cylinders of ammonium perchlorate. Molten metal from aluminum containers may contribute fuel in an instance hot enough to melt aluminum.
Special Fire Fighting Precautions/Instructions: Do not fight fires involving mixtures of ammonium perchlorate and fuels. Ammonium perchlorate is an oxidizing agent and may cause rapid combustion or explosions if mixed with fuels. Burning ammonium perchlorate may produce chlorine, chlorine dioxide, hydrogen chloride, and oxides of nitrogen as well as mixtures with any other compounds involved in the combustion. These are common by-products of combustion and are likely to be serious health concern; thus, keep upwind or wear self-contained breathing apparatus when attempting to rescue.
In Case of Spill or Other Release: (See section 8 for recommended personal protective equipment.) Sweep up material and containerize. Clean contaminated floor surface with water. Ammonium perchlorate is water soluble; thus, manage water to avoid release into the environment. Dispose of in accordance with local, state, and federal regulations.
Normal Handling: (See section 8 for recommended personal protective equipment.) Avoid contact with skin, eyes and clothing. Avoid breathing dust. Wash thoroughly after handling and follow good personal hygiene and good housekeeping practices. Keep containers closed. Handle in a manner to minimize dusting. Use of containers that meet the requirements to be DOT approved shipping containers which are managed in a manner to inhibit intimate mixtures of the container material with the product is recommended. Materials such as plastic drums, steel drums, flexible intermediate bulk containers, and fiberboard containers approved or constructed to the same specifications as DOT requirements are normally safe. FIBC are normally constructed of plastic materials in which intimate contamination soaked into the plastic is difficult to achieve. If in doubt wet and wash the FIBC and manage the water used to wash in accordance with good environmental principles to avoid contaminating drinking water sources or organic materials more subject to intimate mixtures.
Storage Recommendations: Store away from combustibles and flammables. Keep container closed when not in use. Control static electricity and other ignition sources. Store in dry areas away from sources of extreme heat.
Special Mixing and Handling Instructions: Ground and bond process equipment. Mixing ammonium perchlorate with fuels of any type may result in rapid combustion or explosions. When handling materials contaminated with ammonium perchlorate such as dust collector bags or any other combustible material, thoroughly wet the bags with water before handling, keep the bags wet while handling, and use non-sparking tools or tools coated with non-sparking material if non-sparking tools are not available. AVOID friction, impact, or static electricity ignition sources when organic materials are contaminated with ammonium perchlorate. Fire resistant

fabrics do not reduce the hazard. Finely powdered metals are frequently as combustible with ammonium perchlorate as are organics.

Engineering Controls: Ventilate as necessary to minimize dust exposures. Inspect and clean ventilation systems regularly.

Personal Protective Equipment Skin Protection: Wear impervious aprons or rain gear to reduce contamination of cotton or other fiber clothing. Plastic, rubber or latex gloves are recommended. Leather or cotton gloves should not be used unless a management program is implemented to ensure detection of contamination and immediate cleaning and change in case of contamination. Cotton clothing may be used if chance of contact is minimal or if clothing is monitored for contamination and changed if contamination occurs. In any case where combustible protection is used, a strong management system must be in place to monitor contamination and ensure appropriate removal and cleaning or severe risk of fire and personal injury or death exists. There are no known cloth materials that will not combust vigorously with perchlorates including nomex, Kevlar based materials, or clothing that is normally considered fire retardant or resistive. Observation and management of contamination is the only practicable safety measure. See additional recommendations below.

- **Eye Protection:** Under normal conditions, wear safety glasses. Under dusty conditions, wear chemical safety goggles.
- **Respiratory Protection:** Under normal conditions, not required. Where dusty conditions develop, use a NIOSH approved respirator for dusts.
- **Additional Recommendations:** Avoid contamination of cotton or other absorbent material. As in any industrial working environment, workers should routinely wear clean clothes to work. Do not wear any work clothing that has become contaminated with ammonium perchlorate. Remove contaminated clothing immediately and keep wet until thoroughly washed. Keeping contaminated clothing wet minimizes hazards until the laundering is completed. Showering is recommended after handling any industrial chemical. Smoking of tobacco should not be permitted while wearing contaminated clothing. Leather boots may become contaminated and could be a source of combustion damaging feet. Rubber boots are recommended unless a very strict management program to detect contaminated leather boots is in place much as listed on the glove section above.

Appearance: White Crystal	**Physical State:** Solid	**Molecular Weight:** 117.50	**Chemical Formula:** NH4ClO4	**Odor:** None
Specific Gravity (water = 1.0): 1.95	**Solubility in Water (weight %):** 20.8 g/100 ml at 20 C	**pH:** Materials is a solid however, dissolved in water the pH is slightly acidic	**Boiling Point:** None, rather it decomposes	**Melting Point:** Decomposes at 300 C in its pure state, impurities may lower the decomposition temperature significantly.
Vapor Pressure: Solid, none	**Vapor Density (air =**	**Evaporation Rate:** None		

	1.0): At 20 C, None			
Flash Point: Not flammable				

Normally Stable (Conditions To Avoid): Stable under normal conditions. Do not mix with organic materials, reducing agents, metal powders or powdered carbon. Avoid elevated temperatures over 270°C, which can cause spontaneous exothermic decomposition. Cloth fabric of any type including dust collector bags intimately contaminated with ammonium perchlorate is subject to ignition through friction or impact. High-energy static electricity may also serve as an ignition source when contamination or combustibles are intermixed.
Incompatibilities: Sulfuric acid, powdered metals, and intimate mixtures with organics.
Hazardous Decomposition Products: Chlorine, chlorine dioxide, oxygen, nitrogen oxides, hydrogen chloride.
Hazardous Polymerization: Will not occur.
As with any toxicant, dose and exposure are critically important variables to understand any potential toxicity. It is always advisable to minimize dusting and use respiratory protection for environments where substantial dust is generated or where there may be exposure to water with high concentrations of perchlorate. Ammonium perchlorate acts to reversibly and competitively inhibit iodine uptake by the thyroid gland. The half-life of ammonium perchlorate ranges from 8 to 12 hours. Ammonium perchlorate does not bioaccumulate. Perchlorate is not metabolized and is excreted from the kidneys. Harmful if swallowed or inhaled in large doses. In the early 1960s another salt of perchlorate, potassium perchlorate, given in very high doses for weeks of exposure as an oral therapeutic agent to treat hyperthyroidism was reported to be associated with a few cases of aplastic anemia and agranulocytosis (National Research Council, 2005). Since that time, there have been no known reports of aplastic anemia. There have been no reports of ammonium perchlorate associated with aplastic anemia or agranulocytosis.
Immediate (Acute) Effects: Oral LD50: rat; 4200 mg/kg Rat-par-LDLo = 3500 mg/kg Oral LD50: rabbit; 1900 mg/kg Rabbit-par-LDLo = 750 mg/kg Inhalation LC50: No references found. Skin sensitization: not reported to be a skin sensitizer
Delayed (Subchronic And Chronic) Effects:

- **Thyroid:** No long-term health effects have been reported with exposure to ammonium perchlorate. Perchlorate is water soluble, so exposure to ammonium perchlorate can be via water contaminated with ammonium perchlorate or inhalation in the workplace. With chronic exposure, sufficient dose, and duration, ammonium perchlorate may cause thyroidal stores of iodine to be reduced, which may lead to goiter (enlarged thyroid gland) and hypothyroidism. Occupational studies indicated no adverse health effects on workers exposed for 3 years or more to perchlorate. These studies also demonstrate that blood chemistry and hormone values are not altered with occupational exposures as high as 0.48 mg per kilogram body weight (Braverman et al., 2005; Lamm et al., 1999). In 2005, a National Academies of Science Committee reviewed the literature and oral exposures to perchlorate and identified a no-observable-adverse-effect-level 0.4 mg/kg/day in humans. That dose is inhibits iodide uptake by nearly 70 percent without effecting thyroid hormones or thyroid stimulating hormone. The NAS also identified a no-observed-effect-level of 0.007 mg/kg/day in humans, based on Greer, et. al. 2002, which is a dose that does not cause inhibition of iodide uptake. For those individuals that live in areas of the world where endemic iodine deficiency occurs, it is important that these people receive adequate iodine in the diet or are supplemented with iodine.

Appendix E: Partners in Industry

Dr. James Martin
Dr. Martin holds degrees from West Virginia University, Massachusetts Institute of Technology, and George Washington University. He has worked at the NASA Langley Research Center, The University of Alabama, and Boeing. His work has mostly involved the design and evaluation of reusable launch vehicles. Some recent work has been on crew escape for the Shuttle, the Space Launch Initiative, and a robotic lander on the moon. Dr. Martin retired from Boeing when the Launch vehicle business was sold. He continues to be active in aerospace doing consulting, as an Associate Editor for AIAA J. Spacecraft and Rockets, and as Chair of the local AIAA Orange County Section.

Jonathan Mack (Electrical Engineer and Programmer)
Jonathan graduated with a Bachelor of Science from Long Beach State. Currently he is an electronics design engineer involved in hardware and software development including diverse fields such as toys, audio, and currently printing. He has led a 4H project in mechanical, electrical and software design areas in robotics. At home his hobbies mainly focus on improving

DIY (Do It Yourself) knowledge, including everything from mad science projects to more mundane things like welding and cooking (usually not at the same time.)

Guy Heaton (Mechanical Engineer)
Guy graduated with a Bachelor of Science from Pepperdine University. Currently he is a Senior Mechanical Engineer and has been working on printing solutions for 12 years. Responsibilities include designing for injection and blow molding and extrusions. He also does mechanical systems, drive trains, cabling, durability testing, and sheet metal design. When not designing new printers he does manufacturing time analysis, line balancing, and documentation.

Mike Stoop (Fiberglassing, Programming, Design)
Mike Stoop is currently the CTO of PriceDoc, Inc, a healthcare related web services company. Mike has been in the software industry for 30 years and an avid rocketeer for 40 years. Mike achieved his level 3 certification in 2002 and has participated in many individual and team 'M" class and above rocket projects. He has launched K and larger engines with electronic dual deploy many more than 15 times. Mike is also the owner of Madcow Rocketry, a mid/high power rocket kit manufacturer.

Drew, SpaceX (Fiberglassing, Programming, Design)
Mr. Drew Beckett holds BS and MS degrees in aerospace engineering from the Dwight Look College of Engineering at Texas A&M University at College Station. Mr. Beckett developed and operated unmanned aircraft technology demonstrators for the Texas A&M Flight Mechanics Laboratory (later Unmanned Flight Laboratory) while employed by the Texas Engineering Experiment Station. More recently, Mr. Beckett has been in the employ of Space Exploration Technologies where he is responsible for the inertial guidance, navigation, and control sensors for the Falcon 9 launch vehicle and Dragon spacecraft as well as navigating Dragon on-orbit as a mission operator.