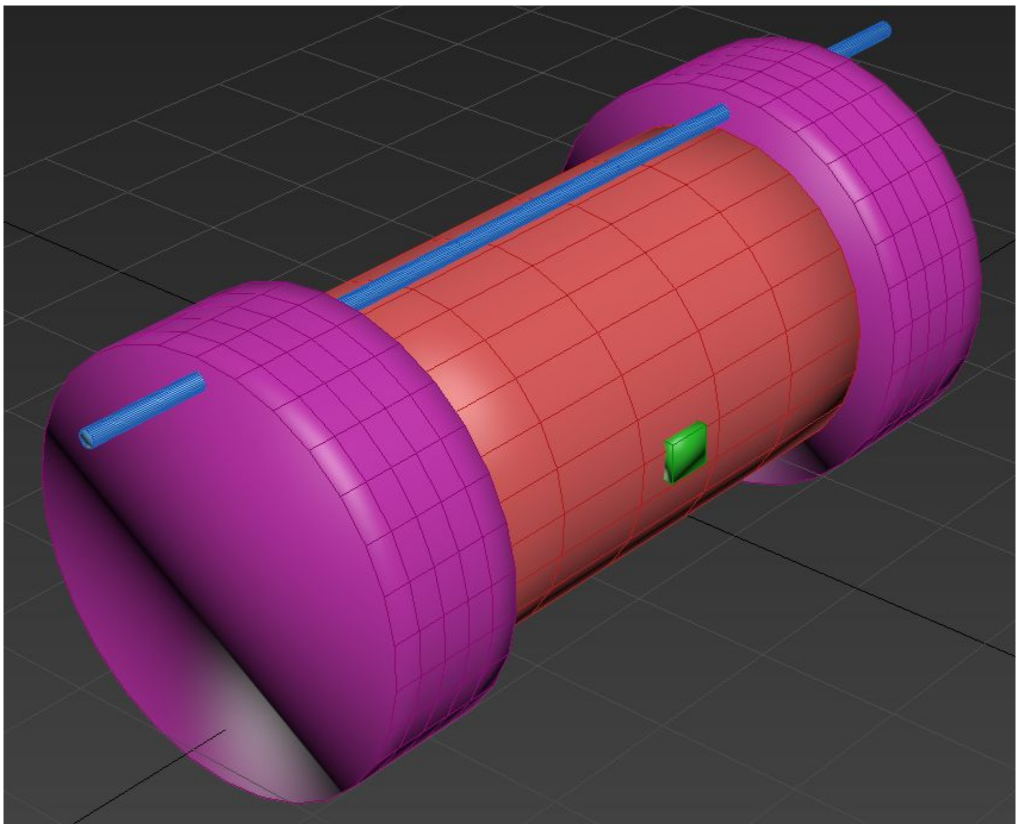
Student Launch Proposal

Rover: Ground Vehicle with On-Board Camera



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AIAA OC Section

September 19, 2018

Brenda (Project Manager)
Aaron, Adelle, Catherine, Elsa, Ekas, Eric, Hugo, Joseph, Julius, Shelly

Table of Contents

1 Organization Information

1.1 AIAA Information

The American Institute of Aeronautics and Astronautics is the professional society for the field of Aerospace Engineering

1.2 Name, Title, and Contact Information for Two Adult Educators

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

Robert has been co-leading TARC teams for ten years and previously did 4H rocketry projects for 13 years; he holds a NAR Level 2 certification. He has a BS degree in Electrical Engineering from USC and has worked as an electronics designer, programmer, and a director of the software department doing embedded programming for thermal printers. Robert worked on the F-20 Tigershark while at Northrop and now spends much of his time engaging students in STEM through rocketry, amateur radio, and ARISS (Amateur Radio on the International Space Station). 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, 4H, and through the AIAA OC Section Educational Outreach.

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 ten years and previously did 4-H rocketry projects for 11 years; she holds a NAR Level 2 certification. 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 30 years with her husband children and grandchildren. Jann is the AIAA OC Section Council member in charge of K-12 education. She has also led 4-H projects in livestock including lambs, goats, and beef. She now spends much of her time engaging students in STEM related projects including rocketry and ARISS through the AIAA OC Section.

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

1.3 Name, Title, and Contact Information of Student Team Leader

Brenda Chen, Student Team Leader
Email: verticalprojectile.rocket@gmail.com

1.4 Name and Title of Safety Officer

Hugo Zhan, Range Safety Officer

1.5 Student Information and Responsibilities

All team members for the Vertical Projectile 2018-2019 team are listed below. All members will be responsible for completing all assignments (such as documentation, presentation, design, construction, and launching). Mentors and advisors will be there only for guidance.

1.5.1 Brenda C. (Student Team Leader)

Brenda is a senior at Woodbridge High School in Irvine, California. This is her third year on the Vertical Projectile team and her first year as captain in continuation of the Vertical Projectile name. She has also participated in TARC for two years previous to becoming the student team leader. She will be enrolled in AP Physics, AP Calculus, AP Economics, and Marching Band this school year.

Brenda will be responsible for the following:

- Maintain regular meetings
- Ensure deliverables are submitted in a timely manner
- Organize project timeline
- Launch Vehicle Management
- Radio License
- Budget Maintenance
- Full Scale and Subscale Design and Construction

1.5.2 Adelle Wang (Co-Captain)

Adelle is a junior at Santa Margarita Catholic High School in Rancho Santa Margarita, California. She is 16 years old and captained a TARC team in the past year. Her interests include medicine, physics, music, and writing. She is a full IB student at SM, has taken the AP Comp Sci A test, and will be enrolled in AP Physics, Calculus BC, and Marching Band in the coming school year.

Adelle will be responsible for the following:

- Full Scale and Subscale Design and Construction
- Outreach Management
- Launch Vehicle Management
- Maintenance of Fast and Efficient Meetings

1.5.3 Hugo Z. (Safety Officer)

Hugo is a senior currently attending Northwood High School. He has a year of experience and captained in TARC rocketry and is interested in math, engineering, and computer science. He has taken AP classes in STEM fields such as Physics, Chemistry, Computer Science, Calculus, etc. He enjoys playing sports and video games in his spare time.

Hugo will be responsible for the following:

- Student RSO
    - Ensure overall safety
    - Ensure performance of all tests
- Payload Maintenance

1.5.4 Ekas C.

Ekas is currently a junior at Northwood High School in Irvine, California. Having been the captain of a TARC team in the past, he joined Student Launch to learn more about programming and enhance his knowledge of rocketry. In addition to rocketry, Ekas is an avid Lincoln Douglas debate-er and competes on the national circuit.

Ekas will be responsible for the following:

- Avionics/Recovery
- Coding of the Avionics/Recovery system

1.5.5 Catherine Cui

Catherine will be responsible for the following:

- Payload Maintenance

1.5.6 Aaron L.

Aaron is a senior at Woodbridge High School in Irvine, California. He has experience using Solidworks and MATlab with OpenEMS, and is interested in the flight dynamics of aircraft and rockets. He has also taken AP tests, such as Physics 1 and C(Mechanics and E/M), as well as Calculus BC, and Chemistry. He is also a member of the Woodbridge High School Mu Alpha Theta team.

Aaron will be responsible for the following:

- Air Brake Maintenance

1.5.7 Eric W.

Eric is an oncoming junior at Crean Lutheran High School in Irvine, California. He just got started with TARC last year and is very interested in rocketry. His fields of interest include math, chemistry, and engineering. He is also a competitive chess player and likes to play board games.

Eric will be responsible for the following:

- Kinetic Energy Calculations
- Energetics Calculations

- Drift Calculations
- CAD drawings and design
- Payload Maintenance

1.5.9 Elsa X.

Elsa will be responsible for the following:

- Rover Release Mechanism

1.5.10 Joseph Y.

Joseph is a student from Laguna Beach High School. He is 17 years old and he is going to be a senior next year. He likes physics and engineering. He used to attended TARC before this project. Also, he is good at coding. He likes to play with arduino and make some device that interesting.

Joseph will be responsible for the following:

- Coding of the Air Brake System
- Payload Maintenance

1.5.11 Shelly Z.

Shelly is a junior at Santa Margarita Catholic High School in Rancho Santa Margarita, California. Her interests include art, music, and chemistry. She participates in marching band and NSDA debate tournaments, and spends most of her spare time doing fine arts, graphic design, and digital design.

Shelly will be responsible for the following:

- Maintenance of the team website
- Visual designs for the rocket, team spirit wear
- Diagrams and Designs as necessary
- Rocket Construction

1.6 NAR/TRA Section for Launch Assistance, Mentoring, Reviewing

AIAA OC Section rocketry is under NAR Section #718. Launches are conducted at Lucerne Dry Lake, located in the Mojave Desert near Lucerne Valley, CA. The Rocketry Organization of California (ROC), which is under NAR Section #538, holds monthly launches around the second Saturday of each month. Many ROC members hold NAR level 1-3 certifications, including AIAA OC Section mentors Bob and Jann Koepke. Mentors Bob and Jann have been members of ROC for many years and have attended multiple launches over the past years. ROC willingly provides mentoring and review assistance to those who ask. Additionally, ROC has an DAA waiver allowing flights up to 7000’ AGL and in-call windows available to 19000’ AGL at their launches. Their website can be found at rocstock.org.

2 Facilities and Equipment

2.1 Description of Facilities

The facility we have for building our rockets and do research is at Areteem. Areteem provided classrooms and whiteboards for us to plan our designs and efficiently make our rockets. The team has or will have 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
- Bent Tweezers
- Exact-o 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 are Jane Koepke, Bob Koepke are also present at IvyMax and the Koepke's workshop to offer advice and answer any of the team members' questions.

2.3 Equipment

2.3.1 Computer Hardware

Each team member brought in a laptop in order to research during our weekly meetings.

2.3.2 Computer Software

2.3.2.1 Google Drive

In order to simultaneously work on our proposals, as a group we used Google Drive to track progress and make edits on our document.

2.3.2.2 Apogee RockSim

This is a CAD program that was used to design and create our rocket. It played a major factor in determining what materials to use, where to place certain parts of our rocket and also how to make sure our rocket was balanced and that the center of gravity was in the correct place.

2.3.3 Tools for Construction of Rocket

All large tools will be provided by the mentors to use and the team will enforce supervision and caution when using said tools (i.e. large drills, sanding machines, etc.)

Other tools include items such as hacksaws, epoxy, hand drills, rulers, etc., all of which will be provided to the team together. Caution will also be taken when handling these tools.

3 Safety Plan

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.

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

Hugo 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 yellow columns are not necessarily dangerous but warrant steady caution.

3.1.4.1 Vehicle Hazards

Possible Hazards/Accidents	Mitigations
The engine fails to ignite when launching the rocket.	Team members will make sure that the igniter is inserted into the engine completely, securing the connection between the engine and the igniter.
The engine is too loose or tight for the motor casing.	Team members will make sure the motor casing matches the corresponding engine size and that the motor casing fits into the motor mount without being too loose or too tight.
The air brakes don't function in flight.	Electronics will be activated at ground level for a test of the air brakes functions. Before the assembly of the whole rocket, the motor for the air brakes will be checked for its functions.
The rocket body bends inward on itself.	The materials used for the body tubes is fiberglass, which can stand against considerable amounts of outside forces. The flight boards, bulkheads, and centering rings on the inside of the body tubes will also support the circular structure of the body tube.
The quick links are not attached securely.	Team members will ensure that all connections between the body tubes and other parts of the rocket are assembled correctly before launching. A checklist will be written for the above tasks, members will be checking and signing off each of the tasks when completed.
The ejection charge does not have enough force to shear the shear pins.	The force required to shear the pins will be accurately noted when they are purchased. Black powder ground tests will be performed to make sure that the force provided from the ejections charges exceeds the force that the pin can withstand. To further make sure that the pin will shear, the backup charge will provide a greater force.

The electronic matches move outside of their specified area.	Team members will make sure that the matches are tightened in their specified area before attaching the shear pins. This task will be placed on the pre-launch checklist.
The motor explodes.	As a high school team, we are not allowed to build the motor and the construction of said motor will be done by a certified individual. The team will ensure that while the motor is in our hands, assuming that it has been assembled correctly, the motor will not be damaged nor will we alter the motor in a way that could cause a malfunction.
Parachute does not deploy because of packing issues.	Team members will check that the parachute is packed correctly into the body tube before launch and make sure the ejection charges will separate the body tubes when parachute is ready to deploy via black powder tests.

3.1.4.2 Payload Hazards

Possible Hazards/Accidents	Mitigations
The camera malfunctions.	Team members will make sure the camera is turned on and functions correctly before the launch.
Batteries are not fully charged.	Team members will make sure to charge battery to max capacity before launch
Batteries fail.	Before launch, team members will use a voltmeter to check if the battery is functional and fully charged.
Payload doesn’t deploy	Before launch, the release mechanism of the sabot will be checked by team members to see if the payload can be released.
The wheels don’t move.	The payload will be tested by team members before the launch to see if the wheels can spin freely and move the rover on ground.
Payload deploys early due to loose sabot.	Team members will make sure that the sabot is not damaged or loose before the launch to ensure the rover doesn't drop from the rocket.

3.1.4.3 Recovery Hazards

Possible Hazards/ Accidents	Mitigations
The backup charges do not go off.	Team members will check if the RRC3 is beeping in the sequence that is shown on the manual.
The backup electronics batteries disconnect.	Battery holders and zip ties will be used to secure the battery in its position. The sturdiness of the battery holder and zip ties will be check before every launch by team members.
The backup RRC3 flight computers are shut down.	Team members will check if the flight computers are beeping and and signing their names on the checklist.
The drogue chute deployed at the incorrect altitude.	Team members will check that RRC3 and the Stratologger are both beeping in their respective sequences as shown on their manuals.
The airbrakes not closing during descent and influencing the recovery.	Team members will upload the most recent code from the computer to the arduino and check if the arduino's respective LED light is blinking.
The drogue chute doesn't deploy.	Team members will make sure the electronics are turned on and check if they are beeping, and members who checked will sign on the checklist. The backup ejection charge can also resolve this issue.
The main chute doesn't deploy.	Solutions include both the backup Flight Computer and the backup ejection charges.
The Stratologger CF Flight Computer is shut down.	Team members will check the Stratologger is beeping in its respective sequence as shown on the manuals, they will sign their names on the checklist after.
The main battery disconnect.	Brand new batteries will be used, and a test will be contacted right before the launch to see if all of the electronics can be powered up correctly.

3.1.5 Risks to Project Completion

Risk	Mitigation

A team member is out sick or busy handling personal matters	Divide duties accordingly
A launch severely damages a launch vehicle prior to PDR, CDR, or FRR submission	Follow all safety checklists with a special emphasis on recovery and motor loading
Deliverables are not delivered on time	Strictly follow a well-thought-out timeline and create documents accordingly.

3.2 NAR and TRA Safety Rule Summary and Compliance

Rules (NAR/TRA means the combination of two rules)	**SL Team Compliance**
Certification NAR: Person(s) will only possess and fly high power motors in the area of certification and also require licensing. TRA: The person who is a certified flyer shall operate and fly a high power rocket.	Only the team mentor with at least Level 2 certification will purchase, possess, and load the high power rocket.
Materials NAR/TRA: Only light material, such as cardboard, fiberglass, with some wood, paper, and plastic, are allowed to fabricate cases, front, or nozzles.	Team members will only use cardboard, fiberglass, with some wood, paper, and plastic as required for the rocket, and team members will not use steel to fabricate cases, front, or nozzles.
Motors 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: All most same as NAR rules; however, TRA rules want team members use the motor with following the purpose of the manufacturer.	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. The motor that is anticipated is the CTI K1085 motor. It falls within the NAR requirements for high school teams building high powered rockets.
Ignition System NAR/TRA: Rockets will be launched with an electrical launch system, and with electrical motor igniters that are installed in the motor only after the rocket is at the launch pad or in a designated prepping area. The launch system will have a	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.

safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.Also, the ignitor should be remotely controlled.	
Misfire NAR: If the rocket does not launch when the button of electrical launch system is pressed, the operator need to remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket. TRA: Do not approach the rocket until the RSO/LCO give the permission.	Team members will remove the launcher's safety interlock or disconnect its battery when the rocket misfire, and not approach the rocket until the RSO/LCO gives permission. If there are not RSO/LCO, team members will wait for at 2 mins to let anyone approach the rocket.
Launch Safety 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 there to warn participants and spectators. Before the rocket is launched, it will not fly if stability cannot be determined. TRA: The person who flys 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.	Team members will make sure there are no any other people in the launch area both before, during, and after launching, amd follow all the rules of NAR. Also, team members will only launch the rocket in the area that Safety Officer will be aware of.
Launcher NAR/TRA: 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	The stable launcher will be guaranteed via rail guide of either an 8 foot 1010 rail or a 12 foot 1515 rail. Team members will install a jet or blast deflector device to prevent the flammable material touch the motor exhaust directly. Team members will check the wind speed and correct the angle before launching the rocket. In windy conditions, the RSO 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.

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. Then there should be a jet or blast deflector device in the rocket to prevent the flammable material touch the motor exhaust directly.	
Size NAR: The rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. The rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor 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.	The total Ns for all the motors is about 2329.9 Ns and therefore complies with the NAR requirement of not exceeding 40960 Ns of total impulse. (I need to know the actual or proposed size of our rocket)
Flight Safety 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. There are no flammable payload allowed on the rocket. No rockets are allowed to be launch if the wind speed in 20 mph or faster. The person who launch the rocket need to 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	Team members will check the wind speed and correct the angle before launching the rocket. If the wind speed is over 20 mph, the launch process will be stopped. And ROC Association has obtained all permissions with state laws to launch at Lucerne Dry Lake.

Launch Site NAR/TRA: The launch site should outdoors, in an open area where trees, power lines, buildings, and people not involved in the 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. And the launcher are not allowed to be located 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.	Lucerne Dry Lake is the designated launch site and is located in the Mojave Desert in Southern California. As a dry lake bed, there is no structure within miles of the radius of the lakebed, such as trees, power lines, or buildings.
Launcher Location NAR/TRA: 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.The launcher will not be closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site. The person(s) who set the rocket need to 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.	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
Recovery System 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. 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.	A drogue parachute and normal parachutes will safely bring down the rocket in multiple sections that will be tethered together. 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	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

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: Nobody should attempt to catch a high power rocket as it approaches the ground. No one should retrieve a high power rocket from a place that is hazardous to people.	rule of not recovering the rocket in bad situations or catching the rocket prior to landing.

3.2.1 Hazardous Material Handling and Hazardous Operations

Hazardous Materials	**Compliance**
Metal.	Team members will only use cardboard, fiberglass, with some wood, paper, and plastic as required for the rocket, and team members will not use steel to fabricate cases, front, or nozzles.
Flammable materials such as paper, cardboard, wood.	Team members will install a jet or blast deflector device to prevent the flammable material touch the motor exhaust directly.
Frangible materials such as plastic, glass.	Team members will not use glass or other frangible materials to fabricate cases, front, or nozzles.
Hazardous Operations	**Compliance**
Launch with surface winds greater than 20 mph or launch a rocket at an angle more than 20 degrees from vertical.	Team members will check the wind speed and correct the angle before launching the rocket.
Launch the rocket horizontally, at the target, during a aircraft pass through, in to the cloud, or beyond the boundaries of the flying field	Both team members and mentors will make sure the rocket launch vertically, and make sure there are no aircraft in the launch area before launch.
Launch the rocket while other groups are installing the rocket on the launch pad.	Team members will make sure there are no any other people in the launch area both before, during, and after launching.
No one hear the announcement before the launch.	Team members will raise their voice to make sure everyone will hear the announcement.
Approach a high power rocket that has misfired	Team members will not approach a high power

without the permission of RSO/LCO.	rocket that has misfired.
Refuse to follow the instruction of RSO/LCO.	RSO/LCO may refuse to allow the launch or static testing of any rocket motor or rocket that he/she deems to be unsafe. Team members will follow RSO/LCO's command.

3.3 Student Briefing

3.3.1 Hazard Recognition and Accident Avoidance

Listed are some of the threats to team members' safety that must be accounted for:

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

3.3.2 Pre-Launch Checklist

The checklist will be finalized by the FRR.

A checklist will be created by our team to prepare for launch. The team will be guided by the checklist to perform safety checks and preparations before launch.

- Preparation for launch and assurance that all safety interlock switches are off and batteries uninstalled.
    - The safety interlock switches will be verified as "OFF" and batteries for the recovery electronics will be installed.
- The battery for the GPSs and payload will be installed but will remain off.
    - The Whistle GPS will be placed in a foam cutout and secured to the shock cord. The parachutes will both be located in the sustainer section of the rocket, with the drogue

parachute packed first and the main parachute. The payload will be turned on throughout the entire flight, and since there is no telemetry but rather an SD card to store the payload data, the SD card will start recording the moment the Arduino's battery is turned on in the ground.

- Four ejection charges will be prepared and installed (1 for the drogue and 1 for the main for each of the redundant and backup electronics).
    - The two ejection charges for the main will be in two separate capsules (created by the mentor) and will be in series. The shear pins can be put into place holding the vehicle sections above and below the avionics bay. The GPS device for the upper section will also be encased in a foam cut out and secured to the shock cord. The rocket can then be placed on the pad (standard launch rail), electronics armed, igniter installed and connected to the electronics launch system. It is necessary only to apply power to the igniter for the launch. The total time should take less than 2 hours.
- Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.
    - There will be shear pins (2mm nylon screws) at all separation points. The shear pins will keep all points of separation attached while the rocket is moving upwards, and this is mainly to make sure that the rocket does not separate before necessary. The primary and backup ejection charges will have enough force to break through the shear pins, ensuring that the main and drogue parachutes deploy.

Vehicle Hazards

Possible Hazards/Accidents	Mitigations
The engine fails to ignite when launching the rocket.	Team members will make sure that the igniter is inserted into the engine completely, securing the connection between the engine and the igniter.
The engine is too loose or tight for the motor casing.	Team members will make sure the motor casing matches the corresponding engine size and that the motor casing fits into the motor mount without being too loose or too tight.
The air brakes don't function in flight.	Electronics will be activated at ground level for a test of the air brakes functions. Before the assembly of the whole rocket, the motor for the air brakes will be checked for its functions.
The rocket body bends inward on itself.	The materials used for the body tubes is fiberglass, which can stand against considerable amounts of outside forces. The flight boards, bulkheads, and centering rings on the inside of the body tubes will also support the circular structure of the body tube.
The quick links are not attached securely.	Team members will ensure that all connections between the body tubes and other parts of the rocket are assembled correctly before launching.

	A checklist will be written for the above tasks, members will be checking and signing off each of the tasks when completed.
The ejection charge does not have enough force to shear the shear pins.	The force required to shear the pins will be accurately noted when they are purchased. Black powder ground tests will be performed to make sure that the force provided from the ejections charges exceeds the force that the pin can withstand. To further make sure that the pin will shear, the backup charge will provide a greater force.
The electronic matches move outside of their specified area.	Team members will make sure that the matches are tightened in their specified area before attaching the shear pins. This task will be placed on the pre-launch checklist.
The motor explodes.	As a high school team, we are not allowed to build the motor and the construction of said motor will be done by a certified individual. The team will ensure that while the motor is in our hands, assuming that it has been assembled correctly, the motor will not be damaged nor will we alter the motor in a way that could cause a malfunction.
Parachute does not deploy because of packing issues.	Team members will check that the parachute is packed correctly into the body tube before launch and make sure the ejection charges will separate the body tubes when parachute is ready to deploy via black powder tests.

Payload Hazards

Possible Hazards/Accidents	Mitigations
Batteries are not fully charged.	Team members will make sure to charge battery to max capacity before launch
Batteries fail.	Before launch, team members will use a voltmeter to check if the battery is functional and fully charged.
Payload doesn’t deploy	Before launch, the release mechanism of the sabot will be checked by team members to see if the payload can be released.

The wheels don’t move.	The payload will be tested by team members before the launch to see if the wheels can spin freely and move the rover on ground.
The camera malfunctions.	Team members will make sure the camera is turned on and functions correctly before the launch.
Payload deploys early due to loose sabot.	Team members will make sure that the sabot is not damaged or loose before the launch to ensure the rover doesn't drop from the rocket.

Recovery Hazards

Possible Hazards/ Accidents	Mitigations
The backup charges do not go off.	Team members will check if the RRC3 is beeping in the sequence that is shown on the manual.
The backup electronics batteries disconnect.	Battery holders and zip ties will be used to secure the battery in its position. The sturdiness of the battery holder and zip ties will be check before every launch by team members.
The backup RRC3 flight computers are shut down.	Team members will check if the flight computers are beeping and and signing their names on the checklist.
The drogue chute deployed at the incorrect altitude.	Team members will check that RRC3 and the Stratologger are both beeping in their respective sequences as shown on their manuals.
The airbrakes not closing during descent and influencing the recovery.	Team members will upload the most recent code from the computer to the arduino and check if the arduino’s respective LED light is blinking.
The drogue chute doesn't deploy.	Team members will make sure the electronics are turned on and check if they are beeping, and members who checked will sign on the checklist. The backup ejection charge can also resolve this issue.
The main chute doesn't deploy.	Solutions include both the backup Flight Computer and the backup ejection charges.
The Stratologger CF Flight Computer is shut down.	Team members will check the Stratologger is beeping in its respective sequence as shown on the

	manuals, they will sign their names on the checklist after.
The main battery disconnect.	Brand new batteries will be used, and a test will be contacted right before the launch to see if all of the electronics can be powered up correctly.

3.4 Hazardous Material Safety

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

In the process of completing the launch vehicle, team members will at times come into contact with hazardous materials. In order to mitigate the dangers posed by these hazardous materials, the below rules must be followed. These materials include, but are not limited to, adhesives, paints, and the materials used in the construction of the vehicle. The manufacturers of these materials have the best understanding regarding the potential hazards, and they publish MSDS for each product.

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

An MSDS (Material Safety Data Sheet) provides an overview explaining how to work safely with and handle certain potentially hazardous chemicals or materials. It is compiled by the manufacturer of the particular material in question. Although MSDS do not have a particular format, they are required to have certain information by OSHA (Occupational Safety and Health Administration) 29 CFR 1910.1200. A list of the required information can be found here:

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

3.4.1 Proper Use of Personal Protective Equipment (PPE)

The team will keep a copy of the MSDS for all materials used in the making of the vehicle so long as an MSDS exists for a certain material. The following safety 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 (for example at the Lucerne Dry Lake launch site)
- Chemical splashes when using paints, solvents, or adhesives
- Objects thrown (intentionally or inadvertently) or swinging into and impacting 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, thinners, or dangerous solid materials.
- Leather gloves to protect against impact, cuts, or abrasions (e.g. in the use of 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, thinners, 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 (ear plugs or ear muffs) must be worn whenever there are dangerously loud noises present, which include:

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

Documents regarding activities that involve working with potentially hazardous materials will be marked with the following:

“HAZARDOUS MATERIAL - SEE MSDS”

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

3.5 Compliance with Federal, State, and Local Laws

The Student Launch team will comply with certain federal, state, and local laws to ensure the legality of this project

3.5.1 Compliance with Use of Airspace: Federal Aviation Regulations 14

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 Cesaroni K1085 which has a propellant mass of 1199g.
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. His information is listed in section 1.2.1 Robert Koepke

3.5.2 Compliance with Code of Federal Regulation 27 Part 555: 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 Compliance with Fire Prevention: NFPA 1127

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 Plan for NRA/TRA Mentor Purchase, Store, Transport, and Use of Motors and Energetics

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.

The team will not be handling the motor until the very last step where the team is on the launch site and ready to load up the rocket. The team mentor will be handling and storing the motor, up until the previously stated moment. From then on, the mentor will continue to keep an eye on the team while it is being loaded.

3.6.2 Energetics

Black powder will be kept in a locked ammo box in its original container. The container 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.

The students on the team will not be storing the black powder themselves. When black powder is needed, students will not be handling the black powder until it is secure and ready to be put through testing or loaded into the rocket for flight. Members will wear clothing that doesn't encourage static when working with black powder or around black powder.

3.7 Written Statement from Team Members Regarding Safety

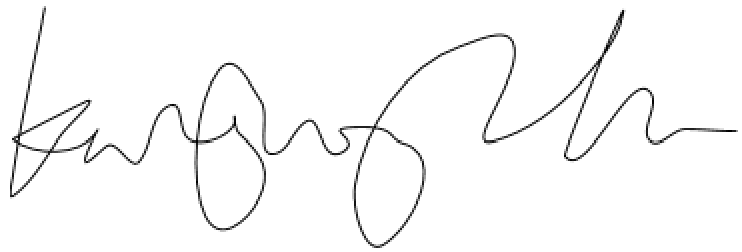
All members that have signed below have agreed to and read the NAR Model Rocket Safety Code:

- Safety Inspections are required to be conducted on each rocket before flight. The team will comply with the Range Safety Officer (RSO) and his/her determination of the safety of the rocket
- The RSO has final say and has the right to deny the team a launch
- The team mentor(s) are responsible for the safe flight and recovery of the rocket. The team will not fly a rocket until the mentor(s) have reviewed and approved the design and determined that it meets the established design and safety guidelines for rockets.
- "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."

- The team will comply with safety requirements or the team will be removed and will not launch the rocket.

Date	Name	Signature
9/16	Brenda Chen	
9/16	Ekas Chawla	
9/16	Catherine Cui	
9/16	Aaron Luo	
9/16	Adelle Wang	
9/16	Eric Wei	Eric
9/16	Elsa Wu	

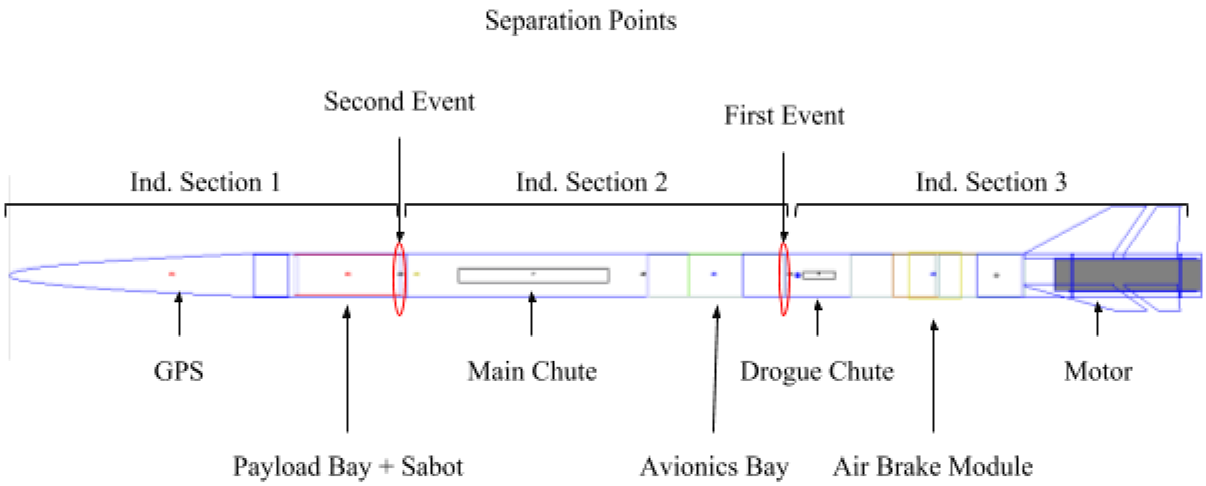
9/16	Joseph You	
9/16	Hugo Zhan	
9/16	Shelly Zhao	

4 Technical Design

4.1 Proposed Rocket and Payload Design

4.1.1 General Vehicle Dimensions, Material Selection, Justification, and Construction Methods

4.1.1.1 Vehicle Design and Dimensions



Diameter	4 in
Length	111.875 in
Vehicle Mass	(without motor) 8350.392g/18.409lbs (with motor before burnout) 10780.392g/23.767lbs (with motor after burnout) 9581.392g/21.123lbs
Independent Section 1	2804.11g/6.182lbs
Independent Section 2	1603.408g/3.535lbs
Independent Section 3	(without motor) 3942.874g/8.693lbs (with motor before burnout) 6372.874g/14.05lbs (with motor after burnout) 5173.874g/11.406lbs
Motor	K1085 (Propellant Mass: 1,199.0, Total Weight: 2,430.0)
Main Chute	72 inches (Descent Rate:17.8931 ft/s)
Drogue Chute	18 inches (Descent Rate: 85.4706 ft/s)

The diagram above shows the locations of the payload bay (red), the avionics bay (green), and the air brake module (blue)

This single-stage rocket will be 111.875” long, have a 4” diameter, and constructed with a fiberglass body tube. It will contain a recovery system that ensures all parts of the rocket will be safely returned and recycled. The first set of fins are 95.25” from the nose cone and the second set of fins are 104.625” from the nose cone. The diameter of the full scale rocket will be 4” in order to have sufficient space for the payload and other electronics without affecting too much on the overall design. The vehicle will include an air brake system that fulfill the altitude requirement of 4000 to 5,500 feet above ground level. The three featured independent sections are tethered together. The fourth section is the rover, which will be deployed on the ground. Descriptions about the air brake system are in section 4.1.7.1.

This launch vehicle will be a single stage modified version of the 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.

Based on past experience, this rocket will be composed of different modules, which allow the rocket to be customizable and a more cost-effective vehicle. If a module is damaged or lost, we can easily make another module and continue using the same rocket.

Additionally, it is stated in the Student Handbook section 2.8 that “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 is recovered separately from the main vehicle using its own parachute.” The launch vehicle will have 4 sections, which meets the requirement.

Please also note that this vehicle does not have any forward canards or forward-firing motors.

4.1.1.2 Material Selection

4.1.1.2.1 Fiberglass

The team 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.

4.1.1.2.2 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

4.1.1.3 Justification

4.1.1.3.1 Fiberglass

Fiberglass is the material chosen for the main rocket body as it is affordable for the team and is suitable for the designs. In addition, fiberglass allows for telemetry data and radio signals to transmit through. Had the team chosen to use carbon fiber as the main material, there would have to be different sections with fiberglass depending on if there requires electronics that need to transmit radio signals.

4.1.1.3.2 Epoxy

The epoxy the team has chosen has proven from 2 years of SLI building that it is suitable for the purposes of this team. It can withstand high temperatures and the team hasn't had any issues with the glue not holding. In fact, the team has had issues with the epoxy holding too well when there was a mistake in the gluing of the pieces.

4.1.1.4 Construction Methods

4.1.1.4.1 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 under section 3.4.1 and Appendix E

4.1.1.4.2 Epoxy

Epoxy is a hazardous material. The safety procedures for handling epoxy can be found in Appendix E.

4.1.1.5 Tracking Devices

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

4.1.1.5.1 Alternatives Considered

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	Additional space required for battery, really expensive, will

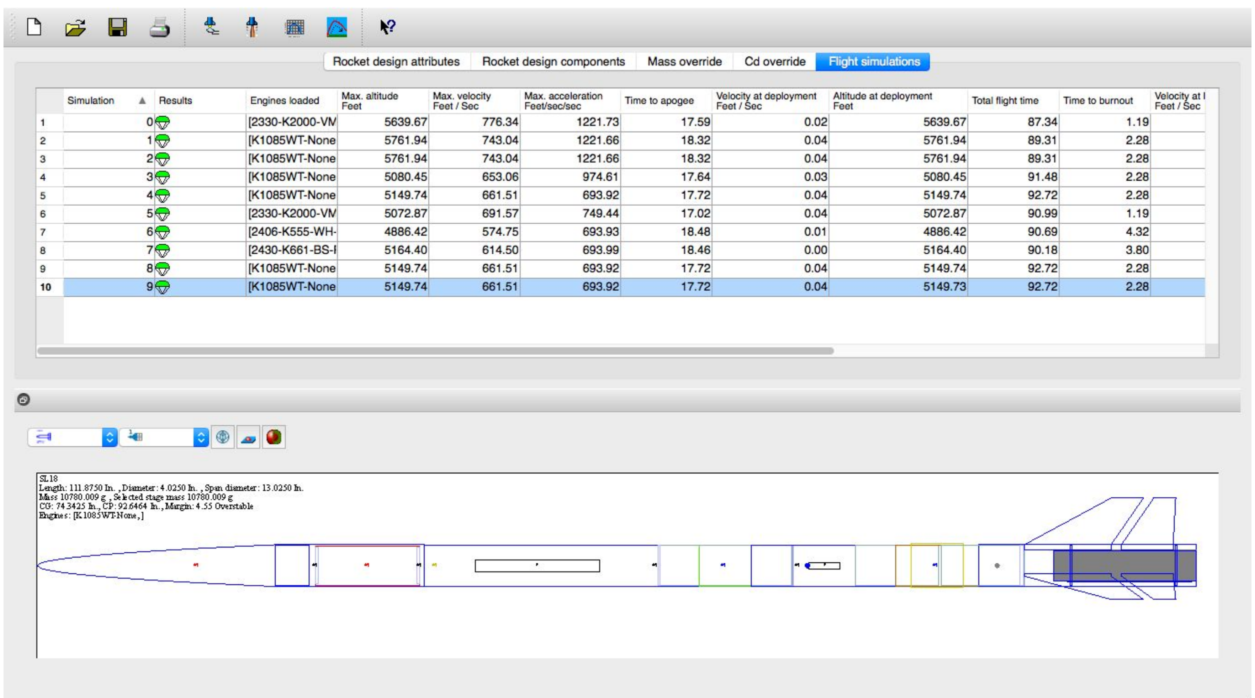
	our experience with Arduino in TARC.	require use to use a new and unfamiliar version of Arduino. Additional telemetry may be required, making it relatively harder to use.

4.1.2 Projected Altitude and Calculation

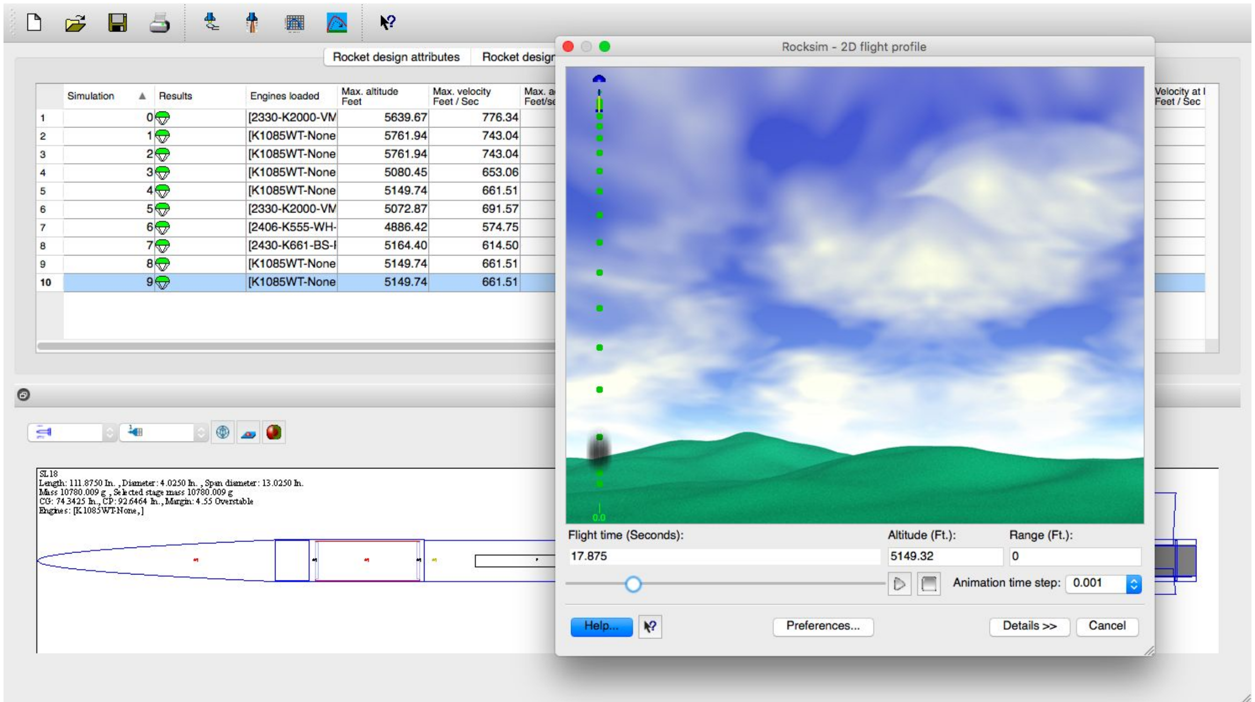
4.1.2.1 Projected Altitude

The current projected altitude of the rocket with a CTI K1085 motor is 5149 ft. This is at conditions of "no wind" according to rocksim.

Due to this simulation, our target altitude for the project will be anticipated to be 4700 ft.

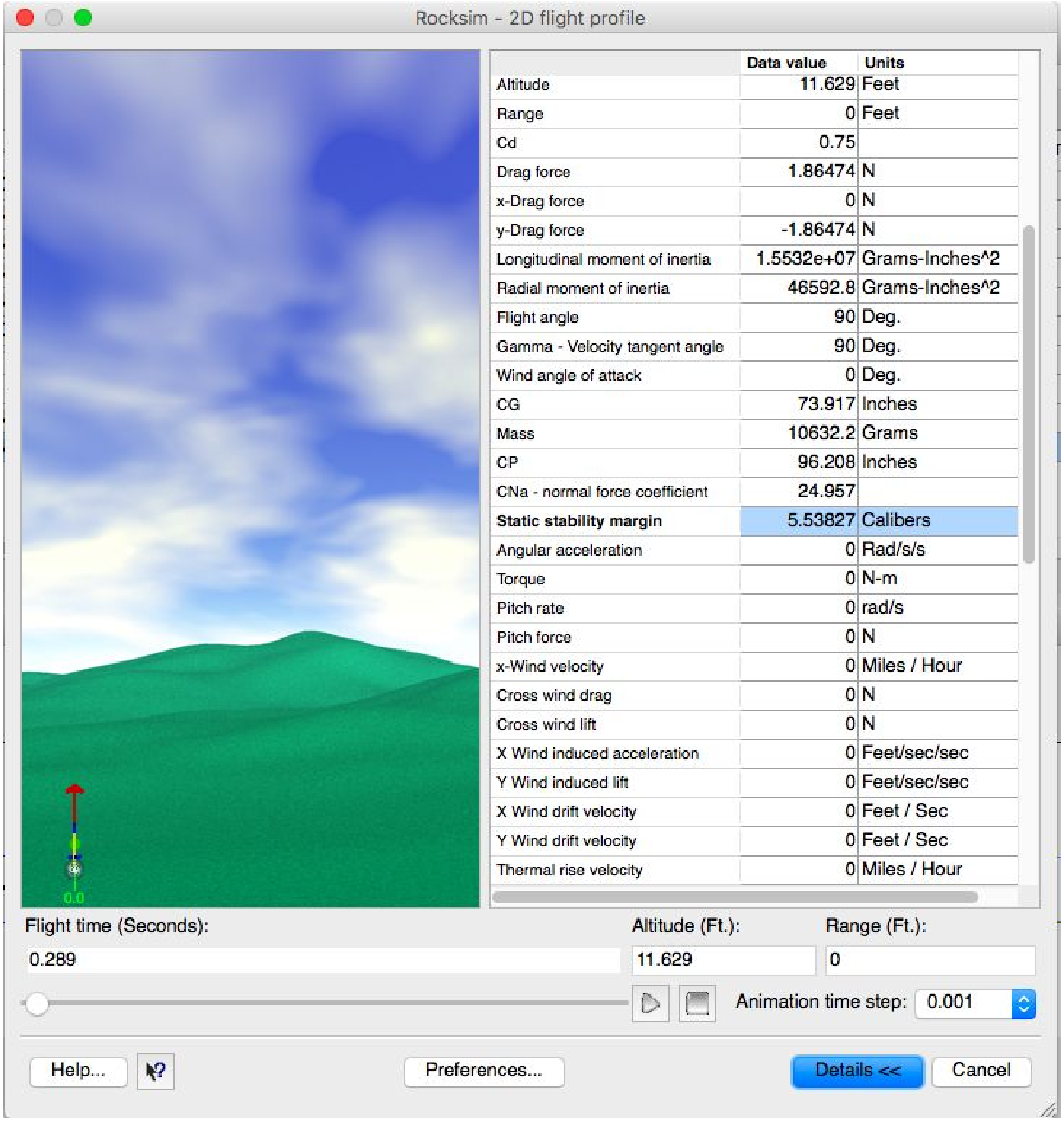


	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deployment Feet / Sec	Altitude at deployment Feet	Total flight time	Time to burnout	Velocity at l Feet / Sec
1	0		[2330-K2000-VM	5639.67	776.34	1221.73	17.59	0.02	5639.67	87.34	1.19	
2	1		[K1085WT-None	5761.94	743.04	1221.66	18.32	0.04	5761.94	89.31	2.28	
3	2		[K1085WT-None	5761.94	743.04	1221.66	18.32	0.04	5761.94	89.31	2.28	
4	3		[K1085WT-None	5080.45	653.06	974.61	17.64	0.03	5080.45	91.48	2.28	
5	4		[K1085WT-None	5149.74	661.51	693.92	17.72	0.04	5149.74	92.72	2.28	
6	5		[2330-K2000-VM	5072.87	691.57	749.44	17.02	0.04	5072.87	90.99	1.19	
7	6		[2406-K555-WH-	4886.42	574.75	693.93	18.48	0.01	4886.42	90.69	4.32	
8	7		[2430-K661-BS-I	5164.40	614.50	693.99	18.46	0.00	5164.40	90.18	3.80	
9	8		[K1085WT-None	5149.74	661.51	693.92	17.72	0.04	5149.74	92.72	2.28	
10	9		[K1085WT-None	5149.74	661.51	693.92	17.72	0.04	5149.73	92.72	2.28	



4.1.2.2 Static Stability Margin

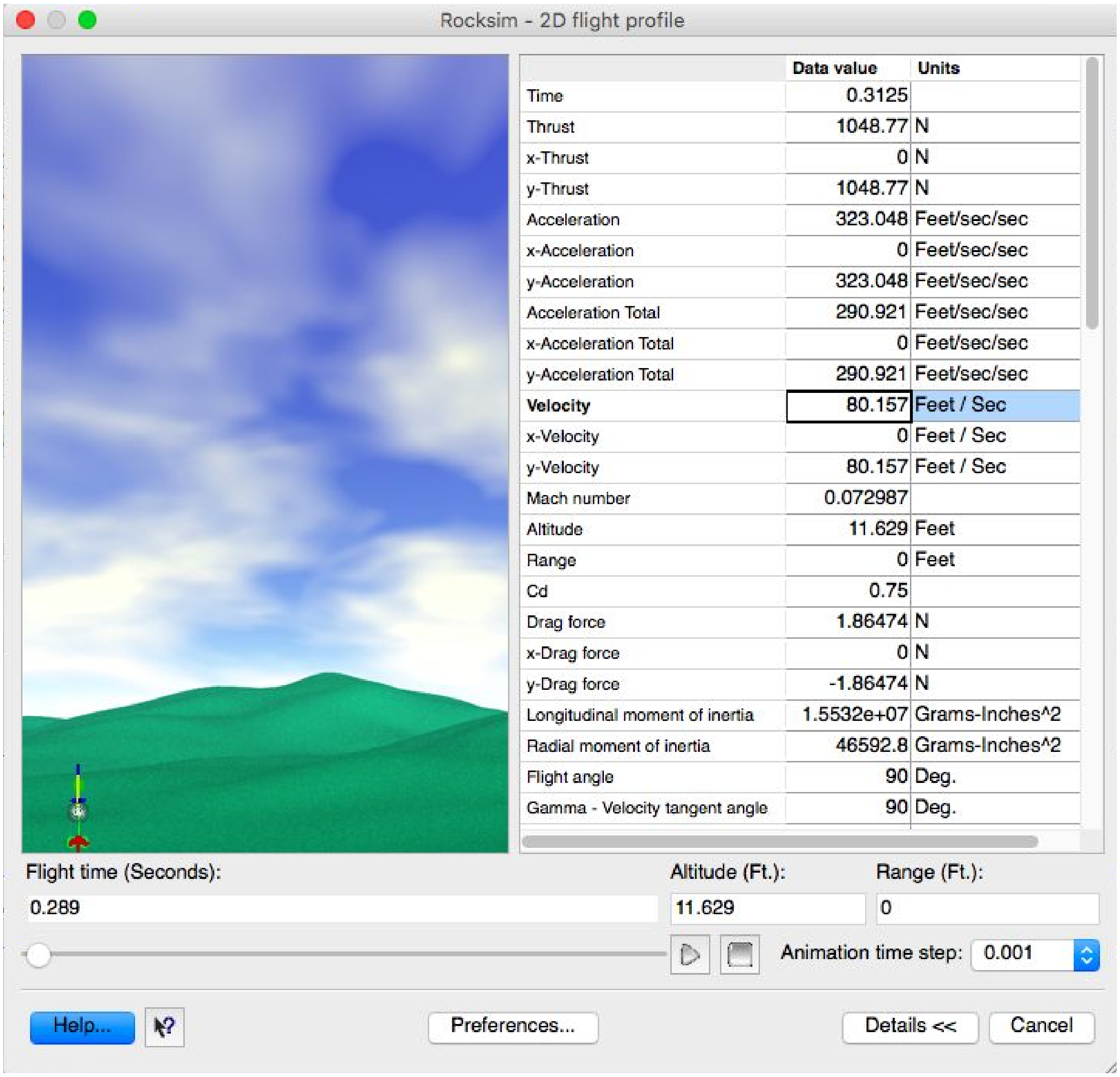
"The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit"



The stability margin is shown to be 5.54 calibers, above the requirement of 2 calibers minimum.

4.1.2.3 Rail Exit Velocity

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



The rail exit velocity is shown to be 80.157 fps.

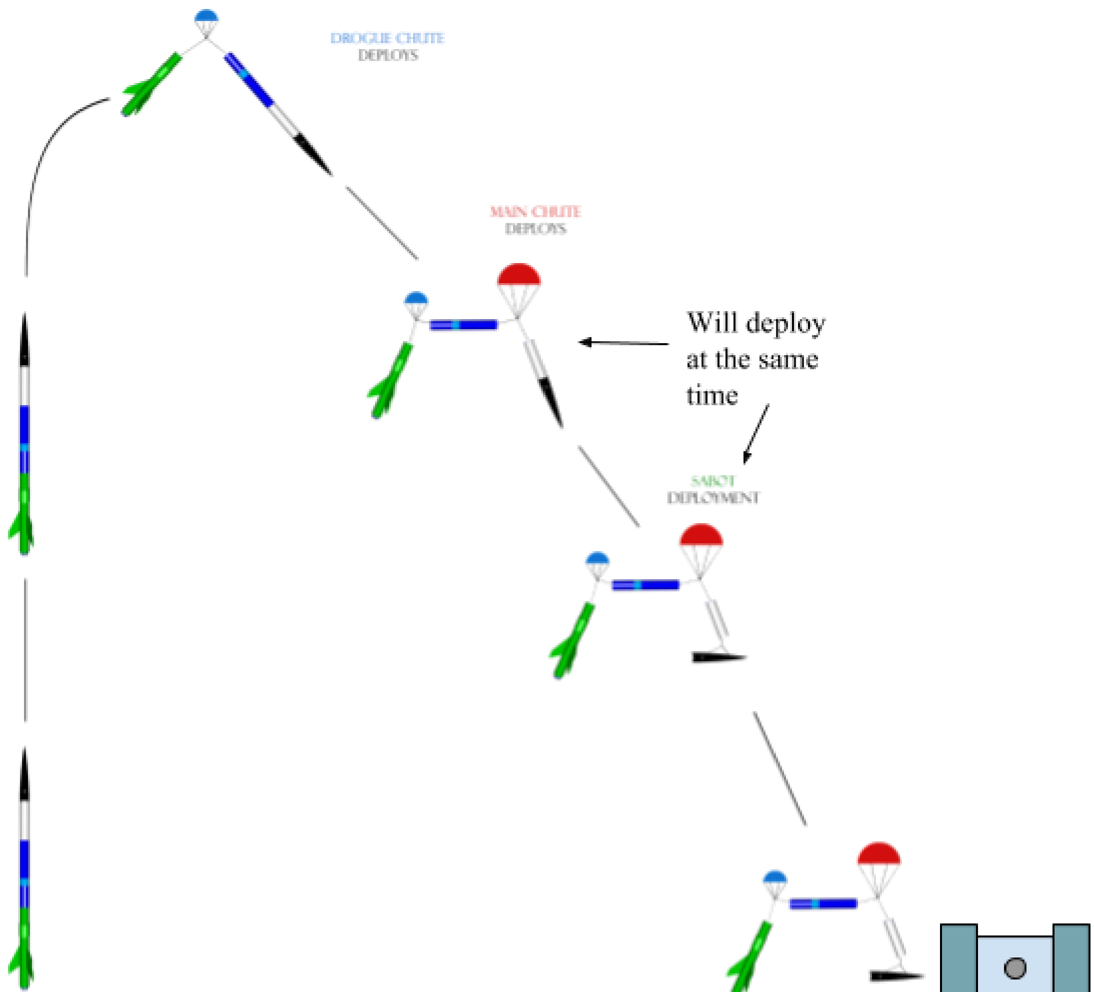
4.1.2.4 Maximum Velocity

"The launch vehicle will not exceed Mach 1 at any point"

The maximum velocity of this vehicle is simulated to be 661.51 fps, which is below Mach 1

4.1.3 Projected Parachute System Design

4.1.3.1 Flight Events



The above diagram shows the flight events of the vehicle. At apogee, the 18” drogue chute will deploy. At 600 feet, the main chute will deploy and the sabot will deploy with it. A yoke will hold the sabot upright through the descent. Once the vehicle hits the ground, the rover will then deploy.

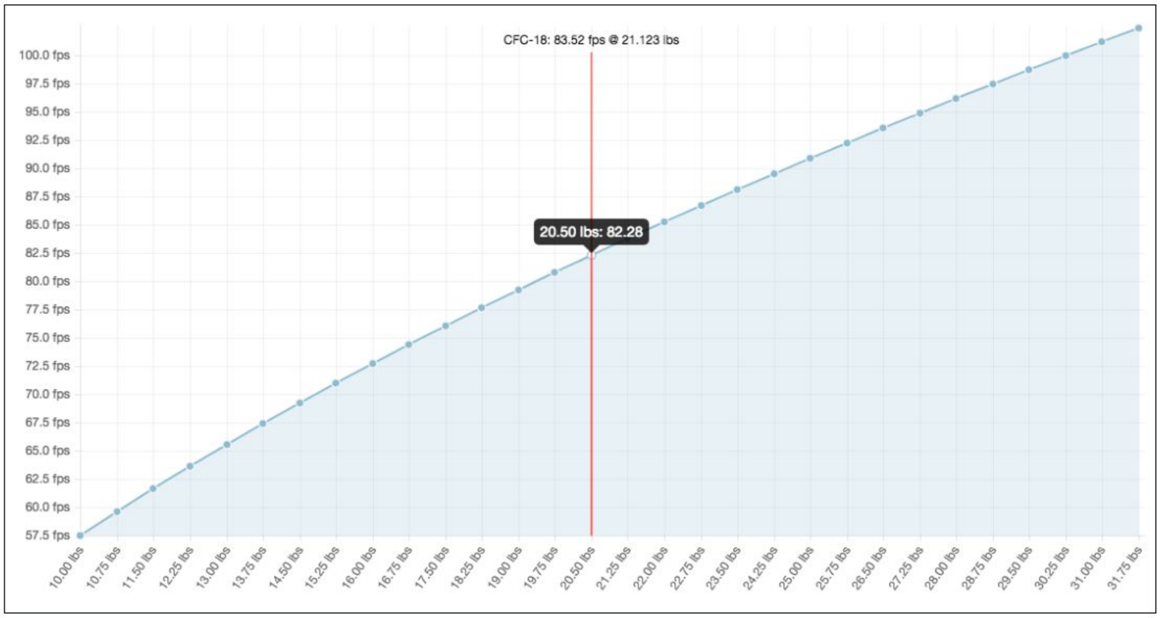
4.1.3.2 Descent Rates

Provided below are the descent rates provided by Fruity Chutes for the chosen parachutes.

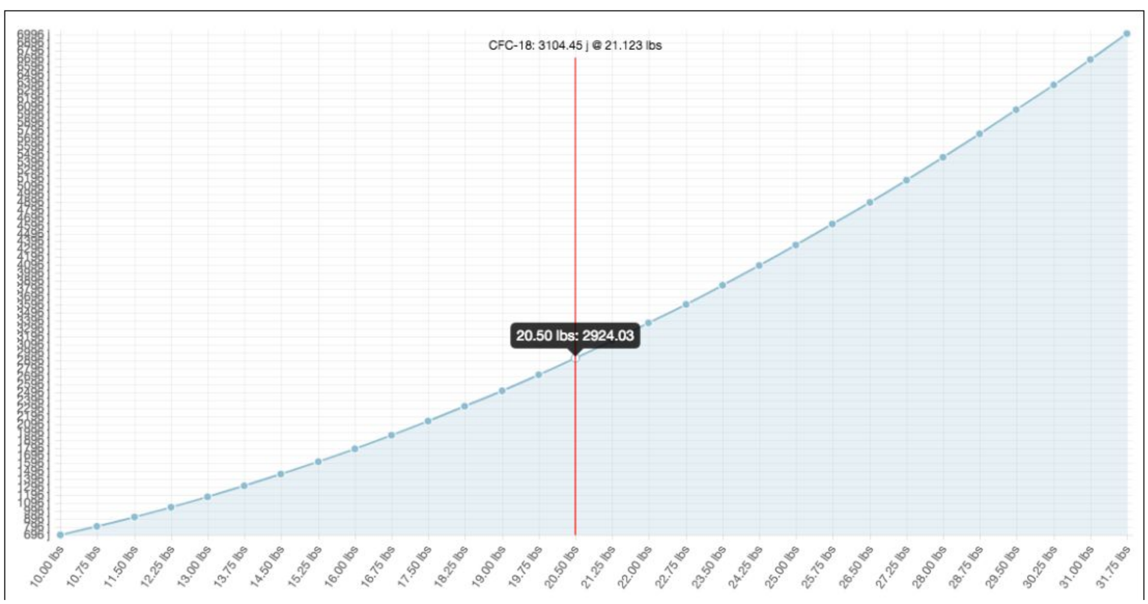
4.1.3.2.1 Drogue Chute

The drogue chute will be an 18” Classic Elliptical parachute.

Descent Rate vs Weight



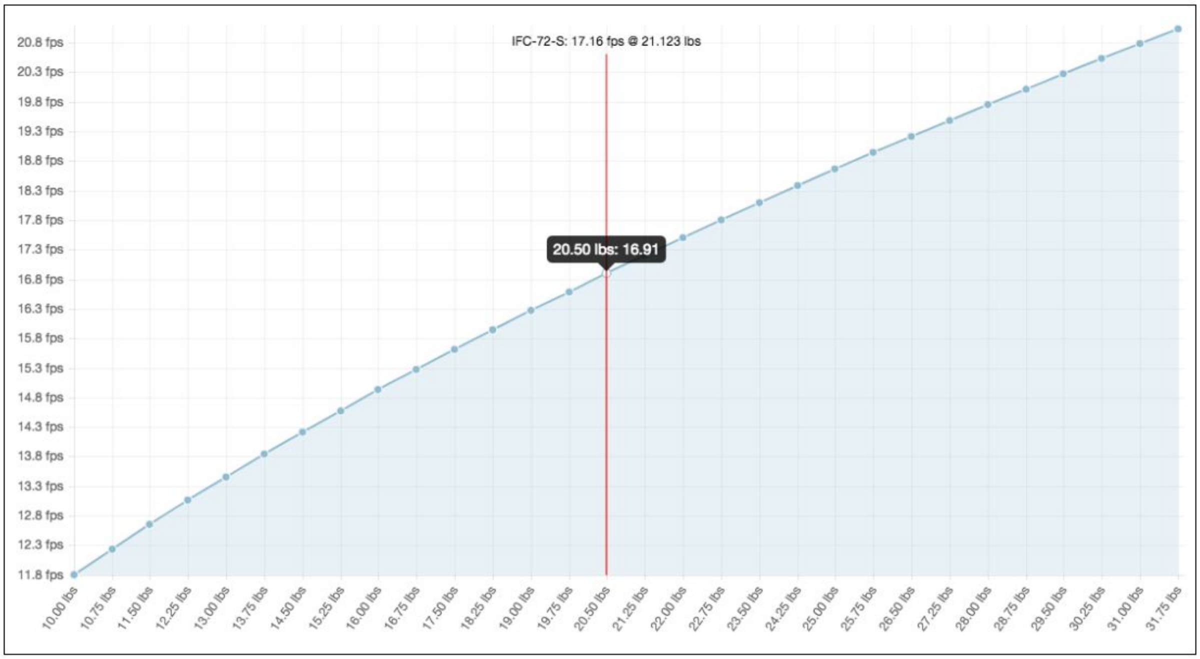
Impact Energy Joules vs Weight



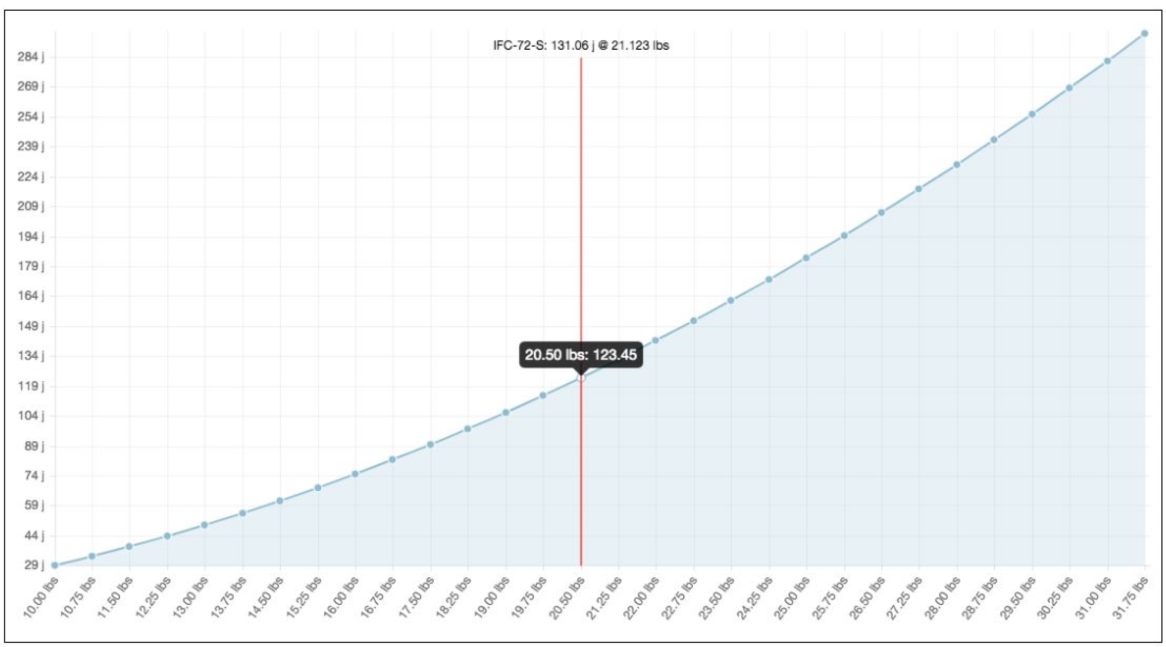
4.1.3.2.2 Main Chute

The main chute will be a 72” Iris Ultra Compact parachute.

Descent Rate vs Weight

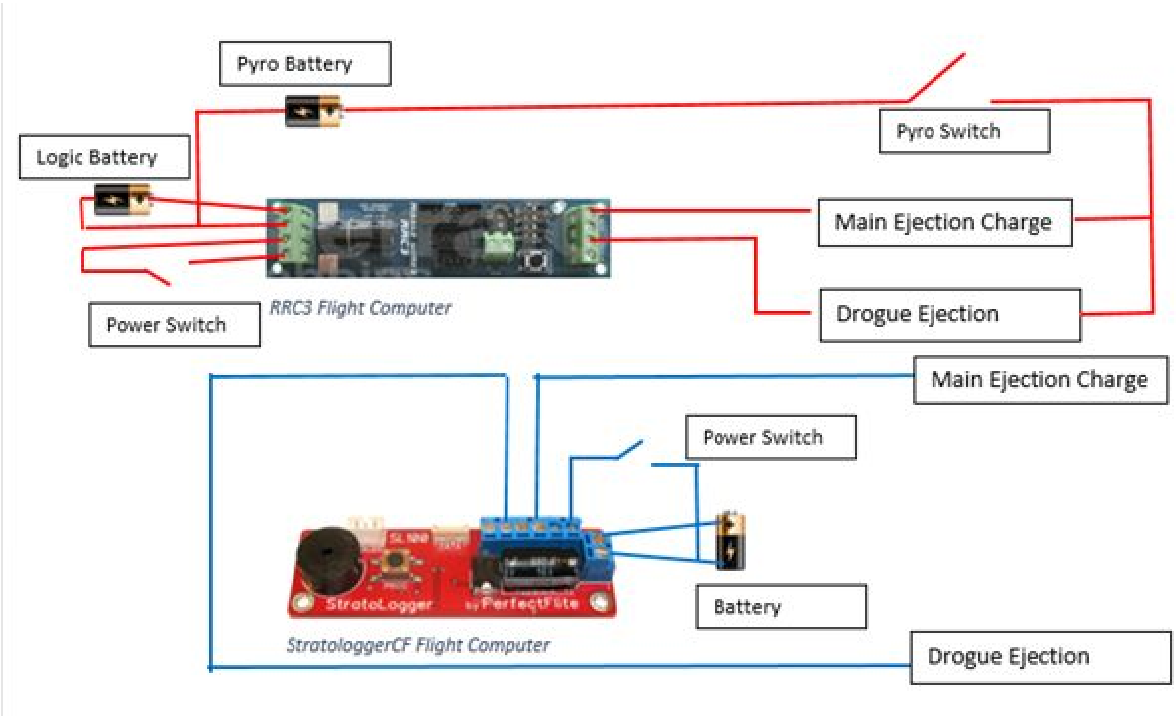


Impact Energy Joules vs Weight



4.1.3.3 Redundant Dual Deploy System

For recovery, as a team we decided to use redundant dual deploy. The top section and the avionics bay will be connected to the parachutes via a nylon shock cord. Recovery will occur in two phases – near apogee an 18” small drogue parachute will be deployed that is designed to slow the rocket for initial descent. At 600 feet, the 72” main parachute will deploy for the vehicle’s final descent.



The important thing about a redundant dual deploy system is that the two circuits used for the deploying of the parachutes do not touch. This makes it so that in the unlikely case that one of the circuits fails, there is another circuit that also triggers the parachute to deploy. This is used in order to maximize the safety of our rocket and make sure the parachute will always deploy for our rocket.

4.1.3.4 Drift Calculations

4.1.3.4.1 20 MPH Winds

$$[(\frac{1\,second}{85.4706\,feet})(4700-600\,ft)+(\frac{1\,second}{17.8931\,feet})(600\,ft)] \times (\frac{20\,miles}{1\,hour})(\frac{5280\,feet}{1\,mile})(\frac{1hour}{3600\,seconds}) = 2390.731\,ft$$

4.1.3.4.2 15 MPH Winds

$$[(\frac{1\,second}{85.4706\,feet})(4700-600\,ft)+(\frac{1\,second}{17.8931\,feet})(600\,ft)] \times (\frac{15\,miles}{1\,hour})(\frac{5280\,feet}{1\,mile})(\frac{1hour}{3600\,seconds}) = 1793.048\,ft$$

4.1.3.4.3 10 MPH Winds

$$[(\frac{1\,second}{85.4706\,feet})(4700-600\,ft)+(\frac{1\,second}{17.8931\,feet})(600\,ft)] \times (\frac{10\,miles}{1\,hour})(\frac{5280\,feet}{1\,mile})(\frac{1hour}{3600\,seconds}) = 1195.365\,ft$$

4.1.3.4.4 5 MPH Winds

$$[(\frac{1\,second}{85.4706\,feet})(4700-600\,ft)+(\frac{1\,second}{17.8931\,feet})(600\,ft)] \times (\frac{5\,miles}{1\,hour})(\frac{5280\,feet}{1\,mile})(\frac{1hour}{3600\,seconds}) = 597.683\,ft$$

4.1.3.4.5 0 MPH Winds

$$[(\frac{1\ second}{85.4706\ feet})(4700 - 600\ ft) + (\frac{1\ second}{17.8931\ feet})(600\ ft)] \times (\frac{0\ miles}{1\ hour})(\frac{5280\ feet}{1\ mile})(\frac{1 hour}{3600\ seconds}) = 0\ ft$$

4.1.3.5 Kinetic Energy Calculations

Overall Rocket

$$Kinetic\ energy = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(21.123lbs)(17.8931ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 105.012\ lbf$$

Independent Section 1

$$Kinetic\ energy = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(6.182lbs)(17.8931ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 30.734\ lbf$$

Independent Section 2

$$Kinetic\ energy = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(3.535lbs)(17.8931ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 17.574\ lbf$$

Independent Section 3

$$Kinetic\ energy = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(11.406lbs)(17.8931ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 56.705\ lbf$$

The calculations show that this rocket design falls within the requirements that each independent section not have a kinetic energy of above 75 lbf upon hitting the ground.

4.1.3.6 Energetics Calculations

The team has a calculator via Google Sheets for the energetics calculations. The energetics will be calculated once the design has been finalized and the charges will be accurate.

4.1.4 Projected Motor Brand and Designation

4.1.4.1 Motor Comparisons

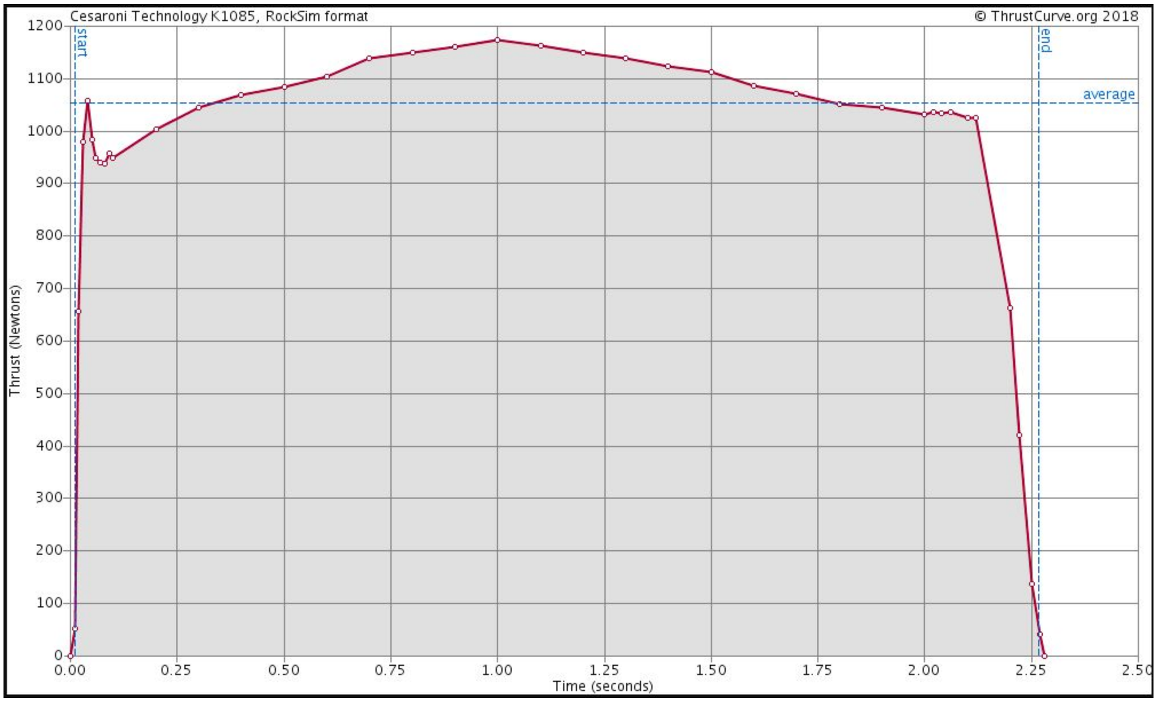
The following table's data is given by the RockSim9 simulation data and thrustcurve.org

Motor	**Total Impulse (Ns)**	**Total Mass (g)**	**Max Altitude (ft)**	**Max Velocity (ft/s)**	**Max Acceleration (ft/s^2)**
CTI K661	2430.4	2528	5164.4	614.5	693.99
CTI K555	2406.2	2759	4886.42	547.75	693.93
CTI K2000	2329.9	2465	5072.87	691.57	749.44
CTI K735	1955.2	2509	5149.74	661.51	693.92
CTI K1085	2412.0	2430.0	5080.44	653.06	974.61

4.1.4.2 Final Motor Choice

The final choice of the motor is the Cesaroni K1085. The reasons of the choice in motor includes the following:

- The CTI K1085 falls within NAR requirements for a K class motor where the max total impulse is 2560Ns and the K1085 has a total impulse of 2412Ns.
- The weight of the designed rocket for the past two years has been heavier than anticipated. Assuming that the rocket design is heavier than what will actually result, the increased altitude and velocity help to ensure the rocket will reach the target altitude.
- Assuming the rocket is heavier, the motor will account for the loss of a couple hundred feet altitude when the actual rocket is built versus on the simulation.
- The weight of the CTI K1085 motor is lighter than most of the other motors compared. At 2430 grams, this helps to ensure that the rocket will not end up too much heavier than anticipated.
- The burnout time of the K1085 motor is estimated to be about 2.1 (thrustcurve.org) and 2.28 (rocksim) seconds. Due to the burnout being so short, the vehicle will be able to put into use the air brake module the team will design
- The thrust curve graph shown by thrustcurve.org for the K1085 motor has a larger spike at the beginning of the flight, indicating a higher velocity at first and therefore a straighter flight. This also indicates greater force upon the vehicle and payload. However, we believe that our design will be able to withstand the force.



4.1.4.3 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.

4.1.5 Description of Projected Payload

4.1.5.1 Overview

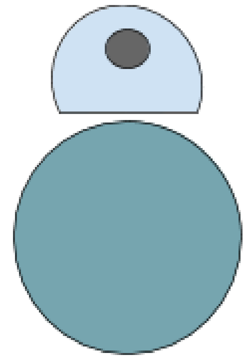
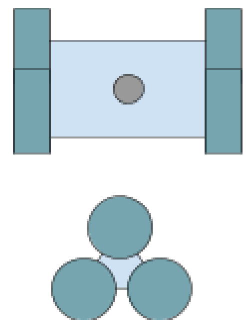
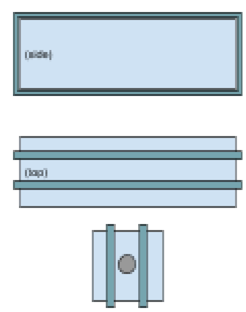
	UAV	Rover	Airplane
Minimal Risk	2	5	3
Minimal Development Time	3	4	2
Least Space Required	4	3	2
Light Weight	4	2	3
Least Research	2	4	2
Ease of Construction	4	1	5
Ease of Testing	1	5	2
Total	20	25	19

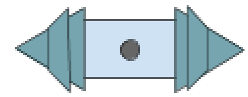
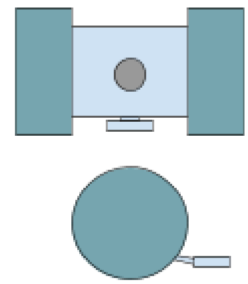
The team eventually narrowed down to three final ideas for the payload choice, a UAV quadcopter ejected during the rocket's descent for detecting the rocket's landing position, a rover that is deployed after the rocket lands, and an airplane that is deployed out of the rocket in its descent. A table consisting of the different aspects the team wanted to consider about each payload idea was compiled, and a rating was given to each of the three ideas. Originally, the UAV was to be selected due to the team's excitement to use it as the payload regardless of the score. However, due to safety concerns and because the rover has the highest score out of the three ideas, the team eventually decided to use the rover idea as the payload.

4.1.5.2 Payload Alternatives

The team considered 5 different rover ideas and considered the positives and negatives per design. Below is a comparison chart briefly explaining the 5 different rovers and the reasoning some choices were not discussed further. The grey on the diagram is the camera location and the teal represents the wheel(s).

Rover Designs	Description	Positives	Negatives	Diagram

BB-8 Inspired	A spherical wheel with a magnet that allows a "head" to attach to the top, yet not physically touch and allow it to move freely as the sphere below it rolls	A design liked by the team, meaning increased enthusiasm toward building it A mechanical challenge for the team	The surface of the farmland that the final launch will be on is not suitable for this specific rover design.	
[Long Beach Rover]()	California State University: Long Beach created a triangular rover for the 2018 SLI featuring a total of 6 wheels, three per corner.	Allows for freedom of movement disregarding its orientation. The rover design also makes it optimal for traversing the terrain of the farm It can easily roll out of the rocket/sabot regardless of the orientation of the rocket/sabot	If the rover were to flip onto another of the 3 sides, how would the camera be able to work?	
"The Tank"	A rectangular rover with 2 tracks running the longer length of the rover.	It can easily move over the tilled farmland we anticipate the rover will be traveling across.	If the rover wasn't deployed out a certain way, it would risk the rover landing on the side without tracks and cause the rover to fail. If the dirt on the farmland sticks to the tracks, it can obstruct the camera.	

“The IDC”	This is a cylindrical rover with cone wheels.	This can easily roll out of the rocket/sabot regardless of the orientation of the rocket/sabot		
“Mr. Beaver”	A cylindrical rover with large tractor like wheels and a “beaver” tail to ensure that the cylinder holding the camera and electronics don’t spin with the wheels	The rover can easily roll out of the rocket/sabot regardless of the orientation of the rocket/sabot. The beaver-tail mechanism helps to stabilize the camera	Possibly an issue with crossing the tilled farmland?	

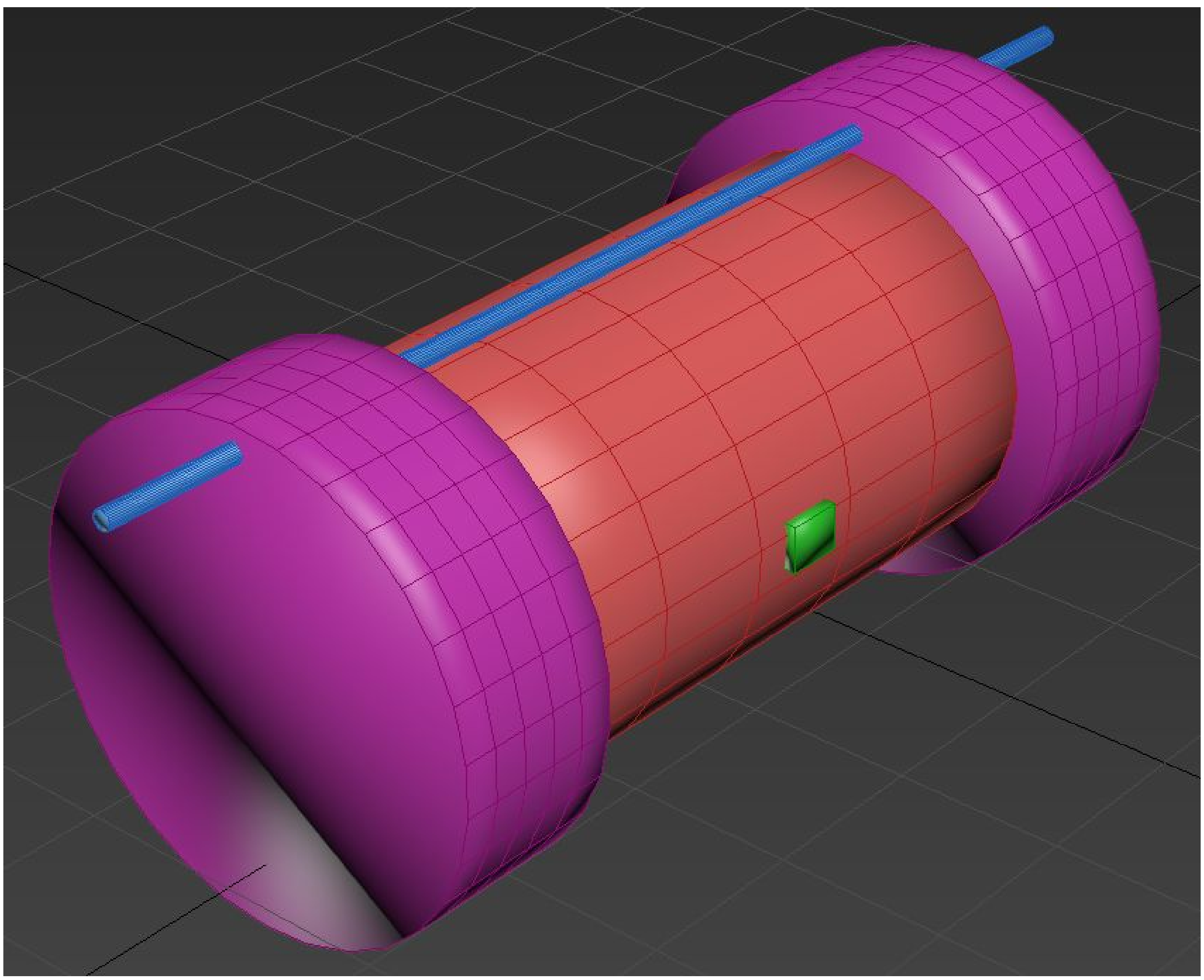
4.1.5.3 Final Design

The rover will be equipped with a wheels on each side and the camera will be placed in the center body. A weight extends from the back of the rover to ensure that the body of the rover stays in the correct orientation. When the rover moves, the weight will tilt the body and drag on the ground to orient the rover so that the camera is always pointing forward, not upward or downward. The rover can turn by having the two wheels running at different speed. The rover will stay inside the body tube next to the nose cone during flight and will be secured in a sabot. When the main parachutes deploy, the sabot that holds the rover payload would be pulled out from the body tube but still connected to the body tube via the tether. Once the rocket lands, the sabot will release the rover, and the rover will roll out to perform its task. The rover will make a trip of 6 ft, turn around and take a photo of the landed rocket parts.

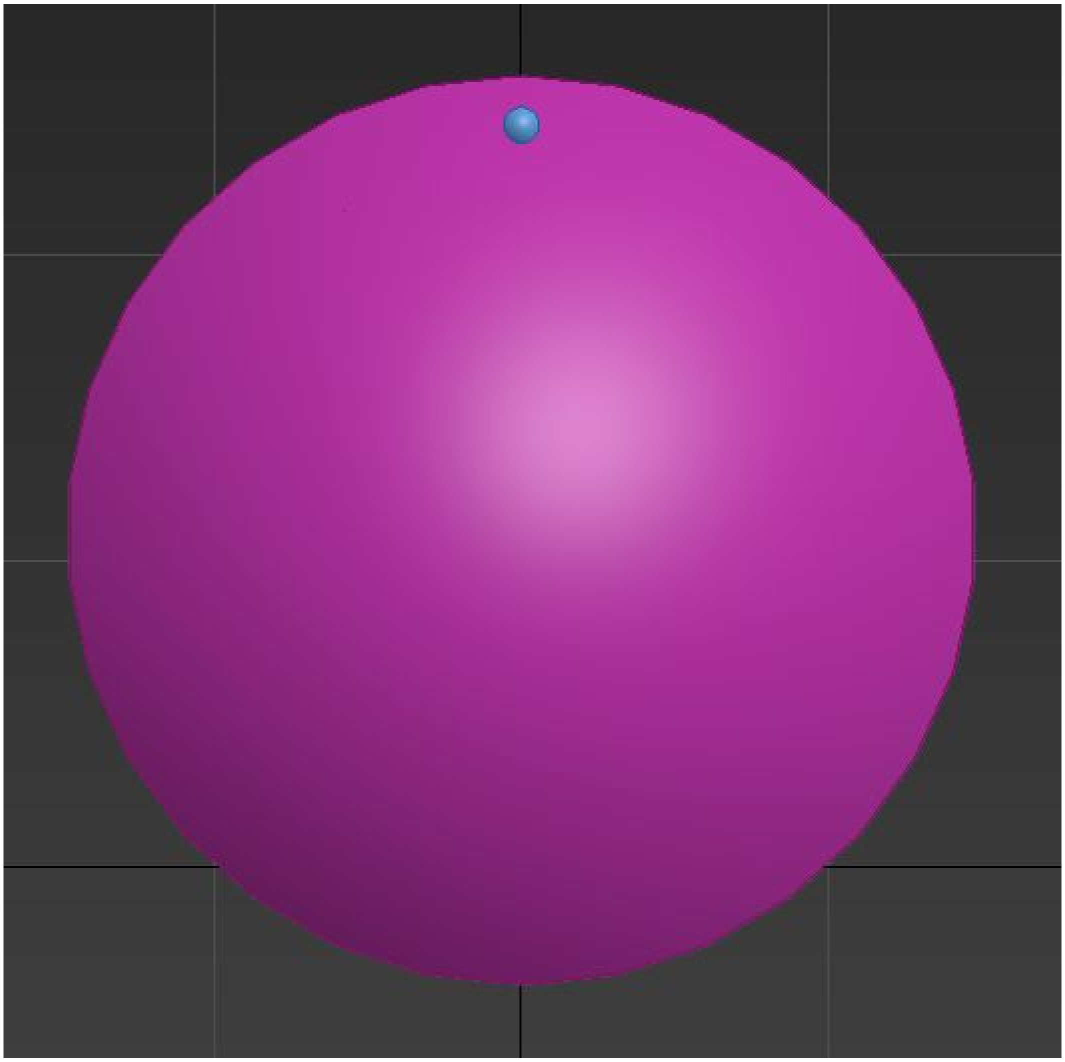
For the following diagrams, please note that the weight at the back of the rover was not included in the diagram. In addition, please refer to the following key for the diagrams:

- Red = Main Rover Body (Electronics)
- Magenta = Wheels
- Green = Camera
- Blue = The rod that will hold the rover to the sabot

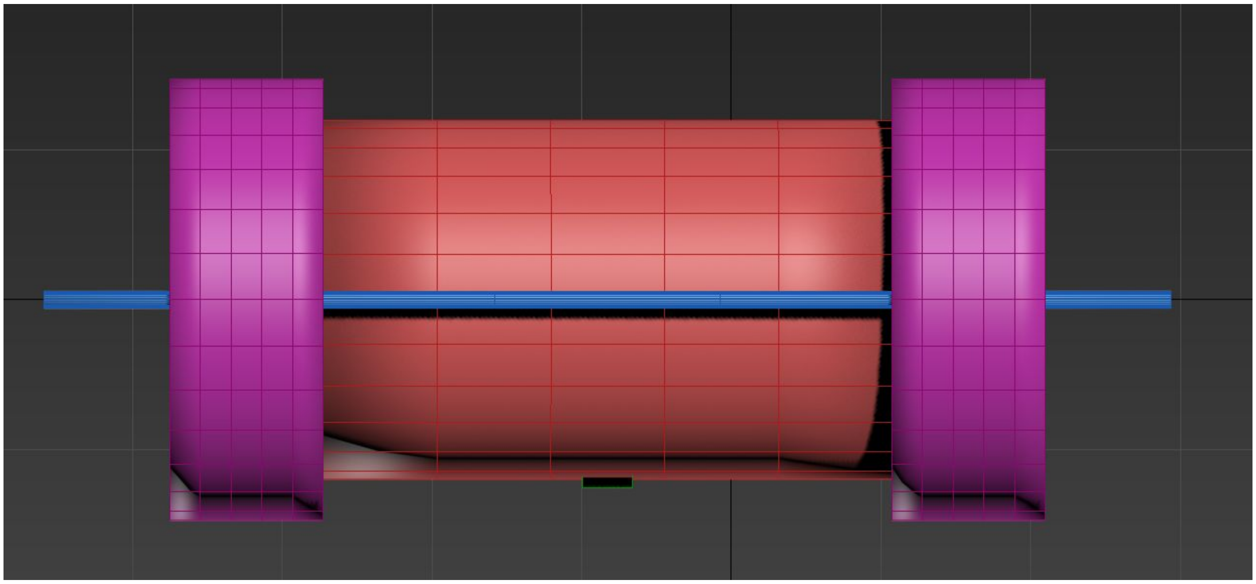
he above diagram features a CAD image of the anticipated rover design while resting in the sabot. The green on the outside of the purple (wheels) represent the bulkheads of the sabot.



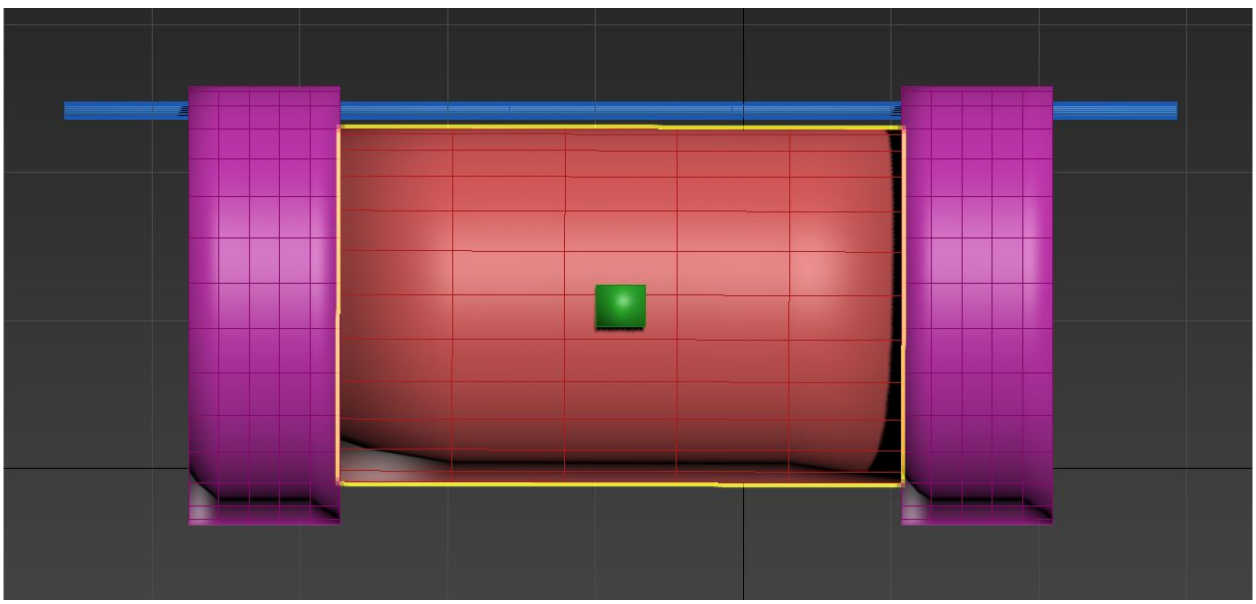
The above diagram shows an overview of the payload. As shown, the payload will be cylindrical and the wheels larger than the body.



This is a side view of the rover. Due to the wheels being larger than the body, it will ensure that the main body will not drag on the ground.



The above diagram shows the top view of the rover



The last diagram featured above shows a front view of the rover.

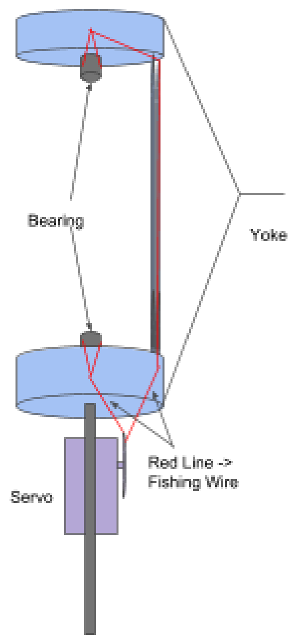
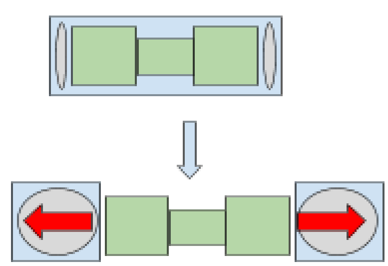
4.1.5.4 Payload Parts

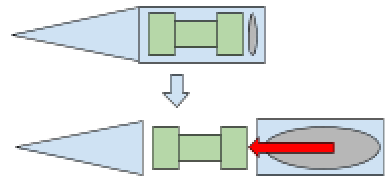
The materials that are speculated to be necessary in building the rover payload.

- GPS
- Small camera capable of transmitting live video and taking picture.
- 3D printer for printing the components of the rover body.
- Gears, wheels, etc.

4.1.5.5 Release Mechanism Alternatives

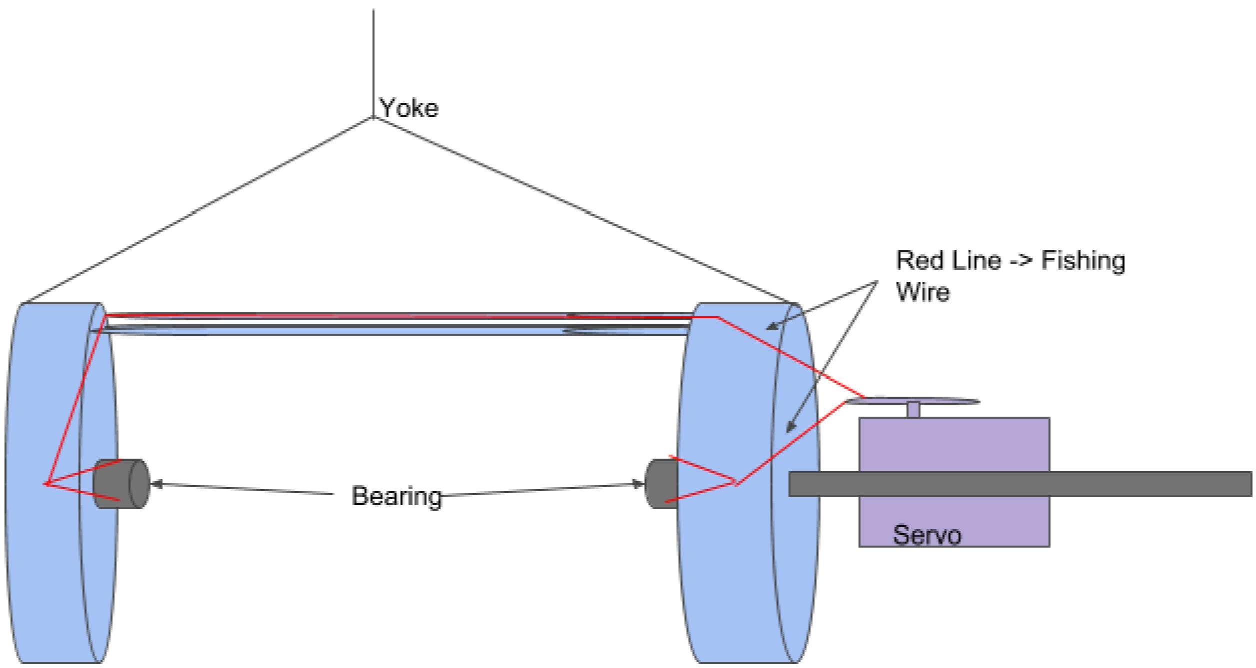
We discussed many different release mechanisms. The following section outlines the different mechanisms considered, the pros and cons, and other comments we had.

Release Mechanism	Design	Positives	Negatives	Comments/ Diagram
Sabot	The sabot fits within the body tube and is pulled out along with the main chute to mitigate the need for another event. It is constructed with three rods holding bulkheads together and a pulley system will hold the rover in place while the rocket descends.	Once the rocket has hit the ground, the design allows the rover to start moving without any obstructions. No explosive charges required near it that could damage the rover Sabot idea has already been mostly developed and tested	Last year's design was made for a UAV so certain aspects will need to be modified The design might requires communicati on between the team and the sabot as the release mechanism might need a signal to release the rover.	A modification from last year's sabot design Design is horizontal, vertical diagram is for ease of visuals 
CO2 Force	Two bags will be inflated with CO2 when the rocket reaches the ground and can be deployed. The separation will be at the middle of the tube and the rover is free to roll.	No explosive charges required near it that could damage the rover	If the CO2 bags do not extend enough, the body tube could open only partially and render the rover immobile.	 Grey ovals are the CO2 bags uninflated and inflated, respectively. The green is the rover. Not to scale

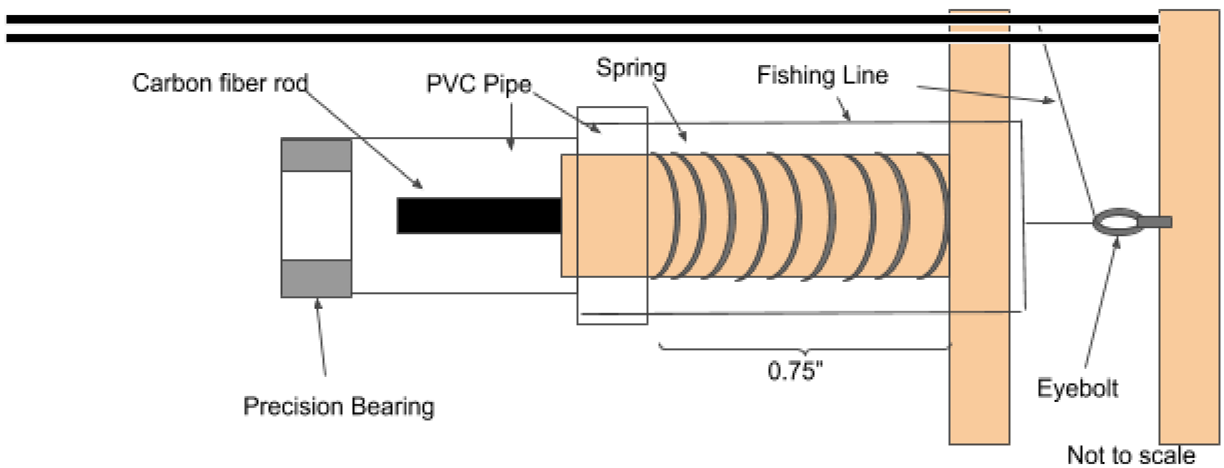
CO2 - eject from nose cone	Similar to the previous design, a bag will inflate with CO2 and push the rover against the nose cone, pushing the rover and the nose cone out together.	No explosive charges required near it that could damage the rover	The nose cone could begin to dig into the dirt and cause it to get stuck.	 Grey ovals are the CO2 bags uninflated and inflated, respectively. The green is the rover. Not to scale

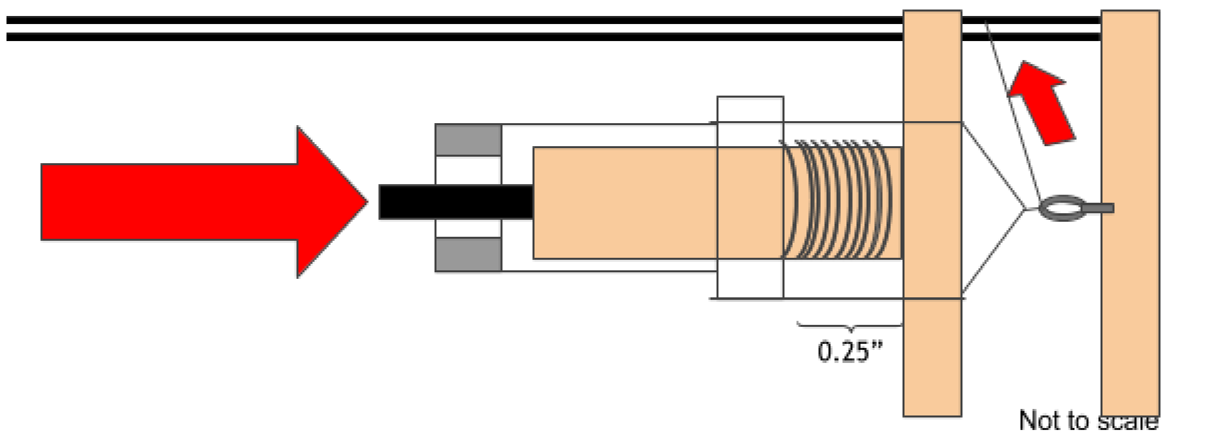
4.1.5.6 Release Mechanism Final Design

Our final design will be a modification of the sabot release that the previous year's team had begun developing. The sabot will be released with the main parachute and will suspend in the air until landing.

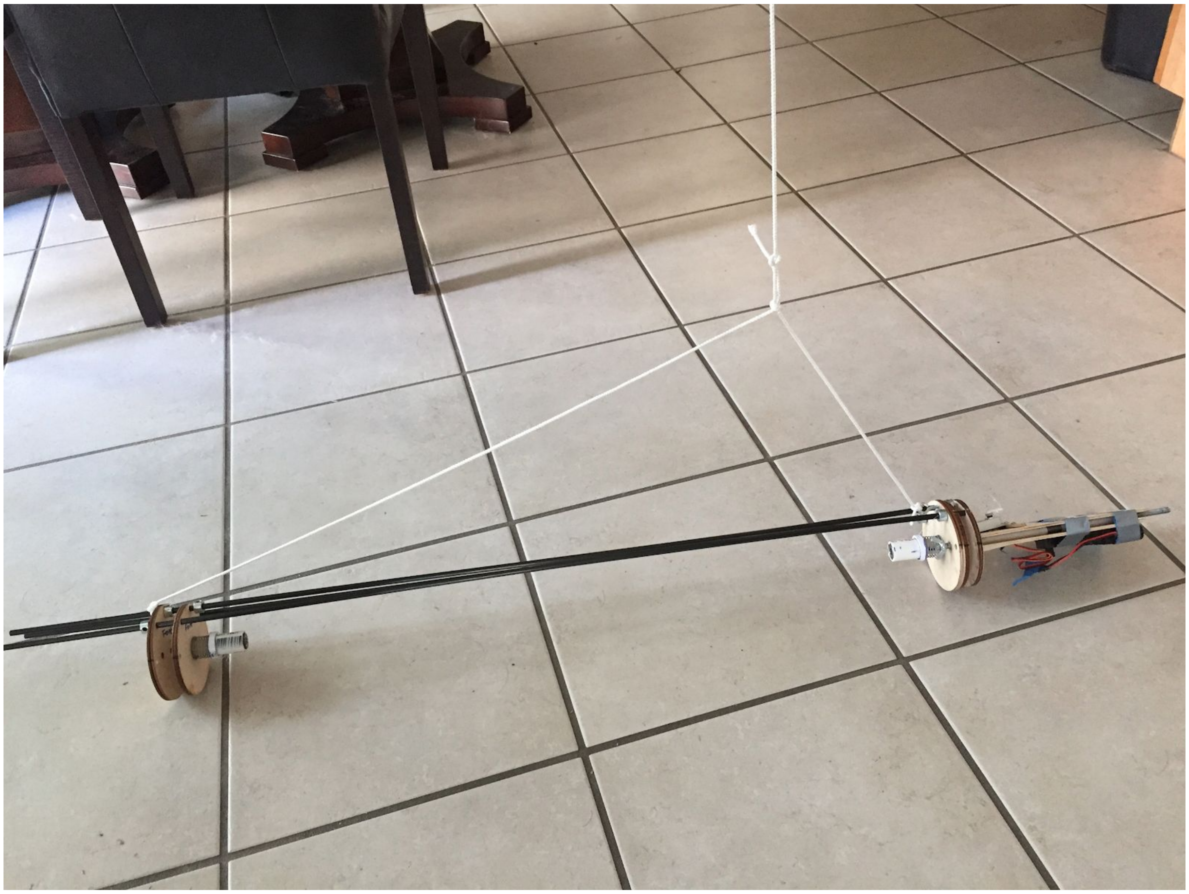


A yoke will ensure that the sabot remains horizontal and in the prime position for the rover to release. A single servo pulls the different fishing lines, which will enable the release of the vehicle. The fishing line linked to the bearing on the left side is fed through the hollow carbon fiber tube, allowing it to reach the servo without issues of tangling or breaking.





The above diagram features how the release mechanism is engaged during flight and until the rocket is fully stationary on the ground. The brown represents wooden components (bulkhead and cylindrical piece)The second diagram shows the contracted mechanism. To contract the PVC pipe mechanism, a servo show in the full servo diagram will pull the fishing wires, and therefore pulling the bearings back. The carbon fiber rod sticking in the wooden rod ensures that the attachment to the rover that rests in the bearing during the flight isn't pulled back alongside the bearing and PVC pipe.



The above photo features the sabot designed from the previous year. There will be many similarities except for the idea that the carbon fiber rods cannot get in the way of the rover moving. A few modifications will be ironed out as necessary as the sabot design for this year is for a rover, not for a UAV.

The upper independent section with the sabot

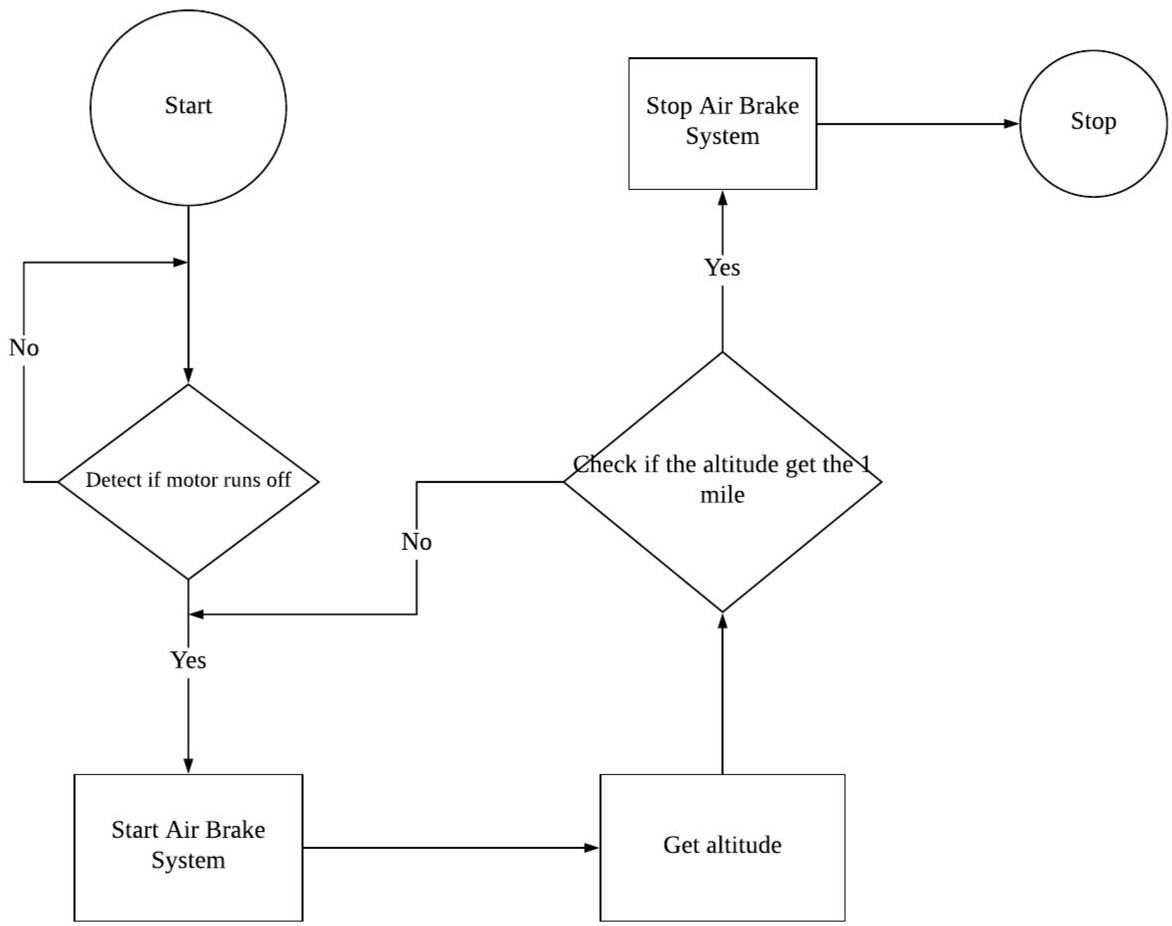
4.1.6 Requirements for Vehicle, Recovery, and Payload

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

4.1.7 Major Technical Challenges and Solutions

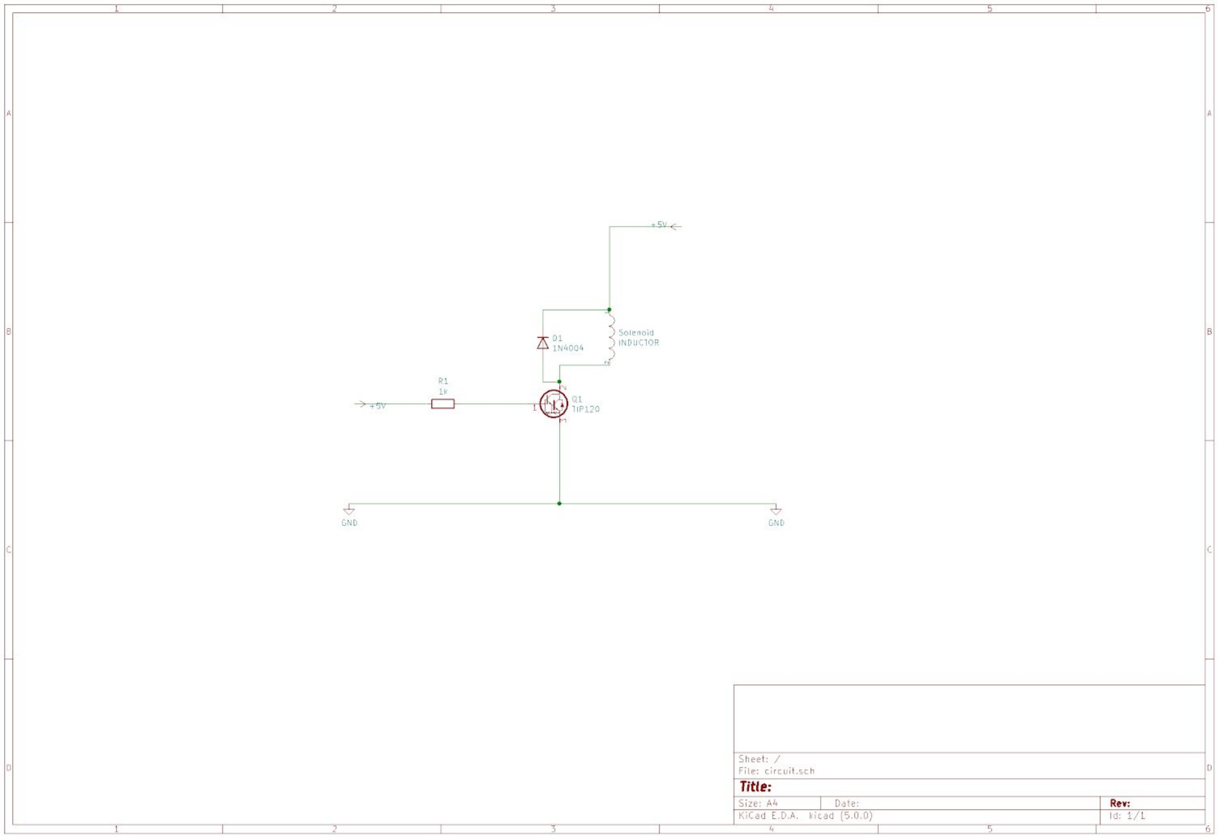
4.1.7.1 Air Brake System On-Board

The air brake system the team has designed is to reach as close to our target altitude as possible.

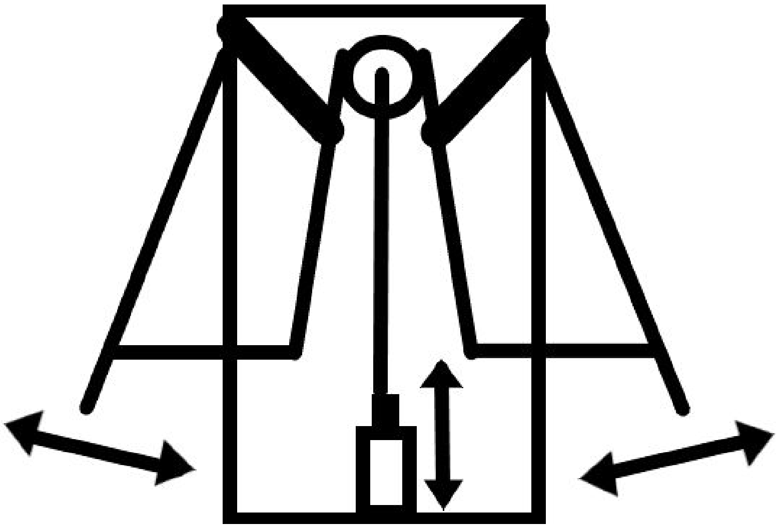


Above is the basic algorithm for the Air Brake design for the 2018-2019 Vertical Projectile Team

The airbrake itself will utilize a solenoid with rocker arm design. In order for this to work, it is possible that three solenoids and rockers will be used. However, this design is not as simple or as power efficient as it could be. Three solenoids are three points of failure, and it is possible to only use 1 solenoid in actuating all three airbrakes. In order to do so, it is possible to actuate all three rocker arms with a single pushrod with three small bumps on the end, with one solenoid on the other end. The end with the bumps will actuate the rockers. This adds an additional point of failure to the design, the new pushrod, but takes away two, resulting in a lower number of possible points of failure and therefore a lower chance of failure. The solenoid will require components that the electric motor will not, as it draws a large amount of power from the arduino, it requires the use of a power transistor and diode. The schematic of the circuitry of the airbrake prototype, with left being the arduino side, and the right being the solenoid side. The arduino side's +5V is a control pin, pin 12 in on the prototype. The solenoid side's 5V is the power from the arduino, with both grounds leading to the arduino.



This is the method of utilizing one solenoid to actuate multiple airbrakes, the solenoid retracts, causing the "camshaft" lobe to push the airbrakes out. It is possible that the "camshaft" will be a different shape, like a hammerhead with two lobes sticking out of the ends, pointing back.



5 Educational Engagement

Our plan for outreach is to get connected with and involved with as many educational programs as possible, such as elementary and middle schools, extracurricular education institutions, etc. We will create flyers on rocketry and explain what rocketry is. The team would like to forge connections with outreach programs in order to spread knowledge of rocketry with events such as rocketry workshops, presentations, etc.

The team plans to engage our community by:

- Guiding Girl Scouts at the Upland Girl Scout Center on October 13th through building model rockets
- Volunteering at Fairview Park for Air Rocketry on October 20-21st

6 Project Plan

6.1 Timeline

Timeline can be found on the following sheets:
https://drive.google.com/open?id=1odzwu1sL2n5n08fKEGrLZkw3e2bZnt5_3HeKFwJZhsI

6.2 Budget

The below budget is a tentative budget as the exact parts have not been confirmed. The budget will be updated as the project goes on.

The amount of a few items has been overestimated.

** Most costs are the listed prices on the MadCow Rocketry site

Description	Unit Cost	Qty	Subtotal	
Subscale Vehicle				
3" Fiberglass Frenzy XL	$226.95	1	$226.95	
3" Aluminum Bulkplate	$15.00	6	$90.00	
3" / 75 mm Black G10 Airframe Bulkplate	$5.00	12	$60.00	
3" / 75 mm Black G10 Coupler Bulkplate	$5.00	12	$60.00	
3" G12 Airframe (30")	$50.00	1	$50.00	
3" G12 Coupler (9")	$22.00	2	$44.00	
3" G12 Coupler (6")	$15.00	3	$45.00	
Total				**$575.95**
Fullscale Vehicle				
3" Fiberglass Frenzy XL	$369.95	1	$369.95	
4" Aluminum Bulkplate	$20.00	6	$120.00	
4" / 98 mm Black G10 Airframe Plate	$6.00	12	$72.00	
4" / 98 mm Black G10 Coupler Bulkplate	$6.00	12	$72.00	
4" G12 Airframe (30")	$58.00	1	$58.00	
4" G12 Coupler (12")	$32.00	2	$64.00	
4" G12 Coupler (9")	$24.00	2	$48.00	
Total				**$803.95**
Avionics/Recovery				
RRC3 Flight Computer	$69.95	1	$69.95	
StratologgerCF Flight Computer	$57.50	1	$57.50	
1" tubular nylon shock cord	$0.55	30	$16.50	
Iris Ultra 72" Compact Parachute - 28lbs @ 20fps; 15lbs @ 15fps	$265.00	1	$265.00	
18" Elliptical Parachute - 1.2 lb @ 20fps	$53.00	1	$53.00	
Total				**$461.95**

Payload				
Carbon Fiber Tube (hollow) 3x2x750mm	$2.10	5	$10.50	
4" Airframe A-Bay Bulkplate	$4.05	8	$32.40	
4" Couple A-Bay Bulkplate	$4.05	6	$24.30	
Total				**$67.20**
GPS				
Whistle GPS	$70.00	1	$70.00	
Cellular Service Fee (3 months free, 5 months to pay)	$40.00	1	$40.00	**$110.00**
Total				
Educational Outreach				
Facility Use	$30	1		
Materials for Outreach Event	$90	1		
Total				**$120**
Travel Fees (10 Members) (Estimated)				
Trips to Lucerne Dry Lake ($3.25/gallon, 128 mi)				
Trip to Huntsville (Roundtrip)	$380	10	$3,800	
Hotel at Huntsville ($120/night, 2 people per room, 6 days)	$120	30	$3,600	
Food ($25/day, 6 days)	$25	10	$1,500	
Total Travel Costs				**$8,900**
TOTAL ESTIMATED SLI PROJECT COSTS				**$11,039.05**

6.2.1 Funding Plan

Our goal this year is to obtain our funds from a variety of sources. One method will be through fundraising, such as fundraising via selling items such as boba milk tea from Lollicup or donuts from Krispy Kreme. Other methods also include, but are not limited to, asking for donations, requesting financial aid from local businesses and companies through explaining the goal of the team, and appealing for discounts from vendors relating to the project plan.

6.3 Plan for Sustainability

6.3.1 Maintaining/Establishing Connections and Partnerships

The SLI team will be actively participating in events and projects that encourage STEM. The team will also maintain contact with established partners and the community.

6.3.2 Educational Outreach

For the past years of Vertical Projectile, the team has participated in the cultural events of schools and provided an air-pressure rocket launch, where the rockets are made of paper, tape, and a penny that is taped to the tip of the rocket. It is anticipated that this year, the team will continue with this activity.

6.3.3 Funding

To support team expenses, the team will actively seek fundraising opportunities and other forms of funding through the project life cycle.

6.3.4 Website

As per NASA SL 2019 requirements, the team is to have a website where the deliverables will be found in PDF format.
Www.verticalprojectile.org is the website where all team documents and more will be posted. NASA SL 2019 will be able to be found under the NASA SL tab, as well as previous year's information.

Appendix A: Technical Requirements Statement of Works

Section	Requirement in SOW	Proposal Section
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).	1.1-1.6

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 assignments, STEM engagement events, and risks and mitigations.	2.1-2.3, 3.1-3.7
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 their team during certain 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.	1.1-1.5.8
1.4.2	One Mentor (see requirement 1.13)	1.6
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 STEM Engagement Activity Report, by FRR. To satisfy this requirement, all events must occur between project acceptance and the FRR due date and the STEM Engagement Activity Report must be submitted via email within two weeks of the completion of the event. A sample of the STEM Engagement Activity Report can be found on page 33 of the handbook.	
1.6	The team will establish a social media presence to inform the public about team activities.	
1.7	Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient.	
1.8	All deliverables must be in PDF format.	
1.9	In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Pgs. 1-2
1.10	In every report, the team will include the page number at the bottom of the page	
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	2.3

	sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.	
1.12	All teams will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted on the launch field. Eight foot 1010 rails and 12 foot 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on launch day. The exact cant will depend on launch day wind conditions.	
1.13	Each team must identify a "mentor." A mentor is defined as an adult who is included as a team member, who will 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 2 flights in this or a higher impulse class, prior to 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 be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend launch week in April.	1.6
Vehicle Requirements		
2.1	The vehicle will deliver the payload to an apogee altitude between 4,000 and 5,500 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,000 feet on Launch Day will be disqualified and receive zero altitude points towards their overall project score.	4.1.2
2.2	Teams shall identify their target altitude goal at the PDR milestone. The declared target altitude will be used to determine the team's altitude score during launch week	4.1.2
2.3	The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner. The Altitude Award will be given to the team with the smallest difference between their measured apogee and their official target altitude on launch day.	3.3
2.4	Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	
2.5	Each altimeter will have a dedicated power supply	

2.6	Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	3.3
2.7	The launch vehicle will be designed to be recoverable and reusable. Reuseable is defined as being able to launch again on the same day without repairs or modifications.	3.1
2.8	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 is recovered separately from the main vehicle using its own parachute.	3.1
2.8.1	Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length	
2.8.2	Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length	
2.9	The launch vehicle will be limited to a single stage	
2.10	The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.	
2.11	The launch vehicle will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components.	
2.12	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 launch services provider.	
2.13	The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).	
2.14	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).	
2.14.1	Final motor choices will be declared by the Critical Design Review (CDR) milestone	
2.14.2	Any motor change after CDR must be approved by the NASA Range Safety Officer (RSO) and will only be approved if the change is for the sole purpose of increasing the safety margin. A penalty against the team's overall score will be incurred when a motor change is made	

	after the CDR milestone, regardless of the reason.	
2.15	Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:	
2.15.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.	
2.15.2	Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank	
2.15.3	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.	
2.16	The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class). The total impulse provided by a High School or Middle School launch vehicle will not exceed 2,560 Newton-seconds (K-class).	
2.17	The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	
2.18	The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	
2.19	All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets	
2.19.1	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.	
2.19.2	The subscale model will carry an altimeter capable of recording the model’s apogee altitude.	
2.19.3	The subscale rocket must be a newly constructed rocket, designed and built specifically for this year’s project.	
2.19.4	Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.	
2.20	All teams will complete demonstration flights as outlined below;	
2.20.1	Vehicle Demonstration Flight - All teams will successfully launch and	

	recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown must be the same rocket to be flown on launch day. The purpose of the Vehicle Demonstration Flight is to validate 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 the intended lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight:	
2.20.1.1	The vehicle and recovery systems will have functioned as designed	4.1.6
2.20.1.2	The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	
2.20.1.3	The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:	
2.20.1.3.1	If the payload is not flown, mass simulators will be used to simulate the payload mass	
2.20.1.3.2	The mass simulators will be located in the same approximate location on the rocket as well as the missing payload mass	
2.20.1.4	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 Vehicle Demonstration Flight.	
2.20.1.5	Teams shall fly the launch day motor for the Vehicle Demonstration Flight. The RSO may approve use of an alternative motor if the home launch field cannot support the full impulse of the launch day motor or in other extenuating circumstances.	
2.20.1.6	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. Additional ballast may not be added without a re-flight of the fullscale launch vehicle	
2.20.1.7	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.	

2.20.1.8	Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.	
2.20.1.9	Vehicle Demonstration flights must be completed by the FRR submission deadline. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. This extension is only valid for re-flights, not first-time flights. Teams completing a required re-flight must submit an FRR Addendum by the FRR Addendum deadline.	
2.20.2	Payload Demonstration Flight - All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown must be the same rocket to be flown on launch day. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent, the payload is fully retained during ascent and descent, and the payload is safely deployed on the ground. The following criteria must be met during the Payload Demonstration Flight:	
2.20.2.1	The payload must be fully retained throughout the entirety of the flight, all retention mechanisms must function as designed, and the retention mechanism must not sustain damage requiring repair.	
2.20.2.2	The payload flown must be the final active version.	
2.20.2.3	If the above criteria is met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.	
2.20.2.4	Payload Demonstration Flights must be completed by the FRR Addendum deadline. No extensions will be granted.	
2.21	An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report.	
2.21.1	Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly the vehicle at launch week.	

2.21.2	Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly the payload at launch week.	
2.21.3	Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.	
2.22	Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	
2.23	The team's name and launch day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	
2.24	Vehicle Prohibitions	
2.24.1	The launch vehicle will not utilize forward canards. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	
2.24.2	The launch vehicle will not utilize forward firing motors.	
2.24.3	The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	
2.24.4	The launch vehicle will not utilize hybrid motors.	
2.24.5	The launch vehicle will not utilize a cluster of motors.	
2.24.6	The launch vehicle will not utilize friction fitting for motors.	
2.24.7	The launch vehicle will not exceed Mach 1 at any point during flight.	
2.24.8	Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with and unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast)	
2.24.9	Transmissions from onboard transmitters will not exceed 250 mW of power.	

2.24.10	Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	
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 deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.	4.1.6
3.1.1	The main parachute shall be deployed no lower than 500 feet.	
3.1.2	The apogee event may contain a delay of no more than 2 seconds.	
3.2	Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.	
3.3	At landing, each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.	
3.4	The recovery system electrical circuits will be completely independent of any payload electrical circuits.	
3.5	All recovery electronics will be powered by commercially available batteries.	
3.6	The recovery system will contain redundant, commercially available altimeters. The term "altimeters" includes both simple altimeters and more sophisticated flight computers.	
3.7	Motor ejection is not a permissible form of primary or secondary deployment.	
3.8	Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	
3.9	Recovery area will be limited to a 2,500 ft. radius from the launch pads.	
3.10	Descent time will be limited to 90 seconds (apogee to touch down).	
3.11	An electronic 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.	

3.11.1	Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.	
3.11.2	The electronic tracking device(s) will be fully functional during the official flight on launch day.	
3.12	The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	
3.12.1.	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.	
3.12.2	The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	
3.12.3	The recovery system 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.	
3.12.4	The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	
Payload Experiment Requirements		
4.1	High School/Middle School Division – Teams may design their own science or engineering experiment or may choose to complete one of the College/University Division experiment options.	4.1.5
4.5.1	Team-designed payloads 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.	
4.5.2	Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.	
4.5.3	The experiment 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.	
4.5.4	Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event.	

4.5.5	Unmanned aerial vehicle (UAV) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAV.	
4.5.6	Teams flying UAVs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	
4.5.7	Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	
	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
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 role and responsibilities of each safety officer will include, but are not limited to:	
5.3.1	Monitor team activities with an emphasis on Safety during:	
5.3.1.1	Design of vehicle and payload	
5.3.1.2	Construction of vehicle and payload	
5.3.1.3	Assembly of vehicle and payload	
5.3.1.4	Ground testing of vehicle and payload	
5.3.1.5	Subscale launch test(s)	
5.3.1.6	Full-scale launch test(s)	
5.3.1.7	Launch day	
5.3.1.8	Recovery activities	
5.3.1.9	STEM Engagement Activities	
5.3.2	Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	
5.3.3	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	

5.3.4	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	
5.4	During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those 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.	
5.5	Teams will abide by all rules set forth by the FAA.	

Appendix B: Proposal Statement of Works

Number	**Requirement**	**Proposal Section**
General Information		
1.	A cover page that includes the name of the college/university or secondary education institution, mailing address, title of the project, and the date.	
2.	Name, title, and contact information (including phone number) for up to two adult educators. (minimum of one required)	1.2
3.	Name, title, contact information of the student team leader.	1.3
4.	Name and title of the student team member who will take responsibility for implementation of the safety plan. (Safety Officer)	1.4
5.	Approximate number of student participants who will be committed to the project and their proposed duties. Include an outline of the project organization that identifies the key managers and technical personnel.	1.5
6.	Name of NAR/TRA section(s) the team is planning to work for purposes of mentoring, review of designs and documentation, and launch assistance.	1.6

Facilities/Equipment		
1.	Description of facilities and hours of accessibility, necessary personnel, equipment, and supplies that are required to design and build a rocket and payload(s).	2
Safety		
1.	Provide a written safety plan addressing the safety of the materials used, facilities involved, and student responsible, i.e. Safety Officer, for ensuring that the plan is followed. A risk assessment should be done for all these aspects in the addition to proposed mitigations. Identification of risks to the successful completion of the project should be included.	3.1
1.1	Provide a description of the procedures for NAR/TRA personnel to perform. Ensure the following: • Compliance with NAR high power safety code requirements [http://nar.org/NARhpsc.html]. • Performance of all hazardous materials handling and hazardous operations.	3.2
1.2	Describe the plan for briefing students on hazard recognition and accident avoidance as well as for conducting pre-launch briefings.	3.3
1.3	Describe methods to include necessary caution statements in plans, procedures and other working documents, including the use of proper Personal Protective Equipment (PPE).	3.4
1.4	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
1.5	Provide a plan for NAR/TRA mentor purchase, store, transport, and use of rocket motors and energetic devices.	3.6
1.6	Include a written statement that all team members understand and will abide by the following safety regulations:	3.7
1.6.1	Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.	3.7

1.6.2	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.	3.7
1.6.3	The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. Therefore, a team will not fly a rocket until the mentor has reviewed the design, examined the build and is satisfied the rocket meets established amateur rocketry design and safety guidelines.	3.7
1.6.4	Any team that does not comply with the safety requirements will not be allowed to launch their rocket.	3.7
Technical Design		
1.	A proposed and detailed approach to rocket and payload design.	4.1
1.a.	Include general vehicle dimensions, material selection and justification, and construction methods.	4.1.1
1.b.	Include projected altitude and describe how it was calculated.	4.1.2
1.c.	Include projected recovery system design.	4.1.3
1.d.	Include projected motor and brand designation.	4.1.4
1.e.	Include detailed description of the team's projected payload.	4.1.5
1.f.	Address the General, Vehicle, Recovery, Payload, and Safety requirements outlined on pages 5-13 of this handbook.	5.1.6
1.g.	Address major technical challenges and solutions.	4.1.7
STEM Engagement		
1.	Include plans and evaluation criteria for required STEM engagement activities. (See project requirement 1.5 on page 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.	6.2.1

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 STEM engagement activities.	6.3
Deliverables required for successful participation are listed below. More details are provided in the Project Milestones: Criteria and Expectations section.		
1.	A reusable rocket with required payload system ready for official launch.	
2.	A scale model of the rocket design must be flown before CDR and a report of the flight data brought to CDR	
3.	A full-scale Vehicle Demonstration Flight and Payload Demonstration Flight must be flown and flight data reported in the FRR and/or FRR Addendum.	
4.	A team social media presence that is maintained/updated throughout the project year.	
5.	Reports, PDF slideshows, and Milestone Review Flysheets completed and submitted to the Student Launch Projects management team by applicable due dates.	
6.	Electronic copies of the STEM Engagement form(s) submitted prior to FRR and within two weeks of the STEM engagement event.	
7.	Participation in PDR, CDR, FRR, LRR, and PLAR.	

Appendix C: Shop Safety Rules

<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.

Appendix D: Launch Safety Rules

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

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

Our team rules completely comply with the rules stated above. The AIAA Orange County Sections rules are stated below and contain a table similar to the one included above.

- The lightweight materials that will be used are; paper, wood, rubber, plastic, fiberglass or only when it's necessary, metal.
- The motors that will be used will be certified for commercially made rocket motors. They will not be tampered with or used for anything except for what is recommended by the manufacturer. Under no circumstances will there be smoking, open flames or any other heat sources within 25 feet of the motors.
- The rocket will be launched with an electrical launch system, and with electrical motor igniters that are installed when the rocket is on the launch pad or in the designated prepping area. The launch system will have a safety interlock that is in series with the unactivated launch switch until the rocket is ready for launch and will use a launch switch that returns to the off position when released. If the rocket has an onboard ignition system for motors and or recovery devices, they will have safety interlock that interrupts the current path until the rocket is at the launch pad. If the ignition systems have a second battery and relay at the pad, then the batter will be disconnected while the rocket is placed on the launch pad, and the igniter will be connected to the launch system.
- The launcher that is used will be a stable device that provides rigid guidance until the rocket has gotten to a speed that ensures it will be stable in flight. It is also pointed within twenty degrees of vertical. If the wind is over five miles per hour, then the launcher length will permit the rocket to attain safe velocity before separating from the launcher. In addition, blast deflector will be used to prevent the motor's exhaust from hitting the ground. In accordance with the minimum distance table, there will be no dry grass around each launch pad.
- If the rocket does not launch, then the launcher's safety will interlock or disconnect the battery. After the launch attempt, we will wait sixty seconds before allowing anyone to approach the rocket. If the ignition system includes a second battery and relay at the pad, that battery will be disconnected before approaching the rocket.
- The rocket will be verified for stability, sound construction, and any previous damage before it is allowed to fly. The rocket will not have a total thrust more than 40,960 N-Sec.

- The launch pad area will be reviewed to make sure there is no one closer to the launch pad than the minimum distance table states. The sky will be checked above the launch site to make sure that there are no airplanes, helicopters, or aircrafts in the area before launching. Someone will state: "range is clear" and "sky is clear" before proceeding to launch. These statements will be followed by a five second countdown to warn anyone in the launch area.
- The rocket will not be launched between the hours of sunset and sunrise or in the dark.
- The rocket will be launched outdoors in opens area where trees, power lines, buildings and person(s) not involved in the launch do not represent a hazard. The lot side must be at least, on its smallest dimension, as one-half of the maximum altitude for which rockets are allowed to be flown at that site, or 1500 feet, whichever is greater.
- The rocket will not be launched at targets into clouds or obscuring phenomena, near airplanes or on trajectories that make it fly directly over the heads of spectators, or beyond the boundaries of the launch site. It will not have a flammable or explosive payload in the rocket.
- The rocket will not be launched to an altitude where the horizontal visibility is less than five miles or if winds exceed twenty miles an hour. The person(s) launching the rocket will fully comply with the Federal Aviation Administration airspace regulations when flying and will make sure our rocket does not exceed any applicable altitude limit in effect at the launch site.
- The launching location will be at least 1500 feet away from any inhabited building or public highway on which traffic flow exceeds ten vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.
- All spectators shall remain behind the person launching the rocket. No person(s) shall be closer to the launch that the minimum safe distance table. Additionally, no person(s) shall be closer to the launch of our rocket than the person who is actually flying the rocket.
- The rocket will use a recovery system so that all parts of the rocket return safely and undamaged and can be flown again. Only flame-resistant or fireproof recovery system wadding and heat shields will be used in our rocket.
- No person(s) will attempt to recover the rocket from power lines, tall trees, or other dangerous places. The rocket must be flown under conditions where it is likely to recovery in spectators areas or outside the launch site. No one will attempt to catch the rocket as it approaches the ground.
- The two jobs that exist to ensure safety are the range safety officer and the launch control officer.
- The RSO (Range Safety Officer): has the overall control and responsibility for the safety of the range and can shut down the launch site if is thought to be necessary. They are responsible to make sure that each rocket flown is safe to fly before it is launched. They make certain the fins and launch lug are present and securely fastened to the body tube. They make sure that the recovery system is functional and the engine is installed properly. Although all persons responsible for designing and building a rocket need to make certain it is safe to fly, the range safety officer has the ultimate responsibility.

  The RSO reserves the right to stop a launch for safety reasons.

- The LCO (Launch Control Officer) is responsible for supervising the actual launching of the rockets and that all conditions are safe to do so. This includes making sure that the launch pads are not armed when people are close to them. Before each launch they must check for people, including spectators, that might be in an unsafe location and check for nearby aircrafts. For the first launch of a rocket, or if the launch includes any unusual risks, the flight will be announced as a "Heads-Up" flight. This person must track each flight until the rocket returns to ground level. Again, although all persons are responsible for designing and building the rocket and need to take these same precautions, the launch control officer has the ultimate responsibility.

Appendix E: 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.

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, CO2 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.

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

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 = 1.0):** At 20 C, None	**Evaporation Rate:** 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.