Proposal for Entry to NASA Student Launch
Project U.R.S.A.[1]

Space Technologies and Rocketry
University of California, Berkeley

September 28, 2016

[1]Upright Recovery and Sight Acquisition

Contents

1 General Team Information

We are the University of California, Berkeley (referred to as UC Berkeley, Berkeley, or Cal) Space Technologies and Rocketry (S.T.A.R.) club.

1.1 Key Contacts

Faculty Advisor	Carlos Fernandez-Pello Professor of Mechanical Engineering Dept. of Mechanical Engineering, UC Berkeley ferpello@me.berkeley.edu (510) 642-6554
NAR Contact	David Raimondi President, Livermore Unit of the National Association of Rocketry NAR Section #534 president@lunar.org (408) 742-5173
Student Team Leader	Jordan Covert President, Space Technologies and Rocketry College of Engineering, UC Berkeley BS Engineering Physics, Expected 2018 ironbender3@berkeley.edu (123) 420-6969
Safety Officer	Grant Posner College of Engineering, UC Berkeley BS Computer Science & BS Math, Expected 2019 grant.posner@berkeley.edu (858) 735-3384

1.2 Team Directory

There are approximately 25 active members on STAR. Members are broken into 8 separate sub-teams, with many serving on multiple teams. The sub-teams and sub-team leads are as follows:

Airframe	**Jordan Covert** ironbender3@berkeley.edu
Budget	Jia Zhen jiazhen@berkeley.edu
Electrical	Jacob Posner jacobposner@berkeley.edu
Outreach	Aaron Togelang atoge1@berkeley.edu
Payload	**Avyay Pancha** apancha@berkeley.edu
Safety	**Grant Posner** grant.posner@berkeley.edu
Recovery	**Adam Huth** ajhuth1@berkeley.edu
Reports	Ryan O'Gorman ryanogorman@berkeley.edu

Note: Names in boldface are key managers of the U.R.S.A. Project.

1.3 Resources

1.3.1 Facilities

Etcheverry Mechanical Engineering Machine Shop Will be used for majority of our machining, especially that of the airframe and deployable landing legs, and the storing of our materials.

Accessibility:

- Hours: (xx to xx)
- 3 team members will receive required training this (Fall) semester, 3 will receive it the following (Spring) semester
- Relevant Equipment:
  - Band Saw
  - Horizontal Band Saw
  - Mill
  - Lathe
  - Waterjet Cutter
  - CNC Mill

Jacobs Institute for Design Innovation Will be used for manufacturing parts on laser cutters and 3D printers in addition to electrical work.

Accessibility:

- Hours: (xx to xx)
- Multiple team members with keycard access and training on relevant machines and tools.
- Relevant Equipment:
  - 3D Printers
  - Vacuum Former
  - Laser Cutters

Moffitt MakerSpace Will be used for general construction, assembly, etc. that does not require specialized machines.

Accessibility:

- Hours: (xx to xx)
- Open to all students.
- Relevant Equipment:
  - 3D Printers

Berkeley Global Campus at Richmond Bay (BGC) We will use this off-site facility for any testing, manufacturing, or construction that would be imprudent to perform on main campus and is not necessary to perform at a NAR or TRA site.

Accessibility:

- Hours: 24/7
- Currently in the process of securing a space at BGC.
- Relevant Equipment:
  - Outdoor testing space.

Homemade Wind Tunnel at a team member's garage Will be used for aerodynamics testing.

Accessibility:

- Hours: Whenever necessary.

1.3.2 Software

Rocket Design and Analysis

- OpenRocket
- Solidworks (CAD and FEA)
- Ansys (CFD)

Manufacturing

- Adobe Illustrator (Laser Cutter)
- MasterCam X9 (CNC Mill)
- Cura (3D Printing)

Electrical

- EagleCAD (Electronics design)
- BlueJ (Raspberry Pi programming)

1.4 Sustainability

STAR was formed last spring, and this is its first time attempting to compete in the NASA Student Launch or any high powered rocket competition. Through participation in new student events, at a campus club fair, and on social media this semester alone STAR has about 20 new team members. Once we have a impressively designed rocket and are able to advertise our participation in NSL or any other competitions, we expect even more success recruiting incoming students and new members to STAR. In addition, we have documented detailed records of all of our work this year in a Google Drive, which we plan to show off to prospective industry partners and members.

1.4.1 Maintaining Communication

The outreach team plans on sustaining itself through regular communication with our sponsors, partners, and people at outreach events. Making sure that we are not forgotten and regularly holding events will allow us to keep a strong presence in the community throughout the years the team will exist.

1.4.2 Data Inheritance

As mentioned above, all of the teams logistical information is available on a common Google Drive account. All this information will be passed on as the team ages, so that we can build on our mistakes.

2 Airframe

2.1 Description

The overall length of the proposed vehicle is 8 feet 6 inches. The diameter of the nose cone and front partition is 6 inches, and the diameter of the booster section is 4 inches. The booster is 4 feet in length. It houses an Aerotech K1050 motor, an avionics bay, and the main parachute. The reduced diameter of the booster section functions to reduce the rockets wake, increasing aerodynamic stability. The booster is connected to the upper section by a 1 foot conical transition that increases the rockets diameter to 6 inches. The transition houses the drogue parachute. The upper section acts as the rockets payload. It houses three parachutes, a separate avionics bay, and landing hardware. This section, which includes the nose cone, is 42 inches in length. The ogive nose cone is 18 inches in length, giving it a length to diameter ratio that is aerodynamically favorable. Three clipped delta fins are attached to the rear portion of the booster section. The three fins provide stability for the rocket, pulling the center of pressure back to create a static margin of approximately 2.04.

2.2 Materials

The main body of the rocket will be constructed from blue tube. Blue tube is strong enough to withstand high impact landings as well as high G-forces experience during takeoff. Its heat resistance is high enough to survive the temperatures of the motors exhaust. Additionally, blue tube has a density of approximately 0.871 ounces/inch^3, which is fairly light when compared with other materials such as fiberglass or phenolic. Blue tube is also much more shatterproof than materials like phenolic, and much easier to work with as compared to materials like fiberglass. These, coupled with its relatively low price makes it an appealing choice for our main airframe.

The nose cone will be constructed out of polycarbonate by vacuum forming over a 3D printed mold. The fins will be constructed from fiberglass because of its high strength and flexibility. The motor will be mounted in an inner tube made of phenolic. Centering rings for the inner tubes will be constructed from wood and cut on a laser-cutter.

2.3 Construction

Most of the airframe will be constructed from 48 inch pre-cut lengths of blue tube. These sections will be cut into smaller pieces using a horizontal band saw. The nose cone will be made from transparent polycarbonate using vacuum-forming techniques. The fins will be made from fiberglass. The transition coupler will be made by hand from carbon fiber for strengthening purposes. Slots for the fins will be machined into the booster section using either a CNC mill or a dremel tool . Epoxy will be used as an adhesive for the fins, centering rings, and the separate parts of the rocket.

2.4 Flight Metrics

Currently, our projected apogee is approximately 5580 feet above ground level. Although the final rocket should project an altitude of exactly one mile, designing a rocket capable of reaching a higher altitude provides enough margin of error in case the final design is over the projected weight. Based on OpenRocket simulations, an allowable excess of up to 28 ounces of added weight would bring the apogee to exactly one mile. Our static stability margin is calculated at 2.04 calibers.

The projected velocity off the rod is approximately 75 feet/second. The maximum acceleration is projected to be approximately 14.5 G's, and the maximum velocity is 533 miles per hour.

2.5 Images

Figure 1: Side View of Rocket

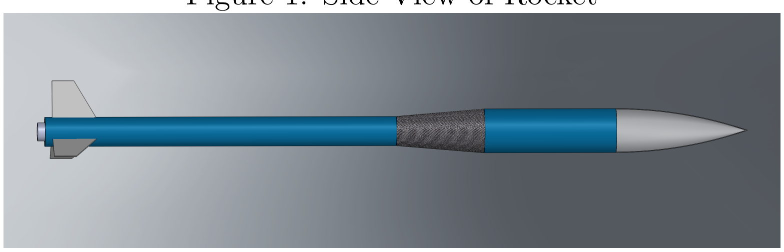
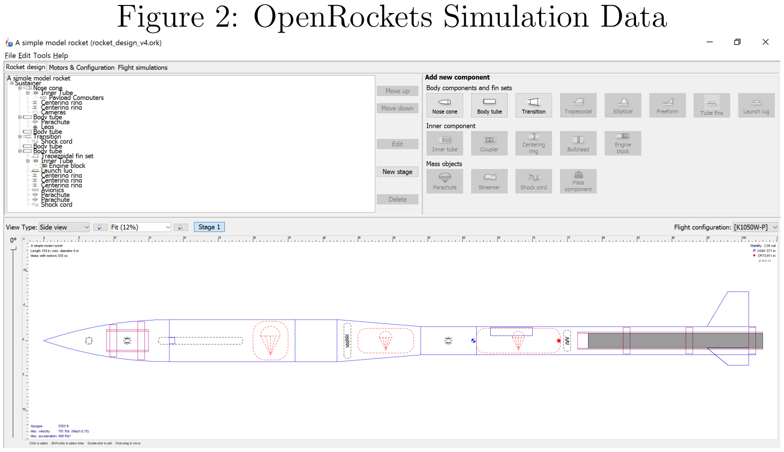


Figure 2: OpenRockets Simulation Data



3 Budget

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper. TODO

4 Electronics

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper. TODO

5 Outreach

5.1 Goals

The teams plan for outreach is to get involved with as many educational programs (schools, museums, libraries) as possible, and develop strong connections with different groups (aerospace and outreach organizations on campus). Additionally, we want to help establish Aerospace courses at our university.

5.2 Projects

5.2.1 Current/Ongoing

KIPP Bay Area Schools KIPP manages 11 charter schools that aim to provide free education to underserved communities and get their students into college. During Berkeley's Turn the Tables Fair (29 Sept 2016), we developed a contact with KIPP's Innovation Team. They are in charge of setting up STEM curriculum and activities for the entire school district. We are currently working with them to plan outreach events where we and other aerospace teams visit and promote the sciences.

CalDay 2016 On CalDay (16 April 2016), we held a booth and talked to prospective and current UC Berkeley Students.

New Engineering Student Orientation 2016 On NESO (23 August 2016), we held a booth and talked to current UC Berkeley Engineers looking for clubs and teams to join.

Calapalooza 2016 Held a booth and talked to current UC Berkeley students looking for clubs and teams to join.

5.2.2 Planned

Habitat for Humanity One of the other groups on campus will be bringing local middle school students over for a campus tour. For the science portion of their visit, we are hoping to hold a demonstration and/or lecture about rockets.

Approval for Rocket Demonstrations California is very picky with rocket launches and as such, we are looking for ways to make launching model rockets easier and more available to all

Aerospace Curriculum at Berkeley While UC Berkeley has a great engineering program and is the number one public university in the world, we do not have an aerospace major, and there are very few aerospace-related classes. We are creating connections with other campus organizations such as the Aero SAE (model airplanes) and AIAA (American Institute of Aeronautics and Astronautics) clubs to petition the school to start an Aerospace program.

5.3 Evaluation Criteria

5.3.1 Interaction Count

The number of students, teachers, and family members will be counted at each event, either through a signup sheet or through manually counting.

5.3.2 Interaction Quality

After or during events, we will occasionally hand out surveys to ask how we are doing and whether or not our outreach has had any strong impact on the individual and/or community. The survey can be found in Appendix B.

5.3.3 Maintained Interaction

Through the signup sheet mentioned in Interaction Count, we will contact students, teachers, and family members afterwards about future events. Part of the survey from Interaction Quality will ask about the effectiveness of maintained communication.

6 Payload

6.1 Motivation

As a primary payload, the landing location detection with a controlled landing (option 1) allows us to build our system around the concept of a reusable payload section. In this aim, SAGITTA-VL (Sight-Aided Ground IdenTificaTion And Vertical Landing) uses a nose-facing camera inside a clear nosecone to achieve detection of the landing zones post main chute deployment (prior to ejection of the payload section). This allows for a significant amount of time to detect and identify the landing zones, while keeping deployment mechanisms for our landing legs and payload parachutes robust, reducing the probability of failure. The nose facing camera interfaces with an onboard avionics suite used exclusively to process the feed from the camera. This allows maximum processing power to be allocated to image processing, as well as providing range tracking ability for both sections of the rocket following payload eject.

The primary mechanism for an upright landing are legs which, during boost and post-apogee, pre-payload-eject, are flush with the body. Post-payload-eject, the activation of the payload recovery system will also include activating the legs so they swing outwards into a position that will facilitate vertical landing of the rocket. Rail-guided secondary sliding supports provide a second point of attachment from the leg to the airframe structure, providing additional stability and strength during the impact event.

The goal of the payload recovery system is three-fold: to reduce the overall energy of the system on impact; to slow the payload system sufficiently where active stabilization of the payload module is not required (pre-impact or post-impact), and; to reduce landing impact damage to the payload section, allowing reuse on future flights.

6.2 Mechanical Design Summary

6.2.1 Payload Description

The payload section of the vehicle consists of the top 18 of the rocket tube, as well as the nose cone. The bottom of the section will consist of an avionics bay, which will contain independent electronics to control payload operations. These electronics are described in Payload Electrical Design Summary. The bottom of the payload section will be attached to the avionics bay for the drogue parachute, and will be eventually separated as an independent section during descent.

The nose cone will be composed of clear polycarbonate, with a nose-facing camera mounted inside. The tubing section will have three cut-out sections spaced at 120o around the circumference of the body these will serve as the outer surfaces of the landing legs used to land the vehicle upright. Each landing leg will have a rectangular aluminum support member along the interior surface. Each leg will be mounted into its positions in the airframe at the bottom of the aluminum frame, via a hinge fixed to the uncut airframe on either side of the leg. In addition, the hinges will be fitted with torsion springs that hold the leg at no more than 110o from vertical. This position will be the landing configuration. For the launch configuration, i.e. when the vehicle is on the launch pad, the legs will be folded so as to be flush with the airframe outer surface, and the top of the aluminum frames will be secured in place by pins. These pins will be electronically moved using a motor, so that they can be retracted at a specific time in order to release the legs to the landing configuration. The outer surface of each leg will consist of a 15 long section of tubing parallel to the longitudinal axis of the airframe. The upper 3 of this section will be 5 in width, with the rest at 3 in width.

Each landing leg will be additionally attached to a vertical rail that runs throughout the length of the payload section, toward the center of the tube. Each leg is attached via a hinged joint and an aluminum sliding support to a rolling joint which slides along the rail. Preliminary geometric analysis shows that a sliding support roughly 60% of the length of the landing leg allows for the maximum range of motion (110°) for the landing legs.

In the upper region of the tubing section of the payload, three small bundled parachutes will be mounted in open containers fixed to the nosecone bulkhead. These containers will be oriented such that the parachutes can be released toward the outside of the vehicle the position of the each parachutes corresponds to the upper, wider section of a landing leg. The parachutes will be secured to eyebolts in the nosecone bulkhead. Additionally, each landing leg frame will have a string that is partially wrapped around its corresponding parachute, such that when the landing leg is deployed, it pulls the chute of the airframe.

6.2.2 Target Detection

Our payload is designed to complete two independent tasks: visual identification of ground targets, and upright landing of the payload section of the vehicle. Target identification is achieved by means of a video camera mounted in the nose of the rocket, which can view the ground through the transparent polycarbonate nose cone. After deployment of the drogue chute, the nosecone and payload section of the vehicle will face the ground, suspended by the shock cord and the drogue parachute. After the main parachute deploys at an altitude of approximately 1100 feet, the falling vehicle will be slowed sufficiently so that the camera can accurately view the ground and provide live image data which can be used to identify and differentiate the targets. Our software package, as described below in Payload Electrical Design, will provide a signal to indicate when the identification has been completed.

6.2.3 Upright Landing

After target detection is complete, the entire payload section will be separated from the drogue parachute avionics bay by means of a black powder ejection charge. This deployment will activate the electronic actuation of the holding pins for the landing legs, causing them to retract and allow the landing legs to fall to the landing configuration. This action will cause the deployment of the payload section parachutes. The chute deployment will cause a sharp increase in drag at the upper region of the payload, while the deployment of the legs will shift the center of gravity of the section downward. This combined action will cause the payload section to rotate into the upright position, which it will maintain as it floats to the ground. When it reaches the ground, it will make contact on the landing legs, allowing it to stay upright. The torsion springs and the central rail mechanism will provide suspension to prevent the legs from folding back up as the section hits the ground.

6.3 Electrical Design Summary

To facilitate the target detection and upright landing, a custom image processing software system will be used. It will be run using a Raspberry Pi system. Target detection will begin after the main parachute deploys, likely at less than 1000 feet above the ground. Higher altitudes mean a higher risk of the targets being blocked from view by clouds, although the software will consider this and similar possibilities anyway.

Once target detection is complete, the software will:

1. Provide proof that the target has been detected, either by saving an annotated image to the computers storage, or by sending a signal with similar proof to the ground;

2. Trigger the charges to separate from the rest of the airframe;

3. Trigger the actuator to remove the pins holding the landing legs in place;

4. Trigger the charges to deploy the parachutes for the upright landing;

5. Confirm that the descent of the payload section is proceeding correctly.

6.4 Payload Procedure

6.4.1 Prelaunch and Ascent

Prior to launch, the payload section will be upright and coupled to the rest of the vehicle, with the landing legs locked in the launch configuration. This configuration is maintained throughout ascent.

6.4.2 Drogue Chute Deployment

During the deployment of the drogue chute, the payload will remain coupled to the drogue chute avionics bay, which is tethered to the rest of the vehicle. This will result in the nose cone facing downward, suspended under the drogue chute.

6.4.3 Main Chute Deployment

The main chute will be deployed from the booster section of the vehicle, with no change occurring in the payload configuration. At this time, the camera used for target identification will activate, and attempt to locate, identify, and differentiate the targets during slow descent.

6.4.4 Payload Deployment

When the camera has successfully identified and differentiated the targets, the software package will provide a signal to eject the payload section. This will also prompt the deployment of the landing legs and parachutes, which will cause the vehicle to turn upright. It will remain in the upright orientation, with legs in the landing configuration and all three parachutes deployed, until it lands on the ground.

6.5 Challenges

There are many challenges associated with high-power rocketry, many of which are unknown. The table below, while not all-inclusive, is a list of anticipated challenges associated with this projects payload and their proposed solutions.

Challenge	Solution

Challenge	Solution
Target Detection	By building a nose-facing camera, there is more allowed time to successfully identify and differentiate between the targets before mechanisms for upright landing begin.
Achieving upright orientation for landing	After target detection and post-payload-eject, there will be two mechanisms that will cause the rocket to angle itself upright. First, the force from the legs folding outwards will shift the center of gravity downward, causing the payload to rotate away from its nose down orientation. Second, once the parachutes deploy and open, they will induce drag at the top of the payload section, causing the payload to completely flip into its upright orientation.
Prevent connection between leg and inner rocket body breaking upon impact with ground	Limit angle between leg and body to no more than 110 degrees at full extension. Let the torsion springs initially used to deploy legs double as a suspension system during impact. Add a support beam that is connected to the leg and body which will provide more support during impact. By adding this other point of contact, the beam will also act as a secondary connection in case the main hinge fails.
Prevent legs from folding back during landing	The three parachutes will decrease the speed of the payload so the force from impact with the ground is lessened. Also, the springs will force the legs downward during landing to keep them in the correct position.
Avoid parachute deployment failure due to snagging	A wider opening for the individual parachutes will be used and the parachutes will be packaged into small bundles to ensure a smooth deployment.

7 Recovery

7.1 Construction Methods

Our avionics bay design will require us to use several different methods in order to construct a functional system. The bulkheads in the rocket will be made using a laser cutter. Using a laser cutter will allow us to make bulkheads that fit snuggly into the body of the rocket and cut precise holes for wires, screws, and U-bolts. The single axle in the avionics bay will be constructed by welding a metal, circular plate to each side of the axle. The platform that holds the altimeters and batteries will be 3-D printed in order to customize mounting of the altimeters, while remaining light and structurally sound. The door of the avionics bay will either be cut on a mill from an existing piece of airframe or made of polycarbonate. In the case of a polycarbonate door, we will 3-D print a mold and pour the resin ourselves.

7.2 General

TODO. Need to address the RFP reqs.

7.3 Avionics Bay Design

The design of our avionics bay (A-Bay) is rooted on two key characteristics: accessibility and safety. In order to optimize the accessibility of our avionics bay, we have decided to take a more unconventional approach to the design and build process. Rather than incorporating a movable sled, on which the altimeters and batteries are mounted, and having to unscrew the bulkhead in order to access the avionics bay, we have designed a door on the side, allowing us to be able to access the inside of the A-Bay with more ease. This door would be completely detachable, with lips on the edges secured tightly to the rest of the A-Bay with O-rings and four primary screws. Furthermore, rather than incorporating the double-axle sled, we decided to build our platform around a single axle. This single axle would run through the center of the platform, allowing the platform to rotate around that axle, even when the door is opened. This would tremendously improve the accessibility of both sides of the platform, becoming a multipurpose access point for the altimeters, batteries, wires, and more. The single axle would be welded into a metal plate on each end, which in turn would be screwed into the plywood bulkheads. This is done in order to distribute the stress of the force on the single axle onto the bulkheads. The bulkheads would be secured completely with an adhesive into the sides of the avionics bay once the door has been designed. Secured onto the outer faces of the bulkheads would be a U-bolt on each side, which would be linked to a parachute on each side with tubular Kevlar shock cords. The drogue chute will be linked to the fore-facing bulkhead while the main chute will be linked to the aft-facing bulkhead. The bulkheads would have small holes to allow the wires from the altimeter to pass through to ignite the black powder charges. Thus, this design incorporates the consistency of the sled design while vastly improving its accessibility.

In regards to safety, we plan on preventing any aberration to the best of our capabilities. This would include using O-rings to keep the A-Bay as airtight as possible, reducing the probability of fluctuations in the altimeter readings. Furthermore, we plan on covering wires in order to redude the risk of fire. Finally, our design is made to require less wire-rearrangement, in the hopes of simplifying the work in making minor adjustments and reducing the risk costly mishaps involving failures in the electronics.

7.4 Parachute Deployment

With our payload requiring enough time to collect the necessary information from the nose of the rocket, our rocket will have the drogue parachute between the avionics bay and the payload and the main parachute between the avionics bay and the booster. We plan on the drogue chute deployment at apogee (5,280 ft AGL, see diagram 4) main parachute deploying around 1,000 ft. AGL (diagram 5) in order to give the payload more time to collect information with the downward pointed camera as well as ample height to detach and deploy its own parachute (see diagram 7-8). As shown in the diagram 6, having the drogue parachute closer to the payload will provide less drag force on the payload and allow the downward pointing camera to hang below the rest of the rocket sections and collect the necessary data.

TODO: insert picture here.

Phase	Event
1	Ignition.
2	Powered flight.
3	Coasting.
4	Drogue parachute deployed at an apogee of 5280 ft. AGL.
5	Main parachute deployed at an altitude of 1000 ft. AGL.
6	Camera in the nosecone of the rocket begins target spotting.
7	Payload section deploys itself from rocket and deploys its legs and parachutes.
8	All sections of the rocket land with a KE under 75 ft-lbf.

Phases of Flight

7.4.1 Kinematic Energy and Drag Equations

TODO: insert picture here.

The following equations are used to calculate the sizes of parachutes necessary to land each part with a kinetic energy less than 75 lb-ft:

$$KE = \frac{1}{2}mv^2 \tag{1}$$

$$F_D = \frac{1}{2}\rho C_d A v^2 \tag{2}$$

Since there are both the drogue and main parachutes, these are two drag forces:

$$F_1 = \frac{1}{2}\rho C_1 A_1 v^2 \text{ and } F_2 = \frac{1}{2}\rho C_2 A_2 v^2.$$

All pieces are connected, so their velocities will be the same; thus the maximum velocity is dependent on the kinetic energy of the heaviest section (m_3), because the other sections will have lower kinetic energies:

$$v_{max} = \sqrt{\frac{150}{m_3}} \tag{3}$$

Since the payload will detach and then land on its own, with its own parachute, the total mass the parachutes must handle is significantly reduced:

$$m_1 + m_2 + m_3 = m_{total} = \text{payload not in } m_3 \tag{4}$$

Terminal velocity will be the maximum velocity, attained when the gravitational and drag forces are equal:

$$m_{total}g = \frac{1}{2}\rho v_{max}^2 C_1 A_1 + \frac{1}{2}\rho v_{max} C_2 A_2 \tag{5}$$

$$v_{max}^2 = \frac{150}{m_3}$$

$$\frac{m_{total} g m_3}{75\rho} = C_1 A_1 + C_2 A_2$$

7.5 Safety

First and foremost, our safety priority is the team itself, which implies that in the situation of unintentional black powder ignition, shock cord snap, bulkhead deformity, or deployment failure, our main objective is to protect the crew from any injuries by removing every individual from harms way.

Our second safety concern is the use of black powder and electronic matches. We will have our mentor purchase both the electronic matches and black powder. They will install both the electronic matches and black powder before all ground tests and launches. While the electronic matches and black powder are being handled, all members of the team will wear protective glasses. Our safety officer will make sure that there are no open flames or substantially hot objects nearby. The members of the recovery team will make sure that the altimeters are off and that no wires are live. During any ground tests, the members of both safety and recovery teams will clear the immediate vicinity of testing and check that all other team members are wearing their protective glasses.

Our third, but also extremely important priority, is the rocket itself. A single perturbation that distorts the performance and ability of the shock cords/bulkheads can jeopardize not only the structure of the rocket, but the success of the competition itself. Thus, any and all aberrations in the designing and testing phase for the implementation of the shock cords and bulkheads must be addressed and fixed. More specifically, our most hazardous situations involving a defective shock cord or bulkhead include, but are not limited to, entanglement of the shock cords during parachute deployment, which would inhibit the lift-off and/or landing of the rocket; busted bulkhead from impact of black powder that might damage the performance of the avionics bays equipment; and others. Thus, CalSTAR is taking the initiative to invest in equipment that would counteract both of those potential issues. For the entanglement dilemma, investing in swivels and possibly a slider parachute would streamline deployment, allowing a greater degree in deployment flexibility while simultaneously improving the consistency of deployment. For the bulkheads, the primary method of counteraction would be investing in a sturdy enough bulkhead, sealed with O-rings and secured firmly with our center rod and U-bolts, in order to minimize possible damage from a high temperature/pressure explosion. With the right equipment and mentality, CalSTAR will ensure that failures in the shock cords and bulkheads will not jeopardize the mission or the life of its members.

Our fourth, and most important, safety concern with recovery is deployment failure. In the case that a parachute deploys prematurely during ascent, we will warn all of those around the site of launch and keep a close watch of the rocket so that team members and spectators can safely clear the area before crash landing. In the case that one or multiple parachutes fail to deploy, we will again warn all of those in the vicinity and keep watch of the rocket in order to clear the area where it may crash. In order to minimize these risks, we will use two altimeters. One altimeter will be the main, the other will be in place for redundancy in the case that the first doesnt work. We will also perform multiple ground test to be sure that we are using the correct amount of blackpowder to break our shear pins and deploy the parachutes.

8 Safety

The utmost concern of the team is safety during all aspects of rocket construction, assembly, and launch. The team's Safety Officer, Grant Posner, will ensure that team operations and procedures are carried out safely according to codes and regulations.

8.1 Risk Assessment

The safety team considers the following items to be some of the most likely or worrisome risks to the completion of the project:

Risk	Effect	Severity & Likelihood	Mitigation
Improper use of power tools	Injury to team members	2C	Require team members to read all relevant safety documents of Jacobs Hall/Etcheverry machine shop before use of equipment; furthermore, experienced team members will supervise less-experienced members to make sure that construction is carried out safely.
Improper handling of hazardous materials/chemicals	Explosion or fire, personal injury (burns, loss of eyesight, cuts, etc.)	2C	Experienced team members/team mentor should supervise all handling of hazardous materials, or the team mentor should handle materials him/herself. Also, use of Personal Protective Equipment and applying lab safety standards can help: wearing safety goggles, lab coats, closed-toed shoes, having minimal exposed skin, wearing gloves, etc.
Transportation: forgetting equipment/parts	Rocket may lack a part that is required for safe flight	2D	The team will maintain a list of all rocket components and required equipment, and each item will have a specified team member who shall ensure that the item is accounted for before transportation.

Risk	Effect	Severity & Likelihood	Mitigation
Launch safety: not covering all items on a checklist	Rocket may be improperly or unsafely set up, launching mechanism could fail, team could fail to abide by regulations (such as the NAR HPRSC)	3B	Call-and-response system for completing a checklist: one team member calls out each checklist item, and a separate member completes the item and verifies it is complete out loud. If there is any confusion, the checklist item should be clarified by the member calling out the items.
Flight testing	Rocket failure or damage; injury to team members and/or spectators	2D	All flight tests will abide by NAR/TRA safety codes, along with applicable federal, state, and local regulations. Checklists will be used (as described above), and all present team members will be briefed on hazard and accident avoidance. Ground tests will be used to ensure stability of the rocket before flight.

Project Risks & Mitigations

8.2 Facilities

The team plans to use Jacobs Hall, the Etcheverry machine shop, the Richmond Field Station, the MakerSpace in Moffitt Library, and occasionally team members residences for design and construction. All the university-owned buildings have safety information and codes, and use of several of these spaces require university training. Team members will read, know, and abide by the facilities rules, and shall also consider safety briefings by the Safety Officer, in order to maximize safety when working on the rocket at any of the listed locations. The planned use of the facilities is described in the Facilities section of this Proposal. TODO: add links to appendices for safety docs. Also make sure that all facilities are covered by this section.

8.3 NAR Member Procedures

Our NAR team mentor will purchase all rocket motors and any energetic devices that the team requires, and also transport, store, and install these devices, or will delegate these tasks to another NAR/TRA-certified member. Our mentor will perform all hazardous materials handling and hazardous operations, or will delegate to a certified and experienced person to perform hazardous operations. Members of the team will never handle a rocket or energetic devices, and will not handle hazardous materials. The team will maintain safety by leaving hazardous operations to experienced, certified people.

At each launch the teams Safety Officer will confirm with the teams mentor that all the requirements of the NAR high power safety code are followed, so that our experienced mentor can supervise operations and ensure that all operations are safe. In particular, the Safety Officer and team mentor will ensure that all safe minimum distances are observed, and that all launch mechanisms (ignition system, motor, launch pad and rod) are safe and abide by codes and regulations.

8.4 Safety and Pre-Launch Briefings

The safety team will present weekly safety briefings to the rest of the team. These safety briefings include any new safety tips or advisories from the previous week, as well as any new hazard analyses or modifications to old hazard analyses, so that the entire team is up-to-date with information about hazardous materials, procedures, or actions. Furthermore, the safety team will give a presentation on hazard recognition and accident avoidance prior to rocket construction, and before any launch, to maintain team awareness of proper safety protocols. This presentation will cover such topics as construction safety, in particular proper use of machine shop equipment and construction accident avoidance; proper use of PPE; launch safety codes; and any other topics that will improve team safety.

Before every launch the Safety Officer will give a pre-launch briefing to the members of the team. This briefing shall include the above briefings on hazard and accident avoidance, and will also include discussion of relevant launch codes and regulations, in particular the NAR high power safety launch code, and will include any pertinent information on local weather conditions, possible failures, rocket recovery plans, and any location-specific hazards.

8.5 Caution Statements and Documentation

Necessary caution statements will be placed in all plans, procedures, and other working documents that pertain to any operation or procedure with risks involved, such as, for example, airframe construction with composite materials. These caution statements will include information on proper use of Personal Protective Equipment, in particular the proper use of safety goggles, closed-toed shoes, and any specialized safety equipment relating to specific tasks such as (for example) the use of respirators while constructing with composite materials and the use of gloves while handling epoxies and glues. Furthermore, these caution statements will reference relevant MSDS data sheets and procedure-specific safety codes and regulations.

Documents for risky (even low-risk) procedures will always be easily accessible to team members observing the procedures. For example, MSDS data sheets will be physically accessible to team members working with chemicals or other materials, and documentation on PPE will be physically accessible close to construction equipment.

8.6 Complying with Applicable Laws

The team will comply with all applicable laws when constructing and launching rockets. Specific plans for federal regulations are as follows:

Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C: Amateur Rockets We comply with §101.23 (General operating limitations). The team shall make calculations and simulations for the rocket of operation to ensure that it is launched in a suborbital trajectory, not launched into foreign territory or launched into any hazardous environments (such as buildings, urban areas, or aquatic landmarks). The rocket will not be launched into any government property, aircraft, or aircraft territory of any sort. Absolutely no live animal or such organisms will be launched in, or attached to, any part of the rocket. The rocket will not ever be launched at a target. The rocket will only be launched vertically, perpendicular to the ground, towards the sky. We further comply with §101.25 (Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets). The team shall be extremely cautious when planning to launch any rocket. If any of the following conditions are met, the rocket shall not be launched: launch into any clouds or vision restriction hazards of more than half of the flight, before sunrise or after sunset, or within 5 miles of any airport or airspace range. All members should be excluded from the appropriate range when launching the rocket, for safety reasons. A member of the safety team shall bring a fire extinguisher to any rocket launch. The team will provide the necessary information to the nearest FAA ATC facility when planning on launching a rocket if the rocketry club does not.

Code of Federal Regulation 27 Part 55: Commerce in Explosives Our NAR mentor will handle all motors and energetic devices legally and safely.

NFPA 1127: Code for High Power Rocket Motors The teams rocket shall be inspected by a Range Safety Officer before launch, and if the rocket does not pass the inspection, then the rocket shall not be launched. Furthermore, the rocket will be designed to be stable in expected operating conditions, and will have a recovery system designed to safely deliver all parts of the rocket to the ground after launch.

NFPA 1127 is largely based on the NAR high power rocket safety code, which the team shall abide by.

8.7 Testing

Testing will be used as much as possible to ensure that the final rocket is stable and safe, and that all the components of the rocket meet design requirements. Sub-scale tests will be used to verify that integration of various components works as planned, and wind tunnels may be used to ensure aerodynamic stability of the rocket.

All tests will be carried out while following all applicable safety codes and regulations, in particular for sub-scale launches.

8.8 Safety Agreement

The team agrees to abide by the following requirements, along with other safety rules:

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.

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. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

See Appendix Appendix A: "Safety Agreement" for a list of safety rules and evidence of team member agreement to the rules.

Appendix A Safety Agreement

It is a particular interest and duty of the safety team to ensure that requirements of safety codes and regulations are met when constructing, assembling, and launching a rocket. To abide by these regulations, and in order to maintain overall safety, each team member must follow these rules:

1. Before any launch, pay attention to the pre-launch and safety briefings.
2. At any launch of our main rocket (not sub-scale), stay at least 200 feet away from the launch site when the rocket is ready to launch, and focus on safety.
3. When constructing the rocket, always wear appropriate clothing (no loose clothing near machinery and power tools) and proper personal protective equipment (PPE), and make sure to read relevant MSDS data sheets.
4. If there is any confusion over how to use a tool or machine, ask a more experienced person for help.
5. Always follow instructions of launch officers at a launch site, including the Range Safety Officer.
6. If our rocket does not pass a safety inspection or does not meet all relevant safety requirements, then we must comply with the determination of the inspection and not launch the rocket.
7. Before a launch the teams Safety Officer and team mentor, along with the Range Safety Officer, have the right to deny the launch of our rocket for safety reasons.

The team as a whole agrees to abide by the following regulations from the Student Launch Handbook:

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.
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. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

Any team member who does not agree to any of the rules above may be refused access to rocket construction or assembly, may not be allowed to attend launches, or may even be removed from the team if necessary.

Print your name and sign below if you agree to follow all the rules above:
TODO: columns for Name & Signature

Appendix B Outreach Survey

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper. TODO

TODO: get safety docs/regs/laws