SEDS 2019 University Student Rocketry Challenge

Design Report

University of Nevada, Las Vegas

Prepared by:

Brandon Fallon, Cody McDonald, Mariana Rodriguez, Edgar Salas-Sanchez

05 July 2019

Contents

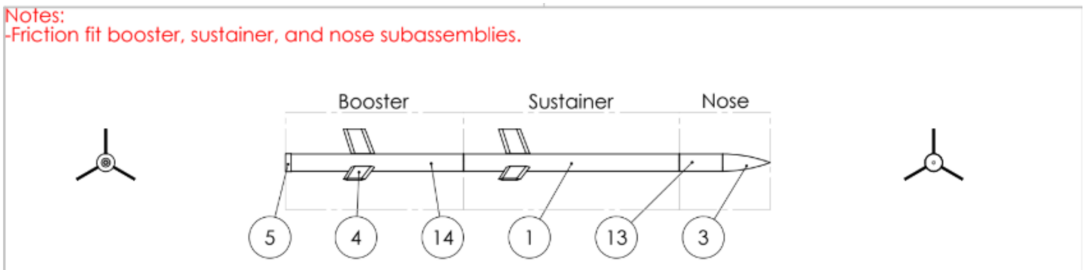
Abstract

The University of Nevada, Las Vegas (UNLV) is competing in the SEDS-USA University Student Rocketry Challenge (USRC), which is geared towards developing a multi-stage rocket to reach the highest altitude possible A.G.L., constrained by a 640 N-s impulse limit. Based on current simulations, the rocket is projected to reach an altitude of approximately 14,050 ft with a maximum velocity of 0.8 Mach. The rocket is designed to accommodate two stages, a booster and sustainer, housing an Aerotech H550 motor in the booster with a total impulse of 312 N-s and an Aerotech H45 in the sustainer with a total impulse of 320 N-s , for a combined total impulse of 632 N-s. The body and nose cone sport a 38mm outer diameter and will be student made thin walled fiberglass. After multiple simulations were performed, it was found that an Ogive shape yielded the best altitude results. There will be 6 fins in total, each laser cut from wood and layed-up in carbon fiber to increase their strength. Each set will be placed relatively high on the body to ensure the rocket is within a desired stability range of 1.0-2.0. The two stages are joined together by a 3-inch-long fiberglass coupler. The electronics will be housed in a 3D printed avionics holder, located inside a coupler in the upper portion of the rocket. It will in contact with the nose cone, allowing for up to 9 inches of electronics space. The upper avionics bay consists of the required Perfectflite APRA altimeter, a student researched and developed GPS unit, and a Perfectflite StratologgerCF, and two 9V power supplies. The StratologgerCF features a two-event timer which will be used to deploy both the drogue and main parachutes. The booster stage contains one timer and a GPS unit, used in conjunction to separate the upper and lower stage, ignite the motor, and locate during recovery. Each stage supports a 16 inch diameter parachute with nylon shock cord attached to eyebolts. These are secured to fiberglass bulkheads that have been epoxied inside. The final rocket is expected to weight 3.82 lbs, which may vary based on manufacturing methods used.

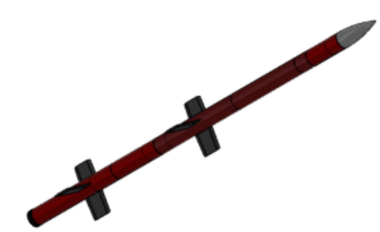
Systems Architecture Overview

Engineering Drawings

This section of the report will be used to describe the physical dimensions of the rocket. The initial design was constructed using RockSim software to ensure a smooth flight. Once completed, all 3D modeling occurred in Dassault System's SolidWorks. SolidWorks is particularly critical to design, as it allows engineers to get a feel for how well different items fit in the rocket prior to construction. **Figure 1** shows the complete rocket and preliminary parts list.



ITEM NO.	PART NUMBER	QTY.
1	Upper Tube SEDS Multi-stage 2019	1
2	Coupler SEDS Multi-stage 2019	1
3	Ogive NoseCone SEDS Multi-stage 2019	1
4	Fin SEDS Multi-stage 2019	6
5	H550 Rocket Motor	1
6	H550 Rocket Motor Sanded Top	1
7	APRA altimeter SEDS Multi-stage 2019	1
8	Parachute Upper SEDS Multi-stage 2019	2
9	Lower Bulkhead SEDS Multi-stage 2019	3
10	Ecap SEDS Multi-stage 2019	4
11	3013T45	3
12	Avionics Coupler SEDS Multi-stage 2019	1
13	4in Upper TubeSEDS Multi-stage 2019	1
14	Lower TubeSEDS Multi-stage 2019	1
15	Timer SEDS Multi-stage 2019	2
16	altimeter	1
17	Battery 9V	3
18	GPS SEDS Multi-stage 2019	1
19	RRC3 SEDS Multi-stage 2019	1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

SEDS UNLV
TITLE:
Rocket Assm - Booster, Sustainer, & Nose - SEDS Multi Stage 2019
SCALE: 1:10 WEIGHT: SHEET 15 OF 1

Figure 1: Complete Rocket Drawing and Parts List

The rocket is currently 44.47 in long with a 38 mm diameter and weighs in at 2.45 lbs dry and 3.95 lbs wet. The rocket utilizes a minimum diameter design to accommodate the motors without centering rings. The current design incorporates two stages, a booster and sustainer. **Figure 2** shows how the booster system will work.

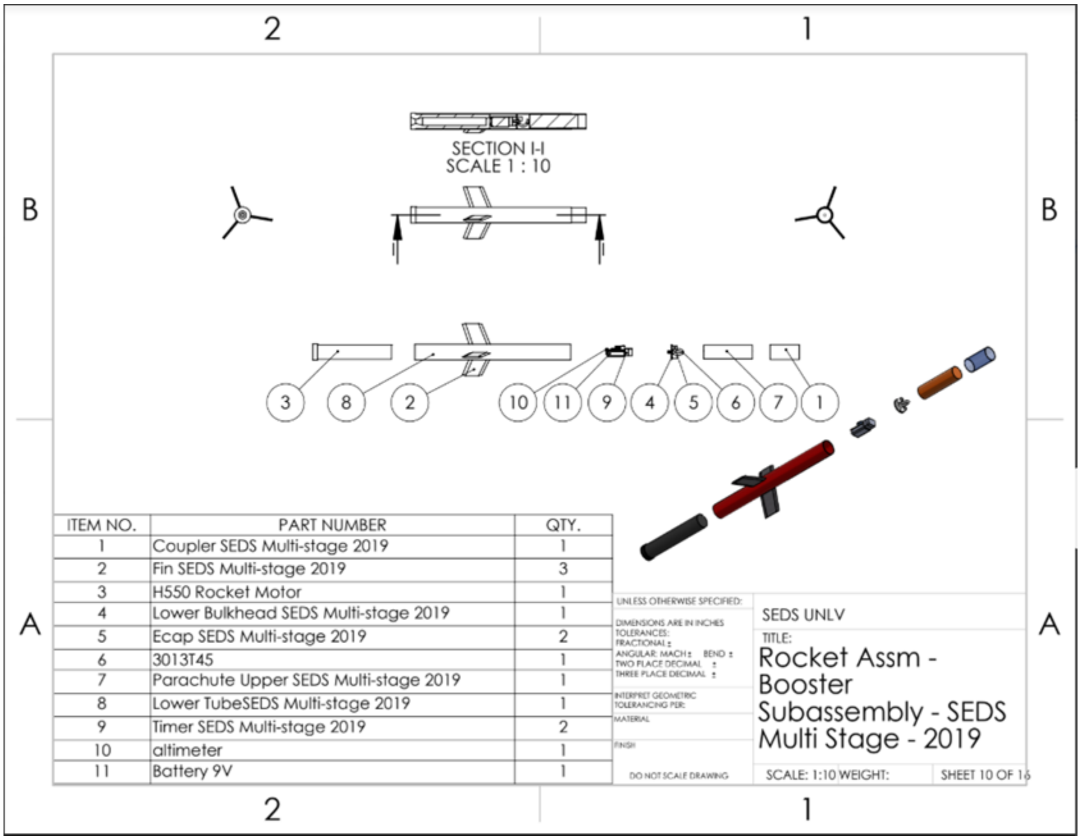
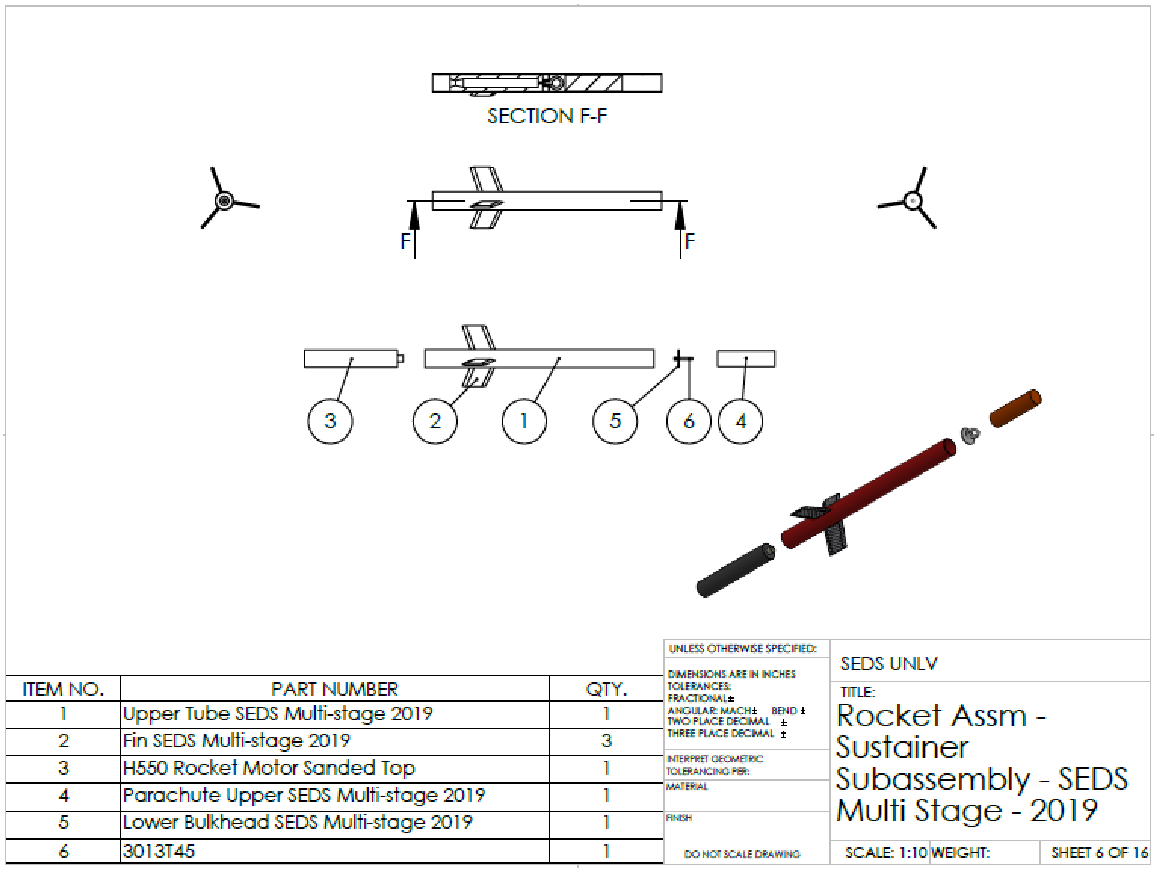


Figure 2: Booster Stage Overview Drawing

The booster stage houses the H550 rocket motor. Tape will be added to the motor to ensure a tight fit is kept. A timed ejection will be utilized, so the electronics are placed above the motor, underneath a fiberglass bulkhead that will be epoxied in. Wires are ran through this bulkhead to connect to igniters on the other side. Two igniters will be placed in the ejection caps, and third in the next motor to ensure ignition. A steel eyebolt is bolted into the bulkhead, which the 16 in parachute can connect to. A coupler is epoxied to the booster stage, effectively connecting the upper and lower stages. The frame is fiberglass and will be student manufactured. A thin walled construction is utilized to reduce weight. It is expected that a thin walled design will suffice since the rocket will not be exceeding Mach 1. **Figure 3** displays the fin design chosen.

Figure 3: Fin Design Drawing

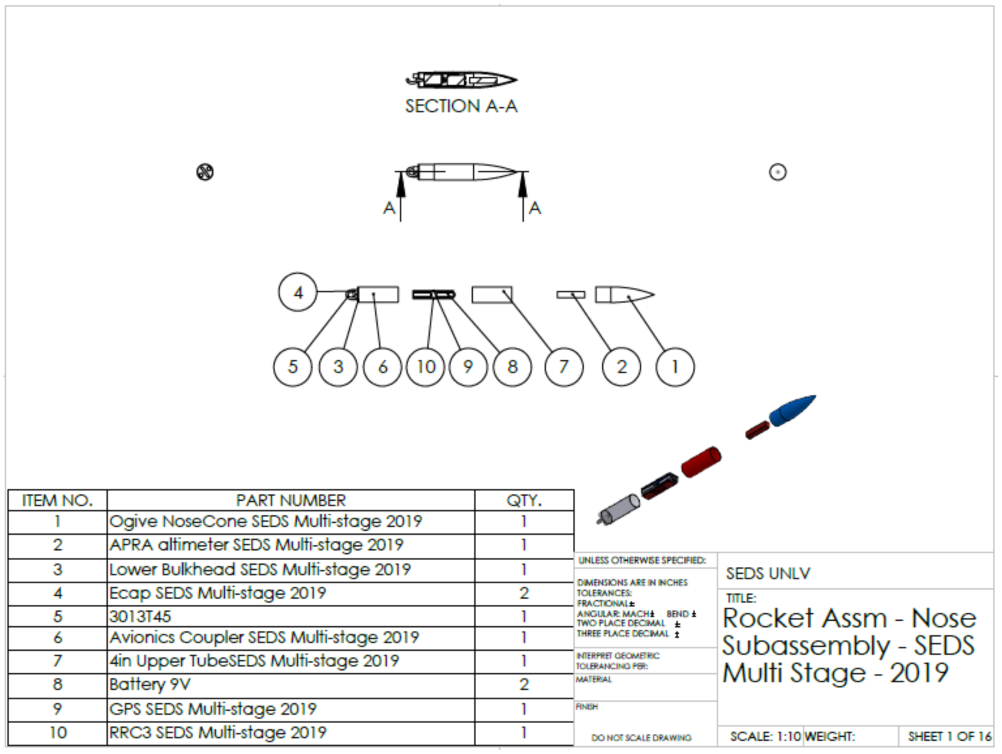
A tapered edge design was chosen because it was initially estimated that the rocket would exceed Mach 2. While this is no longer true, optimal altitudes can still be attained and manufacturing will be significantly easier with an airfoil design. They will have a wood infill layed-up in carbon fiber. It is estimated that the fins will weigh less than 50 g for each set of 3. **Figure 4** details the sustainer design.



ITEM NO.	PART NUMBER	QTY.
1	Upper Tube SEDS Multi-stage 2019	1
2	Fin SEDS Multi-stage 2019	3
3	H550 Rocket Motor Sanded Top	1
4	Parachute Upper SEDS Multi-stage 2019	1
5	Lower Bulkhead SEDS Multi-stage 2019	1
6	3013T45	1

Figure 4: Sustainer Design Drawing

The motor will be placed above the coupler of the rocket underneath. The lip is to be shaved off to accommodate the diameter of the rocket. It will line up next to another fiberglass bulkhead inside. The parachute lies above this, attached to an eyebolt connected to the bulkhead. **Figure 5** shows how the nose cone connects to the upper stage. A detailed view of the nose cone is displayed in **Figure 6**. The nose cone is a total of 5.91 in long with 4.41 in exposed. It will be fabricated in house from fiberglass. Ideally, a thin walled nose cone will be produced with a thickness of 0.1 in. Since the nose cone is not ejecting, it will likely be held in place by pins. Also, worth noting, the shape. It was expected that a $x^{1/2}$ power profile would be ideal for our Mach value of 0.8, however simulations showed that a 3:1 Ogive shaped produced the most optimal results.



ITEM NO.	PART NUMBER	QTY.
1	Ogive NoseCone SEDS Multi-stage 2019	1
2	APRA altimeter SEDS Multi-stage 2019	1
3	Lower Bulkhead SEDS Multi-stage 2019	1
4	Ecap SEDS Multi-stage 2019	2
5	3013T45	1
6	Avionics Coupler SEDS Multi-stage 2019	1
7	4in Upper TubeSEDS Multi-stage 2019	1
8	Battery 9V	2
9	GPS SEDS Multi-stage 2019	1
10	RRC3 SEDS Multi-stage 2019	1

Figure 5: Nose Cone Assembly Drawing

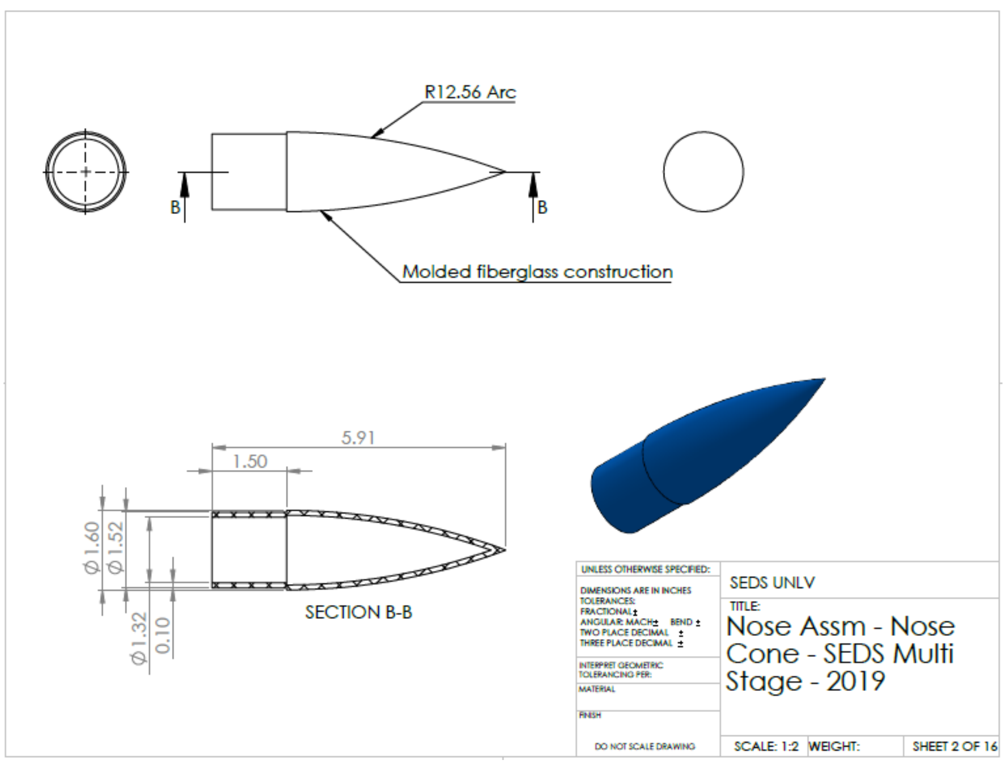


Figure 6: Nose Cone Drawing

A coupler with a bulkhead and eyebolt is placed above the parachute located in the sustainer. This serves as the avionics bay for the upper stage. It connects to a 4 in long fiberglass tube which will be coincident to the nose cone. Ejection charges will be attached to the bulkhead to deploy the upper parachute. Using a coupler will prevent the electronics from being exposed to the environment at deployment.

Manufacturing Methods

The goal for this rocket is to make all the external airframe components from scratch. Starting with the nose cone, a 3D printed model will be used to cast a mold. From the mold, fiberglass strips will be layed up internally until the desired thickness of 0.1 in is achieved. The body tubes will be constructed by applying a fiberglass layup to an aluminum rod. It is anticipated that 3-4 ply of 45-45 fiberglass will work. Each body tube will be vacuum bagged to reduce weight and increase strength. The fins will be laser cut from 1/8 in craft wood. Using a belt sander, the 30 degree taper will be applied to the leading and trailing edge. Following this, a carbon fiber layup will be applied to these fins and vacuum bagged. Based on previous experience, two ply of 45-45 carbon fiber should work. The fiberglass couplers and bulkheads will be purchased from madcow rocketry.

Launch Simulations

Propulsion Systems

The rocket accommodates an Aerotech H550ST disposable solid rocket motor in the booster stage and an Aerotech H45W disposable solid rocket motor in the sustainer. The specifications of each are shown below in **Table 1**.

Table 1: Motor Specifications

Motor Specifications						
	Burn Time (s)	Total Impulse (N-s)	Average Thrust (N)	Maximum Thrust (N)	Total Weight (g)	Propellant Weight (g)
HP-H45W	6.00	320.00	45.00	87.00	365.00	180.00
HP-H550ST	0.60	312.00	552.00	640.00	316.00	176.00

In simulations, it was found that the rocket struggled to get off the ground if a motor a long burn time, but low thrust was utilized. To fix this, the H550 was placed in the lower stage to quickly get the rocket off the ground and the H45 was placed in the upper stage for long term firing.

Stability

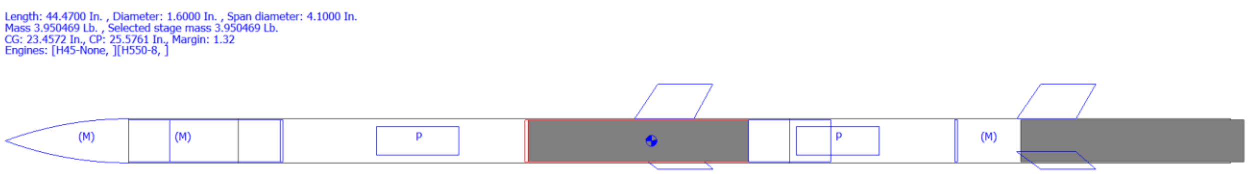


Figure 7: Total Rocket Flight Stability Margin

Figure 8: Sustainer Stage Flight Stability Margin

Figure 7 shows the stability margins for the complete rocket with both the sustainer and booster stages and **Figure 8** shows the stability margin for just the sustainer. Previous experience has shown that a stability margin of 1.0 – 2.0 is desired, with stabilities closer to 1.0 for smaller, lighter rockets being more optimal. Based on our design, a stability margin of 1.32 was attained for the total rocket and a margin of

1.39 for the sustainer. As each motor fires, the CG will shift upwards, causing the stability to fluctuate during select portions of the flight. An analysis of the flight stability margin is shown below given a 3-7 MPH wind condition.

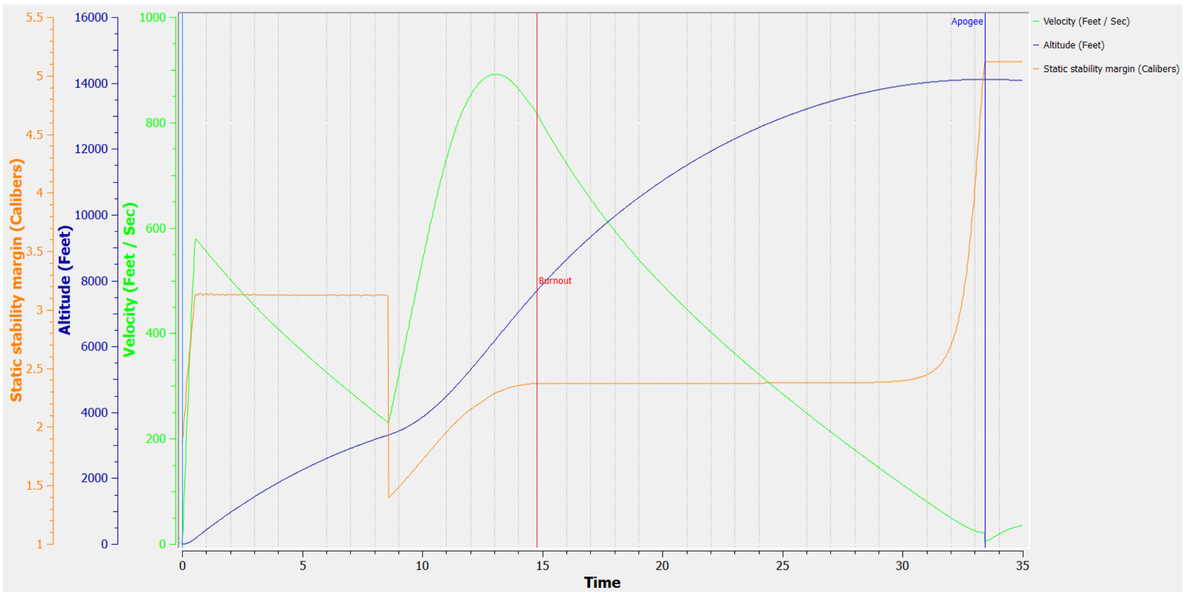


Figure 9: Mid-Flight Stability Margin

The graph displays the stability margin, velocity, and altitude vs. time. As shown, the stability rises to a stability of approximately 3.2 in the coasting phase. During separation, this drops to 1.32 and fires the second motor. Once this motor has fully burned, the stability settles near 2.2 until the parachute is deployed. High stability indicates that the rocket is susceptible to altered flight paths if winds are high. Based on this, it is estimated that some arcing may occur if winds are high.

Flight Simulation Data

The following simulation data is produced using a RockSim flight software. Launch conditions are set for the Jean Dry Lake in Southern Nevada. Typically, the pressure resides around 29.4 in Hg and the altitude hovers between 2800-2900 ft. As such, a pressure of 29.412 in Hg and altitude of 2800 were selected for launch simulations. Being that the launch is likely to occur in the winter months, a temperature of 60°F was selected. The wind speed is tested at 3-7 MPH and 8-14 MPH, both on sunny days. The results of each will be displayed in the figures below.

Trial	Engines Loaded	Max. Altitude (ft)	Max Velocity (ft/s)	Max Acceleration (ft/s/s)	Time to Apogee (s)	Velocity at Deployment (ft/s)	Altitude at Deployment (ft)
59	[H550-8] [H45-None]	14103.71	891.74	1183.63	33.40	230.15	3307.67
60	[H550-8] [H45-None]	14110.27	891.73	1183.63	33.41	230.15	3307.75
61	[H550-8] [H45-None]	14044.62	891.81	1183.56	33.33	230.12	3306.81
62	[H550-8] [H45-None]	14108.23	891.73	1183.63	33.41	230.15	3307.72
63	[H550-8] [H45-None]	14105.77	891.74	1183.63	33.41	230.15	3307.68

Figure 10: 3-7 MPH Wind Altitude Sim Data

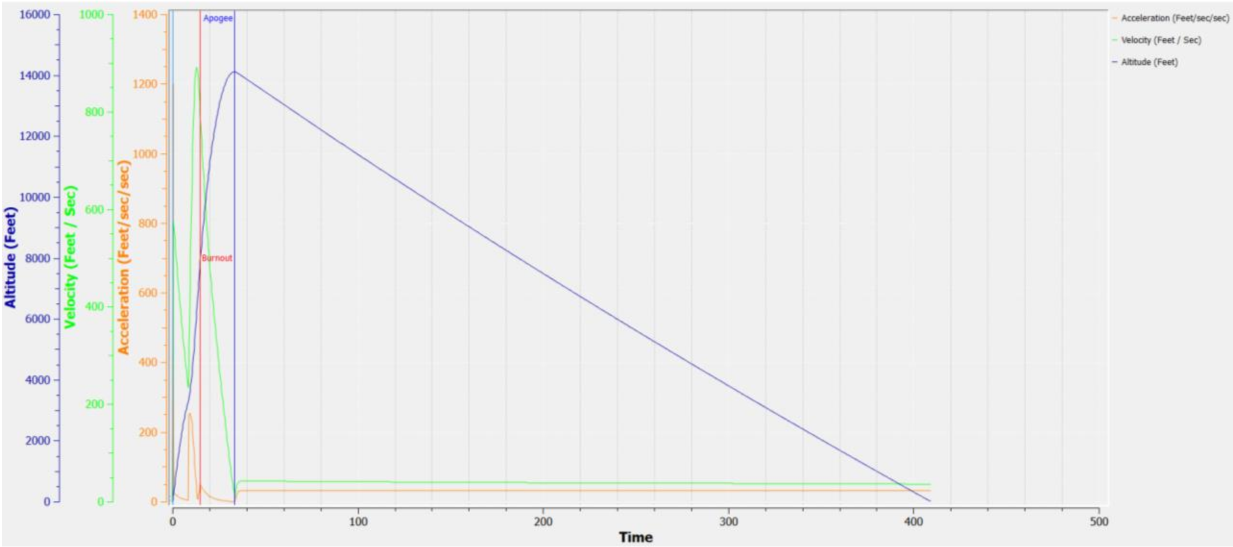


Figure 11: 3-7 MPH Wind Flight Sim Data

Trial	Engines Loaded	Max. Altitude (ft)	Max Velocity (ft/s)	Max Acceleration (ft/s/s)	Time to Apogee (s)	Velocity at Deployment (ft/s)	Altitude at Deployment (ft)
65	[H550-8] [H45-None]	13990.85	891.86	1183.51	33.26	230.10	3306.16
66	[H550-8] [H45-None]	13983.23	891.88	1183.49	33.24	230.10	3305.91
67	[H550-8] [H45-None]	13942.49	891.93	1183.44	33.19	230.08	3305.31
68	[H550-8] [H45-None]	13893.50	891.99	1183.39	33.13	230.06	3304.61
69	[H550-8] [H45-None]	13960.83	891.99	1183.48	33.22	230.09	3305.74

Figure 12: 8-14 MPH Wind Altitude Sim Data

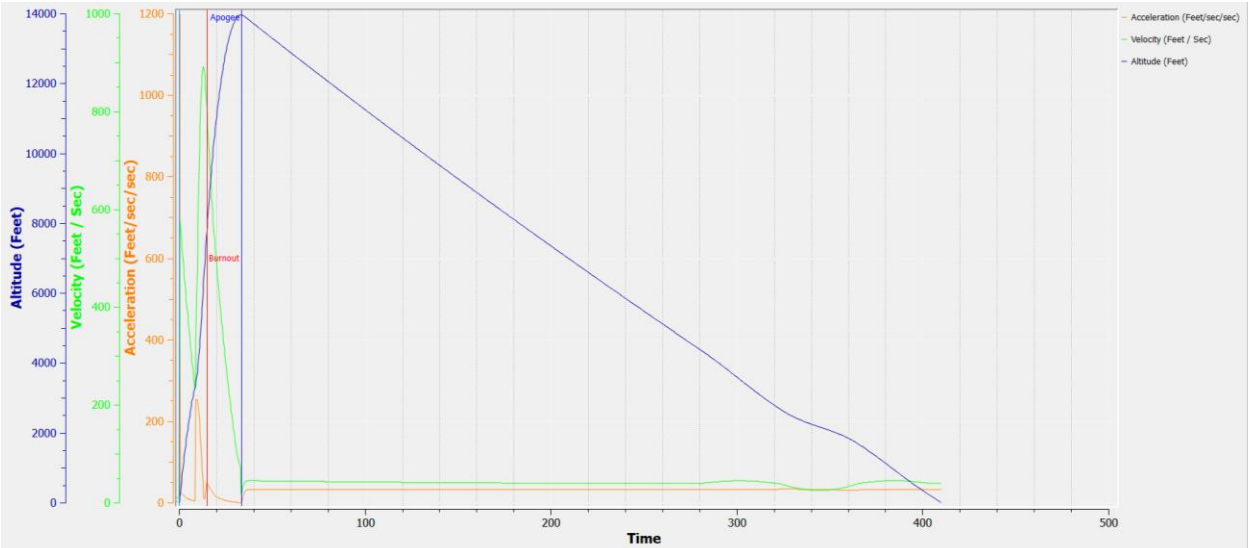


Figure 13: 8-14 MPH Wind Flight Sim Data

Simulation Analysis

From the data, it is evident that the rocket is expected to reach an altitude between 13,900 ft and 14,100 ft. A max velocity of 891 ft/s is achieved, which corresponds to a Mach value of 0.79. Being under Mach reduces airframe complexity significantly and allows for thin walled tubing over thick walled, thus reducing weight and increasing altitude.

Recovery System

Avionics

Overview

The avionics and recovery systems will be composed of five different circuits. These circuits will be split between the upper and lower separation sections of the rocket body. The upper tube will utilize two altimeters. The main altimeter will be the competition standardized Perfectflite's APRA Altimeter. Additionally, the Stratologger CF will be used as a redundant altimeter. The Stratologger CF will also be utilized as an event timer to trigger the deployment times of the drogue parachute as well as the main parachute as it contains a two-event timer feature. The two altimeters utilize barometric sensors to sample altitude readings, so tiny sampling holes will be created around the avionics bay in the upper tube. There will be two identical student developed GPS tracking systems in both the upper and lower bodies of the rocket that will be transmitting coordinates to a RF receiver on the ground. The RF receiver will be connected to either a laptop or smart phone where software will be used to plot the coordinates received throughout the duration of the flight. The lower body will also contain a microTimer2 module to be used as an event timer to trigger the ignition and separation charges of the second thrust phase of the flight. This timer will engage in accordance to a calculated timer that reflects the amount of time it will take for the first booster to burn completely. All avionics devices will be located inside avionics bays which will sit in specific locations in both tubes. The goal of these systems is to provide accurate tracking of the flight vehicles maximum altitude, coordinating the timed events for the parachutes and ignition/ejection charges, along with providing GPS tracking telemetry for proper recovery of the upper and lower bodies of the vehicle.

GPS Tracking System Design Overview

The microcontroller of choice for this module is the Teensy 3.1 ARM microcontroller. The dimensions of the package (1.4" x 0.7") make it ideal for the tight design parameters of the vehicle. The ARM architecture of the microcontroller also allows for multiple UART connections which is a necessity for the operation of the module. One UART channel will be receiving the coordinates from the GPS module while the second channel will be relaying the data to the XBee Pro to be transmitted.

The RF transmitter being used to transmit the GPS coordinates is the XBee Pro Series 1 module. This module was selected for its transmitting power given a 9-volt power source. The module is rated to transmit at an output of 950mA and is projected to offer a two-mile line of sight transmitting range which should suit the needs of the mission. The XBee Pro also allows for multi-point communication, which will allow GPS coordinates from multiple bodies to be received on a singular receiver. The XBee Pro also features u.Fl connectors, which allow for more sensitive antenna to be attached. A 2.4GHz Molex antenna was selected to carry this module as it contains the same operating frequency of the module itself. The antenna offers a greater signal dispersion pattern in addition to being able to be adhered to the outside of the rocket.

The module that will be capturing the GPS Coordinates is the Adafruit Ultimate GPS. This module will affix itself to the nearest satellites to obtain GPS coordinates and output the information in a standard NMEA string. This string can be parsed to make it more easily interfaced with a GPS plotting software. At max the largest current drawn from the module is 10-20mA, which will not affect the rest of our components drawing from the same power source.

The GPS Module and Teensy 3.1 microcontroller both require voltages between the range of 3.3V to 5V, therefore a voltage divider circuit will be used to reduce the power source voltage of 9V to 4.5V using equal resistance resistors. Second, a diode will be used as a safe measure to protect the microcontroller if the power source is connected backwards as it can damage the microcontroller.

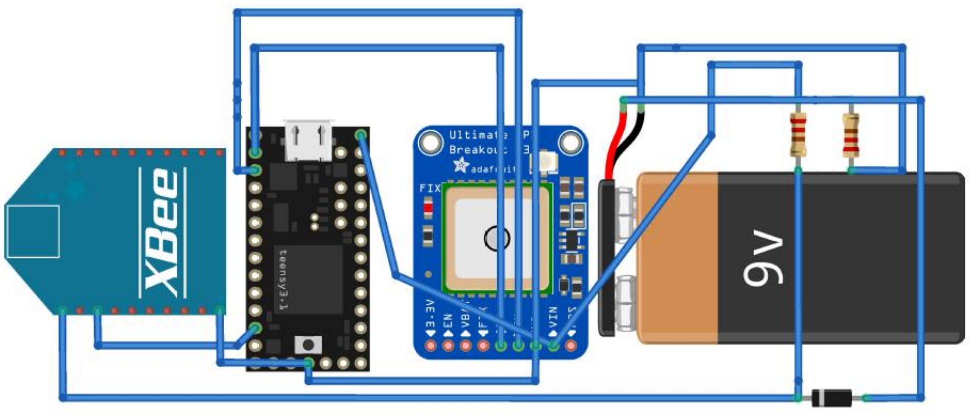


Figure 14: GPS Module Block Diagram

Parachutes

Each of the rocket's stages will utilize a circular parachute. The separation of the booster and sustainer stage will be done with black powder ejection charges. The internal pressure required for separation will be obtained using FFFg black powder contained on the bulkheads. Redundant ejection charges will be installed in both the booster and sustainer bulkheads to ensure successful separation. The first separation will occur after the first coasting phase, where the booster and sustainer will separate and the booster stage parachute will deploy. This separation will be triggered by the Perfectflite microTimer2, which will be programmed to the ideal delay after coasting based on simulations. The second separation will occur at apogee and will be triggered by the StratoLogger CP altimeter housed in the avionics bay in the sustainer stage of the rocket.

The parachutes selected are circular and estimated to have a drag coefficient of approximately 1.5 per manufacturer specifications. The descent rate of the rocket in both the booster and sustainer descent phases is calculated by equating the drag force and gravity force acting on the rocket as it falls. A table summarizing the findings is included below. Calculations are based on the stages' weights after burnout. The estimated weight of the booster stage

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

$$f_g = mg$$

Setting the above two equal to one another, substituting the equation for the area of a circle for A, and solving for velocity yields the following equation. This equation assumes an entirely circular cross-sectional area of the parachute upon descent, where D is its diameter. Resultant calculations using the preceding equation are summarized below. A standard value of 1.229 kg/m^3 is assumed for the air density.

$$v = \sqrt{\frac{8mg}{\pi\rho C_d D^2}}$$

Table 2: Parachute Sizing and Descent Rates

Stage	Dry Mass (lb)	Chute Diameter (in)	Cd	Descent Vel. (ft/s)
booster	1.37	16	1.5	23.43
sustainer	1.77	16	1.5	26.63

Concept of Operations

The intended preparation and flight of the rocket is illustrated below. Pre-flight preparations include preparing the booster and sustainer stage for flight including inspecting and packing recovery components, turning on and installing avionics, and installing the motors. Afterwards, the rocket is to be transported to the launch rail. At the launch rail, the booster igniter is installed. Ignition of the booster igniter starts the next phase: ignition and booster powered ascent. This phase continues and is ideal if the rocket remains stable and upright until the motor burns out. Following the booster burnout, the first coasting phase commences and continues for eight seconds. After eight seconds, the booster and sustainer are separated via ejection charge, deploying the booster parachute. This is controlled by the timer. At the same time, the sustainer motor is ignited. After the sustainer motor burns, the second coasting phase follows. At apogee, the Stratologger CF will signal the second deployment via ejection charge. Once the booster and sustainer are both confirmed to have landed by GPS coordinates and line of sight, the team will recover the rocket.

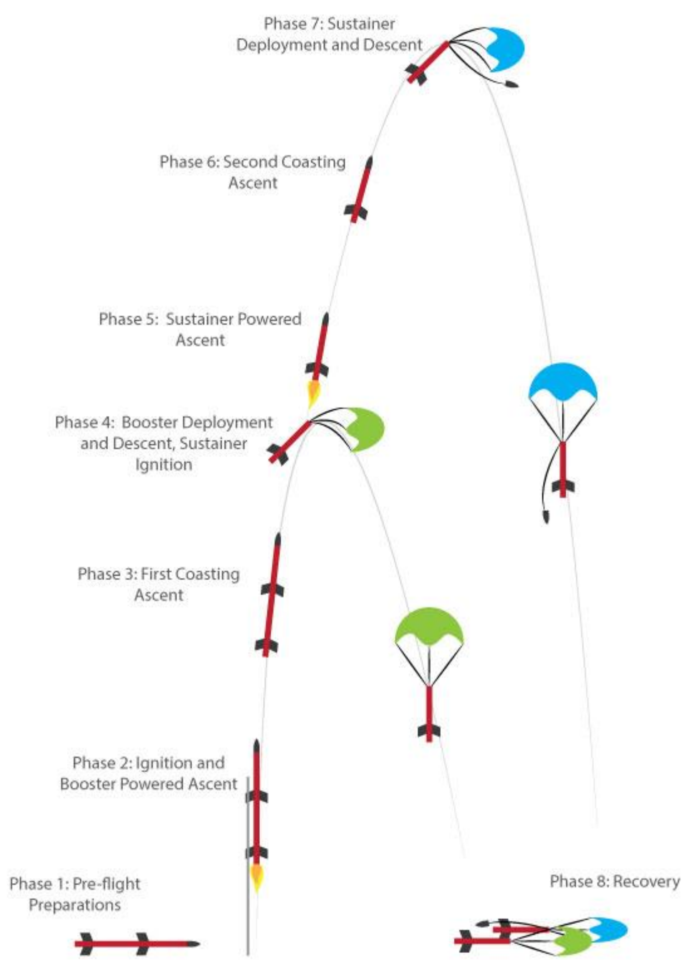


Figure 15: Concept of Operations

Assembly Procedure

The checklist below outlines the preparation of avionics and assembly of the rocket. This constitutes the Pre-flight preparations phase, and includes preparing the avionics, recovery systems, and propellant for flight.

- ☐ Install H550 motor in the booster stage
- ☐ Install H45 motor in the sustainer stage
- ☐ Inspect shock cord and parachute in booster stage, ensure secure connections
- ☐ Inspect shock cord and parachute in sustainer stage, ensure secure connections
- ☐ Connect the microTimer2 and GPS module to the lower body avionics bay.
- ☐ Connect the 9V batteries to the 9V batter connectors on the avionics bay.
- ☐ Enable the arming switches and ensure each component is powered.
- ☐ Ensure the GPS module has found a satellite fix by checking the serial output on a computer.
- ☐ Connect the ejection and ignition charges to the event timer.
- ☐ Insert the avionics bay into lower tube.
- ☐ Connect 1 igniter to each timer
- ☐ Place igniters into the blast caps on booster bulkhead
- ☐ Load black powder into each blast cap on the booster bulkhead
- ☐ Place wadding over black powder on each blast cap and seal with tape
- ☐ Place chute protector around parachute and shock cord, insert into booster stage
- ☐ Connect igniter to one timer, install igniter into H45 motor
- ☐ Secure igniter in motor with tape
- ☐ Connect booster and sustainer tubes, check for alignment
- ☐ Connect the GPS Module, APRA Altimeter, and Stratologger to the upper tube's avionics bay.
- ☐ Connect the 9V batteries to the 9V battery connectors on the avionics bay.
- ☐ Enable the arming switches and ensure each component is powered.
- ☐ Ensure that the startup sounds from the altimeters indicate readiness for flight.
- ☐ Ensure the GPS module has found a satellite fix by checking the serial output on a computer.
- ☐ Insert the avionics bay into the sustainer
- ☐ Connect 2 igniters to Stratologger CF
- ☐ Place igniters into blast caps on sustainer bulkhead
- ☐ Load black powder into each blast cap on the sustainer bulkhead
- ☐ Place wadding over black powder on each blast cap and seal with tape
- ☐ Place chute protector around parachute and shock cord, insert into sustainer stage
- ☐ Connect sustainer and nosecone, check for alignment
- ☐ Notify launch director of launch readiness, await permission to approach launch pad
- ☐ Transport rocket to launch rail
- ☐ Load rocket onto launch rail
- ☐ Install igniter into H550 motor
- ☐ Secure igniter in motor with tape
- ☐ Check ignition circuit for continuity and move to a safe distance
- ☐ Launch

Recovery Procedure

The checklist below outlines the recovery procedures of the rocket. The team will keep eyes on the rocket throughout flight to confirm nominal deployment as outlined in the concept of operations. A minimum of one person will be assigned to watch each of the two stages.

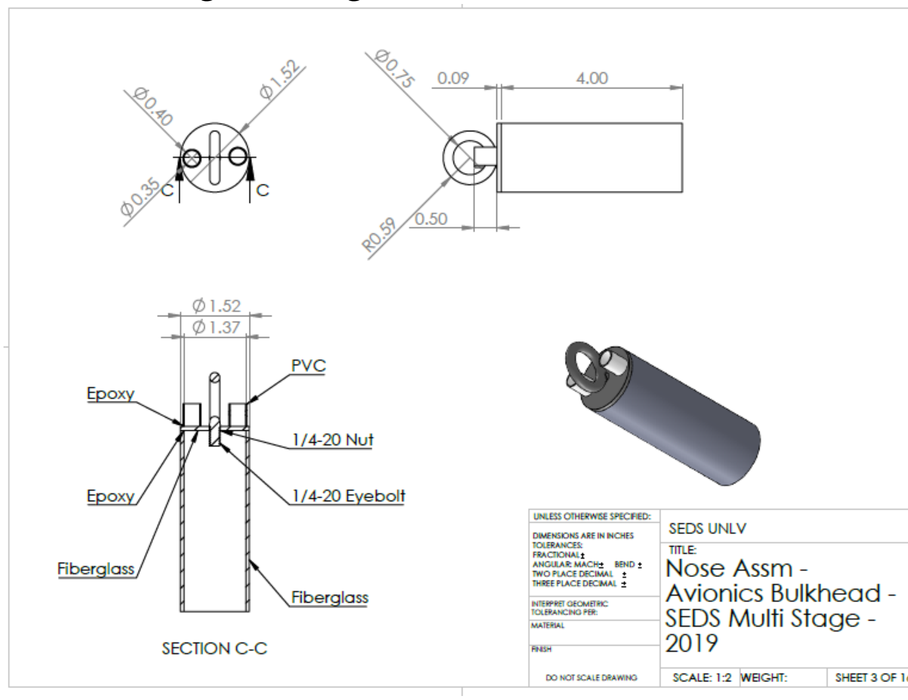
- ☐ Watch for booster stage deployment and follow line of sight
- ☐ Watch for sustainer deployment and follow line of sight
- ☐ Receive GPS coordinates via serial monitor on laptop (Monitor will indicate an “Sustainer” identifier)
- ☐ Wait until coordinates reach a static reading
- ☐ Audible flight completion tones will help indicate location of sustainer
- ☐ Input coordinates into GPS plotting software
- ☐ Head towards audible recovery tone and location indicated by GPS software
- ☐ Retrieve sustainer after confirming all energetics are depleted
- ☐ Receive GPS coordinates via serial monitor on laptop (Monitor will indicate a “Booster” identifier)
- ☐ Wait until coordinates reach a static reading
- ☐ Input coordinates into GPS plotting software
- ☐ Head towards location indicated by GPS software
- ☐ Retrieve Booster after confirming all energetics are depleted

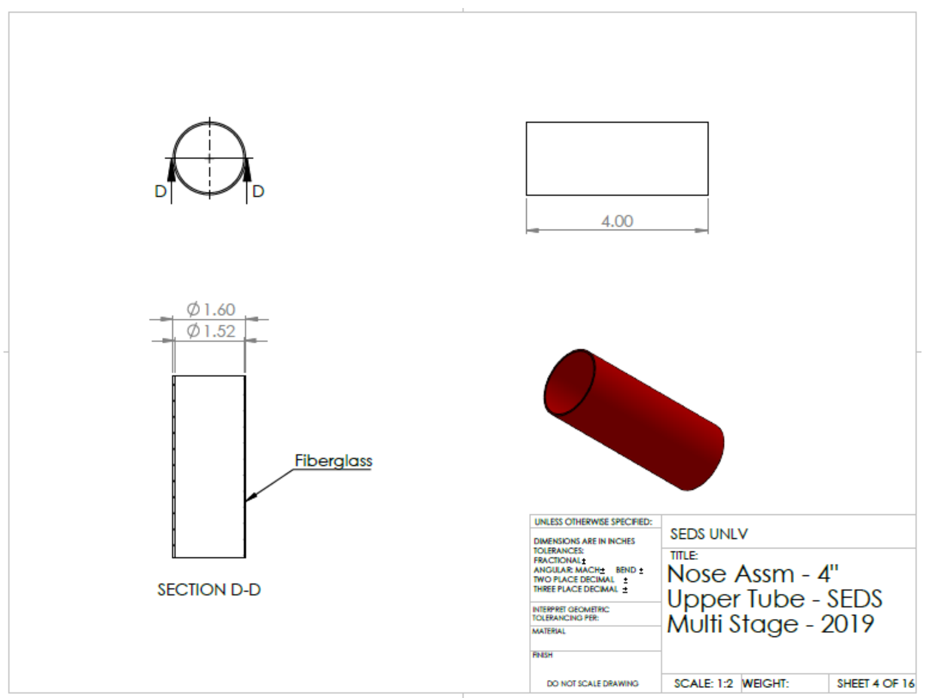
Launch Dates

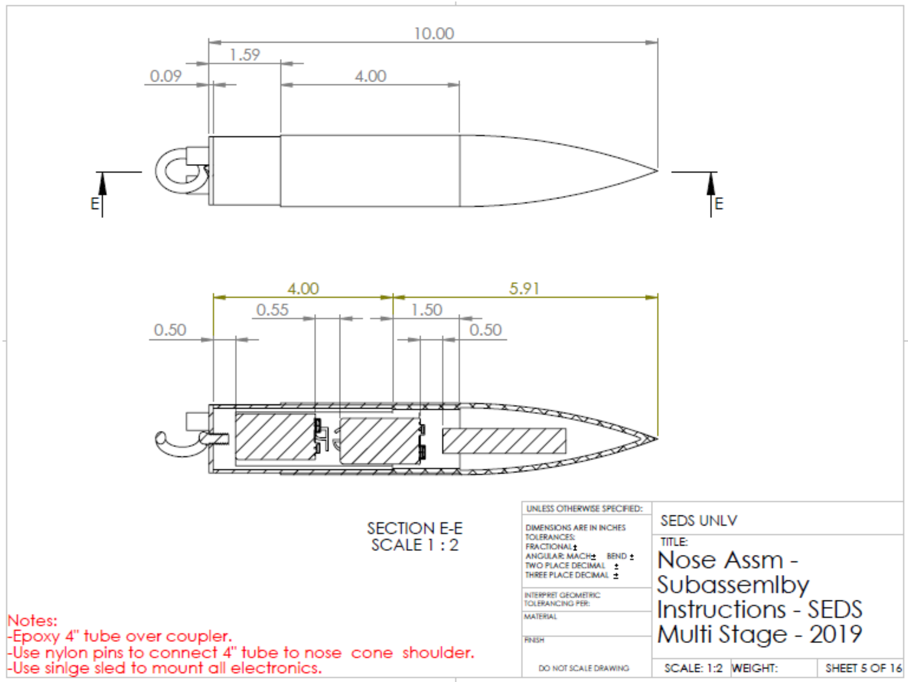
The team intends to launch with the Las Vegas Tripoli chapter. The chapter hosts launches on the third Saturday of every month, with three-day launches in March and October. Launches are held at the Jean Dry Lake approximately 20 miles south of UNLV. The FAA waiver for these launches has a clearance of 4700 ft with call-in windows to 19,999 ft. Manufacturing of the rocket will take place over the summer and fall and is expected to be completed and ready for flight by September. The first three planned launch dates are September 21, October 19, and November 16, 2019. Subsequent opportunities to launch until the closure of the launch window include December 21, 2019 and the third Saturday of the following months, to be specified by the Las Vegas Tripoli chapter (website is only updated one calendar year at a time).

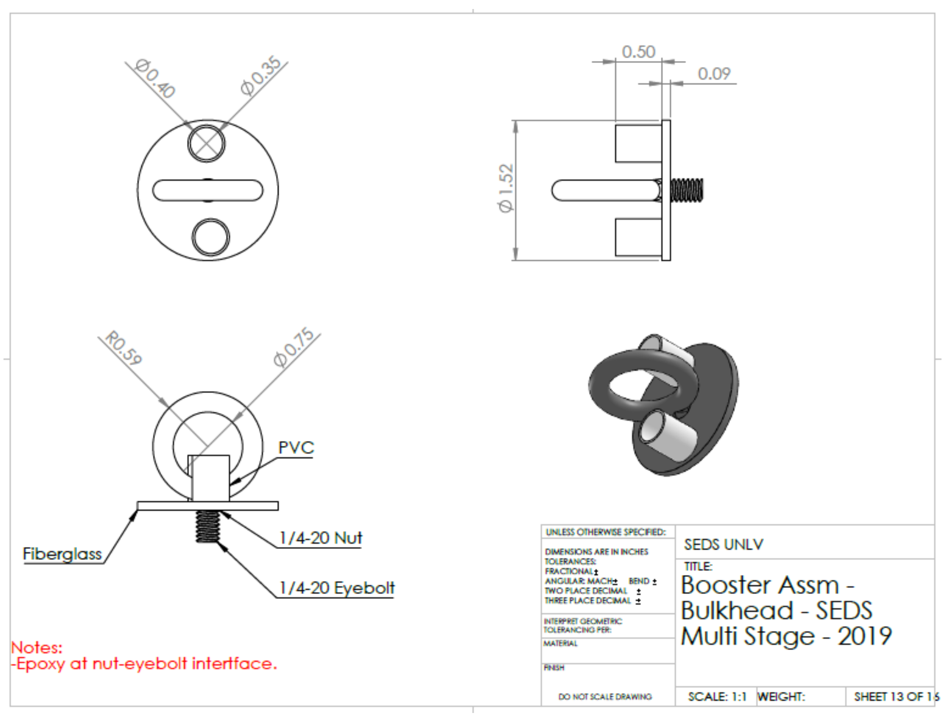
Appendices

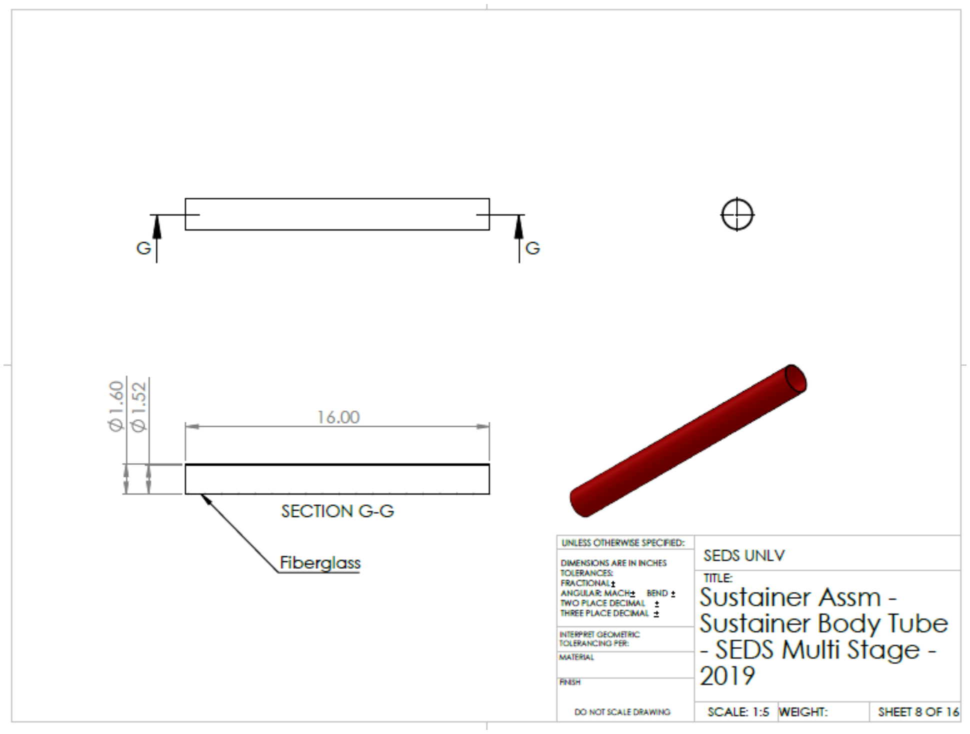
Appendix A: Rocket Design Drawings

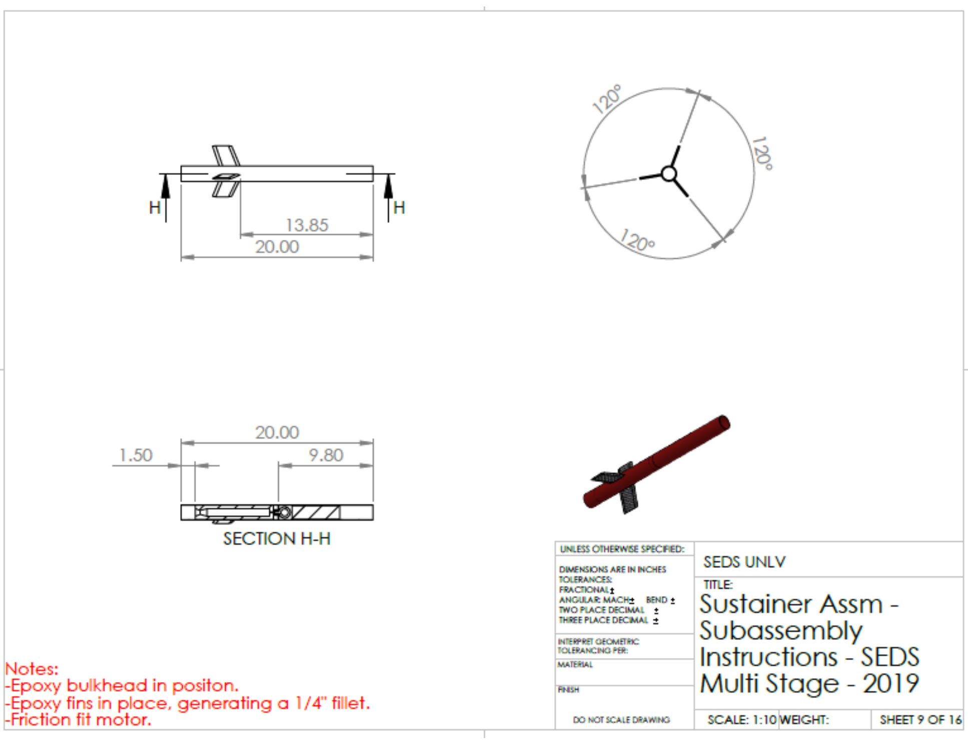


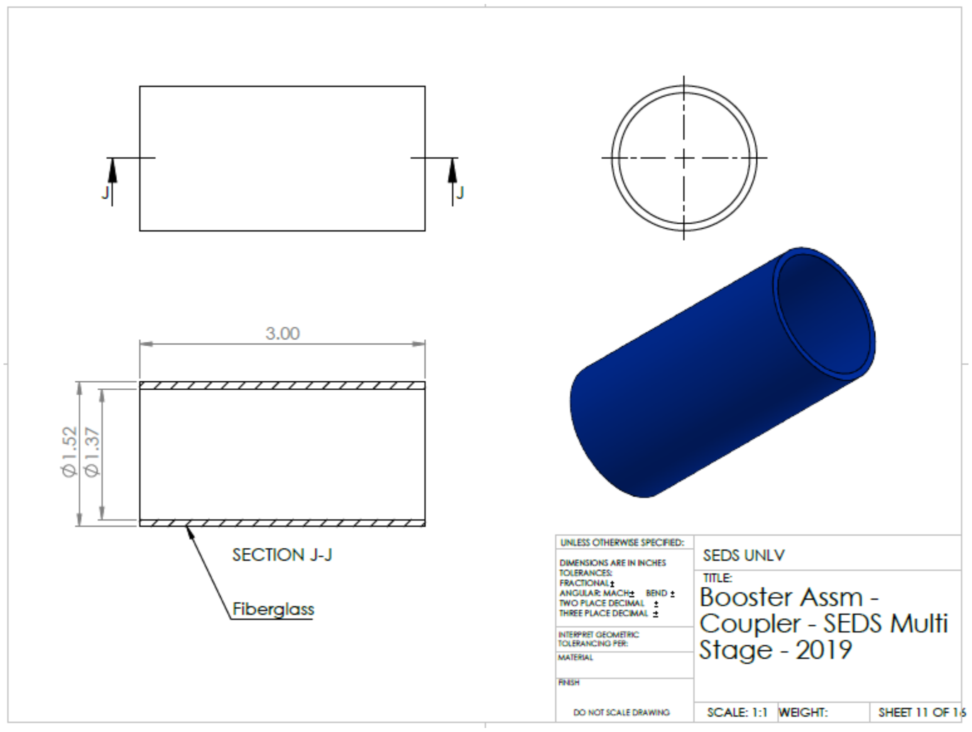


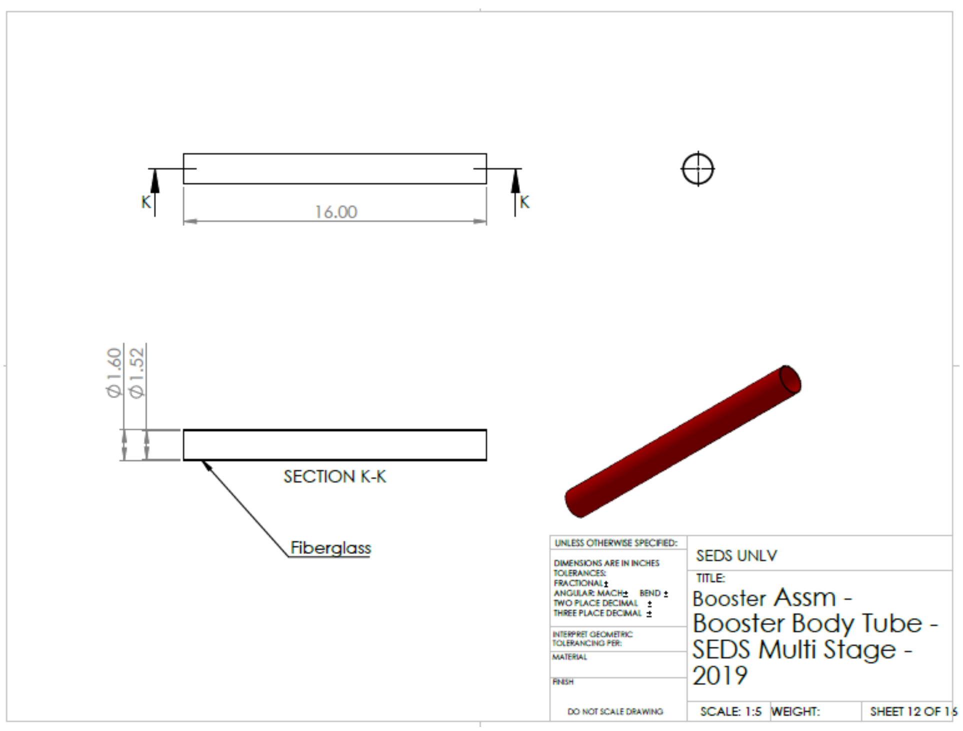

10.00
1.59
0.09
4.00
E
E
4.00
5.91
0.55
1.50
0.50
0.50
SECTION E-E
SCALE 1 : 2
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
SEDS UNLV
TITLE:
Nose Assm - Subassemlby Instructions - SEDS Multi Stage - 2019
SCALE: 1:2
WEIGHT:
SHEET 5 OF 16
Notes:
-Epoxy 4" tube over coupler.
-Use nylon pins to connect 4" tube to nose cone shoulder.
-Use sinlge sled to mount all electronics.

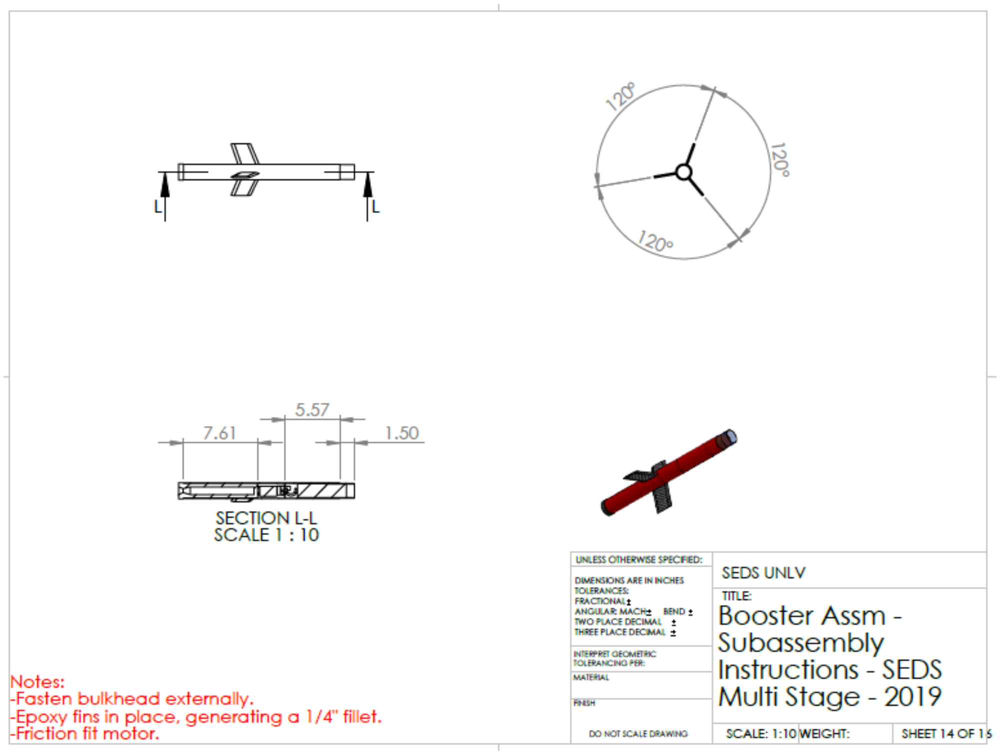

Ø0.40
Ø0.35
0.50
0.09
Ø 1.52
R0.59
Ø0.75
PVC
Fiberglass
1/4-20 Nut
1/4-20 Eyebolt
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
SEDS UNLV
TITLE:
Booster Assm - Bulkhead - SEDS Multi Stage - 2019
SCALE: 1:1
WEIGHT:
SHEET 13 OF 16
Notes:
-Epoxy at nut-eyebolt interface.


G
G
Ø1.60
Ø1.52
16.00
SECTION G-G
Fiberglass
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
SEDS UNLV
TITLE:
Sustainer Assm - Sustainer Body Tube - SEDS Multi Stage - 2019
SCALE: 1:5
WEIGHT:
SHEET 8 OF 16


H
H
13.85
20.00
120°
120°
120°
1.50
20.00
9.80
SECTION H-H
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
SEDS UNLV
TITLE:
Sustainer Assm - Subassembly Instructions - SEDS Multi Stage - 2019
SCALE: 1:10
WEIGHT:
SHEET 9 OF 16
Notes:
-Epoxy bulkhead in positon.
-Epoxy fins in place, generating a 1/4" fillet.
-Friction fit motor.

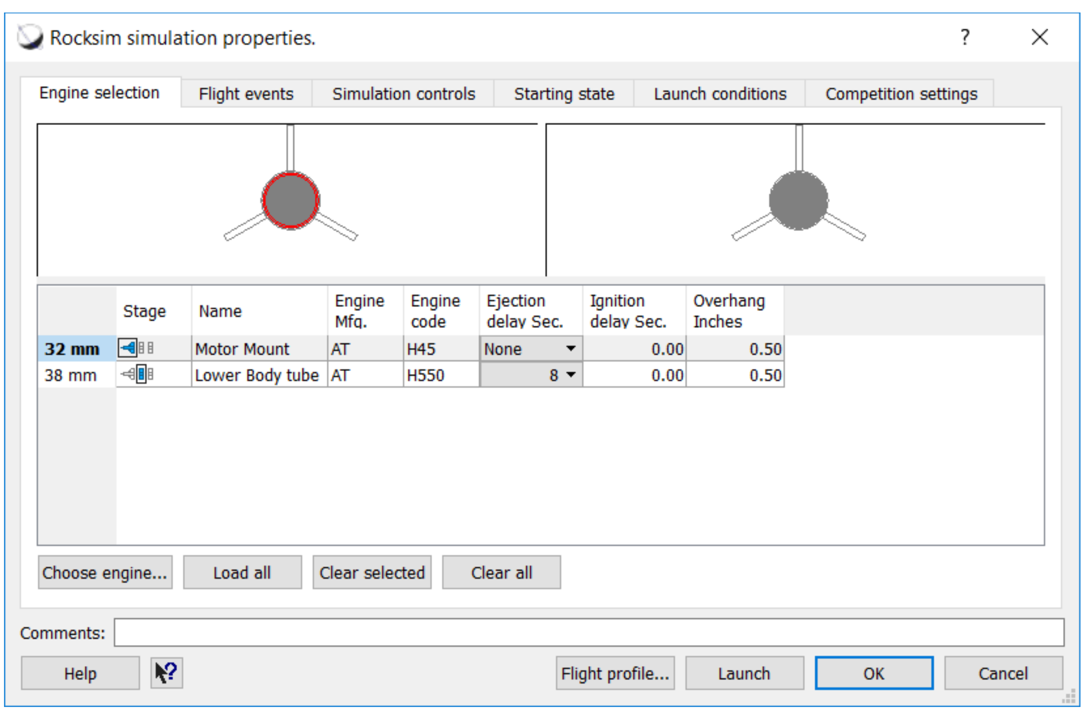

J
J
3.00
Ø1.52
Ø1.37
SECTION J-J
Fiberglass
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
SEDS UNLV
TITLE:
Booster Assm - Coupler - SEDS Multi Stage - 2019
SCALE: 1:1
WEIGHT:
SHEET 11 OF 16


K
K
16.00
Ø1.60
Ø1.52
SECTION K-K
Fiberglass
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
SEDS UNLV
TITLE:
Booster Assm - Booster Body Tube - SEDS Multi Stage - 2019
SCALE: 1:5
WEIGHT:
SHEET 12 OF 16

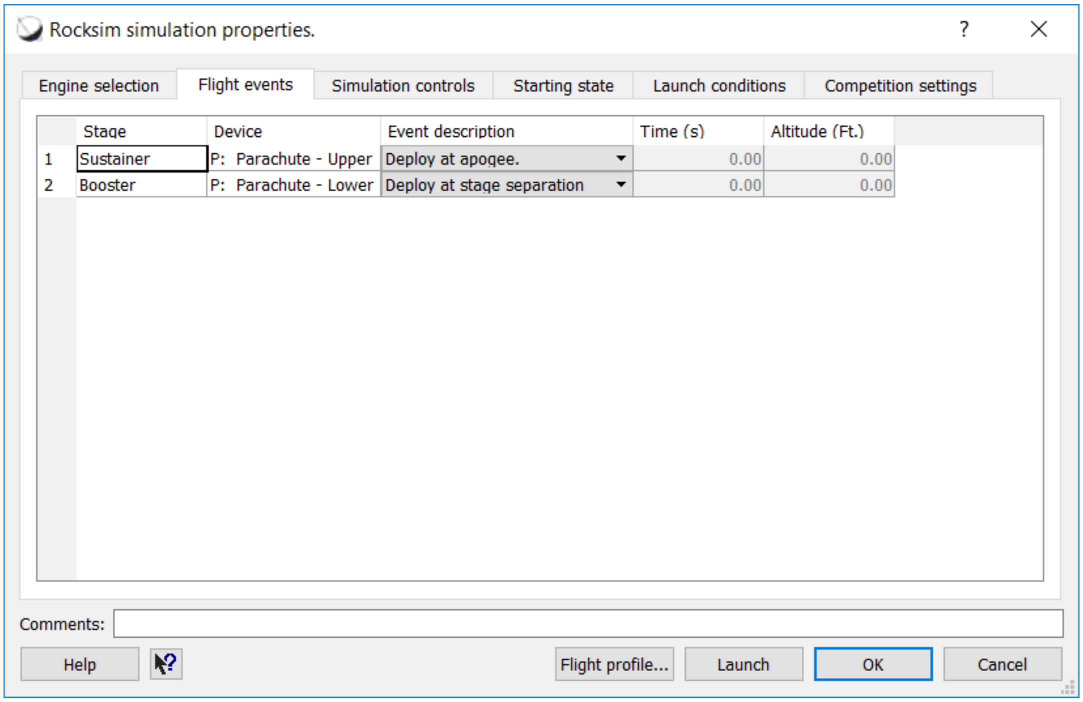


Appendix B: Flight Simulation Parameters

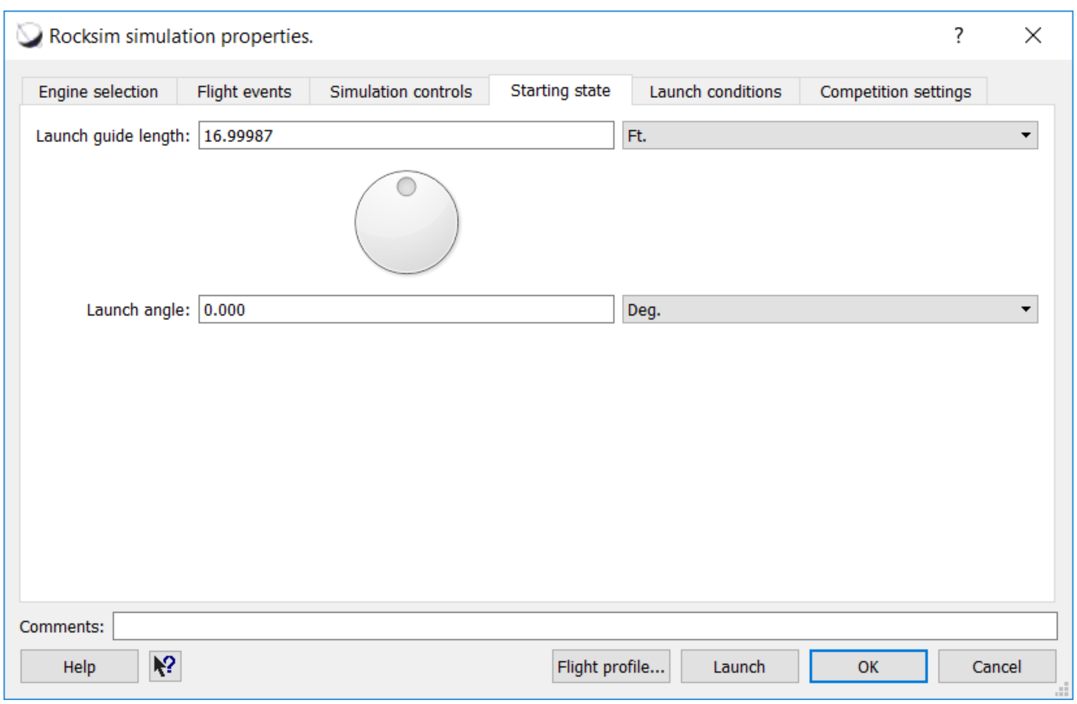
Engine Selection and Parameters



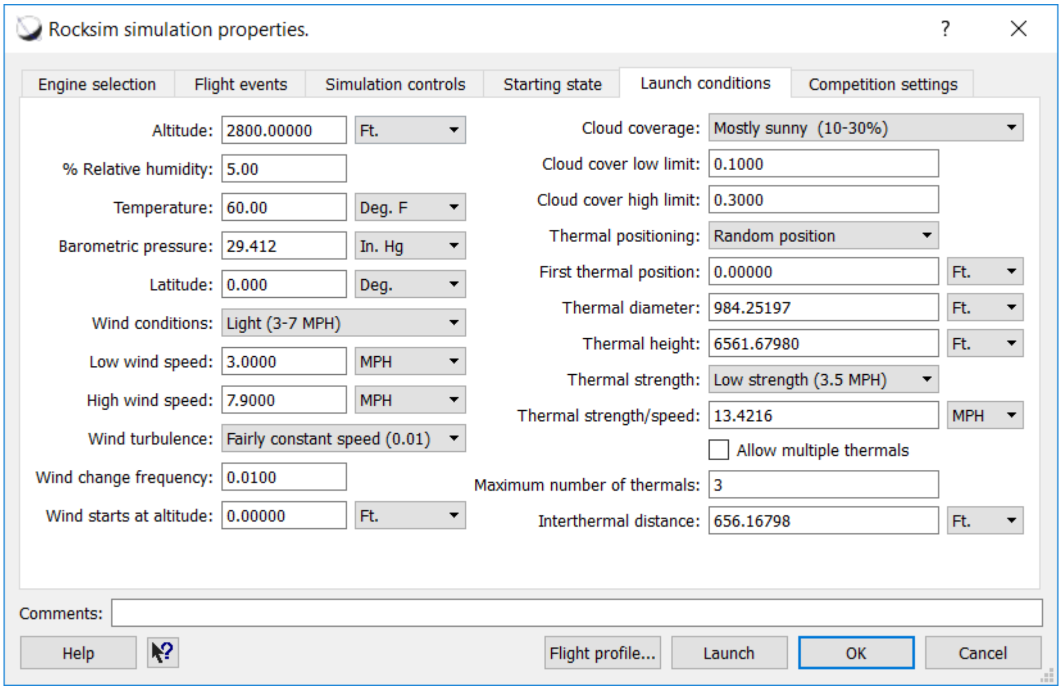
Flight Events



Starting State

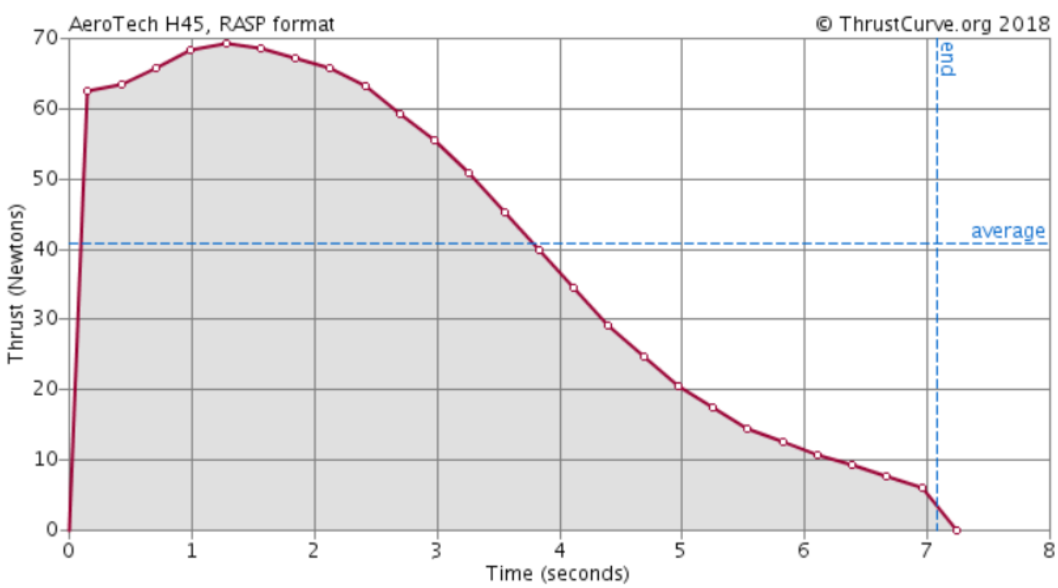


Launch Conditions

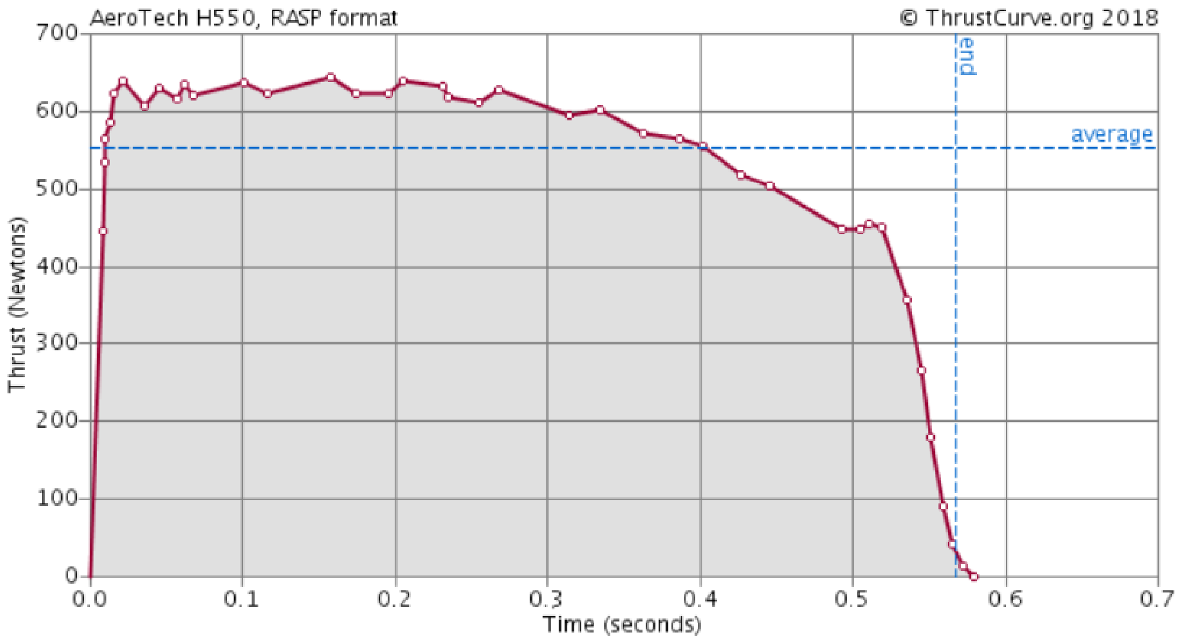


Appendix C: Motor Thrust Curves

Aerotech H45 Thrust Curve (sustainer)

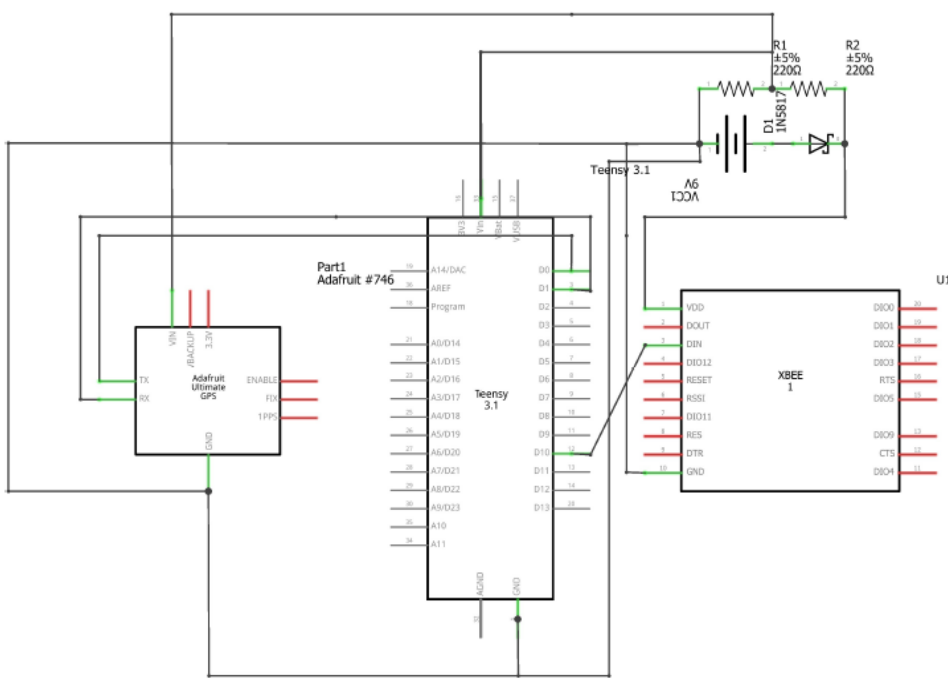


Aerotech H550 Thrust Curve (Booster)



Appendix D: Avionics Schematics

GPS Module Block Diagram



Avionics and Recovery Mission Flowchart