Texas Tech University – Space Raiders

USLI Preliminary Design Review 2019 – 2020

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List of Acronyms

AAA: American Automobile Association
AGL: Above Ground Level
APCP: Aluminum Perchlorate Composite Propellant
CDR: Critical Design Review
CNC: Computer Numerical Control
CG: Center of Gravity
CP: Center of Pressure
DC: Direct Current
EDM: Electrical Discharge Machining
EHS: Environmental Health and Safety
ESC: Electronic Speed Controller
FAA: Federal Aviation Administration
FCC: Federal Communications Commission
FRR: Flight Readiness Review
GUI: Graphical User Interface
HPR: High Power Rocketry
IMMS: Institute of Materials, Manufacturing, and Sustainment
LCO: Launch Control Officer
LED: Light Emitting Diode
LiPo: Lithium Polymer
LPR: Low Power Rocketry

LRR: Launch Readiness Review
LREV: Launch Rail Exit Velocity
MSFC: Marshall Space Flight Center
NAR: National Association of Rocketry
NASA: National Aeronautics and Space Administration
NFPA: National Fire Protection Agency
PCB: Printed Circuit Board
PDR: Preliminary Design Review
PLA: Polylactic Acid
PLAR: Post Launch Assessment Review
POC: Points of Contact
POT-Rocks: Panhandle of Texas Rocketry
PPE: Personal Protective Equipment
RAS: Raider Aerospace Society
RC: Radio Control
RSO: Range Safety Officer
RX: Receive
SDS: Safety Data Sheet
SL: Sea Level
SO: Safety Officer
STEM: Science, Technology, Engineering, and Math
STP: Standard Temperature and Pressure
TRA: Tripoli Rocket Association
TTU: Texas Tech University
TX: Transmit
UAV: Unmanned Aerial Vehicle
USLI: University Student Launch Initiative

Summary

1.1 Team Summary

Team name: Space Raiders
Organization name: Raider Aerospace Society
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Texas Tech's Space Raiders are comprised of 55 students over many different engineering disciplines and applied physics. The design of the rocket is split into 4 teams Safety, Vehicle, Recovery, and Payload. The safety team is responsible for generating the safety protocols and checklists to create a safe work environment that ensures an injury free workplace. The vehicle team is responsible for creating a flight worthy airframe, that is able to house all flight critical components.The recovery team is responsible for making sure that the vehicle is able to be recovered in the way we intended with minimal losses to the airframe. The payload team is responsible for designing, testing, and building their own mission vehicle capable of completing the mission goals set by NASA.

1.2 Launch Vehicle Summary

The launch vehicle will be composed of a composite nose cone housing a 360 degree camera, payload section, recovery section composed of the drogue and main parachutes with the electronics bay, and a booster section housing the motor. The total length of our rocket is about 8.75 feet in length and weighs 51.3125 lb without fastener weight accounted for.

1.3 Payload Summary

The payload rover will travel from the rockets landing location to the ice sample collection. The payload will be controlled once the rocket lands on the ground by a student via remote. The rover will be coming out of the nose cone of the vehicle once landed. Once the rover collects the sample it will then bring the sample at the specified distance.

Changes Made Since Proposal

2.1 Vehicle Changes

Since our proposal, the total length and weight of our airframe has changed significantly. Originally, the fore section of our airframe, which housed our drogue chute as well as the payload, had a length of 26 inches. However, since we decide on moving the payload into the nose cone, that length has decreased from 26 inches to 19 inches. The weight decrease will cause our fin shape and design to change as well in order to meet the proper rocket stability of 2.15 cal.

The design of our bulkheads has changed significantly from our initial proposal due in part to the new functions they have to accomodate. The first noticeable change in design is the nose cone bulkhead. The bulkhead is now to be hollowed out to make room for our payload to slide through during separation at apogee. This changes where we place our eye bolts on the bulkhead, the plan for this is to move them to the edge where they won't interfere or tangle with our ejection. The biggest change comes with the bulkheads that surround our ebay. A new design has been proposed that would allow for shock absorption in the bulkheads themselves. The height of the bulkhead is larger than that of our original idea which means less room inside the rocket body.

The fins have entirely changed in dimensions along with the manufacturing process from the proposal. Originally, we were planning on using either carbon fiber or G10-fiberglass material. However, we are now going with a composite fin design of both carbon fiber and G-10 fiberglass. Additionally, in our proposal's design, our centering rings were going to made from bass wood or plywood, however, our leading design has now changed to maple wood for all 3 rings.

2.2 Payload Changes

The payload design has significantly changed from our proposal. We first planned on having an unmanned aerial vehicle (UAV) but have now proposed on having a rover. The rover will have tread that will help it maneuver throughout the terrain. In between the two treads we will have a chassis made of aluminum box. The aluminum box will serve as a grounder for our two batteries in which each one will connect to two different things. One will be to the raspberry pi that has connection to our GPS as well as our 9 DOF sensor. The other battery will be connected to the motor controller which then connect to the motors. The motors will then run the rover to collect the sample. The rover will collect samples of the ice which will be then transferred into the motor bracket.

2.3 Recovery Changes

In the proposal design, we overestimated the size of the drogue parachute and when calculating the size of it we are calculating it to have a diameter of 1.5 ft. The main reason to have such a sudden change is to help with the performance of the rocket as it descends. The other change to the parachute was a more exact diameter for the main parachute. The predicted size of the parachute was a diameter of 14 ft but it has changed to 15 ft in diameter. The parachutes will be connected by four shock cords, two will be connected to the drogue parachute. We will also have two more shock cords connecting to the main parachute. One is measured at 9.91 ft and another at 7.35 ft. When mentioning the material used for the shock cords as well as the length in the proposal we were able to intel more precise information. One major change from the proposal is to use shock cords made of Nylon.

Vehicle Criteria

3.1 Vehicle Mission Statement

The vehicle's primary purpose is to deliver the payload to the intended target on the ground while also reaching a particular altitude of 5280 ft. In addition to the flight parameters, The mission will be determined a success when the following criteria are met. Launch vehicle performs a stable accent, reaches the target altitude, both parachutes deploy, payload deploys on ground, and the vehicle is still in flight ready condition with no significant damage.

3.2 Vehicle Justification and Mission Success Criteria

3.2.1 Justification Criteria for Vehicle

Within the PDR document itself, we will be outlining our considerations for our vehicle going through each particular part within the vehicle and going through appropriate factors for each part. We will be detailing each of those factors with a summary, the positives and negatives, and a justification for why we are considering for every factor that we have. The team will then choose the best choice from each of those considerations in the leading design section. There, we will present a more in-depth justification for why this is our leading design along with general dimensions and a CAD model of that part.

3.2.2 Mission Success Criteria for Vehicle

We will judge the success of our vehicle off of a couple of different factors. We will use our altitude, landing speed, drift from launch pad, and overall failures as our mission success criteria.

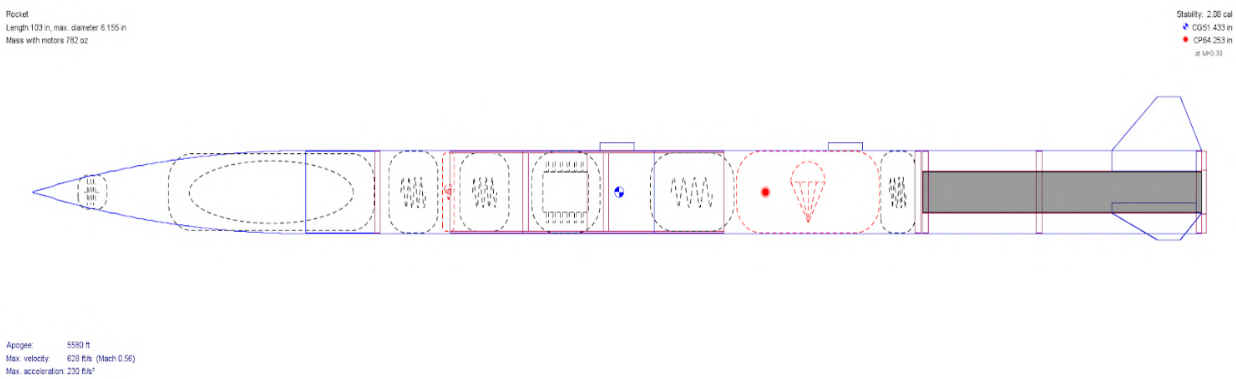


Figure 3.2.2.1

3.3 Launch Vehicle

3.3.1 Airframe

3.3.1.1 Material Consideration

a. Blue Tube

Blue tube is a high density, high strength paper material that has a good impact resistance and is also a great alternative to phenolic tubes. Since the tube is made from paper fiber, it allows us to cut, shape, and sand the tube with the use of formal tools.

The positives of blue tube are better resistance to abrasion with no cracking or brittleness compared to phenolic tubes. This also allows us to avoid the task of having to wrap our tube with fiberglass or Kevlar clothes, thus making it easier to construct and finish the airframe. Relatively low cost compared to carbon fiber tubes. Can be cut, shaped and sanded using standard tools with relative ease. Since the material is made out of paper fiber, the tube can be easily cut for slotting our fins through the frame, as well as adding rail buttons for the launch rail.

The negatives of blue tube the price of blue tube is a bit higher compared to the standard phenolic tubes. The density of blue tube is also higher than phenolic and carbon fiber, meaning the airframe would add more weight to our rocket. The strength of the blue tube itself is a bit less than phenolic tubes, and a lot less than carbon fiber. Due to the lack of strength, the tube has a higher chance of being damaged due to zippering from the shock cords.

Despite having less strength than the traditional phenolic tubing, Blue Tube is more rigid and resistant to abrasion, meaning that overall, the effect of zippering will not be as damaging. Its relatively low cost is also a great factor for choosing Blue Tube since we would be able to focus on using our resources elsewhere. Additionally, the fact that it can be easily cut and shaped with formal tools is a big factor, since we would not have to rely on acquiring special materials for the tube.

This data taken from one of our potential manufacturers, Always Ready Rocketry, demonstrates the material properties from a smaller sample of blue tubing. According to the data, the blue tubing has a break load of approximately 1549 pounds force, which, when scaled up to our body tube length, provides more freedom into increasing our weight load.

3/12/2009

Sample ID: BlueTube.mss   Test Date: 3/11/2009
Method: Tube Compression (Simple Servo).msm   Operator: MTS

Sample Results:
Specimen Results:

Specimen #	Specimen Comment	Inner Diameter in	Outer Diameter in	Platen Separation in	Area in^2	Modulus ksi	Load At Yield lbf
1		3.002	3.128	9.00000	0.60662	559.60219	2974.13082
2		3.002	3.128	9.00000	0.60662	607.10291	3211.11207
3		3.002	3.128	9.00000	0.60662	574.09091	3052.63859
Mean		3.002	3.128	9.00000	0.60662	580.26534	**3079.29383**
Std. Dev.		0.000	0.000	0.00000	0.00000	24.34486	120.71828

Specimen #	Stress At Yield MPa	Peak Load lbf	Peak Stress psi	Energy To Peak ft*lbf	Break Load lbf	Elongation at Peak in	
1	33.80322	2974.13082	4902.72798	14.11096	1504.89966	0.11156	
2	36.49669	3211.11207	5293.38147	20.93077	1607.34466	0.13095	
3	34.69552	3052.63859	5032.14469	18.27847	1534.46427	0.11815	
Mean	34.99848	3079.29383	**5076.08472**	17.77340	1548.90286	0.12022	
Std. Dev.	1.37205	120.71828	198.99895	3.43785	52.72665	0.00986	

Figure 3.3.1.1.a.1

b. Phenolic Tubing Wrapped in Kevlar + Fiberglass

The phenolic tubing poses a greater alternative to the expensive carbon fiber tubing, however, with less strength. While the phenolic is a brittle material, the Kevlar sock and the epoxy should reinforce the material to provide additional strength to the material, thereby reducing the risk of failure and increasing safety.

The positives of this composite are the phenolic would a much more cost-efficient purchase when compared to carbon fiber or blue tube. Our team has past experience with the manufacturing of this phenolic tubing wrapped in Kevlar sock. This will help reduce manufacturing time because the team knows the processes used to manufacture this and has prior tooling for epoxying the tubing. The tubing itself is also stronger than blue tube, which will also be further strengthened when wrapped in Kevlar and fiberglass support to prevent zippering. Phenolic is also a lot lighter than blue tube.

The negatives of this composite are the phenolic tubing is very brittle and is prone to cracking at high impacts. The Kevlar and fiberglass support is an extremely necessary component when it comes to using phenolic tubing. The brittleness of the phenolic is very hindering especially if zippering due to the shock cords occurs, since it would cause a snowball effect essentially splitting our body tube in half. There is also past experiences using phenolic wrapped in Kevlar and fiberglass, where zippering occurred.

This method of reinforcing phenolic tubing with Kevlar and fiberglass is an option that our team has previous experience with. Building our airframe using these materials would save us a great deal of time and effort since we are familiar with the process. Additionally, the reinforcing of the phenolic greatly increases its strength, as well as thickness, thus decreasing the damage that zippering could cause.

c. Carbon Fiber

Carbon fiber is an excellent option due to its high strength to weight ratio and stiffness to weight ratio. The strength of carbon fiber is optimal for withstanding impacts and abrasion of rocketry airframes.

The positives for carbon fiber are for one, the strength of the carbon fiber outmatches that of the blue tube and the phenolic. This strength and rigidity allows the airframe to have greater support in preventing zippering due to the shock cords of the rocket.

The negatives for carbon fiber tubing are that it is an expensive material and if we decide on the cheaper carbon fiber sheets rather than the tubing, the manufacturing of the sheets will be difficult to fit our tight parameters on the rocket. The carbon fiber also blocks radio frequency signals, thus, we would have to redesign how to remotely activate the 360 camera built in the nose cone. The blocked radio frequency signals would also affect our GPS tracker and would force a relocation of the GPS tracker itself. Carbon fiber's strength and stiffness means that it cannot be cut and shaped efficiently using formal tooling.

Using carbon fiber will strengthen our airframe drastically compared to other materials, thus giving the rocket more leeway when withstanding impacts and zippering of the shock cords. The positives of the carbon fiber heavily outway the negatives, since most of our troubles come from obtaining the material, like its hefty price. However, the overall quality that carbon fiber gives to our airframe structure is optimal and efficient when compared to other materials.

This data chart gives the material properties for the carbon fiber based on its classified strength. The carbon fiber rocket tubing that we would be using would be classified underneath the "Commercial High Strength" category.

		Aerospace		
Property	*Commercial High Strength*	*High Strength*	*Intermediate Modulus*	*High modulus*
Tensile Modulus (Msi)	33	32–35	40–43	50–65
Tensile Strength (Ksi)	550	500–700	600–900	600–800
Elongation at Failure (%)	1.6	1.5–2.2	1.3–2.0	0.7–1.0
Electrical Resistivity (μΩ-cm)	1650	1650	1450	900
Thermal Conductivity (Btu/ft-h-°F)	11.6	11.6	11.6	29–46
Coefficient of Thermal Expansion Axial Direction (10^{-6} K)	−0.4	−0.4	−0.55	−0.75
Density (lb/in.^{3})	0.065	0.065	0.065	0.069
Carbon Content (%)	95	95	95	+99
Filament Diameter (μm)	6–8	6–8	5–6	5–8

Figure 3.3.1.1.c.1

d. Fiberglass

Fiberglass is a composite material made of glass fiber and epoxy resin. It is a valid material because it is more cost effective than some of the other options but still has the potential to have a very high tensile strength, especially if it were to be reinforced by small amounts of more expensive materials.

The positives of fiberglass are that fiberglass can be manufactured several ways to fit its application and does not take as much heat or pressure to mold as some other materials, so it is a very versatile material. It also has very good thermal properties, including its ability to dissipate heat and its resistance to burning or corrosion. Fiberglass has a very good strength-to-weight ratio and is stable enough to keep its shape. It also has a very high tensile modulus, which means it can bend to handle the strain its put under. In addition, fiberglass is much cheaper than some of the other materials being considered.

The negatives of fiberglass are that fiberglass has a lower tensile strength than some other materials so it could be prone to zippering or buckling without the appropriate reinforcement.

Using fiberglass allows us to keep our body tube costs relatively low, but also at a high strength. Most importantly, slotting the tubing and shaping it ourselves will save us a considerable amount of time compared to some of the other materials.

e. Canvas Phenolic

Canvas phenolic is made of woven fibers that create a strengthened bond that is stronger than that of paper phenolic.

The positives of the canvas Phenolic is that it has a higher impact strength and compressive strength compared to paper phenolic. It is also relatively cheaper compared to other materials in consideration like carbon fiber. Additionally, using canvas phenolic allows us to cut and shape it with ease and with the use of standard tools.

The negatives of the canvas phenolic are that the canvas phenolic has a lower hardness and temperature index than that of paper phenolic.

Canvas phenolic is also more brittle on its own without the use of any reinforcements like Kevlar or fiberglass.

Canvas phenolic offers us a decent strength body tube at a low cost. Building our rocket using this material will also be extremely fast and efficient since our team has past experience using this type of material.

3.3.1.2 Manufacturing Options

a. Apogee Components Blue Tube

Figure 3.3.1.2.a.1

Apogee Components offers their high strength Blue Tube airframe at around the same inner diameter we are looking for, while also selling it at a reasonably cheap price. Their airframes have an inner diameter of 5.973 inches, and outer diameter of 6.079 inches, with a length of 48 inches. Additionally, the weight is 1188.98 grams and a price of $71.64 for each tube. Through Apogee Components, we would only have to by 2 tubes for $143.28, which would provide more than enough material to build our airframe. Cost Estimate: $143.28

b. Always Ready Rocketry Blue Tube

Figure 3.3.1.2.b.1

Always Ready Rocketry is the manufacturer for the Blue Tubes that are sold by Apogee Rockets. However, by purchasing directly from Always Ready, we are given some more options for our Blue Tube airframe. The airframe that Always Ready offers has a diameter of 6 inches with a wall thickness of 0.074 inches, and a length of 48 inches or 72 inches, with the price of each tube being $66.95 (48 inch) or $105.95 (72 inch). Always Ready gives us an extra option of buying a 72 inch Blue Tube, which could be beneficial if we require more material. In addition, they also provide optional customized slotting for our fins, which would help save us time and work. Cost Estimate: $172.9

c. Public Missiles Phenolic Tubing Wrapped in a Giant Leap Rocketry Kevlar and Fiberglass Sock

Figure 3.3.1.2.c.1

Figure 3.3.1.2.c.2

Figure 3.3.1.2.c.3

The phenolic tube sold by Public Missiles provides the inner dimensions we are looking for with an inner diameter of 6.007 inches, a wall thickness of 0.074 inches, and a length of 48 inches. The is 36.9 ounces and a price of $41.99 per tube. Furthermore, if we purchase the phenolic form Public Missiles, they can provide customized slotting to the phenolic tubes, saving us additional time and resources. The fiberglass and Kevlar support, however, could be purchased from Giant Leap Rocketry, with the Easyglass sock (fiberglass) at a price of $2.09 per foot and the Airframe sock of Kevlar at a price of $3.49 per foot. We also have past experiences purchasing from these companies, thus reducing the amount of time it would take to construct our airframe using the Kevlar and fiberglass support. Cost Estimate: $173.26

d. Madcow Rocketry Carbon Fiber

Figure 3.3.1.2.d.1

The carbon fiber sold by Madcow Rocketry is designed to have a high linear strength, manufactured with premium carbon fiber tow and epoxy. The dimensions of their tubing also fits perfectly with what we were looking for in our own airframe. With the inner diameter being 6 inches, outer diameter being 6.17 inches, and a length of 60 inches. The weight is 17.6 ounces per foot with a price of $539 for each tube. Cost Estimate: $1078

e. Public Missiles Carbon Fiber

Figure 3.3.1.2.e.1

The carbon fiber material that Public Missiles offers also fits the dimensions of the airframe we are planning on using. Their tubing comes with a diameter of 6 inches, a length of 60 inches at a price of $479.95. Public Missiles also offers optional customized slotting for the fins, which would be beneficial by avoiding slotting of the frame ourselves, saving us a great amount of time and work. Cost Estimate: $959.90

f. Apogee Rockets Fiberglass Tubing

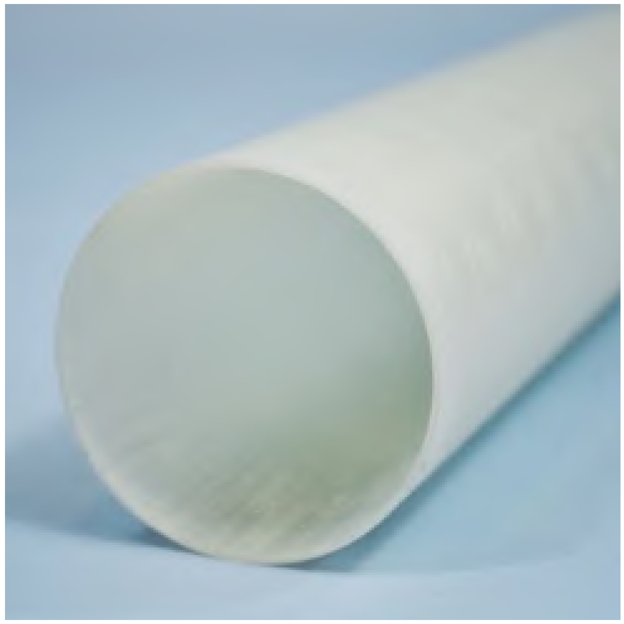


Figure 3.3.1.2.f.1

Apogee Rockets offers fiberglass rocket tubes with 6” diameters and 48” lengths, which fit the dimensions of our rocket. They are sold for $217.14. While they only tubes 48” long, one of the advantages of fiberglass is that they are easily shaped or cut without losing their strength so we could buy several 48” tubes and trim or connect them as needed. The weight of this option is 96.81 ounces. Cost Estimate: $434.28

g. Madcow Rocketry Fiberglass Tubing

Figure 3.3.1.2.g.1

Madcow Rocketry sells 6” fiberglass rocket tubes at 30” long or 60” long with a weight of 24 ounces per foot. They also allow you to customize the tubes so we could request for them to cut slots or trim the frames into the lengths we want. The 60” airframes are sold for $228 and the 30” airframes are sold for $114. Because there are different lengths and the option to customize, ordering from Madcow Rocketry would potentially save us time and work on trimming the tubes ourselves. Cost Estimate: $456

h. Accurate Plastics Inc. Phenolic Tubing

Figure 3.3.1.2.h.1

Accurate Plastic inc. sells 6” canvas phenolic tubes at 48”long and with many different outer diameters. The tube with the wall thickness of .062 is $36.72 a tube but there are thicker walls of .125 in and higher which increases the cost. Cost estimate: $147

3.3.2 Couplers

3.3.2.1 Material Consideration

a. Carbon Fiber

Carbon fiber is a material composed of multiple thin strands of carbon, giving it a high tensile strength, high stiffness and high tolerance to temperature and chemicals. Carbon fiber is as much as ten times stronger than some of the strongest metals at a fraction of the weight. Although carbon fiber is strong, the exact strength of the fiber varies depending on how it was created, and higher quality carbon fiber tubes will be much more expensive.

Carbon fiber should be considered because it provides exceptional strength at a fraction of the weight of other materials. Although the material is expensive, carbon fiber couplers are less susceptible to shattering and zippering unlike the other materials and would save us from buying more parts and using more time to repair the rocket should it be damaged. Carbon fiber is the most reliable material to have the couplers be made out of, as strength is an important factor in rocketry.

The negatives of using carbon fiber couplers is its very high cost. Carbon fiber material is the most expensive material we are considering which would put a major strain in our overall budget. Additionally, since carbon fiber is so tough and rigid, we would need the use of special tools to be able to cut and shape our couplers. Again, putting more of a strain on our resources and expenses.

b. Phenolic

Phenolic is made of synthetic polymers by condensing phenol with an aldehyde and is used in molding and insulation. Depending on the thickness and how the phenolic was constructed, the strength of the tubing varies. No matter the thickness, phenolic is a strong material for support, but is brittle on its own, and would need to be reinforced.

Phenolic couplers is one of our major considerations because although the tensile strength and heat resistance of phenolic is not as high as that of other materials, phenolic still has adequate strength to support an airframe. The cost of phenolic material is also extremely low compared to carbon fiber, which allows us to use our resources elsewhere. More importantly, our team has past experience in using phenolic couplers so the construction time will be more efficient.

The negatives of using phenolic couplers is that they are more brittle than carbon fiber and blue tubes, thus the reinforcement with other materials, such as fiberglass, epoxy, or Kevlar, are extremely recommended to increase its strength. If zippering occurs, the brittleness of phenolic would cause a snowball effect, further damaging our couplers.

c. Blue Tube

Blue Tubes are made of paper fiber, and are easy to sand, cut and shape into the form you need. They are much stronger than the Kraft paper tubes and are good for high powered rocketry. Blue Tubes are very durable and resistant to shattering, as they are used in military tank ammunition.

Blue Tubes should be taken into consideration because they are cheap and stronger than phenolic alone. The couplers, and thus the airframe, would be less likely to shatter or experience zippering because of how shatter resistant Blue Tubes are. If strength is an issue, then the Blue Tube can be strengthened in the same manner as phenolic couplers. Additionally, blue tubes are sold at very low costs.

The drawbacks of using blue tube material for oue couplers is that it is not as strong as other materials like carbon fiber. Because of this, blue tube would be more prone to zippering.

d. Fiberglass

Fiberglass is glass that has been melted and shaped into filaments woven together and reinforced with resin. Fiberglass is used in swimming pools, doors and automobile parts. Like, carbon fiber, it is rather lightweight, but lacks the strength of carbon fiber.

Fiberglass couplers are quite expensive in comparison to Blue Tubes and phenolic, but they are durable and provide a strong alternative to carbon fiber. Fiberglass is a strong consideration for coupler material, as they provide strong structural support, as the purpose of couplers is to joint and support two different components of a rocket.

The negatives of using fiberglass couplers is its overall strength. Since it is not as strong as other materials, it is more prone to breaking and zippering due to the stress of the shock cords.

3.3.2.2 Manufacturer Options

a. Public Missiles Carbon Fiber Couplers

Figure 3.3.2.2.a.1

Public Missiles Ltd offers the couplers with a 6" diameter in tubes in 11.75" and 14.75", priced at $94.95 and $129.95 respectively. Each foot of carbon fiber tubing weighs approximately 18.3 oz.

b. Madcow Rocketry Carbon Fiber Couplers

Figure 3.3.2.2.b.1

Madcow Rocketry also sells 6” diameter carbon fiber couplers. They come in lengths of 12” and 18”, with the former priced at $116.00 and the latter at $174.00.

c. Public Missiles Phenolic Couplers

Figure 3.3.2.2.c.1

Public Missiles offers a phenolic coupler with an inner diameter of 5.86-in with a wall thickness of 0.074-in making the outer diameter 6.007-in. The total length of the piece is 12-in and the weight is 5.4 oz or .3375-lb. The 12” coupler costs $14.99, while the 48” tubing costs $44.99.

d. Always Ready Rocketry Blue Tube Couplers

Figure 3.3.2.2.d.1

Always Ready Rocketry offers 6” diameter Blue Tube couplers in three different lengths: 12”, 16”, and 48”. The 12” Blue Tube costs $19.95, the 16” coupler costs $27.95, and the 48” Blue Tube coupler costs $66.95.

e. Apogee Components Blue Tube Couplers

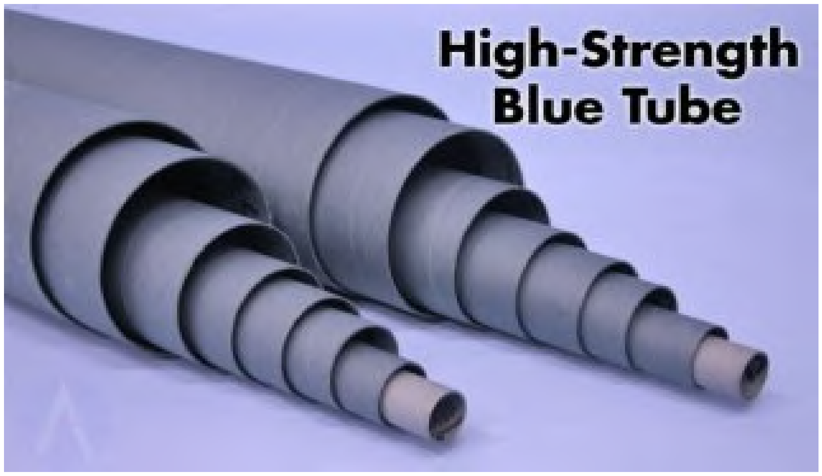


Figure 3.3.2.2.e.1

Apogee Rockets also produces and sells Blue Tube couplers of 6” diameter. The couplers come in lengths of 12” and 48”, with the first option priced at $21.35 per tube and the second priced at $71.64 per tube.

f. Madcow Rocketry Fiberglass Couplers

Figure 3.3.2.2.f.1

Madcow Rocketry offers the couplers in lengths of 12” and 14”, priced at $60.00 and $70.00 respectively.

g. Apogee Components Fiberglass Couplers

Figure 3.3.2.2.g.1

An alternative to Madcow Rocketry is Apogee Rockets, which only produces the 6” diameter tubes in 12” long sections. These 12” fiberglass couplers cost $71.24 per tube.

3.3.3 Nose Cone

The purpose of choosing a specific shape and design for the nose cone is to reduce the overall drag of the vehicle and increase the aerodynamics. The nose cone shapes we are considering are Ogive, Elliptical, and Conical shapes. The nose cone will be a total length of 24 inches, a base diameter of 6.17 inches, and a wall thickness of 0.079 inches.

3.3.3.1 Shape Considerations

a. Ogive

Figure 3.3.3.1.a.1

The Ogive shape is usually used in high-powered rocketry and is formed using a circular arc. Ogive shapes exhibit superior performance characteristics when compared to conical shaped nose cones.

Some of the positives of using an Ogive nose cone is that they have sharp points, which makes it great for supersonic motion, and they have curved surfaces, which are good for strength. The Ogive shape itself also allows for an increase in the nose cone volume. Additionally, it is easily available and can be modified for a specific airframes.

The negative of the Ogive nose cone shape is that it is intended for airframes that go past the speed of sound, hence the sharper nose point. Which, in the case of our rocket, is well beyond the speeds that we will be flying at. The nose cone shape also does not allow the flow to come from a range of angles without creating too much drag.

b. Elliptical

Figure 3.3.3.1.b.1

The profile of the elliptical shape is one-half of an ellipse, with the major axis being the centerline and the minor axis being the base of the nose cone. This shape is popular in subsonic flight (such as model rocketry) due to the blunt nose and tangent base.

The major benefits of using an elliptical nose cone shape is that the round nose allows the flow to come from a range of angles without creating too much drag. Aerodynamically speaking, the stagnation point can be moved without any problems. Compared to the other shapes, the elliptical nose cone provides the least amount of drag. The shape of the nose cone also increases the volume.

The drawbacks of using the elliptical nose cone shape is that at higher speeds, other nose cones shapes, specifically ones with a pointed tip become more effective in flight. Considering our more rounded tip, it would be less useful at those higher speeds.

The data below, taken from one of our potential manufactures, Apogee Components, demonstrated the amount of drag for elliptical shaped nose cones compared to various shapes. As the data shows, the drag caused by the elliptical nose cone is the lowest of the other shapes, however, it is not by any means a drastic difference. While taking into consideration of our intended flight speed, it might be more beneficial to consider the more pointed tipped shapes rather than the rounded elliptical shape.

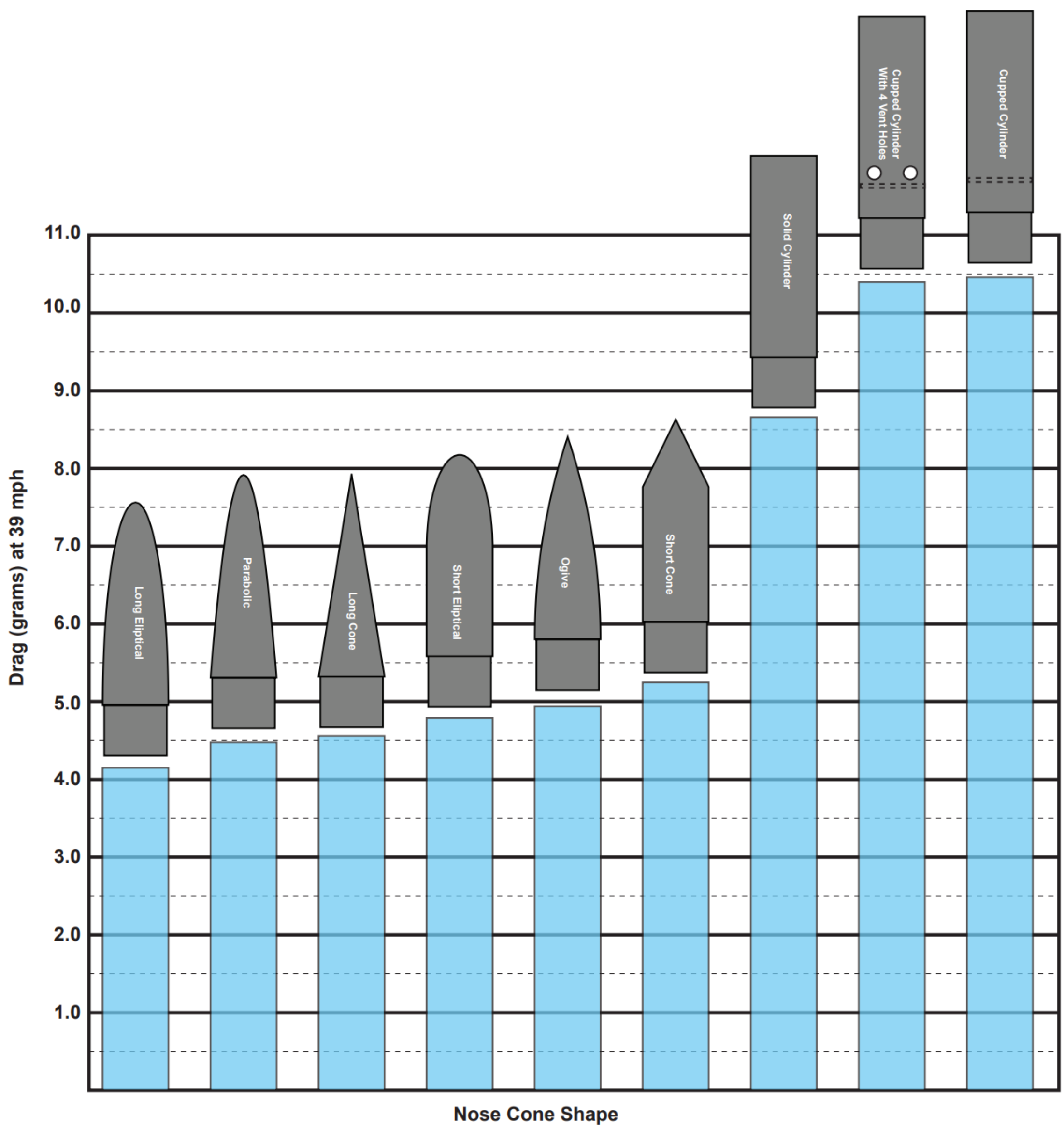


Figure 3.3.3.1.b.2

c. Conical

Figure 3.3.3.1.c.1

Another very common nose-cone shape in rocketry is the conical shape. This shape is often chosen for its ease of manufacture as well as for rockets more intended to go supersonic. The conical shape is designed with straight edges leading up to the tip, dramatically different compared to its counterparts with rounded edges.

The positives for using a conical nose cone shape is that in supersonic flow, the air has no indication of the approaching vehicle. The first contact will cause a sudden change in direction, called a shock. For drag reduction it is important to make the shock as weak as possible, which means that the change in direction should be as small as possible. This can best be achieved by a slender, pointy tip. Additionally, the conical shape allows for efficiently decreasing drag, specifically at above supersonic speeds. Another major positive of the shape is that it is easier to manufacture, thus allowing us to save more time.

The negatives of the conical nose cone shape is that it really is intended for rockets that will be going above supersonic speeds. Which, in our case, the overall practicality of the conical shape will be essentially useless since our rocket will not be reaching any speeds at or past mach 1. More importantly, the conical shape drastically decreases the volume of the nose cone, thus limiting us to the amount of space we have in our nose cone. Additionally, the manufacturing cost of the conical nose cone is usually greater than a blunt nose (since it has more area).

3.3.3.2 Material Considerations

a. Carbon Fiber

Carbon fiber is a very popular material when it comes to strengthening your components. Carbon fiber is manufactured by using layers of carbon fiber fabric made from carbonized rayon are coated with pitch and wound around a mandrel, and then heat-treated to convert the pitch to solid carbon.

The most important reason for considering a nose cone made of carbon fiber is its high tensile strength. Carbon fiber offers the best strength and weight to stiffness ratio compared to any other materials that are typically used for nose cones like balsa wood or fiberglass. This very high strength allows the nose cone to withstand higher impacts and reduce the risk of any abrasions and cracks.

The negatives of carbon fiber come more from manufacturing and availability rather than the material itself. For one, the cost of carbon fiber is extremely high compared to materials like fiberglass. This cost would put a strain on our resources and budget, limiting us from spending more resources elsewhere. Ironically, carbon fibers high strength is also a hindrance when it comes to manufacturing the nose cone. Since the material itself is very strong, the use of formal tools to cut and shape the nose cone would not be viable. We would have to spend additional time and resources in order to find the proper tools that could be used on carbon fiber.

b. Fiberglass

Fiberglass is another common type of material used for nose cones made with fiber-reinforced plastic using glass fiber. The fibers may be randomly arranged, flattened into a sheet, or woven into a fabric. The plastic matrix may be a thermosetting polymer matrix—most often based on thermosetting polymers such as epoxy, or polyester resin.

Some of the positives of using a fiberglass nose cone include its flexibility. The flexibility of fiberglass would allow the nose cone to withstand higher impacts without the risk of breaking. Fiberglass is also a relatively cheap material, and most definitely cheaper than carbon fiber. This low cost would allow us to use our additional resources elsewhere without worrying about the nose cone. Lastly, fiberglass is also very light-weight, reducing the total weight of our rocket. With this decrease in weight, we would have more freedom in increasing our weight elsewhere if necessary.

While it is very flexible, fiberglass is not as strong as carbon fiber. Thus, the amount of impact forces our nose cone could withstand would be considerably less than that of carbon fiber.

c. Polycarbonate and Fiberglass

We are considering having the first part of the nose cone made out of a clear Polycarbonate material, so that we may place a 360 degree camera in the nose cone for inflight recording. The second half of the nose cone would be made out of fiberglass. In order to manufacture this, we would take the fiberglass section of the nose cone and cut it down to the appropriate size where we could then bond the Polycarbonate section to the fiberglass using epoxy and other materials needed to strengthen this.

Using a mix of the 2 materials allows for more usage out of the nose cone.

There is the possibility that this may not be as strong as say a nose cone that is fully fiberglass.

3.3.3.3 Camera Bay

We are considering adding a 360 degree camera at the tip of the nose cone, thus the tip would have to be made out of a clear material. The camera bay will be in between two materials, one that is clear for the camera, and one that is more rigid like either carbon fiber or fiberglass.

3.3.3.4 Manufacturing Options

a. Public Missiles Carbon Fiber Ogive Nose Cone

Figure 3.3.3.4.a.1

Public Missiles offers a premium carbon fiber Ogive nose cone with a diameter of 6 inches. This nose cone was specially made to be used in combination with their 6 inch diameter carbon fiber body tube, which is a component we are already considering for our body tube. By using Public Missiles nose cone, as well as their body tube, we would be guaranteed that both our nose cone and body tube would math together, potentially saving us time and resources compared to if we were to use components made by different manufacturers. The total estimated cost would be $199.95

b. Madcow Rocketry Fiberglass Ogive Nose Cone

Figure 3.3.3.4.b.1

Madcow Rocketry gives two options for a 6 inch diameter fiberglass nose cone. Both options are Ogive shapes, one with 3:1 ratio, and the other with a 5:1 ratio. The cost is significantly cheaper than that of the carbon fiber nose cone from Public Missiles. The total estimated cost for either of the options is $94.95.

c. Apogee Components Fiberglass Ogive Nose Cone

Figure 3.3.3.4.c.1

Apogee Components provides a 6 inch diameter, Ogive shape nose cone with a 5:1 ratio. Their nose cone has a weight of 1043 grams, a length of 30 inches, and a shoulder length of 5.5 inches. The total estimated cost is $113.03

d. Public Missiles Fiberglass Nose cone

Figure 3.3.3.4.d.1

Public missile's nose cone provides us with a 6.007-in diameter along with a 24-in in exposed length, and a shoulder of 5.5-in in length. The weight of the whole nose will be 28-oz or 793.79g. The total cost estimate of this part would be $104.99.

3.3.4 Bulkheads

The purpose of any bulkhead is to act as the anchor of the rocket body, withstanding the forces of separation and stresses of parachute deployment. To this end the considerations we take are based upon the stresses they must withstand.

On the rocket there are 4 total bulkheads: one positioned at the nose cone, two surrounding the e-bay and one at the helm of the motor. All bulkheads require different designs to accommodate the functions of our rocket.

3.3.4.1 Design Considerations

a. Fore Bulkhead

The bulkhead at the nose cone will be slightly different to the other two designs. This design needs to accommodate the payload being able to slide through once the rocket enters its stage of separation after reaching apogee. The consequences of this is that this bulkhead becomes hollow and is thus not air tight as the others will be.

This bulkhead will be of a homogeneous material.

b. Ebay Bulkheads

The criteria that our central bulkheads must meet is that they must be able to withstand the forces of parachute deployment while maintaining and sealing off the e-bay from the charges used for separation.

We started with two ideas behind the construction of the central rocket bulkheads. The original idea is simply another homogenous bulkhead with an eyebolt affixed to it, just as the ones at the nose cone and motor helm would be. The idea that comes after is a composite bulkhead consisting of a solid ring shape, two flexible washers and an air tight cap through which an eyebolt will be secured at several points. This makes for a configuration that would allow some shock of parachute deployment to be absorbed internally within the bulkhead.

The basis of the composite bulkhead is a solid ring, milled in such a way that our threaded rods can be inserted through the edge while providing structural support to the shock absorbing washers. This part is the anchor to all other components of the bulkhead meaning that it must be made out of a sturdy material.

Connected to this ring are the washers, two rings made of high tensile strength material that will resist the forces of parachute deployment. These components are the only thing connected to the eyebolt meaning that they are the first point of failure should stresses exceed expectations.

Finally two caps on either end will seal off compartments of the rocket from each other. To maintain this seal, the caps will be epoxied onto the wooden ring along with a rubber gasket sealing off the area through which the eyebolt will be able to move.

The pros of a composite design is that it can be used to complement a material's individual ability to accomplish a task without interfering with the strengths that the other materials possess. This allows us to attain the strength of a material like aluminum without incorporating metal into the design.

The cons that come with a complex design are that there are more areas that could produce a failure under stress and compromise the integrity of our rocket. Other cons are that this design takes up more room in the rocket and weighs slightly more than a slimmer design.

c. Aft Bulkhead

The bulkhead positioned above the motor has the task of adding structural integrity to the rocket and completely sealing off the rest of the rocket from the motor. For this task the composite design is unnecessary.

3.3.4.2 Material Considerations

a. Marine Grade Plywood

The pros of using marine grade plywood is it is pliable. Marine grade plywood can withstand a fair amount of bending forces before losing its structural integrity and cracking or breaking. In addition to being pliable, marine grade plywood is impact resistant due to the outer layer of plywood being hard dense. Compared to other wood, marine grade plywood is more stable due to its high quality veneers and enhanced properties within the laminated structure. Compared to many other materials, marine grade plywood is affordable and very easy to manufacture.

The cons of using this material is the weight, plywood is fairly heavy and would add additional weight that could be allocated elsewhere.

b. Hardwood

The use of hardwood in the bulkheads is supported by the rigidity and strength that a denser wood could provide. It would be able to provide the proper support to the rocket that a more pliable wood like plywood may be unable to. This is undermined by the fact that denser woods are not only heavier but also harder to manufacture.

c. Nylon 6/6, Extruded

The areas that would incorporate nylon in the bulkhead would be in the special shock absorbing washers. Nylon is able to bend and deform before breaking, therefore acting in a similar manner to a spring. This property gives us reason for nylon’s inclusion, that the eyebolt to which the washers will be connected will be allowed a certain degree of movement by the deflection of the washers during parachute deployment. Nylon is also cheap for the amount of it that we would be using, coming in at only $34.66 total for the 4 washers needed.

d. Fiberglass caps

The use of fiberglass in the design is meant to utilize fiberglass’s rigidity and tensile strength to seal off either end of the composite bulkhead. The pros of doing this is that fiberglass is relatively lightweight and inexpensive to manufacture into specialized shapes.

3.3.5 Launch Lugs

The purpose of launch lugs on rockets are to guide the rocket off the ground and maintain contact with the rocket until the proper velocity is reached and the rocket can self-maintain its trajectory. We have determined that the optimal placement of the launch lugs are on Cg and the second one placed at least 2 airframe diameters apart which conveniently allows us to use our Cp location. The 2 Rail buttons that we have decided to consider in our design process are standard buttons that we have used in the past and manufactured ourselves, and the more advanced linear rail buttons.

3.3.5.1 Public Missiles Large Urethane Linear Rail Lugs

We have decided that our leading design will be the Public Missiles linear rail button due to many factors such as the increased contact area with the launch rail as well as the reduced friction with the launch rail due to the composition material being urethane vs the standard buttons being made of brass or a similar material.

Below is a CAD model of the Public Missiles Launch Lugs.

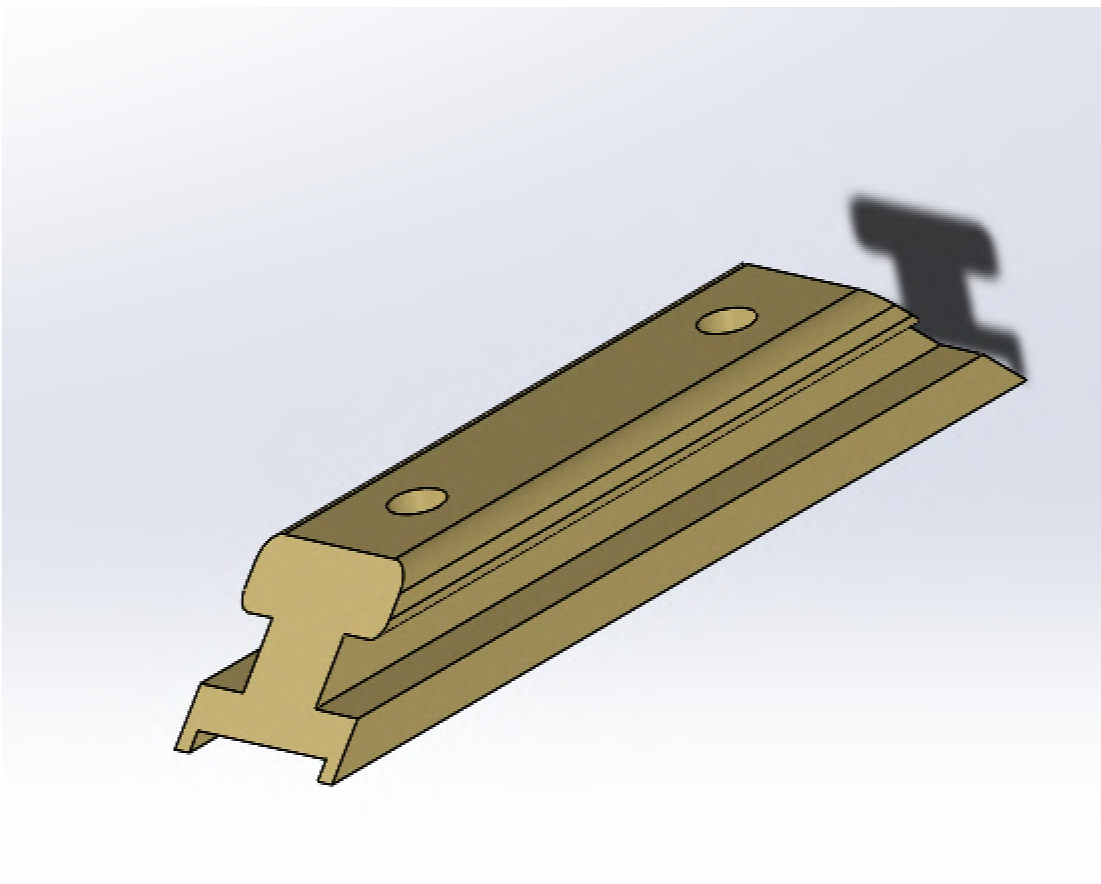


Figure 3.3.5.1.1

Linear Launch Rail Button (leading design)

3.3.5.2 Alternative Launch Lug Design

We currently have access to small rail bottoms that we have used for previous launches. They provide a small surface area for the launch to follow and we have no knowledge on the original manufacturer.

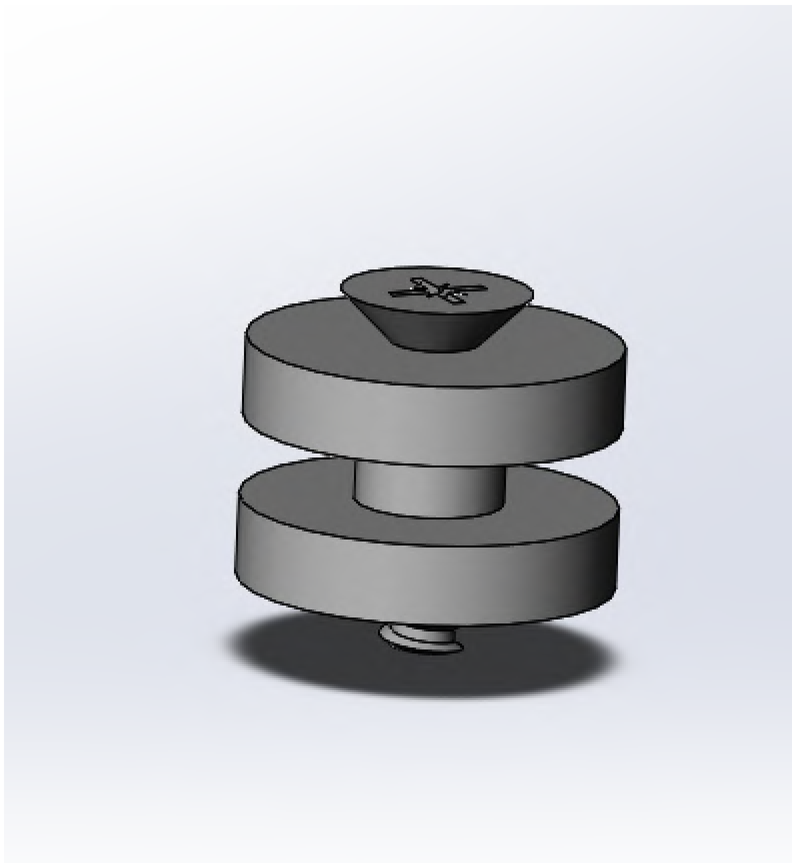


Figure 3.3.5.2.1

Launch Rail Button (alternative design)

3.3.6 Fins

The fins play a pivotal role in the stability of the rocket, and the rockets ability to maintain its orientation and intended flight path. Thus, the sizes and shapes of the fins are directly proportional to the size and weight of the rocket.

3.3.6.1 Material Considerations

a. Fiberglass

G-10 fiberglass is a composite material made by layering fiberglass sheets, soaking them in epoxy, and compressing the material together until it is cured. Fiberglass is also a very popular material in rocketry, especially for fin design and construction.

The positives of using G-10 fiberglass is it is already manufactured and cured. Thus, it would save us a considerable amount of time and resources. The only thing we would have to construct and manufacture ourselves would be cutting and shaping the fiberglass into the desired fin shape we need. Coincidently, by using fiberglass material we would be able to cut and shape it with the use of formal tools. Additionally, this is a cost effective material since most manufacturers offer it at a relatively low price. Another positive of using G-10 fiberglass is that it is very rigid, but also flexible enough to keep from snapping under high loads. Thus, recovering the fins would be a lot easier since it will withstand higher impacts. This material is also low in weight, which contributes to the overall shaping of the fins since weight is a major factor in fin stability.

The negatives of using G-10 fiberglass is its tensile strength is lower than other materials such as carbon fiber. Without proper reinforcement, fiberglass fins have a higher risk of breaking as the impact with the ground, since fiberglass tends to be prone to internal fracture.

Additionally, the flexibility of fiberglass will also be prone to fin flutter which could potentially break the fin as well as steer our rocket off course.

b. Carbon Fiber

Carbon fiber is a strong material that could easily withstand the impact flight and landing with its high weight to stiffness ratio. This material is also another popular option for rocketry, especially for fins since carbon fiber has a better rigidity than most materials.

Carbon fiber is a great option for the fins due to its ability to withstand higher impacts compared to that of fiberglass. Its great rigidity also means that the fins will resist fin flutter, which will protect our fins from breaking during flight and avoiding our rocket from steering off course.

The negatives of using carbon fiber is that it is extremely expensive when compared to other materials. Furthermore, using carbon fiber is also harder to manufacture, as it is not as easy to cut through with the use of formal tools, thus would require us to spend resources in acquiring those tools. Additionally, carbon fiber does not bond to as many materials like fiberglass does, limiting us to what materials we could use on our fins.

c. Fiberglass-Carbon fiber composite

The Fiberglass-Carbon fiber composite would be a thin sheet of carbon fiber surrounded by two sheets of fiberglass bonded with epoxy. This would combine the rigid properties of carbon fiber as well as the more flexible properties of fiberglass.

The reason for using this combination of materials is that it provides us with the best of both worlds, combining the stiffness of carbon fiber with the strength and flexibility of the fiberglass. This allows for us to have a stronger fin design that can withstand the forces of flight as well as impact forces. Additionally, this reduces the cost of using an all carbon fiber fin design since we would only have to use a single sheet for each fin, sandwiched in between two fiberglass sheets. Furthermore it would also reduce the overall weight of the fins.

The negatives of combining both fiberglass and carbon fiber together is having to manufacture it, causing us to use more time, effort, and resources on constructing the fins. This also introduces more risks of errors occurring and the material not containing the strength it should have. Additionally, having to manufacturing the composite fins takes time away from working on other important sections of the vehicle.

3.3.6.2 Shape Considerations

a. Trapezoidal Fin Shape

Figure 3.3.6.2.a.1

The trapezoidal fin shape is shaped exactly like a trapezoid. This shaped reduces the induced drag. However, this shape also provides the most induced drag compared to our other options like the clipped delta and elliptical fin shapes. Manufacturing these types of fins are also extremely easier than elliptical fins since trapezoidal ones only consists of straight edges.

b. Clipped Delta

Figure 3.3.6.2.b.1

The clipped delta fin shape is another type of fin that acts similar to that of the trapezoidal fin shape. The amount of induced drag created by the clipped delta fin is slightly less than the trapezoidal, yet larger than the elliptical fin.

c. Elliptical

Figure 3.3.6.2.c.1

The elliptical fin shape produces the least amount of induced drag. This shape was specifically designed to provide lower drag at the fin of the tip since the area of the shape is reduced as it gets closer to the tip. This is the best option for our fin shape if we want to minimize drag as much as possible.

The data below, taken from one of our manufacturers, Apogee Rocketry, demonstrates the amount of induced drag of each fin shape. Additionally it provides more data on the specific angle of attack of the rocket.

Table: Angle of Attack

Angle-of-Attack		Elliptical	Trapezoidal	Square	Rectangular	Clipped Delta
0°	Drag Force	9.508	10.690	9.023	11.337	9.357
5°	Drag Force	12.052	12.262	10.567	11.685	10.907

Table 3.3.6.2.c

3.3.6.3 Mounting Method

There are 2 typical methods of mounting fins to the rocket body. The first method includes mounting the fins directly to the outside of the airframe. The second method and the one that we will be implementing is mounting the fins through the airframe and directly to the motor tube. The second option vastly increases the strength and durability of the fins to sustain the impact of landing. Also by mounting the fins to the motor tube the likelihood of the vehicle sustaining fin flutter is greatly reduced.

3.3.7 Motor

Multiple motors are being considered to account for potential design changes to the rocket. The three motors we are considering for the vehicles propulsion system are the Cesaroni L-1395, Cesaroni L-1115 and Cesaroni L1355-SS. These Cesaroni motors are all L-class, 4 grain, reloadable, solid propellant motors that provide the ideal characteristics to achieve our apogee goal under a variety of scenarios. These three motors have identical dimensions of 75.00 x 621.00 mm (2.95 x 24.45 in). These motors most appropriately satisfy the specified design parameters outlined by the USLI handbook with the rocket's current configuration. These motors meet all of the necessary design/flight criteria, bringing the rocket within the required apogee range.

3.3.7.1 Motor Selection

a. Cesaroni L-1395

This table details the specs of the Cesaroni L-1395-BS motor:

Mass	4320g (9.52-lb)
Maximum Thrust	1779.90 N (400.48-lb)
Apogee with Motor	5222 ft
Burn Time	3.51 s
Propellant	Blue Streak

Table 3.3.7.1.a

The relationship of the thrust of this motor with respect to time is shown in the thrust curve, which allows for an evaluation of motor performance. Figure 3.3.7.1.a.1 shows the thrust curve data for the L-1395 motor.

The greater maximum thrust and more accurate to our target apogee are the reasons why the L-1395-BS motor is being considered.

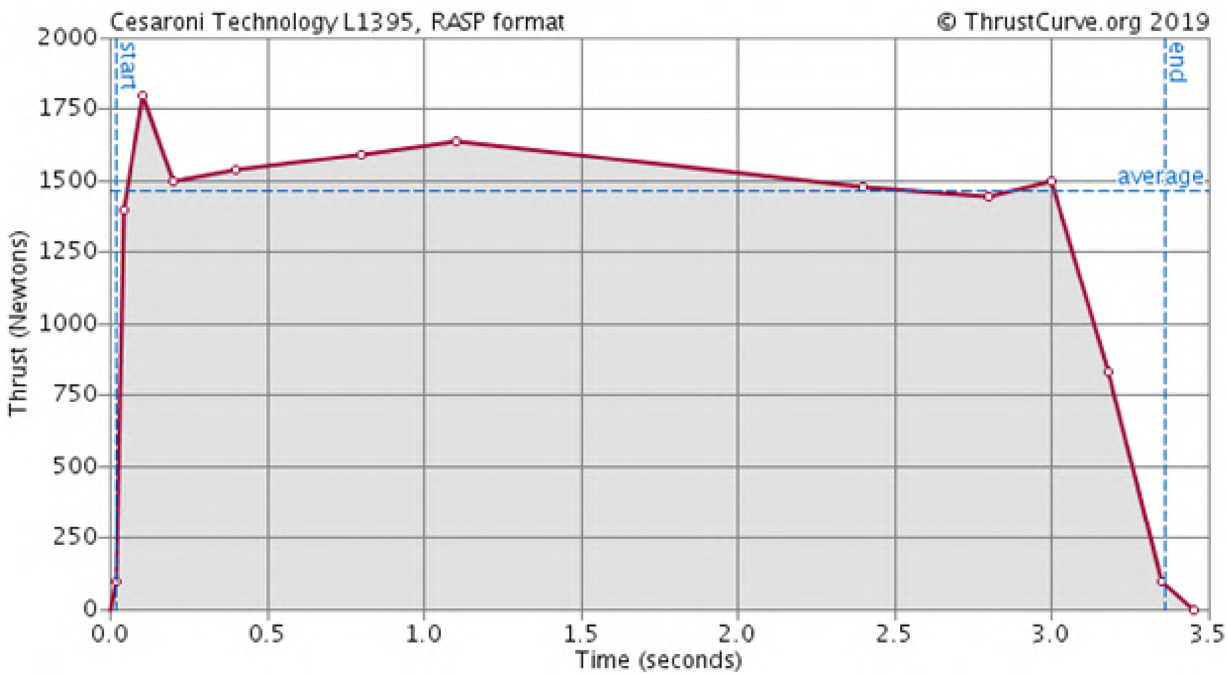


Figure 3.3.7.1.a.1: Thrust Curve for Cesaroni L-1395 Motor

b. Cesaroni L-1115

This table details the specs of the Cesaroni L-1115 motor:

Mass	4404g (9.71-lb)

Maximum Thrust	1713.25 N (382.48-lb)
Apogee with Motor	5100 ft
Burn Time	4.48 s
Propellant	Classic

Table 3.3.7.1.b

The relationship of the thrust of this motor with respect to time is shown in the thrust curve, which allows for an evaluation of motor performance. Figure 3.3.7.1.b.1 shows the thrust curve data for the L-1115 motor.

This greater burn time and the motors ability to achieve a higher apogee is why this motor is being considered; in the event of the rocket's design weight increasing, this motor will be able to attain an equally appropriate apogee.

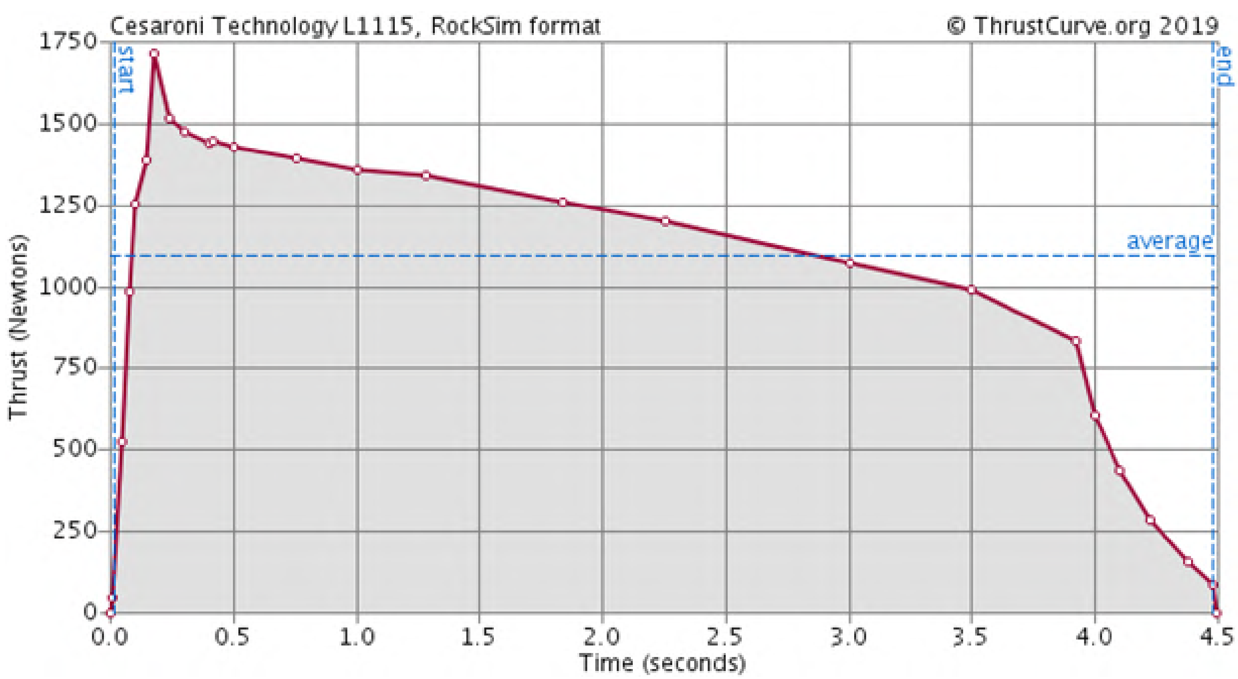


Figure 3.3.7.1.b.1

c. Cesaroni L-1355-SS

The Cesaroni L-1355-SS has a mass of 4962 grams (10.94 lb) and delivers a maximum thrust of 1792.20 N (402.9 lb) for a burn time of 3.0 seconds, launching the rocket to an apogee of 4257 feet, with the rocket's current weight configuration.This motor uses Smokey Sam propellant.

This table details the specs of the Cesaroni L1355-SS motor:

Mass	4962g (10.94-lb)
Maximum Thrust	1792.20 N (402.9-lb)
Apogee with Motor	4257 ft
Burn Time	3.0 s
Propellant	Smokey Sam

Table 3.3.7.1.c

This motor is being considered in the event that the vehicle design changes decrease the overall weight of the rocket. The lesser burn time of this motor accompanying a lessened vehicle weight would deliver the rocket to the appropriate apogee.

The relationship of the thrust of this motor with respect to time is shown in the thrust curve, which allows for an evaluation of motor performance. Figure 3.3.7.1.c.1 shows the thrust curve data for the L-1355-SS motor.

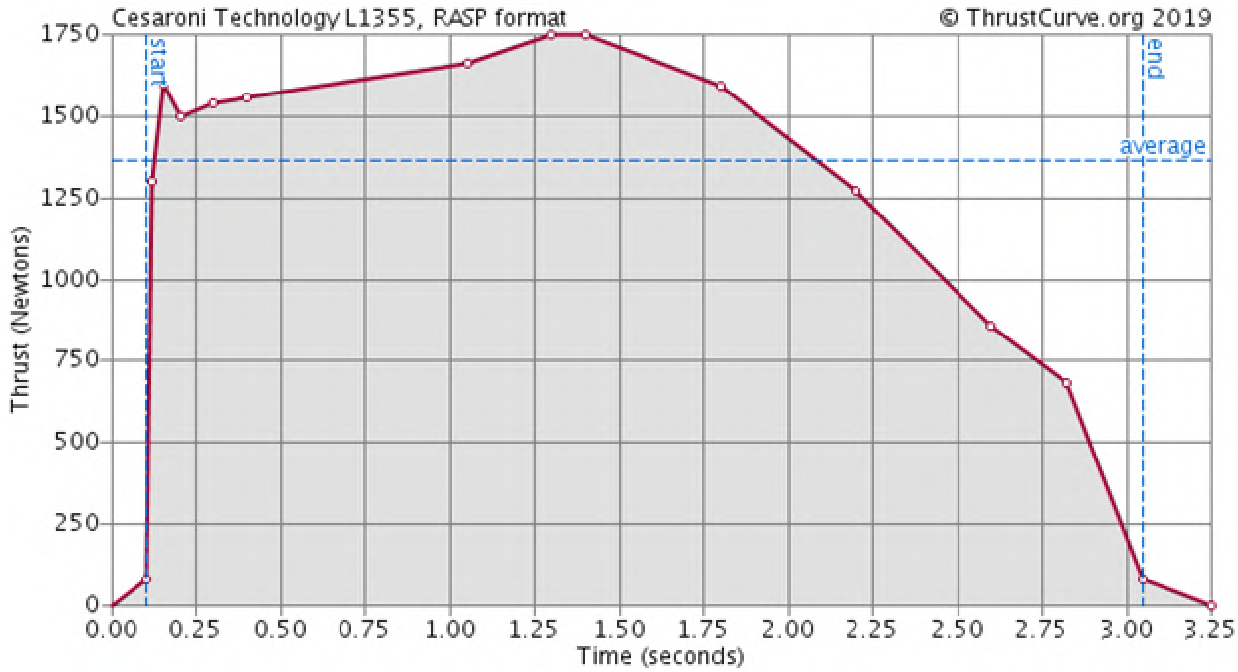


Figure 3.3.7.1.c.1

3.3.7.2 Motor Casing Options

The two motor casings we are considering is the Cesaroni 75mm 4 grain L-Class motors are the Cesaroni Pro 75 4G reloadable motor casings and the RMS-75/5120 by Aerotech.

a. Cesaroni Pro 75 4G Reloadable Motor Casing

The Cesarino motor casing is manufactured from thin wall 6061 - T6 aluminum tubing with a clear anodized coating for corrosion protection. This motor has dimensions of 608.33 mm (23.95 in) long, and has an outer diameter of 75.311 mm (2.965 in). The Pro 75 motor case is lightweight yet strong enough and able to withstand well over 3000 psi of internal pressure. The cost of this motor casing is $415.22.

b. Aerotech RMS-75/5120

The Aerotech motor casing dimensions are 602.488 mm (23.72 in) long, has an outer diameter of 75.311 mm (2.965 in) and weighs 1018 grams (2.244 lb). This casing is an aircraft grade aluminum hardware consisting of 3 parts. The case is anodized to make it easier to find if it ever should fall to the ground. The forward closure screws onto the front end of the case and serves multiple purposes. First, it holds the hot gasses of the burning propellant and keeps them from shooting forward into the body of the rocket. The aft closure screws onto the base of the aluminum case. Like the forward closure, it is a bulkhead that holds all the hot gas in the case so the motor can produce thrust. Getting the casings and closures can be more expensive than Cesarino, but you have more options for forward and aft closure depending on your needs. The cost of this motor is $459.03

3.3.7.3 Centering Rings Material Options

The Centering rings main purpose is to keep the rocket motor stable during the extent of the flight. There are a few metrics that go into the design of the centering rings The Inner Diameter, Outer diameter, thickness and material type. The inner and outer diameter is fixed by the size of the motor and rocket casing. The dimensions for centering rings that we are going with are an outer diameter of 6 inches, and inner diameter of 3.1 inches, and a thickness of 0.5 inches.

a. Bass Wood

Density(lb/in^3): 0.0116

Price/Board foot: 6$

Shrinkage volumetric due to temperature change: 15.8%

b. Oak
Density(lb/in^3): 0.0228
Price/Kg: 5$
Specific Heat: 0.0547516 J/m^3
Shrinkage volumetric due to temperature change: 13.5%

c. Fiberglass
Density(lb/in^3): 0.055
Price/Kg: 1.13398$
CTE (Coefficient of Thermal Expansion) (in-in-F): 6-8 X 10^-6

d. Carbon Fiber
Density(lb/in^3): 0.050
Price/Kg: 0.0505782$
Specific Heat: 1.13 J/g-°C
CTE (Coefficient of Thermal Expansion) (in-in-F): 1 X 10^-6

e. Maple Wood
Density(lb/in^3): 0.02727
Price: $75.00 for a 1x8x96 inch wood piece

While the woods expand more due to temperature change and present the chance for added weight, they have the lowest cost in comparison to carbon fiber and fiberglass. The carbon fiber would most likely beat out the red oak in terms of tensile strength, however seeing as how the centering rings are not load bearing this can be neglected. The Oak would be the better option over the Bass due to its lower cost/BoardFoot and its overall better rigidity however it is much more difficult to cut compared to bass as the bass wood can easily be cut on a laser cutter where as the oak would require a cnc mill, However is a novel shape is to be considered for the centering rings then it may be beneficial to use oak for is price, strength and ease of access.

3.3.7.4 Motor Retention Options

Motor retention's main purpose is to make sure that the motor stay in the body of the rocket and made it safely to the ground without dislodging. There are a few parameters that go the motor retention piece needs to be. The inner and outer diameter are fixed by the body of the rocket and the motor. We found 2 options to use for the motor retention:

a. 6061-T6 Aluminum Motor Retention

Price: $37.00
Installed with screws
Manufacturer: Aero Pack Inc.
Weight: 139 g

Pros: Lightweight so won't weigh down the rocket as much as the stainless steel, durable so it won't break, cheap so keeps costs low, easy to ship through an online site, easy to install with screws, no adhesive used

Cons: Could possibly break on impact with the ground since it is aluminum

b. Stainless Steel Motor Retention

Price: $72.22
Installed with screws
Manufacturer: Aero Pack Inc.

Pros: Installed with screws which means that it is easy to take off and install, durable so it won't break on impact, fair pricing compared to the other option, easy to ship using an online sight, no adhesive used
Cons: Heavy which weighs down the rocket, uses more of the budget.

3.3.8 Electronics Bay

3.3.8.1 Altimeters

Altimeters in HPR have 2 main purposes, recording flight data and deploying the parachutes for recovery of the airframe. According to a NASA USLI requirement, we are required to house two barometric altimeters within the confines of the airframe. The section where all the mission-critical electronics are housed is called the e-bay. This year we are proposing the use of two altimeters with 9v alkaline batteries, due to the reliability of the redundant altimeters along with the relative stability and longevity of the alkaline batteries. In addition to the two altimeters, we will also include a GPS based tracker for ground-based recovery. These components will be housed in an e-bay compartment within the airframe. We are currently considering 2 options for altimeters, the Missile Works RRC3 and the Perfectflite StratoLoggerCF. We found that both of these altimeters provide compelling reasons to choose one over the other, and we also have experience in the past using the RRC3 from Missile Works. Ultimately we believe that the StratoLoggerCF is the best option for our application, due to the high performance, low cost, and proven reliability of the altimeters by other teams. The two GPS trackers that we are considering are the Missile Works T3 GPS tracking system and the Missile Works RTx/GPS System, The RTx/GPS system does everything the T3 does with the same accuracy, but in real time during flight which is not needed, So we have decided on utilizing the T3 system to reduce complexity and weight. We are also considering the use of 3 different arming switches for the altimeters and tracking system all with their own benefits. The three we are considering have different actuation methods, Apogee component’s rotary switch, Perfectflite’s snap action switch, and FeatherWeight Altimeters magnetic switch. All of our potential choices have benefits over other options, but the one that we are currently considering is the magnetic switch due to the fact that the airframe does not have to be cut to accommodate the switch, also the minimal size and weight play a large factor in our design as well.

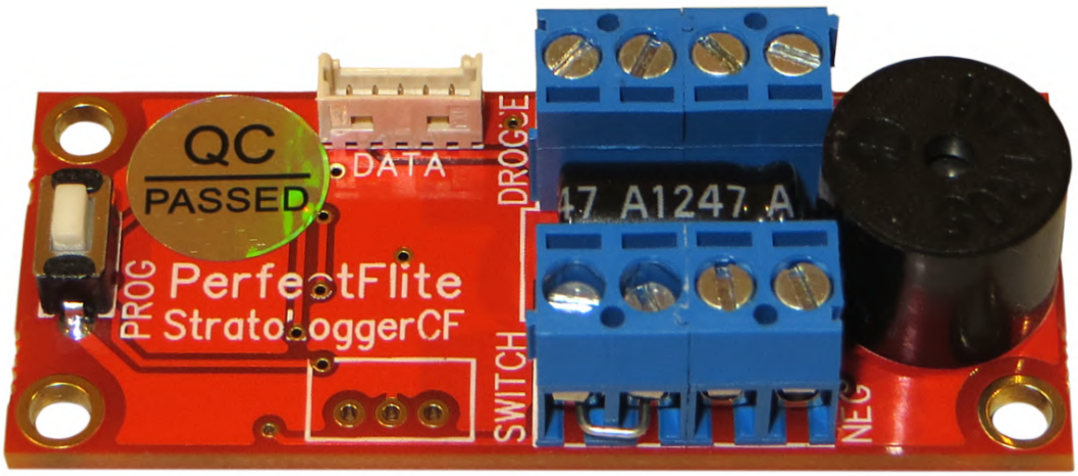


Figure 3.3.8.1.1

StratoLogger CF (leading design)

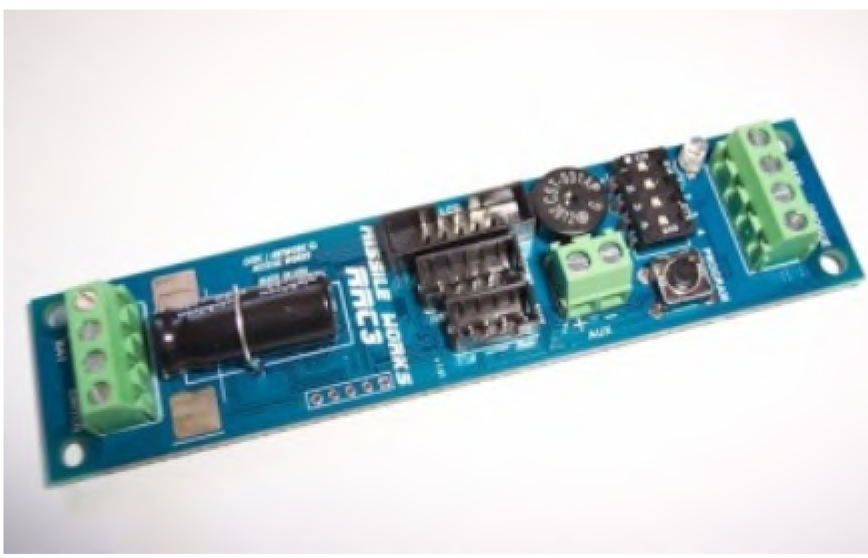


Figure 3.3.8.1.2

Missile Works RCC3 (alternative design)

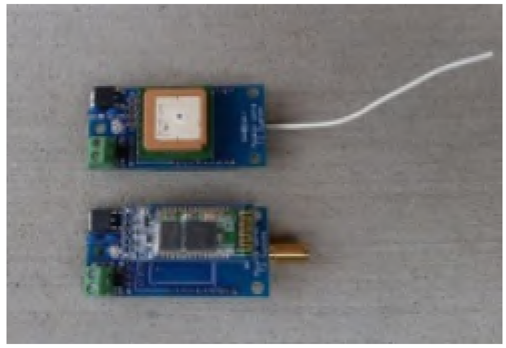


Figure 3.3.8.1.3

T3 GPS Tracker System (leading design)

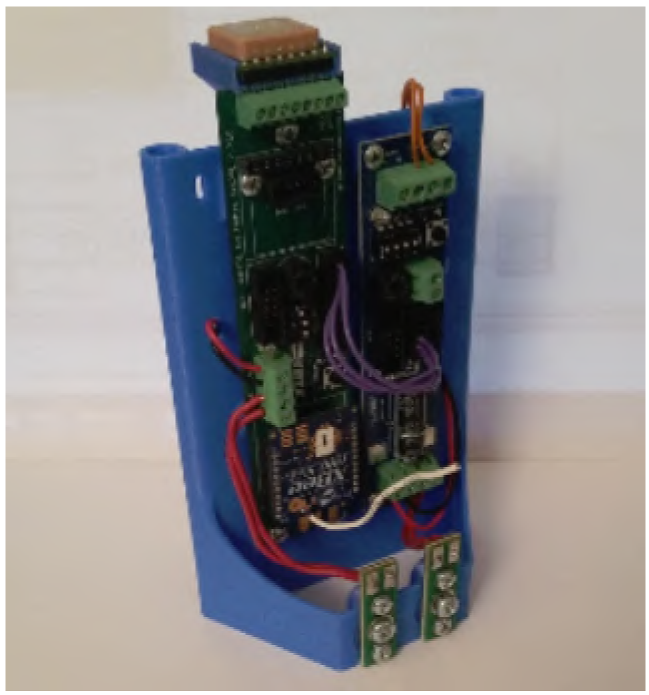


Figure 3.3.8.1.4

RTx/GPS Tracker System (alternative design)

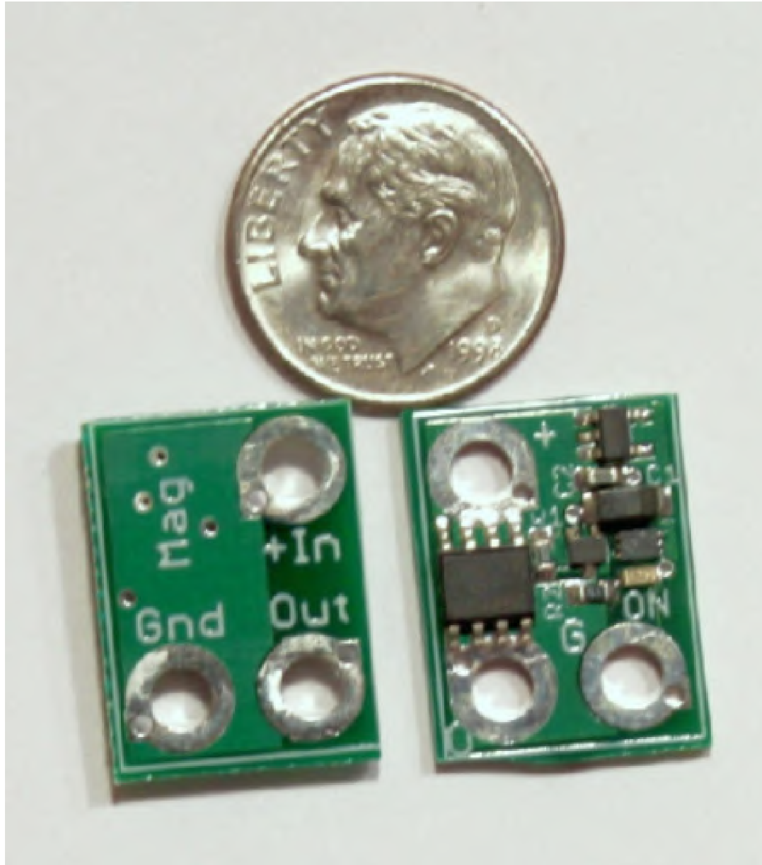


Figure 3.3.8.1.5

Magnetic Switch (leading design)

Figure 3.3.8.1.6

Snap Action Switch (alternative design)

Figure 3.3.8.1.7

Rotary Switch (alternative design)

3.3.8.2 Electronics Bay

The electronics bay or Ebay for short is responsible for housing the electrical components essential for recovery. In our case it also acts as its own airtight section of the rocket body which separates the drogue and main parachutes. We have designed the Ebay to minimise size and weight inside the rocket while also containing redundant altimeters, a tracking system, and a power system capable of powering all the electronics for at least 2 hours and up to 5 as required by NASA.

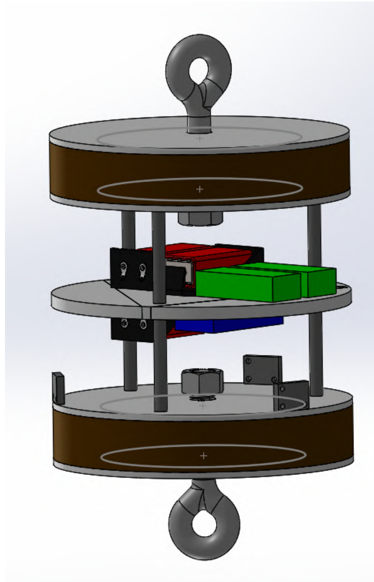


Figure 3.3.8.2.1
Ebay(leading design)

3.4 Recovery Subsystem

3.4.1 Parachutes

The parachute material as well as the shape of the parachute will determine the performance of the descent of the rocket. However, as the performance of the parachute increases so does the price. To properly select a parachute shape and material, multiple requirements along with cost, weight, and size must be considered to maintain compliance with USLI regulations:

- Rocket Weight
- Drogue deployment at apogee
- Main parachute deployment no lower than 500 feet
- Descent time limit of 90 seconds
- Landing radius of 2,500 feet from launch pad
- Maximum kinetic energy of 75 ft-lb at landing

The rocket weight is considered because the larger the weight of the recovered section, the larger the recovery system needed. Since the drogue deployment will occur at apogee, a small drogue parachute with a moderate drag coefficient needs to be selected. For both the drogue and main parachute, a large drag coefficient will result in high drift while a low drag coefficient will result in a large amount of kinetic energy upon landing. The goal of the main parachute deployment is to deploy as low as possible to reduce drift, yet minimize kinetic energy upon landing. If the main parachute is deployed too soon, the rocket could drift outside of the landing radius.

3.4.1.1 Parachute Shapes

A cruciform parachute is being considered for the drogue parachute as it is performs well under high speeds due to its low drag coefficient of 0.4. When comparing the area of the cruciform parachute to the other shapes, its area is quite low. This is ideal because a low coefficient of drag is desired for the drogue parachute. If the drogue parachute slows the rocket too much, the drift will be too large.

Figure 3.4.1.1.1

Figure: Cruciform Parachute

Flat sheet parachutes are mainly used for lower speeds, as they have a drag coefficient of 0.7. This is a relatively low coefficient of drag for a main parachute. While it could help stabilize the rocket during its functions as a drogue parachute, the coefficient of drag is a bit high for a drogue parachute. The calculations to determine the area would also be complex. However, the cost for this type of parachute is low compared to the other parachute options. The flat sheet parachute is made just as it is named. It consists of a large, flat sheet of material, tethered together by shroud lines.

Figure 3.4.1.1.2

Figure : Flat Sheet Parachute

This is a panel shaped parachute sized at 16 ft in diameter sold by rocketman which could be used as our main parachute within the rocket. The parachute has a weight of 2-lb, a drag coefficient of 0.97, a packing volume of 10-in in length for a 6-in inner diameter airframe for a total of 282.74-in^3 in total packing volume, and a descent rate of approximately 15 ft/sec for the weight of our vehicle. It's cost estimate is $180.00.

Figure 3.4.1.1.3

Figure : Panel Parachute

Elliptical parachutes have a relatively high coefficient of drag. The coefficient of drag for this type of parachute is 1.6. Since the coefficient of drag is high, an elliptical parachute is being considered for the main parachute. The large area of this parachute results in the large coefficient of drag. A vent hole is located in the center of the parachute to stabilize it. The cost of this type of parachute is average compared to the other parachutes on the market while being considered reliable and stable.

Figure 3.4.1.1.4

Figure: Elliptical Parachute

The Iris Ultra toroidal parachute has the highest coefficient of drag from the other parachutes compared in the report. The coefficient of drag for the parachute is 2.2 which creates a great stability for the rocket as it descends. This parachute, just like the elliptical parachute, is being considered as the main parachute. The cost for this parachute runs higher than other parachutes on the market but will perform better.

Figure 3.4.1.1.5

Figure: Iris Ultra Toroidal

Table: Parachute Shapes

Parachute Type:	Stability:	Drag Coefficient:	Performance Type:	Cost:
Cruciform	Good with any speed.	0.4	Low and high-speed drogue.	~$200
Flat Sheet	Reasonable at slow speeds and poor at higher speeds.	0.7`	Main or drogue.	~$70
Panel	Rotates and spins with good vertical stability at any speeds.	.97	Main	~$180
Elliptical	Good with lower speeds and performable at higher speeds.	1.6	Main or drogue	~$200
Iris Ultra Toroidal	Good with high speeds and performs at lower speeds.	2.2	Main	~$900

Table 3.4.1.1.a

Table : Parachute Shape Matrix

Type of Parachute:		Cruciform		Flat Sheet		Panel		Elliptical		Iris Ultra Toroidal	
Requirements	Weight	Grade: (1-5)	Rating	Grade: (1-5)	Rating	Grade: (1-5)	Rating	Grade: (1-5)	Rating	Grade: (1-5)	Rating
Cost	30%	3	0.9	4	1.2	4	1.2	3	0.9	2	.6
Drag Coefficient	40%	2	0.8	3	1.2	4	1.6	4	1.6	5	2.0
Performance	30%	3	0.9	2	0.6	3	0.9	4	1.2	5	2.0
Total:		2.6		3.0		3.7		3.7		4.6	

Table 3.4.1.1.b

*This table is based off of a performance ratio of 20fps. The coefficient of drag for each style of parachute was given by Fruity Chutes and the costs vary between different companies.

3.4.1.2 Parachute Materials

Multiple Parachute material options were considered with two being considered more seriously. The possibility of using canvas or silk were tossed around with kevlar and nylon being to two leading considerations.

a. Nylon

Nylon is an affordable material with a high elasticity. Its elasticity is extremely beneficial when considering the parachutes initial deployment during terminal velocity. As the parachute expands, the elasticity of the nylon will prevent a snapping force felt by the parachute once it is fully inflated. However, nylon has a low thermal resistance, making it more likely to burn when the ejection charges go off. This can be accounted for through the parachute packing methods.

b. Canvas

Canvas material has been used for particularly old parachute models as it is a very heavy-duty fabric. This material was not highly considered due to its low elasticity and low resistance to mildew. Due to the weight of the fabric, the rocket body would also be significantly heavier.

c. Silk

Silk, like canvas, was previously used as a parachute material because it is heavy-duty, easily packaged, and lightweight. However, when comparing its cost to that of nylon, it is very expensive. Although the drag coefficient would be ideal for a drogue parachute, nylon would be a more cost effective option.

d. Kevlar

Kevlar, being the strong synthetic fabric that it is, would serve as a good parachute. However, it is quite costly and less abrasion resistant than nylon. From previous experience, kevlar can be quite difficult to work with, while Nylon is easily implemented.

3.4.1.3 Parachute Sizing

The parachute sizes were determined via the kinetic energy requirements (the maximum kinetic upon landing cannot exceed 75 ft-lb.) First, the maximum velocity at landing was determined from the kinetic energy equation.

$$KE = \frac{1}{2}m\upsilon^2$$

Where KE is the kinetic energy in ft-lb, m is the weight in lbs and the velocity, v, is measured in ft/s. Since the rocket sections will remain connected by shock cords, the mass of the entire rocket, excluding the fuel, will be taken into account. The mass is recorded to be 41.64 lbs without fuel. After plugging in values, the maximum velocity at landing was calculated to be 10.77 ft/s.

The maximum landing velocity was then used to calculate the minimum main parachute diameter needed to comply with the landing kinetic energy requirement.

After establishing the equation for drag force,

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

Where,

$$A = \frac{\pi}{4}d^2$$

The minimum diameter for the main parachute can be determined.

$$d = \sqrt{\frac{8Wg}{\pi \rho C_d {v_{max}}^2}}$$

W is the weight in slugs, g is the gravitational constant in ft/s^2, rho is the density of air in slug/ft^3, and the velocity, v, is in ft/s. Using an elliptical shaped parachute drag coefficient of 1.6, and the density of air (0.0765 lbm/ft^3), the minimum diameter of the main parachute was determined to be about 13.23 ft, meaning the minimum parachute area would need to be about 137.47 ft^2.

a. Rocket Man 16ft Standard Parachute

This is a panel shaped parachute sized at 16 ft in diameter sold by rocketman which would be used as our main parachute within the rocket. The parachute has a weight of 2-lb, is made out of nylon, a drag coefficient of 0.97, a packing volume of 10-in in length for a 6-in inner diameter airframe for a total of 282.74-in^3 in total packing volume, and a descent rate of approximately 15 ft/sec for the weight of our vehicle. It's cost estimate is $180.00.

Figure 3.4.1.3.a.1

b. Rocketman High Performance CD 2.2 Parachute

This is a panel shaped parachute sized at 16 ft in diameter sold by rocketman which would be used as our main parachute within the rocket. The parachute is made out of Kevlar and the weight is higher than the nylon based one. It is characterized by a very high carrying capacity of 2500 pounds per line and a descent rate of approximately 17ft/sec. for the weight of our vehicle. It's cost estimate is $245.00.

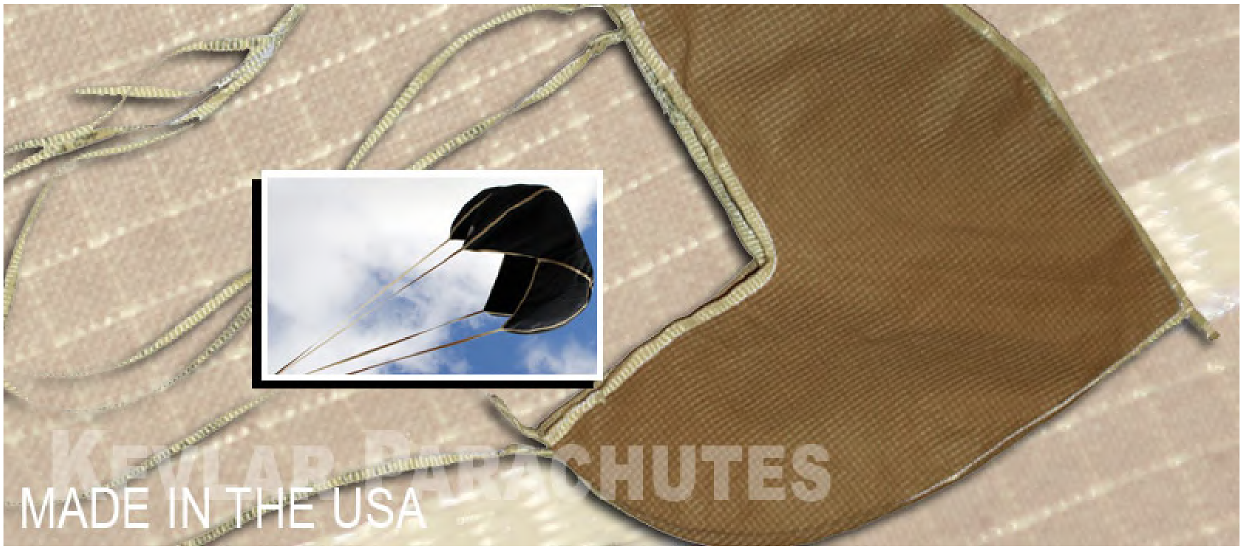


Figure 3.4.1.3.b.1

c. Kevlar Flame Proof Parachutes

This is an elliptical parachute shaped size at 192-in diameter sold by rocketman which would be used as our main parachute within the rocket. The parachute is made out of Nylon and the weight is 65.2 oz., a packing volume of 11.52-in in length for a 6-in inner diameter airframe for a total of 325.85-in^3 in total packing volume, and a descent rate of approximately less than 15 ft/sec for the weight of our vehicle. It's cost estimate is $620.00.

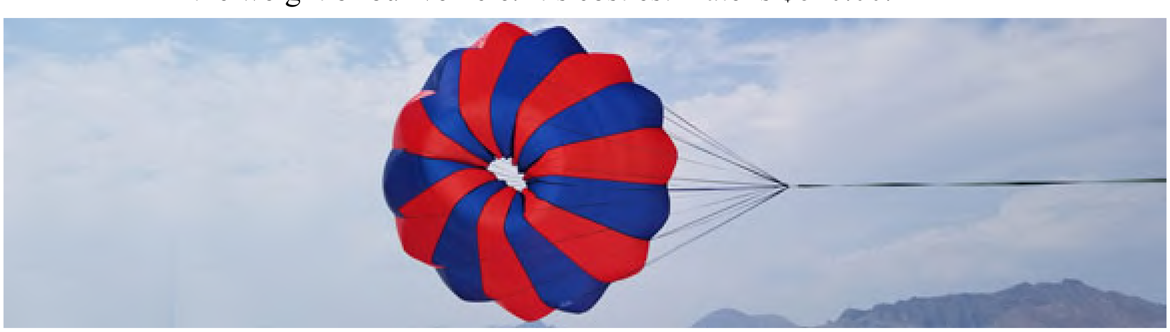


Figure 3.4.1.3.c.1

3.4.2 Shroud Lines

Shroud lines connect the canopy of the parachute to the rocket itself. Standard shroud length is typically 115-150% of the canopy diameter. There are a few ways to attach shroud lines to the canopy, each with different stress capacities. On small rockets that do not exert much impulse force on the shroud lines, merely looping them through corners of the canopy will work. For rockets that exert more stress on the lines, more durability can be achieved by using an “over the top” connection. In this design, shroud lines start at the anchor point on the rocket and run to the canopy, then follow the canopy to the top where it descends through the spill hole and reattaches to the anchor point. Other ways to increase durability are to use a stronger material for the canopy itself, and/or to sew the shroud lines onto the canopy. Three primary materials were considered for the shroud lines.

3.4.2.1 Kevlar

Kevlar is strong and fire resistant with a high tensile strength to weight ratio. However, it is sensitive to shock loads and stretches minimally under such shock loads. A certain amount of “give” is needed in the shock cords because they will quickly become taught under the opposing forces from the parachute and anchoring point on the rocket.

3.4.2.2 Nylon

Nylon is lightweight, affordable, and less likely to zipper compared to the other options. Nylon;s lower zippering chance is due to its higher elasticity and softness. As previously mentioned, nylon’s thermal resistance is not high. It is very susceptible to burns and abrasions after multiple uses.

3.4.2.2 Technora

Technora is lightweight, functions well under high pressure, and has a high shock load resistance. It is not, however, fire resistant, and becomes weak when exposed to direct flame. This becomes a concern when addressing the heat from the ejection charges.

3.4.3 Shock Cords

The purpose of the shock cords is to tether each section of the airframe to the parachutes. As the rocket will be utilizing a dual-deployment system, a drogue parachute will connect the nose-cone/payload (fore) section to the ebay and a main parachute will connect the ebay to the motor section (aft) of the rocket. One shock cord will be used to connect the fore section to the ebay while two shock cords will be used to connect the aft to the ebay section. Due to the heat levels inside and outside of the rocket, the shock cords must have a high thermal resistance. Another major factor is the structural integrity of the shock cords. They must endure the opposing recovery forces from the parachutes and rocket weight, meaning they must be strong. While strength is essential, elasticity is also important. To minimize immediate force exerted on the bulkheads, and prevent lines from snapping, the shock cords need elastic properties.

3.4.3.1 Nylon

The two materials up for consideration are Nylon and Kevlar. Nylon has a higher elasticity, meaning it will absorb more kinetic energy during ejection and will exert less force on the bulkheads. Nylon is also less likely to cause zippering, as it is softer than Kevlar. Although it has a low thermal resistance, that can be addressed and accounted for through packing methods, further discussed in Section 3.4.5.

3.4.3.2 Kevlar

Kevlar's higher strength to weight ratio will require a smaller diameter of cord to absorb the same amount of force. This is beneficial when considering the rocket's total weight. As previously stated, the purpose of the shock cords is to withstand recovery forces and maintain connection between rocket sections. Kevlar can achieve this through its high tensile strength. Kevlar also has a higher thermal resistance than Nylon, but is more susceptible to abrasions.

3.4.4 Ejection Charges

Electronic matches (known as E-matches) are being used to ignite the charges needed for parachute deployment. These E-matches are positioned inside of all charges, receiving a signal from the altimeter at predetermined altitudes to ignite. Traditionally, there are two methods of separating and deploying recovery systems in rockets: black powder charges and carbon dioxide charges. The former being the most common at altitudes comparable to this USLI competition.

3.4.4.1 Black Powder

Black powder offers simplicity in function, where ignition of the powder is the only concern. Due to previous rocket builds, most Space Raiders members have experience launching rockets with black powder ignition charges. However, increased temperatures after ignition may damage one of the parachutes or the electronics bay along with residue.

3.4.4.2 Carbon Dioxide

Carbon dioxide charges offer advantages at high altitudes (20,000 feet or more) where black powder does not have enough oxygen to properly ignite. Cost and weight are two primary concerns regarding a carbon dioxide separation system. The added weight of CO2 canisters and the system itself may push the limits of our rocket reaching the required altitude.

3.4.5 Packing Methods

In congruence with a dual stage deployment method, a drogue and main parachute will be housed in separate compartments adjacent to the ebay on either side. The drogue parachute will deploy from the fore end of the rocket, slowing and stabilizing the vehicle's decent. At 500 feet, the main parachute will deploy from the aft end, guiding the rocket to the ground.

To place the parachutes within the rocket, a packing method will be utilized. Three methods are being considered and addressed in order of complexity: roll-and-wrap, deployment bag, and pressurized pack. Each method has a different pack density, related to the compression of the parachute, as well as pros and cons related to the chute's extraction, inflation, and integration into the rocket. Whatever method we choose will be subject to multiple ground tests to preemptively catch recovery issues.

3.4.5.1 Roll-and-Wrap

Addressing the most simplistic of the options first, the roll-and-wrap method involves folding and rolling the parachute into a compact cone, wrapping the cone with the shroud lines and stuffing the rolled parachute chute into the rocket body. This method works particularly well for smaller chutes and takes a minimal amount of time. The disadvantages of this method include low extraction and inflation control. If mispacked, the roll-and-wrap method can result in tangled shroud lines or parachutes that don't inflate entirely, negating some of the much-needed drag. This method also requires that an independent flame-retardant material be wrapped around the parachutes and chords to prevent interference from the ejection charges. The roll-and-wrap method has the lowest packing density of the three options considered. (No additional cost)

3.4.5.2 Deployment Bag

The deployment bag is a moderately complex packing method. A deployment bag consisting of one large pocket and straps under which the shroud lines would be folded will be purchased. The parachute will be folded and placed in the large pocket/bag; the shroud lines will then be folded in an organized fashion and tucked under the straps on the outside of the bag. Due to its organization, this method allows for a higher packing density as well as reliable deployment, both in terms of extraction and inflation. The bags can also be flame-retardant themselves, requiring one less item in the parachute compartment. Generally, this method has the best balance of simplicity, reliability, and consistency. ($20 - $50 for single deployment bag)

3.4.5.3 Pressurized Pack

The pressurized packing method is the most complex mechanism for packing a parachute. Typically used by the military and government, the pressurized pack involves pressing the parachute into a small container made of carbon fiber. This is normally used for massive chutes but gives the highest packing density of all options. It also requires CO2 canisters to compress the chute into the pack and release it. This method is reliable, yet generates the most cost of all three methods. ($150- up)

3.4.6 Fasteners

The purpose of fasteners in the recovery design is to have a connection point from the parachute shock cords to the bulkheads inside of the rocket's air frame. This connection point is established using various different types of fasteners. The two main fasteners under design consideration are eye-bolts and u-bolts.

3.4.6.1 Eye-Bolt

An eye-bolt is a fastener composed of a threaded shaft with an o-ring welded onto one side of the shaft. This type of fastener provides a secure connection from a large object to a cable or chain via a single contact point. This directs the force inside the bolt along a single line of action, helping to reduce the effects of any unwanted torque upon the object. However, when using this fastener, the single connection to the object creates a stress concentration at that point, increasing the potential for failure.

3.4.6.2 U-Bolt

A u-bolt is a fastener made of a curved shaft, shaped into a “U” with both ends of the shaft having a threaded end secured into an object. This fastener distributes the force on the bolts between the two different connections, halving the force felt by the object. However, this fastener allows unwanted torque to be easily distributed to the object because the connection point with the ring is free to slide while the two different connections points allow the bolt to pull unevenly on the object and spin it out of control.

3.4.6.3 Shear Pins

Another subsection of fasteners to address are the shear pins. Shear pins are used to secure two different sections of the airframe together at launch and are designed to break at a calculated pressure, allowing the rocket to break apart and the recovery system to deploy. The two different materials typically used to create shear pins are Nylon and Fiberglass.

a. Nylon

Nylon is used because, like fiberglass, it is easy to break and resistant to vibrations. Nylon is also a more ductile material, so it is able to shift slightly during launch without breaking. This helps to prevent any separation as the sections rotate slightly during flight.

b. Fiberglass

Fiberglass was considered because it is an easy material to break with very little force required to do so. It is also highly resistant to any vibration forces, helping to prevent any premature breaks. This is beneficial because the shear pins are designed as the weakest part of the rocket. Although they are needed to be weak, they shouldn't be so weak that they’ll break unders strong vibration forces.

3.5 Leading Vehicle Design

3.5.1 Nose Cone

We will be separating the nose cone into two sections, one section being composed of Polycarbonate and one section being composed of fiberglass with the two sections bonded with epoxy. The reason for the composite is due to our wanting to house a 360 degree camera to record the flight, and we needed the transparent material (being Polycarbonate) to have the high video quality. We also plan to use our nose cone as a CANSAT for the payload where we will be tethering the payload to the CANSAT itself, however that will be detailed more within the payload section.

There are no viable options for a 6-in in inner diameter polycarbonate tubing, so our solution is obtain a 2.6-in diameter Polycarbonate nose cone and then bond it to the 6-in in inner diameter fiberglass nose cone to solve this problem. We also plan to have the fiberglass will also provide more strength for the nose cone to reduce failure while under high concentrations of stress. A 12-in long and 6-in diameter coupler will be used to attach the nose cone to the fore section of the airframe.

The construction of this nose cone would include taking the fiberglass nose cone of the base diameter of 6.17 inches and cutting it with a bandsaw down to appropriate size where there is a 2.6-in diameter hole left for the Polycarbonate to be bonded onto the fiberglass using epoxy and proper supporting material. In regards to the safety of the manufacturing of the nose cone, we will be having a senior technician in the Advanced Prototyping and Manufacturing Facility making the cut to size the fiberglass nose cone down to be bonded with the Polycarbonate nose cone. We will also get express approval through our mechanical engineering department safety officer (For further safety information, reference 5.2.1 Personnel Hazard Analysis in the safety section of our document)

These are the final dimensions of the nose cone:

Table: Nose Cone

Shape Fiberglass	Ogive
Base OD Fiberglass	6.17”
Base Wall Thickness Fiberglass	0.079”
Weight Fiberglass	28 oz (1.75 lb)

Exposed Length Fiberglass	24”
Shoulder OD Fiberglass	6.007”
Shoulder Wall Thickness Fiberglass	0.125”
Shoulder Length Fiberglass	5.5”
Base OD Polycarbonate	2.65”
Base Wall Thickness Polycarbonate	0.075”
Estimated Mass of Polycarbonate	0.66-lb
Exposed Length Polycarbonate	8.75”
Shoulder wall thickness Polycarbonate	0.075”
Shoulder OD Polycarbonate	2.65”
Shoulder Length Polycarbonate	2”
Estimated Mass of Fiberglass	2.42-lb
Estimated Mass of System	3.08-lb

Table 3.5.1.1

For our current purposes, the best option for us to pick is the Public Missile’s fiberglass nose cone, FNC-6.0, for the fiberglass portion of the nose cone, it provides the exposed length and diameter that we are looking for. It will end up costing $104.99. As for the Polycarbonate portion of the nose cone, we believe that Sunward’s clear polycarbonate nose cone would best fit our design, and could be easily cut and shaped to fit into the fiberglass section of the nose cone.

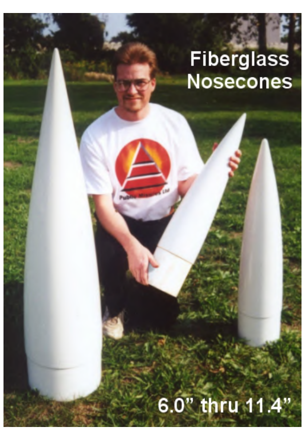


Figure 3.5.1.1.2 Figure 3.5.1.1.3
https://publicmissiles.com/product/nosecones

This is a Solidworks CAD model of the nose cone. The more transparent piece of the nose cone is the Polycarbonate section and the other is the fiberglass section. They will be bonded using epoxy as symbolized with the fillet

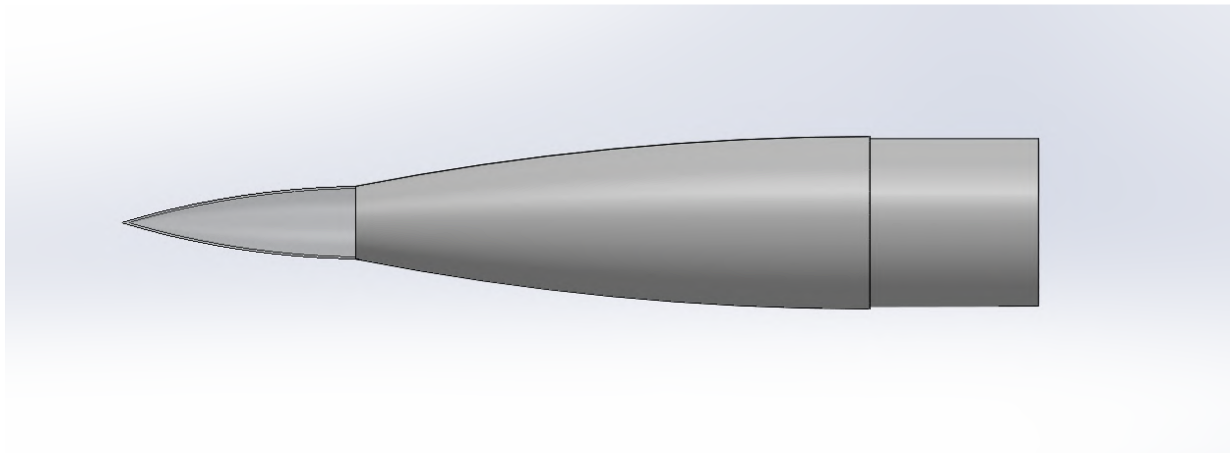


Figure 3.5.1.1.4

3.5.2 Airframe

The body tube will be separated into 3 main sections; one holding our drogue chute with a length of about 19 inches (fore section), the other containing our electronics bay with a length of about 11.5 inches (Ebay section), and lastly the section containing our main parachute as well as our motor with a length of about 48 inches (aft section). These sections will be secured together using 2, 12 inch couplers. The complete body tube will have an estimated length of 78.5 inches, with an inner diameter of 6.007 inches, an outer diameter of 6.155 inches, and a wall thickness of 0.056 inches.

The entire body tube will be constructed out of premium carbon fiber material. The reason behind this decision was to minimize the overall damaging effect of zippering on our rocket airframe. Carbon fiber provided the highest tensile strength than any of our other material considerations, which provides better rigidity to our body tube. Additionally, the carbon fiber material will also be able to withstand stronger flight forces as well as higher impacts. Thus, by using carbon fiber, recovering the body tube sections will be considerably easier since we are using a more rigid material.

The manufacturing of our carbon fiber body tube itself will be taken care of by our manufacturer Public Missiles. Additionally, Public Missiles will also provide us with customized slotting, including the slot length and width we decide on. Their tubing comes with a diameter of 6 inches, a length of 60 inches at a price of $439.95. Our total cost will be $879.9 for two 60 inch body tubes in order to satisfy our 78 inch airframe, which will also provide us with extra material just in case it is needed.

These will be the final dimensions of our airframe

Table: Airframe

Fore Section Carbon Fiber	
Base ID	6.007”
Base OD	6.155”
Base Wall Thickness	0.056”
Section Length	19”
Estimate Mass	0.93125-lb
Ebay Section Carbon Fiber	
Base ID	6.007”
Base OD	6.155”
Base Wall Thickness	0.056”
Section Length	11.5”
Estimated Mass	1.0315-lb
Aft Section Carbon Fiber	
Base ID	6.007”
Base OD	6.155”
Base Wall Thickness	0.056”
Section Length	48”
Estimated Mass	2.35-lb

Estimated Mass	4.31275-lb

Table 3.5.2.1

Figure 3.5.2.2

This is a CAD model of our airframe and its three sections, also including our two couplers that will be used to secure each section. The three black sections are the carbon fiber airframe separated into the fore section, ebay section, and aft section in that order from left to right (or down up). The remaining two brown sections are the phenolic couplers

Figure 3.5.2.3

3.5.3 Bulkheads

We plan to pursue using the shock absorbing bulkheads which are the bulkheads that are a composite material consisting of marine grade plywood, nylon, and fiberglass. The bulkhead as seen below will have a wooden part in the center (identified by the brown part) which will have two nylon washers connected to its interior bolted 6 times between the nylon washer and the wooden holder. These two parts will then be capped off with two fiberglass caps (identified by the white) with an eye-bolt through the whole bulkhead.

We want to pursue these because with the way that they are designed, these bulkheads would act as a shock absorber for the impact that these bulkheads will receive upon the deployment of the parachutes.

We plan to use 4 of these bulkheads within our rocket, one for each connection with a parachute. One bulkhead will be in the fore section of the rocket, two bulkheads in the ebay, and one more in the aft section of the rocket. It is important to note that the outermost diameters for the fore and aft section bulkheads will be larger at 6.007-in in size and the two ebay bulkheads will be 5.865-in in size. This is due to the ebay section being housed within the couplers of the rockets.

We plan to manufacture these parts using a 4th axis CNC machine that we have within our Advanced Prototyping and Manufacturing Facility. Thus reducing the cost, allowing us to save more resources for components elsewhere.

The final dimensions for the bulkheads:

Table: Bulkheads

Bulkheads Marine-grade Plywood	x1
OD (Fore/Aft section bulkheads)	6.007”
OD (ebay section bulkheads)	5.865”
Outermost Thickness	1.252”
ID for Outermost Thickness	4.25”
Innermost Thickness	0.25”
ID for Innermost Thickness	2.50”
Number of Bolts	6
Bolt Hole Diameter	0.16”
Estimated Mass (Single Fore/Aft Section)	0.46-lb
Estimated Mass (Ebay Section)	0.37-lb
Nylon Washer	x2
OD	3.75”
ID for Eye-Bolt	0.50”
Number of Bolts	6
Bolt Hole Diameter	0.16”
Estimated Mass of single washer	0.11-lb

Fiberglass Cap	x2
OD (Fore/Aft section bulkheads)	6.007”
OD (Ebay section Bulkheads)	5.865”
ID for Eye-Bolt	0.50”
Outermost Thickness	0.125”
Inner Cylinder OD	4.25”
Inner Cylinder ID	4.00”
Inner Cylinder Height (Base Bulkhead not included)	0.5”
Estimated Mass (Single Fore/Aft Section)	0.29-lb
Estimated Mass (Ebay Section)	0.28-lb
Estimated Mass of Single Bulkhead (Fore/Aft)	1.26-lb
Estimated Mass of Single Bulkhead (Ebay)	1.15-lb
Estimated Mass of System	4.82-lb

Table 3.5.3.1

This view below is a CAD model of the assembled bulkhead that we have to clarify the explanation above. The first fiberglass cap was made transparent to see the nylon washer inside being bolted down to the wooden interior.

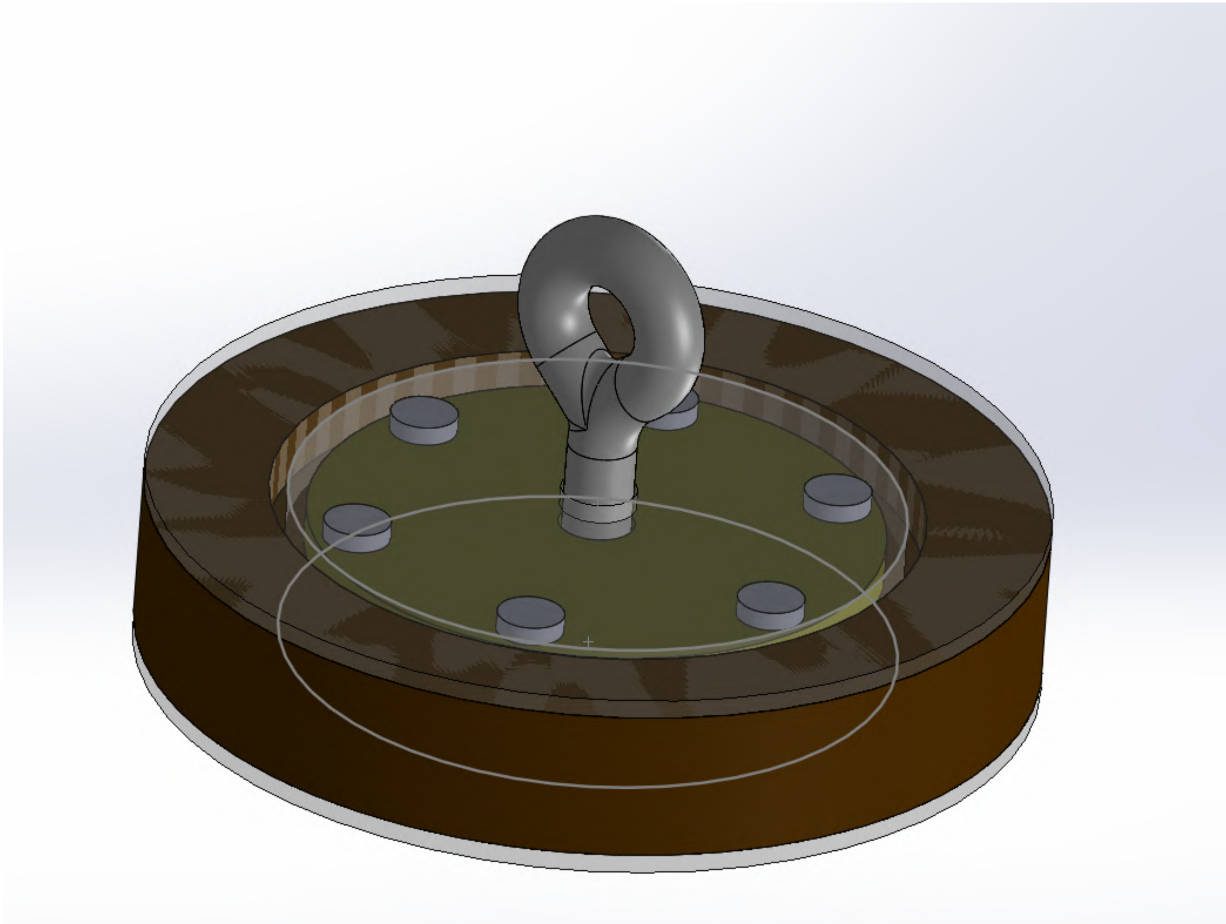


Figure 3.5.3.1

Table: Specification Part

Color	Part
Grey	Eye Bolt
Grey	18-8 SS Bolt
Brown	Wooden Part
Yellow	Nylon Washers
White	Fiberglass Caps

Table 3.5.3.2

This is an exploded view of the bulkhead with the top part being the eye-bolt. The white parts being the fiberglass caps, the six grey parts being the simulated bolts and nuts that will be used on the bulkhead, the brown part being the wooden interior, and the yellow parts being the nylon washers.

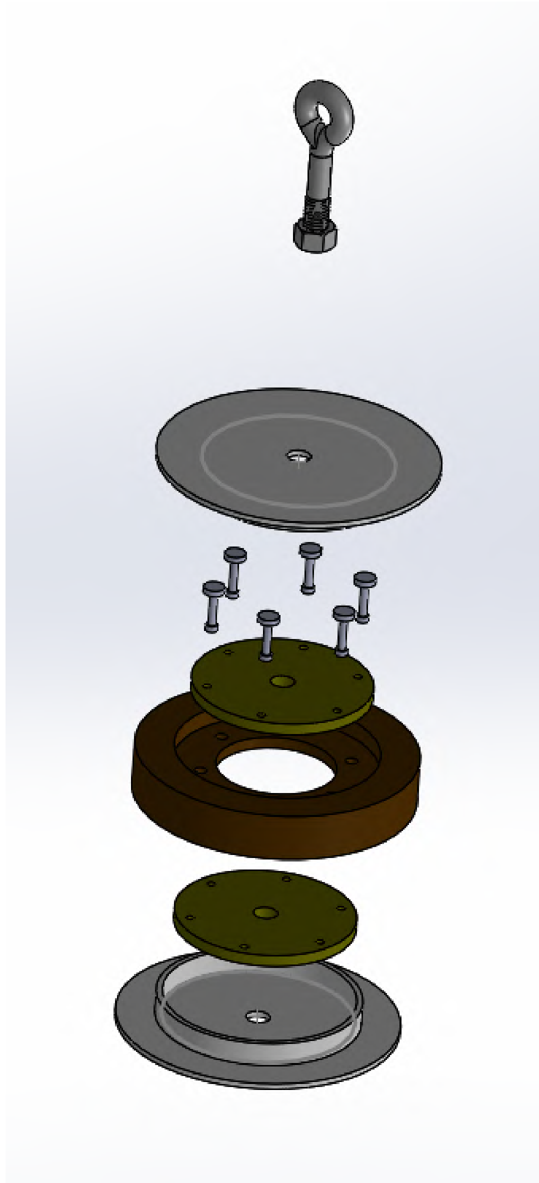


Figure 3.5.3.2.2

3.5.4 Launch Lugs

The airframe will have 2 linear launch rail buttons as described in the launch launch lug section above. They will be ordered from Public Missiles, and be made of Urethane plastic. They will be placed on the airframe at Cg and Cp and secured with screws and epoxy.

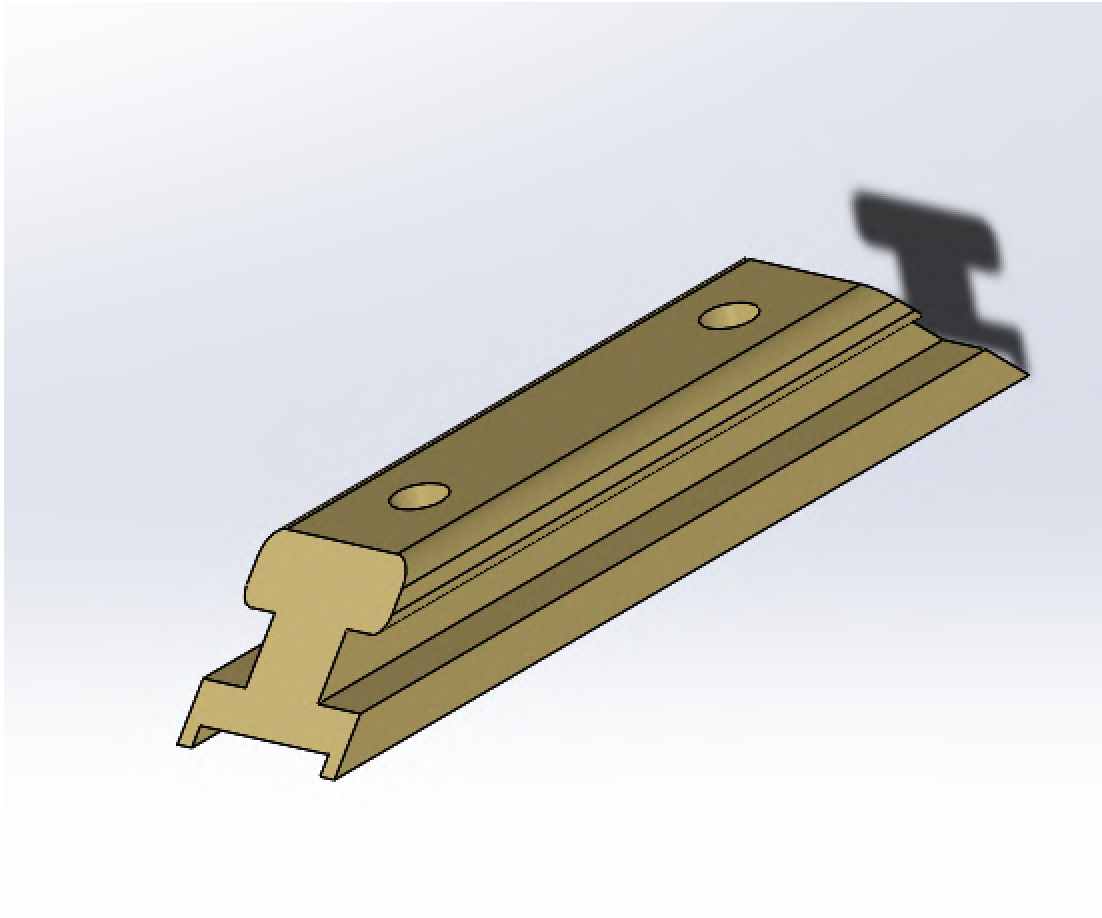


Figure 3.5.4.1
Linear Launch Rail Button (leading design)

Table: Launch Lugs

Launch Lug	x2
Length	3.00”
Width	0.65”
Height	0.5”
Estimated Mass of Single Launch Lug	0.02-lb
Estimated Mass of the system	0.04-lb

Table 3.5.4.1

3.5.5 Fins

There will be a total of 3 fins on our rocket. Our fins will have a trapezoidal shape which will give us a stability of 2.15 cals. Each fin will have a root cord of 7.9 inches, a tip cord of 1.95 inches, a height of 4 inches, a sweep length of 4.02 inches, a sweep angle of 45.1 degrees, a fillet of 0.25 inches, a fin tab length of 7.4 inches, a tab height of 1.528 inches, and a tab position of 0.25 inches. The fins will be designed to go through our airframe and be secured to the motor tubing. The base of the fins will be glued, using epoxy, to the motor tube as well as epoxied onto the top of the fins where they are connected to the outside of the rocket. On top of the outer epoxy layer on the fins, we will also be putting a fillet.

Our fins will be constructed using a composite design of fiberglass and carbon fiber materials. Essentially, there will be a thin layer sheet of carbon fiber epoxied in between two other layers of fiberglass sheets. The reason for choosing this composite design is to take advantage of both fiberglass and carbon fiber properties. With the thin carbon fiber layer in between the fiberglass, it will provide the fins with higher internal strength and rigidity in order to withstand higher impacts. This structure will help minimize potential breaking of the fins as well as minimizing fin flutter. The reason for covering our carbon fiber sheet with fiberglass is to take advantage of fiberglass's flexibility. By having our fins be more flexible, it will further increase the amount of impact forces our fins can withstand.

The final dimensions of the fins are represented in the table below.

Table: Dimension of fins

Fins Carbon Fiber/Fiberglass Composite	3 Fins Trapezoidal Shape
Stability	2.15 cals
Root Cord	7.9"
Tip Cord	1.95"
Height	4"
Sweep Length	4.02"
Sweep Angle	45.1 degrees
Fillet	0.25"

Fin Tab Length	7.4”
Tab Height	1.528”
Tab Position	0.25”
Fin Thickness	0.06”
Estimated Mass of a Single Fin	0.13-lb
Estimated Mass of System	0.39-lb

Table 3.5.4.a.1

This is the CAD model of the side view of one of the fins. The fins are uniform in their thickness of 0.06-in, so there is no need for another view.

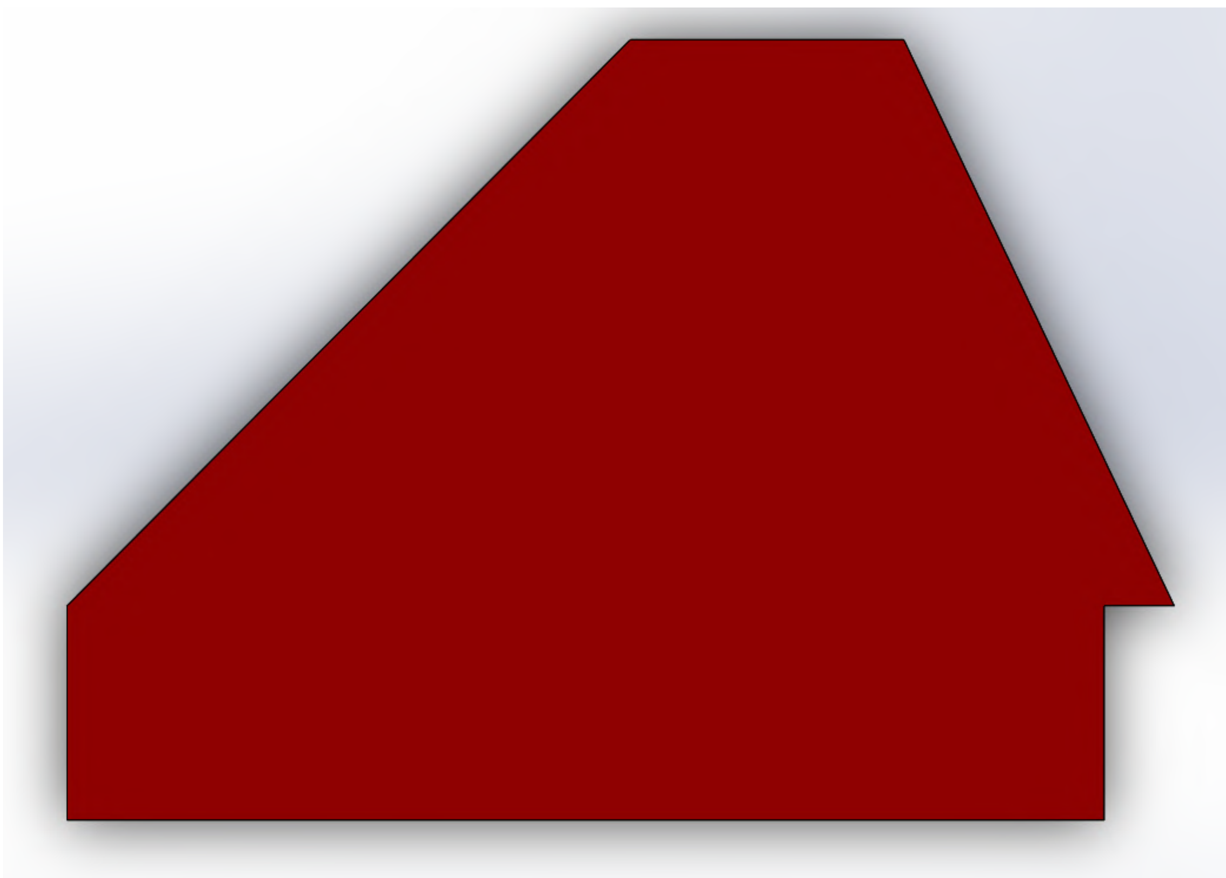


Figure 3.5.5.1

3.5.6 Motor

The motor we will be using is the Cesaroni L-1395 BS. This is a 4 grain, reloadable, L-class motor, that uses solid blue streak propellant. The motor as a diameter of 2.95 inches, a length of 24.45 inches, a mass of 9.52 lbs, and delivers a maximum thrust of 1779.90 N (400.48 lbs) for a burn time of 3.51 seconds. This power would yield an apogee of 5854 feet, which is just a little higher to our goal height of 5280 feet. The motor would have an estimated cost of $300.

The motor casing we decide on is the Cesaroni Pro 75 4G Reloadable Motor Casing, which is manufactured from thin wall 6061 - T6 aluminum tubing with a clear anodized coating for corrosion protection. This motor has dimensions of 23.95 inches in length, and has an outer diameter of 2.965 inches. The Pro 75 motor casing is lightweight yet strong enough and able to withstand well over 3000 psi of internal pressure with a cost of $415.22. To complement this motor casing we are also using the 6061-T6 Aluminum Motor Retention, at a cost of $37.00 manufactured from Aero Pack Inc. The retention is lightweight with a mass of 139 grams. Around the motor casing, there will be a thin piece of blue tube used to keep the motor casing in place with an outer diameter of 3.1-in and an inner diameter of 3.0-in. This blue tube tubing will be where the fins and centerings will be mounted to. We Lastly to stabilize our motor during flight, we chose to use 3 maple wood centering rings, one in the fore of the motor tube, one in the center, and one aft of the motor tube. Our team also has past experience using the same motor, motor casing, and motor retention. Thus, considerably reducing the amount of time we will spend on constructing these components together.

The table below shows the dimensions of all the motor components.

Cesaroni L-1395 BS Motor	
Diameter	2.95”
Length	24.45”
Estimated Mass (including casing)	9.52 lbs
Max Thrust	400.48 lbs
Burn Time	3.51 s
Yield Apogee	5854 ft
Cesaroni Pro 75 4G Motor Casing	

Length	23.95"
OD	2.965"
Blue Tube Casing	
Length	23.95"
OD	3.1"
ID	3.0"
Estimated Mass	0.36-lb
6061-T6 Motor Retention	
Mass	0.309-lb
Estimated Mass of System	10.189-lb

Table 3.5.6.1

This is a CAD model of the motor with the motor casing, blue tube casing, centering rings, and motor retention.

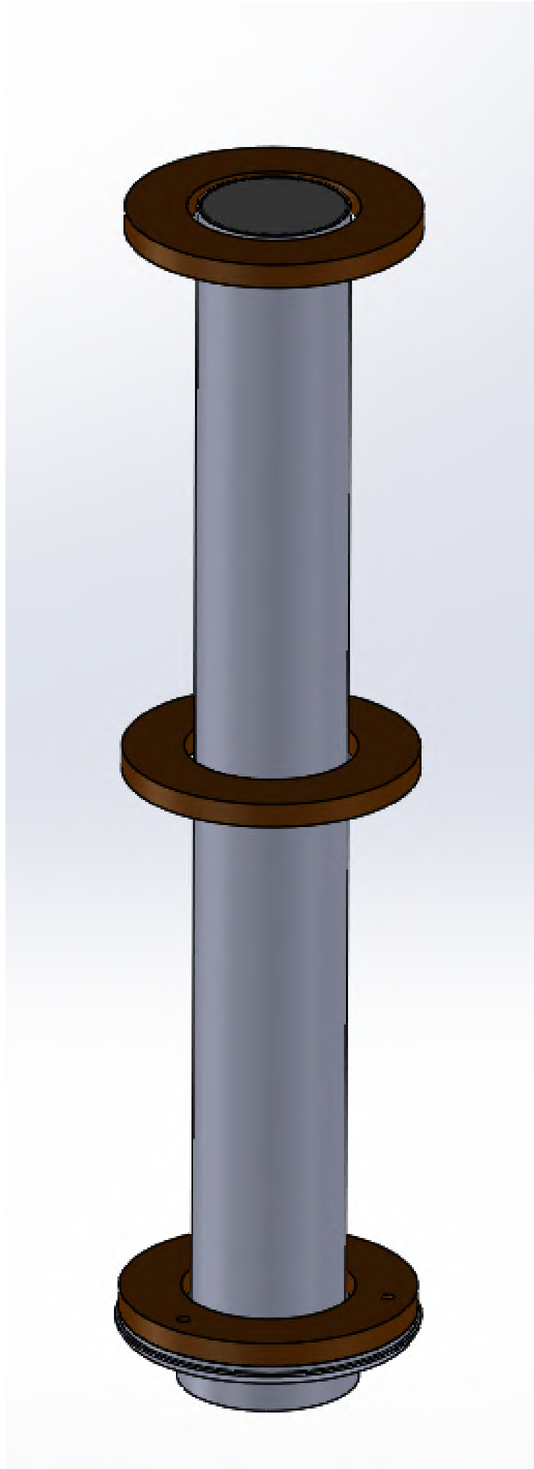


Figure 3.5.6.1

3.5.7 Couplers

There will be 2 couplers in our airframe. Each coupler will have a length of 12 inches, an outer diameter of 6.007 inches, an inner diameter of 5.859 inches, and a wall thickness of 0.074 inches. The density of our couplers are also estimated to be 0.326 ounces per inch cubed. Our first coupler will be used to secure our aft section with the ebay section, and our second coupler will be used to secure our ebay section with our fore section. Both couplers that are connected to our ebay section will be statically secured using screws and bolts. The fore and aft sections of our airframe will be secured to both couplers using shear pins.

Both couplers will be constructed out of phenolic material. We decided on using phenolic because of its considerably low cost. Since we are already planning on using carbon fiber for the airframe sections, which already puts a strain on our overall budget, by using phenolic we would be able to save our resources. Additionally, the phenolic material lets us cut and shaped the couplers using tools we already have, thus additionally saving more of our resources. Most importantly, our team has past experience using phenolic couplers and handling the manufacturing and construction, so we are more comfortable using the material.

The manufacturing of our couplers will be taken care of by our manufacturer Public Missiles. Public Missiles will provide us with couplers that have an inner diameter of 5.859 inches, a wall thickness of 0.074 inches, a length of 12 inches, and a weight of 5.4 ounces all at a price of $14.99. We specifically chose to use the phenolic couplers provided by Public Missiles because they will be an exact fit to each of our airframe sections. Since we will also be using Public Missiles carbon fiber airframe, their couplers were designed to perfectly fit with their body tubes. Thus, we would not have to waste time and resources shaping our couplers around our body tube.

Below is our final dimensions for our couplers.

Couplers Phenolic	2 Couplers
Base ID	5.859”
Base OD	6.007”
Base Wall Thickness	0.074”

Section Length	12”
Density	0.326 oz/in^3
Estimated Mass of a Single Coupler	0.32-lb
Estimate Mass of System	0.64-lb

Table 3.5.7.1

3.5.8 Centering Rings

There will be a total of 3 centering rings connected to our motor in our aft section of the rocket. Each centering ring will have dimensions of 6 inches for the outer diameter, 3.1 inches for the inner diameter, a thickness of 0.5 inches, and a density of 0.02727 lb/in^3 for about 1.13 lbs. There will be one centering ring at the front of the motor, one in the center, and one in the back to provide optimal stability to our motor tubing while the rocket is in flight.

All 3 of our centering rings will be constructed out of maple hardwood. We will be cutting and shaping the centering rings ourselves with the use of store bought hardwood. The reason for choosing maple wood for centering rings is because it offers a great weight to stiffness ratio. It is fairly strong when compared to the other wooden materials. Most importantly, the cost of using maple wood is significantly lower than that of fiberglass or especially carbon fiber. The plank of maple wood will cost us about $75 which will be more than enough to manufacture the 3 rings ourselves.

The final dimensions for our centering rings are below.

Maple Wood Centering Rings	3
Base ID	3.10”
Base OD	6.00”
Base Wall Thickness	0.50”
Weight	1.13 lbs
Density	0.02727 lb/in^3
Estimated Mass (Single Centering Ring)	0.25 lb
Estimated Mass (Single Centering Ring	0.25-lb

with holes)	
Estimate Mass (Whole System)	0.75-lb

Table 3.5.8.1

3.5.9 Ebay

The final dimensions of the Ebay components (not including bulkheads that are already mentioned) are

Circular Plate	x1
OD	2.90”
ID	0”
Thickness	0.25”
Rod	x3
Diameter	0.25”
Length	4.00”
GPS Tracker	x1
Length	2.08”
Width	1.00”
Height	0.50”
Altimeters	x3
Length	2.00”
Width	0.84”
Height	0.50”

9V Battery Dimension	x3
Length	1.75”
Width	0.96”
Height	0.61”
9V Battery Housing Dimension	x3
Length	2.15”
Width	1.18”
Height	0.77”
Estimated Mass (Whole System)	4-lb

Table 3.5.9.1

This is a CAD model Assembly for the electronics bay followed by the exploded assembly. There are two of the shock absorbing bulkheads of smaller diameters to fit inside the couplers where the ebay will be housed (Identified with same colors as seen before). There is a middle circular plate where we will house all the electronics within the ebay (Identified by the dark gray plate). There are three rods connecting the two bulkheads and the middle circular plate (Identified by the dark gray rods). Within the ebay itself, there are three 9V batteries and their housing components (identified by the red for the batteries and black for the housings). Next are the two altimeters (Identified by the green blocks) and GPS tracker (Identified by the blue block) seen on the circular plate. The three magnetic activators are also modeled (identified by the dark gray blocks with three holes in them on the bottom bulkhead at the edge of said bulkhead)

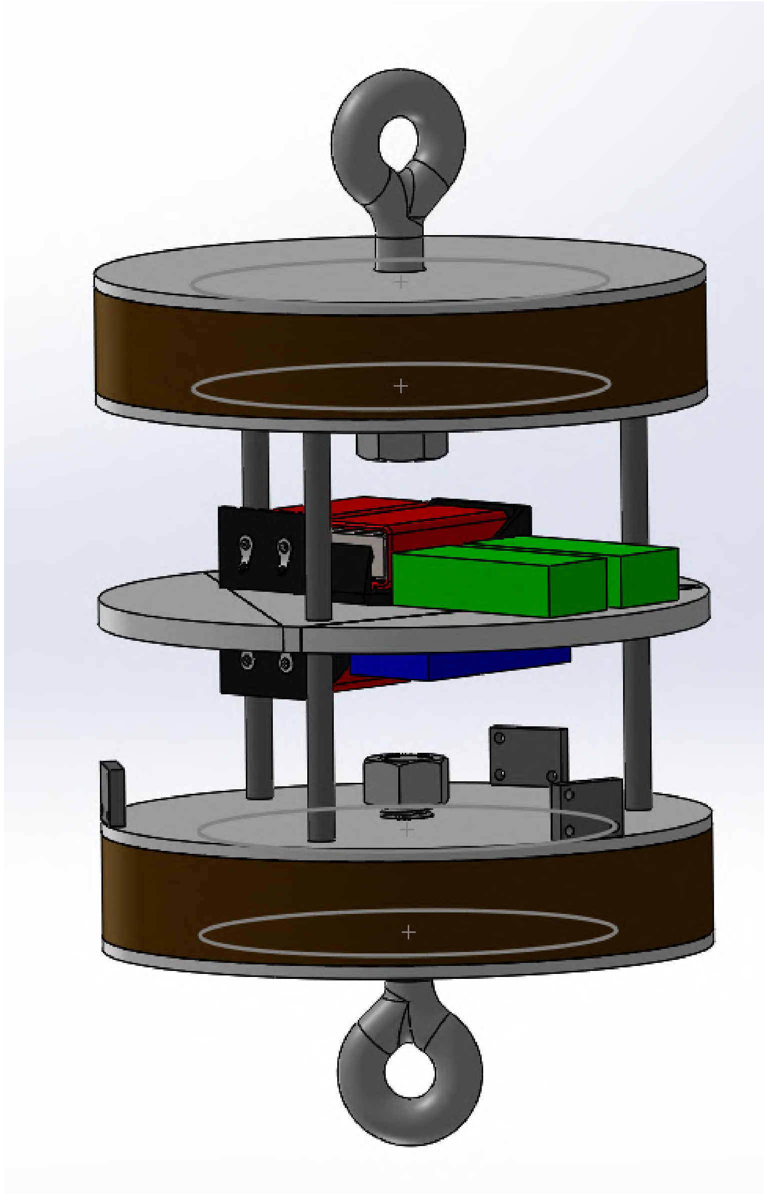


Figure 3.5.9.1

3.5.10 Drogue Parachute

The parachute shape selected for the drogue is a flat sheet parachute with a diameter of 1.5 feet. This shape was selected because of its drag coefficient, size, area, and manufacturer. The parachute will be purchased from Top Flight Recovery for about $10. The drogue parachute will be made of ripstop nylon fabric and attach to six shroud lines, also supplied by Top Flight Recovery.

3.5.11 Main Parachute

The parachute shape selected for the drogue is a toroidal shape parachute with a diameter of 14 feet. Specifically, the parachute will be an Iris Ultra 168" Compact Chute purchased from Fruity Chutes for $889. The main reason this parachute was selected was its coefficient of drag (being 2.2). This shape was also selected because of its size, weight, packing volume, and shroud lines. Due to a large diameter needed for the main parachute, Fruity Chutes was the main manufacturer considered. The main parachute will also be made of ripstop nylon, contributing to its lightweight. The combination of the lightweight material and toroidal design result in a low packing volume. Attached to the main parachute will be spectra shroud lines, also supplied by Fruity Chutes.

3.5.12 Shock Cords

To connect the individual sections of the rocket, 1" tubular nylon webbing shock cord purchased for about $70 from Fruity Chutes will be used. Since the rocket sections are all remaining connected via shock cords, large amounts of kinetic energy will be experienced by the shock cords. Nylon was chosen because it is soft (meaning it is less likely to cause zippering) and will absorb more kinetic energy during ejection.

3.5.13 Shear Pins

Since the shear pins are designed to be the weakest part of the rocket, yet still need to remain intact during launch, nylon was chosen. Due to nylon's resistance to vibrations, it will serve well in the form of shear pins. Nylon was also chosen because of its slight ductility. During the vibrations of launch, the nylon shear pins won't prematurely break.

3.5.14 Ejection Charges

Black powder charges will be used as the separation and deployment method for the recovery subsystem. Black powder was chosen due to its simplicity in function and the teams previous experience with it. The parachutes and ebay will need to be shielded from the residue

To properly calculate the amount of black powder needed for the ignition charges to increase the internal pressure, breaking the shear pins, the force required to break the shear pins needs to be found first. This can be calculated using the shear force calculation where tau is the shear strength of nylon in psi, A is the area of a shear pin in square inches, and the force required to break all of the shear pins is measured in pounds force.

$$F = \tau A_{sp}(\#\ of\ shear\ pins) = (10000\ psi)\frac{\pi}{4}(0.086\ in)^2(2) = 116.176\ lb_f$$

The calculated force can then be substituted in the following equation to find the pressure required to shear the shear pins where the force is measured in pounds force, A is the area of the bulkheads measured in square inches, and the pressure required for shearing is measured in psi.

$$P = \frac{F}{A_{bh}} = \frac{116.176\ lb_f}{\frac{\pi}{4}(5.859\ in)^2} = 4.309\ psi$$

Once the pressure is known, the mass of the ejection charges can be calculated through the Ideal Gas Law where P is the pressure in psi, V is the volume in inches cubed, m is the mass in grams, R is the gas constant measured in inches pound force per rankine pound mass, and T is the ignition temperature of the black powder in rankine.

$$m_{fore} = \frac{PV}{RT} = \frac{(4.740\ psi)\frac{\pi}{4}[(6.007\ in)^2(5.75\ in) + (5.859\ in)^2(6\ in)]}{\left(266\ \frac{in \cdot lb_f}{R \cdot lb_m}\right)(3307\ R)} \cdot \frac{7000\ g}{lb_m} = 12.25\ g$$

$$m_{aft} = \frac{PV}{RT} = \frac{(4.740\ psi)\frac{\pi}{4}[(6.007\ in)^2(16.2\ in) + (5.859\ in)^2(11\ in)]}{\left(266\ \frac{in \cdot lb_f}{R \cdot lb_m}\right)(3307\ R)} \cdot \frac{7000\ g}{lb_m} = 28.50\ g$$

The mass of the black powder charges for both the fore and aft sections are calculated to be 12.25 grams for the fore section and 28.50 grams for the aft section. To ensure the ejection of both the drogue and main parachutes, the backup charges will be sized 25% larger than the primary charges. The backup charges for the fore and aft sections will be 15.31 grams and 35.63 grams, respectively.

3.5.14 Packing Method

Deployment bags are the preferred parachute packing method. Both the main and drogue parachutes will be pack in deployment bags. This will help prevent tangling of shroud lines and shock cords. The shroud lines will also stagger when coming out of the deployment bag, helping to prevent them from snapping. This method was also chosen because it allows for higher packing densities and the deployment bags protect the parachutes from high levels of heat from the ejection charges.

3.6 Mission Performance Prediction

3.6.1 Kinetic Energy

After choosing a 14 ft diameter main parachute with a toroidal shape and a drag coefficient of 2.2, the kinetic energy at landing can be calculated. Rearranging the drag force equation to solve for landing velocity results in a landing velocity of 10.17 ft/s which is smaller than the previously calculated maximum landed velocity required to stay within kinetic energy landing requirements.

$$v = \sqrt{\frac{2Wg}{\rho C_d A}} = \sqrt{\frac{2(41.64\ lbs)(32.17\frac{ft}{s^2})}{(0.0765\frac{lb_m}{ft^3})(2.2)(\frac{\pi}{4})(14\ ft)^2}} = 10.17\ \frac{ft}{s}$$

With the landing velocity known, the KE kinetic energy at landing can be calculated.

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{41.64}{32.17\frac{ft}{s^2}}\ lbs\right)\left(10.17\frac{ft}{s}\right)^2 = 66.94\ lb \cdot ft$$

The calculated kinetic energy at landing falls within the requirement of 75 ft-lb at landing.

3.6.2 Descent Times

To accurately determine the descent time, the descent from apogee to the main deployment and from main deployment to the ground must be calculated separately and then added together. To calculate the descent time, the equation for speed was used.

$$t_{descent} = \frac{Distance}{v}$$

The distance between apogee and the deployment of the main parachute is 4,920 feet. To calculate the velocity between apogee and main deployment, a flat sheet drogue parachute with a 1.5 ft. diameter and drag coefficient of 0.4 is used.

$$v = \sqrt{\frac{2Wg}{\rho C_d A}} = \sqrt{\frac{2(41.64\ lbs)(32.17\frac{ft}{s^2})}{(0.0765\frac{lb_m}{ft^3})(0.7)(\frac{\pi}{4})(1.5\ ft)^2}} = 168.27\ \frac{ft}{s}$$

With the known velocity, the descent time can be calculated,

$$t_{drogue} = \frac{Distance}{v} = \frac{4920\ ft}{168.27\frac{ft}{s}} = 29.24\ s$$

The same formula can be used to calculate the descent time from the main parachute deployment to landing,

$$t_{main} = \frac{Distance}{v} = \frac{500\ ft}{10.17\frac{ft}{s}} = 49.16\ s$$

Adding the two descent times together results in a total descent time of 78.40 seconds, which falls within the requirement of a 90 second maximum descent time.

3.6.3 Drift Calculations

To ensure that the rocket does not drift outside of the half mile landing radius, drift calculations were completed. Wind speeds ranging from 0 mph to 20 mph in increments of five were used to calculate drift. To obtain the drift, the following equation was used,

$$Drift = Windspeed * (t_{drogue} + t_{main})$$

Table: Calculated Drift

Windspeed (mph)	Drift (ft.)
0	0.0
5	600.7
10	1201.4
15	1802.2
20	2402.9

Table: 3.6.3.1

Alternative Calculation Confirmation:
MATLAB

To confirm calculations, a MATLAB code was run to calculate kinetic energy, velocities, parachute sizes, and rocket drift. The difference in the outputs is due to more decimal places being kept through calculations to obtain more accurate data. Shown in the figure below are the calculated values via MATLAB.

```
CONSTRAINTS
Max. Velocity at landing: 10.7657 ft/s
Min. Parachute diameter: 13.2271 ft

DROGUE PARACHUTE
A 1.50 ft. diameter Drogue Parachute is chosen.
Velocity between Apogee to Main Deployment: 168.27 ft/s
Section KE's from Apogee to Main Deployment:
 Nosecone section: 2890.07 lb-ft
 Fore, Ebay, Aft sections: 7252.30 lb-ft

MAIN PARACHUTE
A 14.00 ft. diameter Main Parachute is chosen.
Velocity at landing: 10.17 ft/s
Kinetic Energy at landing: 66.93 lb-ft
Section KE's from Main Deployment to Landing:
 Nosecone section: 10.56 lb-ft
 Fore & Ebay section: 6.77 lb-ft
 Aft section: 42.55 lb-ft

DESCENT TIMES
Descent time from Apogee to Main Deployment: 29.24 s
Descent time after 500 ft: 49.17 s
Total Descent Time: 78.40 s

DRIFT
Wind Speed (mph)       Drift (ft)
  0                      0.0
  5                      575.0
  10                     1149.9
  15                     1724.9
  20                     2299.9
```

Published with MATLAB® R2019b

Figure 3.6.3.1

3.6.4 Launch Day Target Altitude

Our main goal on launch day is to launch our vehicle to a target altitude of 5280 ft or 1 mile. This goal was set by majority vote in one of the first meetings by the team.

3.6.5 Flight Simulation

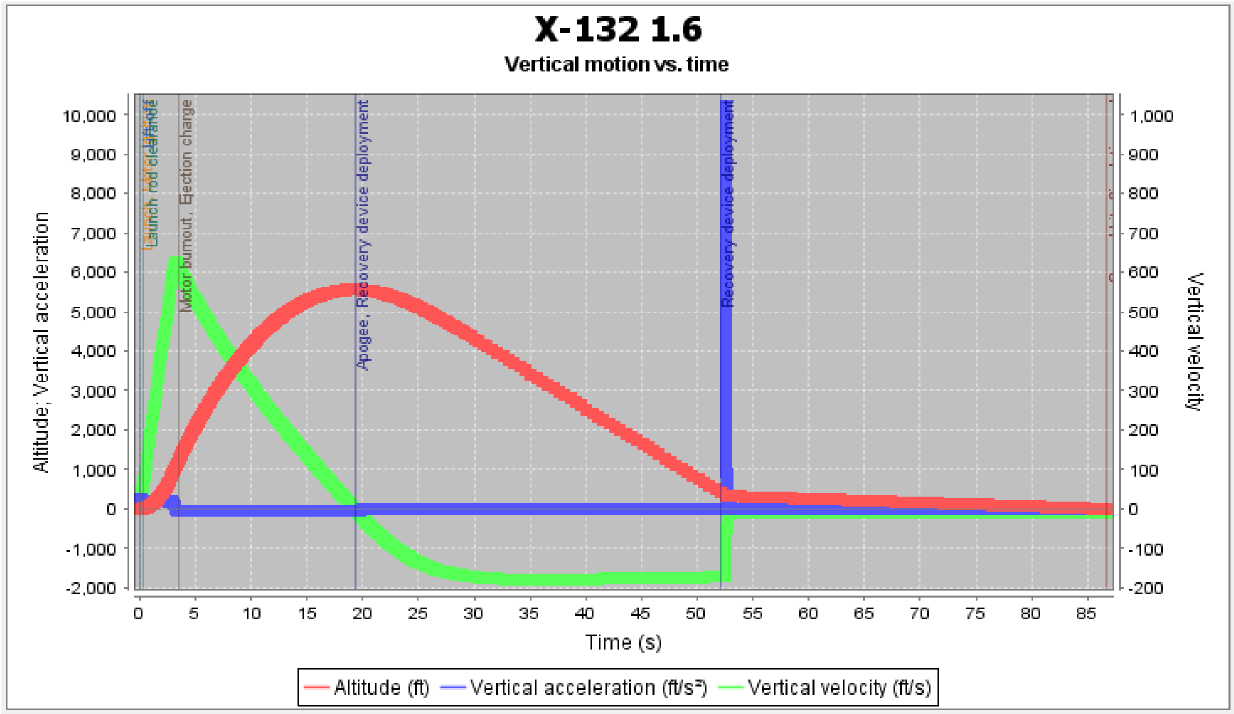


Figure 3.6.5.1

Above is our predicted flight parameters as determined by open rocket, and below are the actual numbers derived from the plot.

Velocity off Rod	Apogee	Velocity at Deployment	Optimum Delay	Max Velocity	Max Acceleration	Time to Apogee	Flight Time	Ground Hit Velocity
62.5 ft/s	5222 ft	179 ft/s	15.2 s	594 ft/s	220 ft/s^2	18.6 s	80.8 s	10.6 ft/s

Table:3.6.5.1.a

Payload Criteria

4.1 Payload Mission Statement

The main goal of the payload is to retrieve an ice collection sample at one of the sample collection sites on launch day after a successful deployment/separation from the rocket.

4.2 Payload Justification and Mission Success Criteria

4.2.1 Payload Justification Criteria

Within the PDR document itself, we will be outlining our considerations for our payload, going through each particular part within the payload, including the mechanical, electrical, and software subsystems, and going through every appropriate factors for each part. We will be detailing each of those factors with a summary, the positives and negatives, and a justification for why we are considering for every factor that we have. The team will then choose the best choice from each of those considerations in the leading design section. There, we will present a more in-depth justification for why this is our leading design along with general dimensions and a CAD model of that part.

4.2.2 Mission Success Criteria

We will judge the success of our payload based off of its survival after launch, deployment/separation from the main rocket body, ability to traverse the terrain to get to one of the five ice collection pads, and its ability to retrieve some of the ice sample using our collection method.

4.3 Payload Vehicle Subsystem

4.3.1 Payload Housing

We have gone through multiple different considerations when it comes to the decision of the CANSAT that we want to use. The two primary options are listed below where we detail the idea of storing a CANSAT within the fore section of the airframe or using the nose cone itself as a CANSAT.

4.3.1.1 Nose Cone

The rover resides inside of the nose cone with a due bulkhead system this is to prevent gunpowder and breakage pressure from reaching the payload during descent. The second bulkhead is secured to the nose cone for the extent of the flight using a servo activated lever arm mechanism housed within the nose cone. After the nose cone and rocket has landed and is static, the lock will disengage and the rover will push out the second bulkhead and maneuver it self out of the rocket and towards its objective which is the ice sample collection area.

4.3.1.2 CANSAT (Airframe)

The panels of our airframe are designed to be sectioned in a manner that allows for them to be secured during the descent stage of its flight and deployed after touchdown of the JetPaC. These panels will be spring loaded and secured by nylon monofilament, which will be severed by a nichrome coil will act a resistance element in an electrical circuit generating heat to cut the monofilament. This mechanism is modeled below.

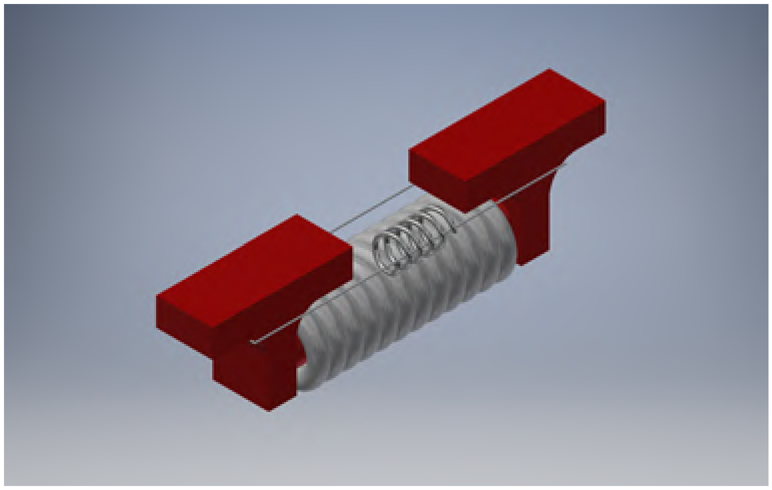


Figure 4.3.1.2.1

The red bracket will be secured and recessed into the CANSAT's body panels to reduce drag and ensure minimal chance of unplanned separation of the panels. They will be secured by hardware and an epoxy fillet to ensure that the chances of them fracturing are minimized. The leading material selection for the bracket is G10 fiberglass, with alternative materials being Nylon, and PEEK plastic. G10 was selected over Nylon and PEEK because of its machinability and the team's prior experience with machining G10. G10 will provide the necessary flexural strength for our application.

The separation of the panels will occur after RSO has given permission for the egress of our payload and will be controlled by the same microcontroller that will initiate the landing leg deployment.

Regarding the deployment of both the landing legs and grid fins, a similar mechanism will be used however in a configuration that accommodates torsional springs, instead of compression springs.

4.3.1.3 CANSAT (JetPac)

This CANSAT, designated Jettisoned Payload Carrier (JetPaC), will be jettisoned from the primary launch vehicle, descend in a stabilized descent to a collection area.This design would call for the integration of the nose cone with the CANSAT itself. This staging is clarified in the graphic below which depicts the JetPac's jettisoning event, descent stage, recovery event, and our mission solution's egress.

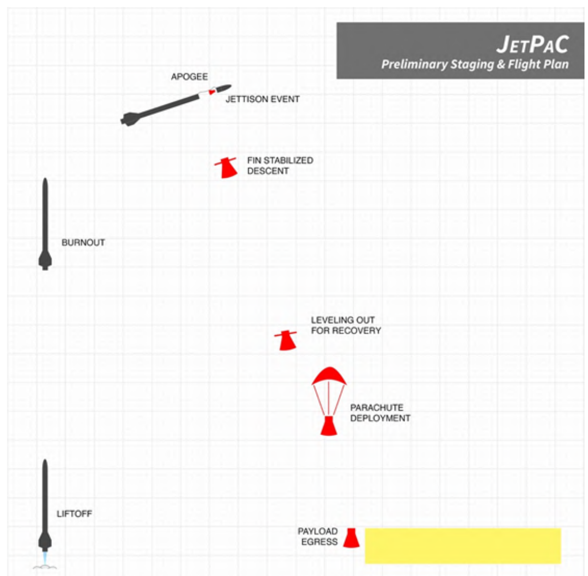


Figure 4.3.1.3.1

The initially proposed design called for a droplet shaped capsule with control and stabilizing surfaces aft (downstream) of the leading surface. This shape is desirable because the shape has a naturally low center of gravity, which could aid in stabilizing the CANSAT's descent. The initial design is shown below in a computational fluid dynamic (CFD) simulation used to verify the aerodynamic dimpling of the leading surface.

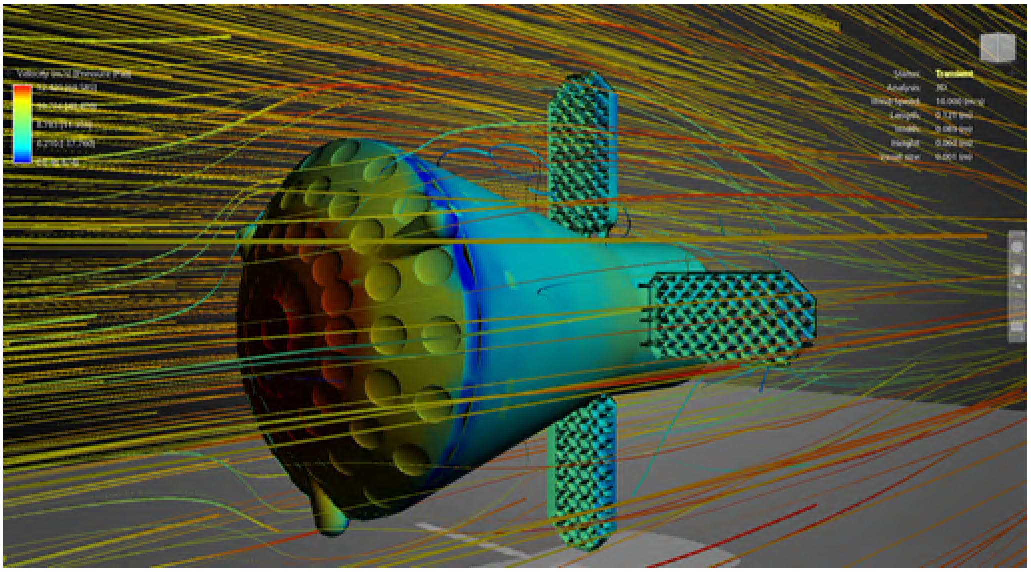


Figure 4.3.1.3.2

4.3.2 Rover Movement

There are many methods to maneuver the payload from the rocket to the ice collection site. These include, Wheels, Treads, and Legs. The importance is the ease of maneuverability, as little complexity as possible and cost.

4.3.2.1 Wheels

Wheels provide a simple method for maneuvering about as the motor shaft can be the axle of the wheel and they provide an increased amount of torque based on the radius. We are considering 3D printing them or buying RC car wheels from a manufacturer, both attached to a hinge at the body. A benefit of using wheels, is that they are easy to print and attach to the body. They are lightweight, have higher maneuverability, and speed. wheels do however add complexity to the system when suspension and dynamic ability to climb rocks and awkward terrain is needed.

One of the manufacturers for wheels that would be viable is RC Planet, which offers trencher tires with a width of 1.83 inches, and an outer diameter of 4.35 inches. These tires are around the size of our payload and have a relatively low cost of $27.16.

4.3.2.2 Treads

Treads are most versatile in terms of awkward terrain movement and overall maneuverability. We, again, are considering 3D printing both the Driver Wheels and treads. Treads will give us a large surface area to be in contact allowing for more torque to be useful without this being lost. They are also dynamic, allowing us to traverse rough terrain and correct for any faulty deployment by possibly running the rover upside-down if necessary. Cons of treads are low speed and maneuverability. They are harder to repair and maintain than individual wheels.

To manufacture the treads, we plan on using a 3D printer provided by Texas Tech, thus allowing us to produce them with a reduced cost. The treads will be printed out of ABS plastic and pinned together to give them shape and stability, while still allowing for pivoting.

4.3.2.3 Legs

This is the most complex option for movement of our rover. Though they offer the most dynamic ability for traversing any terrain, implementing legs will have a high cost, require more coding and motors, and would have less of an ability to transport our collection system reasonably.

4.3.3 Suspension

4.3.3.1 Torsion Bars

The most common form of tank track suspension is torsion bars. They attach to each wheel individually from the body with a solid rod and a rotational hinge at the end. It allows each wheel to flex by itself as the tracks move. The advantages of torsion bar suspension are the flexibility and durability of the bar. It takes up less interior space for things like the electrical box and motors. The disadvantage of the torsional bar is that it does not provide a progressive rate spring to increase mobility. Another disadvantage is that there can also be added complexity when attempting to achieve a highly stable system.

4.3.3.2 Spring Loaded

Spring loaded suspension is another common form of tread suspension. It involves using either linear or pregressive rate springs to arrange the wheels into a variety of rigs, providing different amounts of mobility or endurance depending on the specific design chosen, Christie or Vertical volute. The negatives of spring-loaded suspension are the lack of durability and ease to fix.

4.3.4 Chassis

4.3.4.1 Electronic Box

One of the options for our payload chassis is using an electronic box. The electronic box's purpose is to house all the electronic devices within a rectangular shell. Within the chassis we will be storing the battery, battery charger, GPS unit, motor controller, micro controller, and 9-DOF sensor.

The positives of using a rectangular shaped box are one, organizing the electronics will be considerably easier since most of them fit the shape of our box. Additionally, designing around this shape, specifically when it comes to our payload movement options, would be significantly easier as well. Attaching treads would be simple, as compared to a spherical shape.

The negatives of using this design is that fitting the payload into our airframe would be more of a challenge. Our payload retention system would have to take into account the shape of our electronic box.

4.3.4.2 Spherical Ball

Our alternative option is a spherical ball chassis for storing our electronics. With this design.

Some of the positives of using this design is that it increases the maneuverability of our chassis in the event that our payload is flipped. With the spherical shape, it gives our chassis a better probability of handling those types of situations. Another positive of using this design is that it easily fits into the shape of our airframe. When designing our retention system, we would not have to consider the shape of the chassis as much as we would compared to the rectangular box.

The drawbacks of using a spherical design is that it considerably makes organizing the electronic devices within the chassis more of a challenge. The shape is more restrictive, since most of the devices are rectangular in shape. Additionally, the rest of our payload would need to be designed around the spherical shape, posing a more of a challenge.

4.3.5 Ice Collection Methods

4.3.5.1 Adhesive

One method of collection being considered is an adhesive material, that the sample could stick to. This is a very simple method that would require less complex code and equipment compared to the front loader. We would have two bars mounted on a track, with the adhesive between them, that would allow for the bars to slide down until it is touching the lunar ice sample, and then come back up to avoid hitting the ground and losing the material.This is a good option due to its simplicity and inexpensiveness. This would only require one motor to be used. The tracks and bar would be 3D printed using PLA. The adhesive pad being considered is a thin double-sided high bond foam pad.

The cons of using an adhesive material is the risk of the adhesive not being sticky enough to pick up the lunar ice. Also, the material could lose its adhesiveness prior to attempting the mission, thus not allowing it to pick up the sample.

4.3.5.2 Ramp

Another method of collection we are considering is a low inclined ramp. Similar to that of the adhesive collection method, this is a very simple method and easy to design and manufacture. The low inclined ramp would attach to the back of the rover in between the treads. The rover would be driven backwards to collect the lunar ice, and then continue to its next destination.

The pros of using this collection methods is its simple, easy to manufacture, and attach to the rover. This also does not require a motor to control it.

The cons of using a ramp, is it may collect the material depending on how big the samples and the sample piles. Also, the sample could fall off the ramp prior to making it the 10 feet.

4.3.5.3 Frontloader

The third method of collection we are considering is a front loader, similar to that of a tractor. Using this method would allow for us to easily collect and contain the lunar ice sample. We would use two small brushless motors, one would control the arm, the other would control the pitch of the bucket. These motors would be stored inside the main section of the rover and would require additional motor controllers.

The pros of using this collection method is it ensures we will be able to gather and contain the lunar ice sample. It is already a proven design used for farm equipment, thus this helps ensure our success in completing the mission. Additionally, manufacturing the front loader is a fairly affordable option as it would be 3D printed using PLA.

The negatives of this material is having to use multiple motors and motor controllers, motor controllers add increased complexity and require the addition of a larger circuit protection due to over current issues from the motors. In addition,this takes up more space that would be used for other electronics and wiring.

4.4 Payload Electronics Subsystem

4.4.1 Batteries and power

4.4.1.1 Voltage Regulator

The Voltage regulator steps up the voltage of the batteries to be usable by the Microcontroller and the Motors and their controllers.

a. Adjustable Step-Down Voltage Regulator Module. 1.5-35VDC Output

Figure 4.4.1.1.a.1

This table outlines some of the key specs of the Adjustable Step-Down Voltage Regulator Module

Input Voltage	4.5-40 VDC
Output Voltage	1.5-35 VDC
Output Current	2A
Full load Temperature Rise	40 C
Voltage Regulation	+/- 0.5%
Dynamic Response Speed	5% 200uS
Efficiency	Up to 92%
Switching Frequency	150 kHz
Size	42mm x 20mm x 10mm

Table 4.4.1.1.a

This is a voltage regulator which reduces the original voltage input to a lower voltage output. This specific voltage regulator can accept an input voltage range of 4.5V-40VDC and has an output voltage between 1.5V-35VDC with a max current of 2A as seen in the specs table. The cost per part is $6.95. We will need 4 voltage regulators resulting in a total cost of $27.80.

b. 600W DC-DC Step-up Transformer - 10-60V in, 12-80V out

Figure 4.4.1.1.b.1

This table outlines some of the key specs of the 600W DC-DC Step-up Transformer

Input Voltage	12V-60VDC
Input Current	0-15A
Output Voltage	12V-80VDC
Output Current	0-10A
Conversion Efficiency	95%
Short Circuit Protection	5x20mm Fuse
Size	8.5cm x 6.2cm x 6.0cm

Table 4.4.1.1.b

This is a voltage regulator which reduces the original voltage input to a lower voltage output. This specific voltage regulator can accept an input voltage range of 12V-60VDC and has an output voltage between 12V-80VDC with a max current of 10A as seen in the specs table. This voltage regulator is quite large in comparison to other voltage regulators and also comes with a heatsink attached on its bottom.

4.4.1.2 Samsung 25R

The purpose for using the Samsung 25R 18650 2500mAh 20A Battery is to help power the rover. The eight 2,500 mAh battery provides enough energy for the rover to last for approximately five hours. The total cost of it will be $30.00.

This table outlines some of the key specs of the Samsung 25R

Model	Samsung 25R / INR18650-25R
Size	18650
Style	Flat Top
Protected	No
Rechargeable	Yes
Nominal Capacity	2500 mAh
Continuous Discharge Rating	20A
Nominal Voltage	3.6V
Approximate Dimensions	18.33mm x 64.85mm
Approximate Weight	43.8 g

Table 4.4.1.2.a

The positive aspect of using this battery is that the nominal capacity is 2500 mAh while having a voltage of 3.6V. This batteries performance to cost ratio is great compared with other batteries it is also rechargeable. The battery is very reliable since it is the most widely used 18650.

The negative aspect of using this battery is that it needs a special charging method called balance charging. Where you charge each individual cell of a lithium ion battery equally, and at the same time. The LiPo battery could also be a safety factor if not properly taken care of because of the material in the battery.

4.4.2 Microcontrollers

The Microcontroller provides as the main processor for our rover, it reads data from the sensors and GPS module, and uses this to interface with the motor controllers` which control the motors to move the rover to the target location. The Motorcontroller is the brains of the rover and as such is one of the most vital parts to the rover.

4.4.2.1 Nvidia Jetson Nano

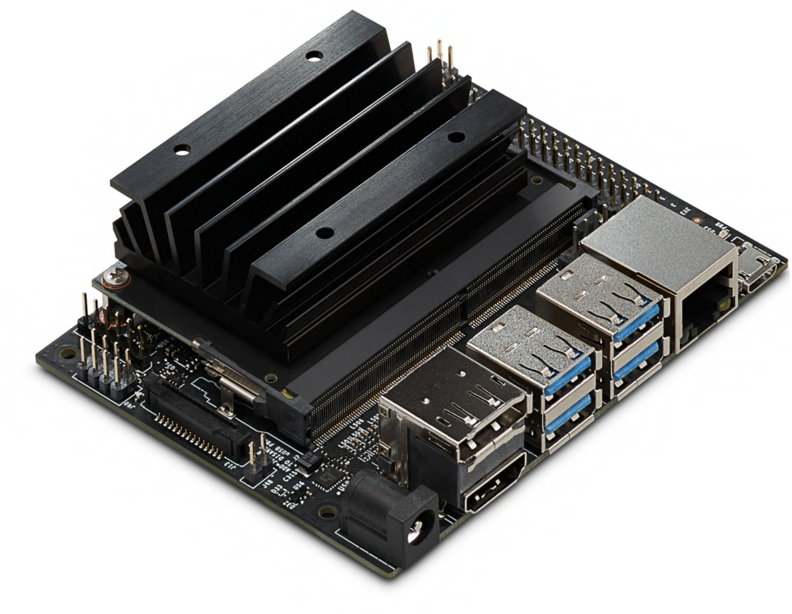


Figure 4.4.2.1.1

At $99, the Jetson nano is the smallest, most powerful single board computer provided by Nvidia. Running OpenCV, it is great for AI applications such as image recognition and movement.

This table outlines some of the key specs of the Nvidia Jetson Nano

4gb of LPDDR4 RAM
4k video Encode at 30fps
4k video Decode at 60 fps
128-Core Maxwell Gpu
Multiple onboard communication methods (I2C,I2S,SPI,UART)
QuadCore Arm-Chip

Runs Linux-OS
5 Watt Power consumption
A57-cortex clock speed: 4.6 MHz
5v 4Amp Power Supply

Table 4.4.2.1.a

The positives of using the Nvidia Jetson Nano is that it is the smallest and most powerful microcontroller provided by Nvidia. Additionally, its memory and video specs are exactly what we are looking for in a computer board. With 4 gigabytes of LPDDR4 RAM, our payload will have more than enough memory to withstand what we will be storing in it. The 4k video encoder/decoder at 30/60 fps respectively give us a higher quality and refresh rate that can be received at faster times. The power consumption is also optimal for what our payload will be handling. At 5 watts of power consumption, it would allow us to use smaller batteries while also increasing our battery life.

The negatives of using this microcontroller is one, it produces a lot of heat. Thus, putting a strain on the board as well as the electronic enclosure. With too much heat, our board is more likely to overheat, rendering our board, thus payload, useless. The price of this microcontroller is also relatively high compared to our other options. At $99 this puts a strain on our budget.

4.4.2.2 Raspberry Pi 4

Figure 4.4.2.2.1

It is a simple microprocessor made by the company Raspberry Pi with its 4gb version costing 55$.

This table outlines some of the key specs of the Raspberry Pi 4

Up to 4Gb of Ram LPDDR4
Cortex-A72 clock speed: 1.5GHz
4k video Encode at 30fps
4k video Decode at 60fps
5V 3Amp Power Supply (Absolute minimum 2.5Amps)
Runs a Flavor of Linux

Table 4.4.2.2.a

The major positive of using the Raspberry Pi 4 is that our team has previous experience using this type of microcontroller. Thus, we already have an idea of what type of devices are compatible with the Raspberry Pi. Additionally, the encoder and decoder specs are ideal for what we were looking for in a microcontroller. With 4k video, our pixel quality and refresh rate is optimal for our payload. Most importantly, the price of the Raspberry Pi is very cheap compared to other options. At $55, we can spend more of our resources elsewhere.

The negatives of using the Raspberry Pi is that the poor GPU could pose a problem to computer vision capabilities. Another downside to the Raspberry Pi is its lack of a dedicated GPU as well as its onboard graphics is lack luster in comparison to that of the nvidia jetson However, in every other metric the Raspberry Pi beats the nvidia jetson. It has the newer arm based chip it has the same ram capabilities and has the same capabilities in terms of video encode and decode.

4.4.3 9-DOF Sensors

4.4.3.1 Adafruit 9-DOF Sensor Breakout of the BNO055

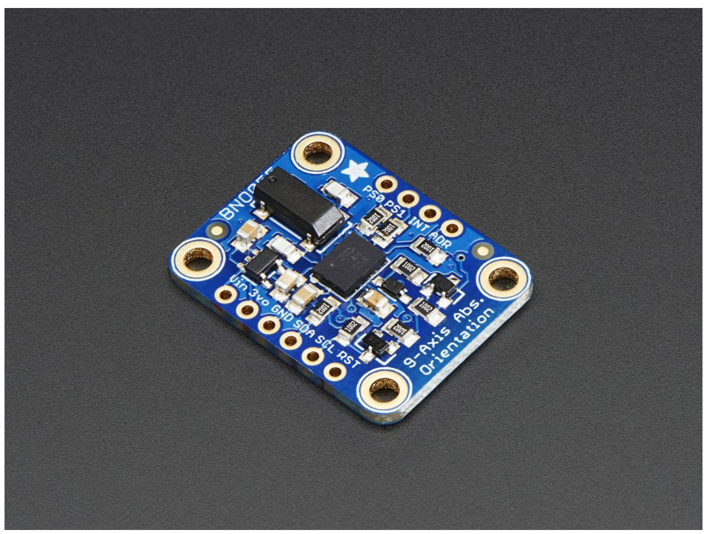


Figure 4.4.3.1.1

The BNO055 will help track our payload's x, y, and z directions as well as the acceleration. Thus, helping us determine how are payload will be moving and maneuvering through the terrain it has to get through to collect the ice sample. All at a price of $34.95

This chart includes benefits of the Adafruit 9-DOF Sensor

	Absolute Orientation: (Euler Vector, 100Hz) a three axis orientation data based on a 360° sphere
	Absolute Orientation: (Quatenrion, 100Hz) Four point quaternion output for more accurate data manipulation
	Angular Velocity Vector: (100Hz) Three axis of 'rotation speed' in rad/s
	Acceleration Vector; (100Hz) Three axis of acceleration (gravity + linear motion) in m/s^2
	Magnetic Field Strength Vector: (20Hz) Three axis of magnetic field sensing in micro Tesla (uT)
	Linear Acceleration Vector: (100Hz) Three axis of linear acceleration data (acceleration minus gravity) in m/s^2
	Gravity Vector: (100Hz) Three axis of gravitational acceleration (minus any movement) in m/s^2
	Temperature: (1Hz) Ambient temperature in degrees celsius
	Uses I2C communication.

Table 4.4.3.1.a

The positives of using this sensor is that it provides the most amount of sensors that calculate just about everything we need for our rover design. This specific sensor is significantly more accurate than any other of our options. Additionally, this sensor has a very low footprint. Giving us more space to work with inside our electrical enclosure. For the low price of $34.95, this sensor is efficient, optimal, and accurate, just what our payload requires.

The negatives of this 9-DOF sensor is that there is a 1% error across each sensor leading to up to 5% difference in some cases. However this is the worst case scenario, normally you'd experience much less than 1%.

4.4.4 GPS Options

The GPS module is essential for calculating the rover's geographical position. It's antenna needs to receive data from at least four satellites for accurately calculating the position and time. Based on this criterion, three potential candidates are: SAM-M8Q Sparkfun GPS Breakout, Adafruit Ultimate GPS Breakout + Raspberry hat, and Adafruit Fona 808 GPS Breakout.

4.4.4.1 SAM-M8Q Sparkfun GPS Breakout

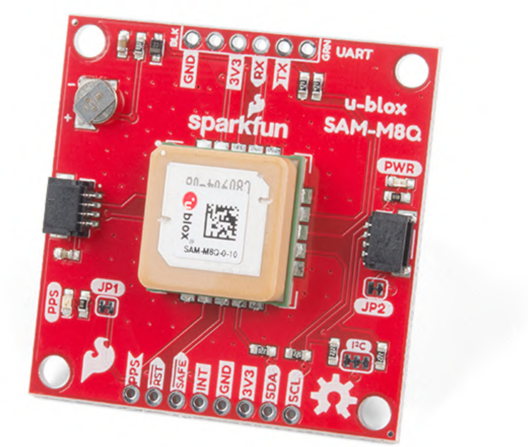


Figure 4.4.4.1.1

SAM-M8Q GPS Breakout has a 72 channel GNSS receiver. This improves the preciseness and lock time while using an onboard rechargeable battery that provides power to the RTC. Further, with an in-built antenna, it has one of the fastest cold start times and refresh rate. The total estimated price is $39.95.

	Cold Start time	Refresh rate	Antenna	GNSS Channels
SAM-M8Q	26 seconds	18 Hz update frequency	Internal patch antenna	72 acquisition channels

Table:4.4.3.2.a

4.4.4.2 Adafruit Ultimate GPS Breakout + Raspberry hat

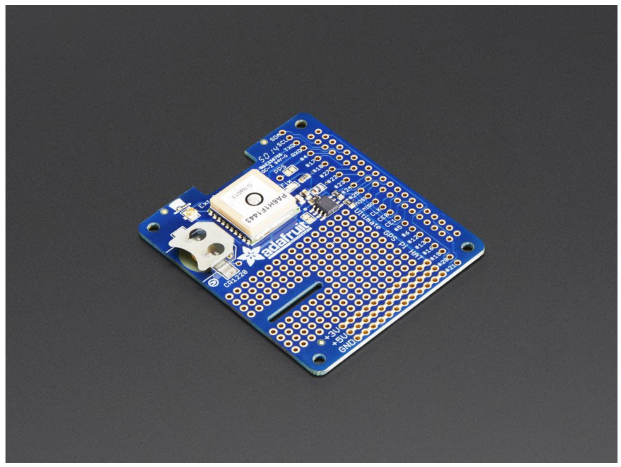


Figure 4.4.4.2.1

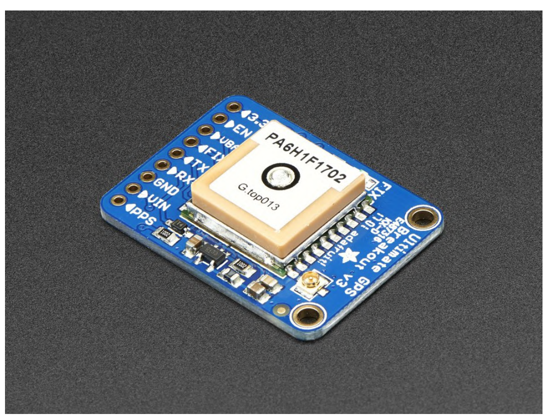


Figure 4.4.4.2.2

Adafruit Ultimate GPS breakout + Raspberry hat has pre-existing compatibility with the microcontroller, making it another favorable option. At a total estimated price of $39.95 for the Adafruit and $44.95 for the raspberry hat.

	Cold Start time	Refresh Rate	Antenna	GNSS Channels
Ultimate GPS Breakout	32 seconds	10 Hz update frequency	Internal patch antenna + u.FL connector	66 acquisition channels

Table:4.4.3.2.b

4.4.4.3 Adafruit Fona 808 GPS Breakout

Figure 4.4.4.3.1

Finally, Adafruit Fona 808 uses both cellular and GPS tracking and uses the latest SIM 808 with integrated GPS. Only significant drawback to it is the lack of accessories that come out of the box for its cost. At a total estimated price of $49.95

	Cold Start Time	Refresh Rate	Antenna	GNSS Channels
FONA 808	32 seconds	Unspecified by manufacturer	External uFL cellular Antenna	66 acquisition channels

Table: 4.4.3.2.c

4.4.5 Camera

4.4.5.1 Camera Module V2

Figure 4.4.5.1.1

The module V2 is a camera specifically designed for use in Raspberry Pi's. The module V2 has a Sony IMX219 8-megapixel sensor that supports

1080p30, 720p60, and VGA 90 video modes as well as still captures for photographs capable of 3280 x 2464 pixels. The camera itself is attached to the CSI port of the Raspberry Pi with a 15cm ribbon cable and has the dimensions of 0.98” x 0.90” x 0.35” with a weight of 3.4 grams. The camera is accessed through the MMAL and V4l API’s.

Some of the positives of the module V2 are its compatibility with our rover. Since our rover design centers around the Raspberry Pi 4, and since the camera was intended with the use of Raspberry Pi’s, implementing this camera to work with our payload will be no issue. The camera also comes at a relatively small size and a low cost of $29.95.

The negatives of using the V2 is that the ribbon cord’s width might be too large and take up too much space. Additionally, we would also have to test the power consumption rate of the camera since the manufacturers do not exactly specify that data. If power consumption tends to be higher than expected, and affecting the rest of our rover, the camera would be essentially useless, wasting more of our resources.

4.4.5.2 Arducam IMX298 Camera Module

Figure 4.4.5.2.1

Arducam’s IMX298 Camera Module is made to be used with any Raspberry Pi model, including the Raspberry Pi 4, and more. It plugs in to the MIPI CSI-2 port of a Raspberry Pi. This module can capture video at 4672×3496/7fps, 1080p/55fps and 720p/120fps resolutions. It has a 30 fps frame rate at 16 dMP and uses SONY 1/2.8-in CMOS, which utilizes Exmor-R technology to improve image capturing. This module has dimensions 40.0 mm x 40.0 mm but the weight and ribbon length are not specified.

The pros of using this camera module include the fact that it's designed for use with Raspberry Pi, making it very simple to implement it in our design without having to modify anything. It also has a higher resolution and better sensor than the V2 camera module, while achieving a low dark current and ensuring smear-free use. Arducam, itself, is known for its innovative Raspberry Pi camera modules and how they are much more versatile than standard Raspberry Pi camera modules.

On the other hand, the price of this camera module is a more expensive option at $59.99. Additionally, while it connects directly to the Raspberry Pi motherboard, because it is manufactured by Arducam, it requires the user to use Arducam's software and commands. This module also doesn't provide the power consumption rate so it would need to be tested to ensure that it doesn't affect the rest of the rover. There is a risk with this camera since the weight and ribbon length are not provided and could possibly prohibit us from using this product. However, it also would be possible to contact the manufacturer to determine these specifications before purchasing the product.

4.4.6 Motor

4.4.6.1 Motor Controllers

Our preliminary design requires at least two motors to provide enough torque for our treads and the ability to utilize the tank method of turning. Each motor requires its own motor controller or a motor controller that is capable of handling more than one motor. One of the biggest concerns is that if the current is not managed properly or you do not have a large enough grounding plane to sink your current into you could lose your entire system. To stop this from happening, many circuits have over and under current protection, However this is still not enough and more protection for the electrical motors, driver boards and computer and sensors is necessary, the protection of the circuit will be discussed in a later section. The main considerations when comparing motor controllers is amperage, speed control, number of motors and most importantly protection of motor, motor controller and of the otter boards connected to the motor controller.

a. Adafruit DRV8871 DC Motor Driver Breakout Board

This motor controller provided by Adafruit offers the best overall quality compared to its size and price. Adafruit is also a manufacturer we are familiar with, thus are more confident in adding their devices to our payload.

This specs for this motor controller are:

- 6.5V to 45V motor power voltage
- Up to 5.5V logic level on IN pins
- 565mΩ Typical RDS(on) (high + low)
- 3.6A peak current
- PWM control
- Current limiting/regulation without an inline sense resistor
- Undervoltage lockout
- Overcurrent protection
- Thermal shutdown

The positives for using this motor controller are that it is very small, allowing us to save more space within our electronic box. It is also very cheap at only $7.50 for each controller. Thus saving us resources as well as space.

The negatives, however, are that it is not as powerful as other options. This device has a very low current when compared to other options.

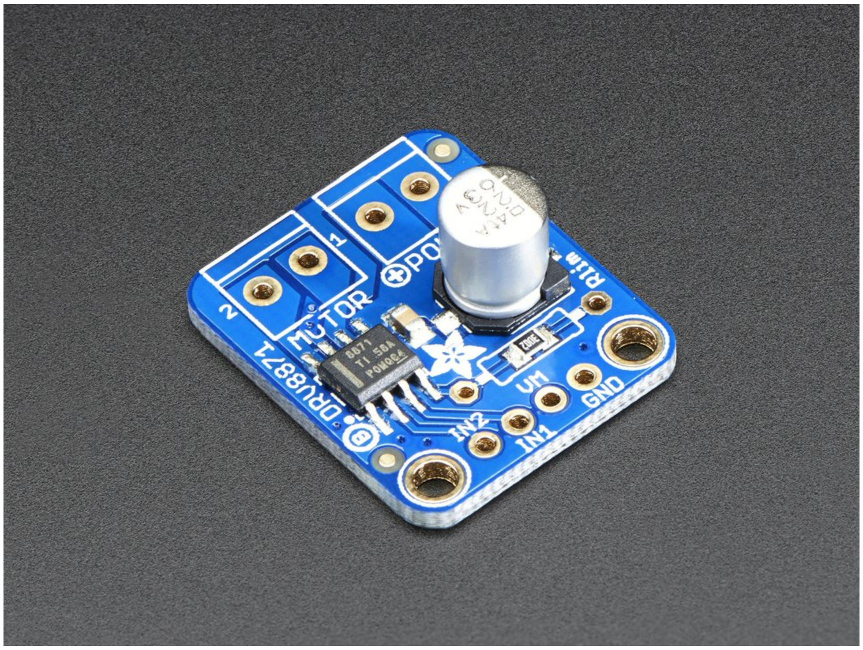


Figure 4.4.6.1.a.1

b. FSESC 4.12 50A Based on VESC 4.12

An alternative option for motor controllers is this FSESC from Flipsky. This is a powerful motor controller, normally used for electric skateboards. Additionally, this motor controller is highly modifiable and easily compatible with VESC software.

The specs for this motor controller are below

PCB	4 Layers
Current	50A continuous (240A peak)
Voltage	8V-60V
BEC	5V@1.5A
BEC type	Internal Driver Support
Motor Control Interface	PPM signal (RC servo), analog, UART, I2C
Frequency	PWM input

Weight	80g
FSESC4.12 Size	110mm x 40mm x 20mm

Table 4.4.6.1.b

The positives of using this motor controller is that one, it is very powerful and has a high current output. Which is more than enough for our payload. This high current also means it will be able to provide enough torque level to handle our payload movement.

One of the biggest drawbacks of this motor controller is its very high price. At $85.00, this really puts a strain on our budget and resources. Another negative is that these motor controllers are fairly large, meaning they take up a significant amount of space on our payload.

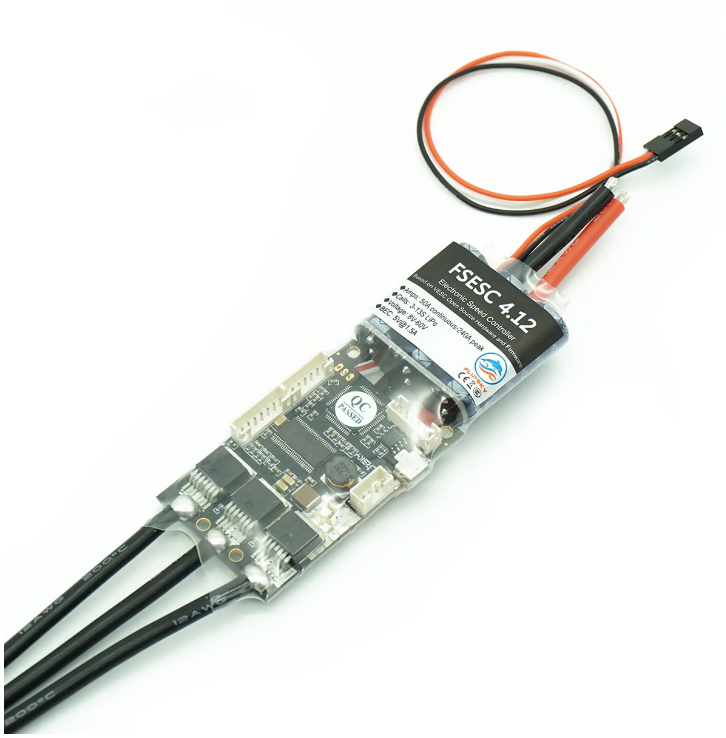


Figure 4.4.6.1.b

4.5 Payload Software Subsystem

4.5.1 Programming Language

4.5.1.1 C++

C++ is a coding language based on C, it is a low level language with a multitude of libraries and easy hardwear integration.

4.5.1.2 Python

Python is a high level language which has advanced number manipulation libraries.

4.5.1.3 MATLAB

MATLAB is a coding language that is used and taught to the engineering students at Texas Tech University and therefore many of the students express familiarity with the language

4.6 Payload Leading Design

4.6.1 Rover Movement

The Rovers main method of movement is tank treads. Tank treads provide the stability and traction required when moving through rough terrain. This traction is due to the high surface area of the tracks them self in reference to the size of the rover. In terms of suspension for these treads we will be using belt strength as the tracks ride are designed to ride along the motor housing to increase tension. The tension here acts as a suspension without the need for torsion bars,

In terms of our rover size we are using incredibly high powered motors, this is because in most cases we will be undervolting them and providing bursts of high current torque when it is necessary to get through a divot or in its self-righting protocol. This self-righting protocol is a method of producing torque on either side of the rover to create a swaying motion back and forth till it has landed back onto its tracks.

Our choice of Motor Controller is to allow for a high enough current output to supply out motors with the necessary instantaneous torque necessary to get over any obstacles it may encounter in the duration of its mission.

4.6.2 Suspension

The current leading design does not include tank track suspension, Because the added support and rigidity gained does not outweigh the increased complexity. However, if we decide later in the design process to add suspension, the design will add torsion bars due to its ease of design and increased stability. It can combine rollers on either side of the robot to make it easier to handle suspension of the system. It will be our best option to spring the torsion bar with a linear spring and have a pivot point attracted to the rover for each torsion bar. This allows each roller to come inward slight when going over uneven surfaces, like plowed fields.

4.6.3 Chassis

Our Chassis consists of out electronics box and our motor mounts. The electronics box acts as the main chassis for the robot with the motor mounts mounting to the front and back sides of the electronics box. The electronics box is made of aluminium because it acts as a grounding plane for our electronics which helps to prevent from overcurrenting which can be experienced when working with DC motor. This is especially prevalent due to the fact that we are using a quite powerful motors and their for even with the onboard circuit protection the addition of further fly back diodes it is still absolutely necessary to have a large grounding plane in order to maintain a satisfactory level of success assurance in the event of an overcurrent. the added security necessary when working with large motors.

4.6.4 Ice Collection Methods

To collect the ice sample we will be using a method of a low incline ramp located in between the treads and coming from one of the motor mount housings. The rover will drive to the sight at which point it will turn around and run backwards over the samples with its ramp facing towards the samples, the samples are carried upwards into the motor mount housing where they are stored once enough of the sample has been collected the rover moves 10ft away from the collection site. Due to our tight space requirements and our versatility in movement this method makes the most for collecting the ice sample as there are no moving parts associated it just uses the movement of the rover itself to pick up the sample.

4.6.5 Batteries/Power

18650 are the best option in our case due to their small size, high capacity and ease of cell pack creation. We chose to use the samsung 25R because they offer a very high capacity which due to the use of high current motors we will need the larger capacity.

The motors and the microcontrollers will have separate power systems to prevent over or under currting on either of the boards, this means each one will require their own individual step up voltage regulator.

4.6.6 Microcontrollers

The MicroController provides the control for the robot, interfacing with all the sensors and motor drivers, for this we have chosen to use the raspberry pi 4 B 4gb. The raspberry pi provides a highly advanced arm processor on top of a 4gb's of Ram creating the ability for high computation and large variable storage in a small form factor, this in conjunction with its small currant usage and compatibility with other components.

4.6.7 9-DOF Sensors

The Bno055 9-dof Sensor provides the most accurate position data by using each of its axis to computate more accurate data as a relative to one another, no other sensor in this price range and low current consumption offer this making the Bno055 the most effective sensor chip we could use. Using this in conjunction with the GPS module will allow for even more percies data representation for better path planning.

4.6.8 GPS

The Adafruit Ultimate GPS board provides highly accurate data, and can run off of a coin cell for over 7 years making it a highly versatile and reliable GPS module. This is the main reason as being able to track your inter accent and decent while onboard the rocket could provide nice telemetry data in case of the need to head back to launch site or any position along the trajectory of the rocket.

4.6.9 Motor Controllers

The Fsesc 4.12 DC Motor controller provides enough max current at 50Amp continuous and 280Amp peak to allow the motors to reach a torque level required for going over objects and righting itself. The Fsesc 4.12 provides over and under current protection, regenerative braking. If Current protection is reached it will slowly reduce motor speed down unless current is to high in which it fully stop the motor.

4.6.10 Retention Method

To retain the the rover inside of the nose cone a secondary bulkhead is in place to prevent black powder residue as well as the pressure of ejection from reaching the payload, this secondary bulk head stays in place through the extent of the flight via a locking mechanism located on the inside of the nose cone, when the nose cone lands the locking mechanism disengages and the rover pushes out the secondary bulkhead and rolls out of the nose cone.

Safety

5.1 Mission Statement

Safety is of the utmost importance to our team. We want to ensure everyone is gaining the experience of designing and manufacturing of the rocket in a proper and safe manner. To avoid injuries and operate in a professional work environment, it is important that we establish a precedent in safety for the present and future of the project itself and for the future of the student organization. We understand the significant risks associated if any negligence is shown while handling materials, chemicals, rocket motors, electrical components, etc. We understand that, if misused, some materials can be toxic, carcinogenic, explosive and or in some cases, fatal.

5.1.1 Risk and Delay Statement

The Safety Officer for the team is Nolan Shelton. He shall be responsible for the overall safety of the project. Additionally, there are two deputies that will carry out similar duties in order to enforce the required safety measures are utilized during all project activities. Maintenance of MSDS sheets and all other safety assessments fall under the responsibility of the Safety Officer. The Safety Officer will be responsible for checklists and final sign off sheets for all mission-related activities. All documentation will be prepared by the subteam responsible for the activity with the Safety Officer's assistance. The Safety Officer will issue a final check off and maintain a copy of the document. All documentation allows the members to perform their activity in correct and safe manner. All members participating in an approved activity will attend a safety briefing in regards to the potential hazards that can occur.

The extensive documentation of all activities is necessary for assuring a safe work environment. Safety is a top priority in this project, and the team is willing to take all measures necessary to provide a safe work environment. The Safety Officer and his deputies will make sure the safety requirements set by NASA, NAR, and NFPA are met through the review of all procedures and checklists.

5.1.2 Risk Assessment

For our safety risk assessment, we will use a traditional risk assessment matrix to identify the probability and severity of hazards that we might encounter during the project. Table 5.1 defines the probability codes, Table 5.2 defines the severity codes, Table 5.3 presents the description of the severity/probability combined codes, and Table 5.4 presents the overall matrix drawing from definitions in the prior three tables. These tables and the subsequent matrix will be used to later identify safety hazards throughout our proposal, but are defined here.

Probability Levels Table

Description	Percentage
A - Frequent	85%> chance of occurance
B - Probable	50% to 85% chance of occurance
C - Occasional	15% to 50% chance of occurance
D - Remote	1% to 15% chance of occurance
E - Improbable	<1% chance of occurance

Table 5.1.3.1

Severity Definition Table

Description	Personnel Health	Equipment Health	Mission Health
1 - Catastrophic	Loss of life/severe injury	Destruction of equipment	Possibly irrecoverable setback/Major reconstruction, mission success could be lost
2 - Critical	Severe injury	Major damage of equipment	Reconstruction required, but mission success is still possible
3 - Marginal	Moderate injury	Moderate damage of equipment	Moderate reconstruction, mission success is probable
4 - Negligible	Minor injury	Minor damage of equipment health	Minor reconstruction, mission success not affected

Table 5.1.3.2

Risk Assessment Levels Table

Total Risk	Acceptance Level
High Risk	Unacceptable
Medium Risk	Undesired. Will require rigorous documentation and mitigation to obtain approval through proper safety channels
Low Risk	Acceptable. Documentation required and approval through proper safety channels
Minimal Risk	Acceptable. Light documentation, approval through safety channels.

Table 5.1.3.3

Risk Assessment Matrix

Probability vs Severity	1 - Catastrophic	2 - Critical	3 - Marginal	4 - Negligible
A - Frequent	1A	2A	3A	4A
B - Probable	1B	2B	3B	4B
C - Occasional	1C	2C	3C	4C
D - Remote	D1	D2	D3	D4
E- Improbable	E1	E2	E3	E4

Table 5.1.3.4

5.2 Personnel Hazard Analysis

This will outline a table of the most hazardous points during the project, their hazard, description of hazard, risk assessment classification (RAC), and prevention methods.

Personnel Hazard Table

Hazard	Description	RAC	Prevention
Manufacturing of G10 fiberglass fins	During the manufacturing of fiberglass, there is a risk of eye, skin, and respiratory irritation.	1C	Wear the proper PPE of a respirator and clothing concealing all exposed skin along with working in a well ventilated workspace. Another option is to let the staff from the mechanical engineering shop handle the manufacturing.
Manufacturing of G10 fiberglass nose cone	During the manufacturing of fiberglass, there is a risk of eye, skin, and respiratory irritation.	1C	Wear the proper PPE of a respirator and clothing concealing all exposed skin along with working in a well ventilated workspace. Another option is to let the staff from the mechanical engineering shop handle the manufacturing,
Epoxying the airframe	When applying the epoxy to the airframe, we must avoid contact between epoxy and skin to avoid skin irritation and skin injuries.	4B	We will wear the proper PPE of gloves, long sleeves, pants, and closed toed shoes to avoid contact between the epoxy and skin.

Electrical Shock in ebay/Payload assembly	Exposed wiring along the ebay and payload can create a risk of electrical shock that can range from minor to severe injury.	1C	Grounding strips will be required for all members handling mission critical electronics. The electrical wiring will be inspected and documented by the electronics team lead to identify and avoid dangerous wires.
Launch Motor Failure	Failure to launch due to motor failure could be caused by manufacturing, the buying of faulty motors, or improper installation of the motor in the rocket body tube.	1C	The motor will be bought from a reputable company rather than manufactured ourselves. It will be assembled with proper precision under the guidance of professionals (being our shop technicians and/or industry advisor).
Pre-detonation of black powder	This is caused by faulty altimeters or wiring which can cause heavy damage in the vehicle and payload device.	2C	We will buy reputable altimeters and provide proper code that will be tested prior to launch.
Failure of detonation of black powder charge	This is caused by faulty altimeters or wiring which can cause heavy damage in the vehicle and payload devices.	3C	We will have a second altimeter to go off in the ebay of the rocket, acting as a backup if the first one fails.
Land-sharking of rocket	This is caused by instability within the rocket and can result in severe injuries to the participants and heavy damage to the vehicle and payload device.	1C	Create a thorough design within CAD software to increase stability and take advice from shop technicians, manufacturers, and faculty advisors.

Entanglement of the drogue and main parachute	This is caused by deployment of drogue and main parachute in rapid succession or the drogue getting stuck within the rocket due to the payload failing to deploy.	2D	Ensure that the drogue launches at apogee and the main much lower. Also includes the use of black powder for payload exit.
Zippering of the rocket in the air	This is caused by failure to properly calculate the forces exerted, greatly damaging the rocket.	2A	We will tape the shock cords to slow the deployment of the parachutes.
Payload jettisoning from CANSAT	This is caused by failure to properly separate the payload from the CANSAT. This can result in severe damages to payload section and slight risk for participants.	2D	Prevented by proper recovery put into place, effective handling, and deployment of payload within CANSAT.
Motor handling errors	This is caused by lack of proper handling and can lead to severe injuries.	1C	Safe handling practices will be implemented by the vehicle team lead along with guidance and help from industry advisor

Table 5.2

5.2.1 Hazardous Materials

This section will outline two tables of the most hazardous materials that we might encounter during the duration of this project (two tables for organizational/spatial purposes). The first table will outline the material, use of that material, manufacturer, and link to SDS sheet. The second table will list the material, hazard and its effects, risk assessment classification (RAC), and prevention methods.

Hazardous Materials Table

Material	Use	Manufacturer	SDS Sheet
Epoxy	The bonding of the airframe and the kevlar together	West System	Appendix III 5.1
Black Powder	Recovery Deployment of main and drogue parachute	GOEX Powder	Appendix III 5.2
Lithium Polymer	Used for the batteries within the ebay and payload sections of the rocket	Venom Group	Appendix III 5.3
Cyanoacrylate	Bonding of interior components of the rocket	Arrowhead Forensics	Appendix III 5.4
Fiberglass	Used for the construction fins	Current inc.	Appendix III 5.5
Carbon Fibers	Used to manufacture the airframe	Public Missiles	Appendix III 5.6

Solid Propellant Motor	Used to propel the rocket to apogee	Cesaroni	Appendix III 5.7
Kevlar Sock	Used as structural support for the airframe	Giant Leap Rocketry	Appendix III 5.8

Table 5.2.1.1

Risks of Hazardous Materials and Prevention

Material	Hazard	RAC	Prevention
Epoxy	Appendix III 5.1	4B	Work in a well ventilated area with proper PPE.
Black Powder	Appendix III 5.2	2C	Work alongside Tripoli Rocketry Association mentor, Bill Babash, on charge sizing and placement.
Lithium Polymer	Appendix III 5.3	1C	Take proper precautions while charging and while placing battery in the rocket as defined by manufacture.
Cyanoacrylate	Appendix III 5.4	1C	Work in a well ventilated area with proper PPE.
Fiberglass	Appendix III 5.5	1C	Work in a well ventilated area with proper PPE.
Carbon Fibers	Appendix III 5.6	1C	Work in a well ventilated area with proper PPE.

Solid Propellant Motor	Appendix III 5.7	3C	Work alongside Tripoli Rocketry Association member, Bill Balash, while handling and installing motor, and preparing electronic ignition system.
Kevlar Sock	Appendix III 5.8	1C	Use proper PPE while installing Kevlar sock to prevent skin irritation.

Table 5.2.1.2

5.3 Personal Protective Equipment (PPE)

We plan to use the maximum amount of PPE that is required for any certain application. The PPE that we will be utilizing:

Personal Protective Equipment Table

PPE Item	Item Purpose
Air Filtering Masks	Air filtering masks prevent inhalation of harmful substances during painting and working with other harmful chemicals.
Closed-Toe Shoes	Closed-toe shoes help protect the students' feet from falling foreign objects, especially those that are sharp or heavy.
Fume Hood	Fume hoods allow ventilation of the work environment. Proper ventilation allows the workspace to be clean and safe from harmful fumes.

Hair Ties	Hair ties allow avoidance of possible hair burns.
Hearing Protection	Hearing protection is necessary as sound can be trapped and amplified in the workspace.
Leather Work Gloves	Leather work gloves allows protection from sharp tools and fires.
Long Pants	Long pants are a universal PPE item that allow prevention from multiple hazards, including: chemical splashes, burns, and cuts.
Long-Sleeved Shirts	Long-sleeved shirts allow prevention of arms being impacted by chemical splashes, burns, and debris.
Safety Glasses	Safety glasses shield the eyes from foreign particles and fumes, preventing damage and irritation.

Table 5.3

In addition to all of the PPE items listed above, all members will work with due diligence in order to protect themselves and each other from work-related injuries.

5.4 Failure Modes and Effects Analysis (FMEA)

This section will identify possible points of failure that can affect the rocket and have effects on the safety of the team and other personnel at the launch site. Identification of FMEA allows the team to construct a safe rocket based on the possible points of failure that are common in rocketry.

Structures				
Failure	Cause	Effect(s)	Risk	Prevention
Buckling of the Body Tube	Overload on Body Leading to Extreme Axial Stress	Vehicle Loss, Internal Component Loss	E1	Perform stress analysis using CAD as well as perform tests using higher load standards.
Failure of Bulkhead	Overload of Forces on Hardpoints	Airframe Damage, Structural Integrity Loss, Attached Component Loss	D2	Institution of an increased safety factor in design in order to avoid launch failure.
Slippage of the Bulkhead	Error in the Epoxy Application to the Bulkhead	Structural Integrity Loss, Attached Component Loss	D2	Inspections of the bulkhead after placement in the rocket will occur during testing to ensure there are no mistakes.

Cracking of the Body Tube	Material Defects, Holes Drilled in the Body Tube	Vehicle Loss due to Failure of Body Tube	E2	Strict inspection of the materials used during construction of body tube. Limit drilling of the tube in order to maintain integrity.
Failure of Coupler	Rocket Bending	Structural Integrity Loss	D2	Design coupler for testing under bending loads that exceed expectations.
Collapse of Nose Cone	Unprepared for Force Overload on Nose Cone, Improper Installation	Unable to Relaunch, Loss of Attached or Contained Components	E2	Cautious building of nose cone and precise installation will be put in place to ensure the nose cone survives. Testing will study the integrity of the nose cone.
Failure of Fins	Improper Installation of Fins to the Airframe, Fluttering Fins	Airframe Damage, Fin Loss	D2	Inspection and testing of fin installation will occur before launch.
Motor Tube is Off-Centered	Misalignment of Motor Casings or Centering Rings	Airframe Damage, Unstable and Unpredictable Projection of the Rocket	2C	Precise alignment of the motor casing will occur during rocket construction. Close inspection will occur before the launch.

Table 5.4.1

Propulsion				
Failure	Cause	Effect(s)	Risk	Prevention
Catastrophic Failure of the Motor	Damaged Motor, Defect in Manufacturing	Critical Damage to All Rocket Components, Injury to Personnel	E1	Motor will be selected from certified distributors and manufacturers for quality control.
Failure of Motor Ignition	Defect in Manufacturing, Failure of the Igniter	No Ignition of Motor, Rocket Remains on Launch Pad	D1	Follow all procedures in NAR safety code. Have backup motor(s) to replace the failed motor in supply if applicable.

Table 5.4.2

Recovery				
Failure	Cause	Effect(s)	Risk	Prevention
Failed Ignition of Ejection Charges	Disconnection in Wiring, Loss of Power	Failure to Properly Deploy Recovery System	D3	Secure all connections to attachment points. Inspect batteries during launch preparation. Possibly install a backup system.

Flame Damage to Components	Inadequate Thermal Protection	Recovery System Damage	3B	Recovery system components shall be flame retardant.
Premature Ejection	Altimeter Malfunction, Inaccurate Altimeter Readings	Airframe Damage, Component Damage	2C	All wires will be shielded. Usage of reliable altimeters to ensure accuracy of ejection charges.
Premature Separation	Failure of Shear Pins	Airframe Damage, Component Damage	2C	Sections will be secured with reliable shear pins.
Recovery Attachment Point Failure	Quick Links Come Undone or Hardware Fails	Complete Loss of Recovery System	D3	Visual inspection of all links and knots before launch. Select hardware for system that has a high safety factor.
Sections Self-Impact	Sizing of Bridle is Improper, Parachute Placement is Improper	Airframe Damage, Component Damage	2C	Inspection of rigging and bridle sizes will occur to prevent collision of rocket sections.
Separation Failure	Inadequate Black Powder Charge, Improper Placement	Failure to Properly Deploy Recovery System	D3	Follow all procedures in NAR safety code. Have backup motor(s) to replace the failed motor in supply if applicable.

Uncontrolled Inflation of Parachute	Oversized Parachute, Parachute Packed Improperly	Internal Component Damage, Rocket Peak Load is Increased	2C	Methods of parachute packing and deployment will be tested.

Table 5.4.3

Payload				
Failure	Cause	Effect(s)	Risk	Prevention
Batteries Catching on Fire	Improper Charging of Batteries	Open Flames, Burns	D3	Secure all connections to attachment points. Inspect batteries during launch preparation. Possibly install a backup system.
Metal Components on Rover Becoming Projectiles	Improper Linear Spring(s) Installation, Payload Construction Faulty	Linear Springs Detach From Payload Becoming Projectiles, Bystanders Hit by Projectiles	D2	Recovery system components shall be flame retardant.
Motor(s) Catching on Fire	Motors Stall with Continuous Current Draw	Destruction of Electrical Components,	2C	Sensors will be put in place to start and stop motors during motor stall to prevent continuous current draws.

		Burns from Flames		
Overcurrent Issues	Large Amount of Flowback due to Current Requirement of Motors	Electronic Components Destroyed due to Short-circuit	2B	Install flyback diode with combination of resistor for overcurrent production as well as using our aluminum chassis as a grounding plate.
Premature Ejection of Rover	Early Ejection of Drogue Shoot, Retainment Failure	Aerodynamic Changes, Unpredictable Flight Path, Payload Becomes a Projectile, Bystanders Hit by Projectiles	E3	All wires will be shielded. Usage of reliable altimeters to ensure accuracy of ejection charges.

5.4.4

5.5 Definition of Risks Associated with the Project

Risk	Probability	Consequence	Prevention
Complexity of Components	Medium	Medium	Component designs will be discussed in order to develop the most simplistic yet effective component. Additions to the design will be added after a consensus amongst the team.
Destruction of Components During Testing	High	High	Tests that involve a risk of component destruction will be limited to scale models and on specific materials if applicable. Spare components will be on hand but can increase risk of an overbudgeting situation.
Missing Component(s)	Medium	Medium	In order to ensure all parts arrive on time, orders will be complete ahead of schedule to avoid running into issues.
Missed Deadline(s)	Low	High	All deadlines will be identified beforehand, allowing the organization to set internal deadlines to ensure all assignments are completed and submitted before the due date.
Over Budget Spending	Medium	Medium	Parts will be ordered from reputable vendors to ensure quality control. Research will be required in order to find the most cost effective part/component.

Table 5.12

5.6 Environmental Concerns

The environment is no question one of the main factors that can affect the desired outcome of the launch. Not only can the environment have an effect on the outcome of the project, but the project itself can have an impact on the project itself. This Environmental Hazard Analysis considers how a specific section of the launch vehicle or airframe may fail from environmental factors. The analysis does not include launch canceling environmental hazards such as extreme weather because the mitigation would be to cancel the launch and there is no effort the team can make to prevent this outcome.

In addition, the Fire Marshall will always be notified of testing or launching and on the site with our area currently in a fire ban.

Environmental Hazards				
Failure	Cause	Effect(s)	Risk	Prevention
Excessive Wind Speeds	Possible Storm Fronts	Unpredictable Flight Path, Possibility of Rocket Turning Into Projectile, Recovery is Off Site	2C	Monitor wind speed. Cancellation of launch will occur if wind speed exceeds 20 miles per hour (MPH)
Inclement Weather	Storm Fronts	Electronic Component Damage	1C	Store all electronic components in waterproof containers until launch. Monitor and maintain knowledge of the weather forecast.

Launch Pad Damp/Wet	Precipitation	Electronic Component Damage	1C	Store all electronic components in waterproof containers until launch.
Low Visibility	Cloud Ceiling is Low, Dense Layer of Fog	Tracking of Rocket and Vehicle will be Difficult	2C	Monitor and maintain knowledge of the weather forecast.
Terrain	Launch Field Obstructed by Terrain Features	Failure to Reach the FEA Successfully	2B	Perform adversity testing on different types of terrains and obstacles to ensure maximum capability.
Waste	Trash is Left On Site	Pollution of Earth	D2	Trash bags will be readily acceptable

Table 5.13

6.1 Project Plan

6.1.1 Project Compliance

Requirement*	Compliance
1.1. Students on the team will do 100% of the project including design, construction, written reports, presentations, and flight preparation. An exception to this includes assembling the motors, handling black powder or any variant of ejection charges, and preparing and installing electric matches (to be done by the team's mentor). Teams will submit new work. Excessive use of past work will merit penalties.	We are a part of the RAS student organization which is comprised only of students from Texas Tech University. Therefore, it can be guaranteed that 100% of the project design, construction, reports, presentations, and flight preparations will be completed by Texas Tech students. The extent of the adult mentor's influence will be purely guidance on the project and giving input from their experience and insight.
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/mitigations.	This requirement is fulfilled by sections 6.1, 6.2, 1.4, 5.1, and 3.2, respectively.
1.3. Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR). They may or may not have access to certain activities during launch week due to security restrictions. In addition, FN may be separated from their team during certain activities on-site at Marshall Space Flight Center.	Currently we are in the recruiting phase of our year and will finalize our team roster by the PDR.
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. 1.4.2. One mentor (see requirement 1.13). 1.4.3. No more than two adult educators.	Currently we are in the recruiting phase of our year and will finalize our team roster by the PDR.

1.5. The team will engage a minimum of 200 participants in educational, hands-on 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 viewed on page 35.	We are currently working diligently with the Engineering Outreach department at TTU to develop and present at multiple STEM outreach events.
1.6. The team will establish a social media presence to inform the public about team activities.	We will link our social media handle in each of our email signature blocks, starting with the proposal.
1.7. Teams will email all deliverables to the NASA project management team by the deadline as specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, the inclusion of a link to download the file will be sufficient.	Our proposal will be submitted by September 16th to both of the emails listed in the RFP. The file for the proposal will be linked as an attachment to the email.
1.8. All deliverables must be in PDF format.	The proposal will be converted from a Google Docs file to .pdf before delivery.
1.9. In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Our comprehensive table of contents will be at the beginning of the document after the cover page.
1.10 In every report, the team will include the page number at the bottom of the page.	The page numbers will begin after our cover page and be located in the bottom middle 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, a video camera, a speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.	SR will be fully prepared for all video teleconferences with supporting equipment including but not limited to, a webcam, a computer with solid internet connection, a microphone, and a speaker.
1.12. All teams will be required to use the launch pads provided by Student Launch's	We will utilize the proper launch hardware to make use of the Student Launch Services

services provider. No custom pads will be permitted on the launch field. At launch, 8-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.	Provider's launch system. Furthermore, we will calculate our apogee based on the cant angle of the launch system.
1.13. Each team must identify a "mentor." A mentor is defined as an adult who is included as a team member. He or she 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. He or she also must have successfully flown and 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/mentor attend launch week in April.	Our Tripoli mentor is defined within the leadership overview chart section 1.2. Bill Balash is a level 3 certified member of the Tripoli Rocketry Association.

Requirement	Compliance
2.1 The vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL). Teams flying below 3,000 feet or above 6,000 feet on Launch Day will be disqualified and receive zero altitude points towards their overall project score.	We are projected to hit a target altitude of approximately 5222 ft which is within the range parameters given for launch day.
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.	The targeted altitude goal for our rocket is approximately 5280 ft.
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. This altimeter may also be used for deployment purposes	The ebay will consist of two altimeters each run by its own 9V battery.
2.4. The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	We intend for our recovery system to work as stated with the drogue and main parachutes carrying the rocket bodies down. The descent of the rocket is calculated to be 10.17 ft/s, which will keep the rocket body reusable upon landing.
2.5. 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. 2.5.1. Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length. 2.5.2. Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	The rocket will have 3 separate sections. It will have a payload, ebay, and motor sections.

2.6. 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.	The altimeters and batteries will be tested prior to launch to ensure that they will last up to five hours.
2.7. The launch vehicle and payload 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, although the capability to withstand longer delays is highly encouraged.	The altimeters and batteries will be tested prior to launch to ensure that they will last up to five hours.
2.8. 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	We will utilize launch systems provided by NASA.
2.9. 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).	All the circuitry components will be confined to the rocket.
2.10. 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). 2.10.1. Final motor choices will be declared by the Critical Design Review (CDR) milestone. 2.10.2. 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	The current motors that we are running our simulations on are for the L-1395 which is commercially available and uses approved propellant according to the NAR and TRA. The final motor choice will be decided by the CDR.
2.11. The launch vehicle will be limited to a	The launch vehicle will be confined to a

single stage.	single stage.
2.12. 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).	We are currently planning on utilizing a L-Class motor.
2.13. Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria: 2.13.1. 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. 2.13.2. 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. 2.13.3. The full pedigree of the tank will be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.	We will not incorporate any pressure vessels in our design.
2.14. 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.	According to our current OpenRocket design we have a stability margin of 2.15, which is over the required 2.
2.15. Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	The only structural protrusion on our rocket is our fins, which will be located at the bottom of the airframe, behind the CP.
2.16. The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	Our current design and motor selection maintain a minimum of 62.5 fps LREV.
2.17. All teams will successfully launch and recover a subscale model of their rocket prior	We will be constructing our sub-scale and testing it prior to December. It will be

to CDR. Subscales are not required to be high power rockets. 2.17.1. 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. 2.17.2. The subscale model will carry an altimeter capable of recording the model's apogee altitude. 2.17.3. The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project. 2.17.4. Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.	considered a L1 class HPR. The design will reflect the flight charistics of the full-scale rocket. We will also include altimeter data in the CDR as well as a video link of the launch in the email containing the CDR.
2.18. All teams will complete demonstration flights as outlined below. 2.18.1. 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 8 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: 2.18.1.1. The vehicle and recovery system will have functioned as designed. 2.18.1.2. The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year's project. 2.18.1.3. The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply: 2.18.1.3.1. If the payload is not flown, mass simulators will be used to simulate the payload mass. 2.18.1.3.2. The mass	We will complete all testing well before the deadlines to make sure all relevant flight data is available to input inthe FRR and/or FRR addendum.

simulators will be located in the same approximate location on the rocket as the missing payload mass. 2.18.1.4. 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. 2.18.1.5. Teams shall fly the launch day motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the launch day motor or in other extenuating circumstances (such as weather). 2.18.1.6. 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 full-scale launch vehicle. 2.18.1.7 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 (RSO). 2.18.1.8. Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement. 2.18.1.9. Vehicle Demonstration flights must be completed by the FRR submission deadline. No exceptions will be made. 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. 2.18.2. 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 and the payload is fully retained until it is deployed (if applicable) as designed. The following criteria must be met during the Payload Demonstration Flight: 2.18.2.1. The payload must be fully retained until the intended point of deployment (if applicable), all retention mechanisms must function as designed, and the retention mechanism must not sustain damage requiring repair. 2.18.2.2. The payload flown must be the final, active version. 9 2.18.2.3. If the above criteria are 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. 2.18.2.4.Payload Demonstration Flights must be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.	
2.19. An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASArequired Vehicle Demonstration Re-flight after the submission of the FRR Report. 2.19.1. 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. 2.19.2. Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight	We will complete all testing well before the deadlines to make sure all relevant flight data is available to input in the FRR and/or FRR addendum.

requirement will not be permitted to fly the payload at launch week. 2.19.3. 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.	
2.20. 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.	We will include labels with team information in all sections next to the flight separation points.
2.21. All Lithium Polymer batteries will be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	We will create special mounting hardware that will protect the Li-Po batteries from sudden shock during the flight.

Table 6.1.

6.1.2 Team Derived Requirements

Vehicle	• Vehicle will have an apogee of 5280 ft • Vehicle will not exceed 60 lbs • Vehicle will not exceed 10 ft in height • Vehicle subscale will be built before the end of December • Vehicle will retain all sub-systems for duration of the flight
Recovery	• Team will not utilize more than 40 grams of black powder • Shock cords will not be longer than 3

	times the body section
Payload	• Payload will only be released on 0 agl

Table 6..1.2

6.2 Budget

For the 2019-2020 competition season, we have partitioned our budget into separate sections to more efficiently allocate and track funds. We have separated our budget into the following five sections: Safety, Vehicle, Payload, Recovery, and Transportation. The tables below detail our preliminary budget for each sub-system and our proposed travel budget.

Expense:	Quantity:	Subquantity:	Unit Cost Estimate	Cost:	Source:
First Aid Kits	2 Kits	2 150 piece	$0.00	$0.00	RAS
Fire Extuingsher	1 Extuingsher	1 ABC Class	$0.00	$0.00	RAS
Safety Glasses	24 Pairs	ANSI certified	$0.00	$0.00	RAS
Work Gloves	4 Boxes	4 50 pair boxes	$0.00	$0.00	RAS
				Total:	$0

Table 6.2.1: Safety Budget

Expense:	Quantity:	Subquantity:	Unit Cost Estimate:	Cost:	Source:
Airframe	3	2	$479.95	$959.90	Public Missiles
Couplers	2	2	$14.99	$29.98	Public Missiles
Nose cone(small)	2	1	$24.99	$24.99	Public Missiles
Nose cone(large)	2	1	$199.95	$199.95	Sunward
Bulkheads(nylon)	4	2	$63.75	$127.50	Plastics International
Bulkheads(fiberglass)	4	2	$0.99	$1.98	Fiberglass Supply Depot
Bulkheads(nylon)	4	1	$15.00	$15.00	Mcilvain
Centering Rings	3	1	$75.00	$75.00	Home Depot
Motor	2	2	$300.00	$600.00	Chris Rocket Supplies
Motor Retention	1	1	$37.00	$37.00	Rocketarium
Motor Casing	1	1	$415.22	$415.22	Apogee Components
Launch Lugs	2	2	$29.95	$29.95	Public Missiles
Fins	3	3	$102.75	$308.25	Apogee Components
				Total:	$2,824.72

Table 6.2: Vehicle Budget

Expense:	Quantity:	Subquantity:	Unit Cost Estimate:	Cost:	Source:
GPS Module	1	1	$45.00	$90.00	Adafruit
Rasberry Pi 4 4gb	1	1	$55.00	$110.00	Amazon
FSESC Motor Controller	2	4	$85.00	$340.00	Flipsky
Brushless Motor	2	4	$50.00	$200.00	Ebay
9 DOF BNO055	1	2	$35.00	$70.00	Adafruit
1/8" Steel Pins	1	10	$2.45	$24.50	Home Depot
Black ABS Filiment	1	2	$19.00	$38.00	Amazon
Aluminum Electronics Enclosure	1	2	$14.00	$28.00	Polycase
Samsung 18650 Li-Po Batteries	8	16	$3.50	$56.00	18650batterystore
Misc.			$50.00	$50.00	SR
				Total:	$1,007

Table 6.3: Payload Budget

Expense:	Quantity:	Subquantity:	Unit Cost Estimate:	Cost:	Source:
StratologgerCF	2	2	$49.46	$98.92	PerfectFlightDirect
Magnetic Arming Switch	3	3	$25.00	$75.00	Feather Weight Altimeters
T3 GPS Tracking System	1	1	$154.95	$154.95	Missile Works
Shock Cords	20.6 yd	2 14 yd	$30.13	$60.26	FruityChutes
Main Parachute	1 Chute	14 ft dia.	$889.82	$889.82	FruityChutes
Drogue Parachute	1 Chute	1.5 ft dia.	$8.05	$8.05	Top Flight Recovery
				Total:	$1,287.00

Table 6.4: Recovery Budget

Expense:	Quantity:	Subquantity:	Unit Cost Estimate	Cost:	Source:
Vehicle	2 Vehicles	1 Van & 1 Truck	0	$0.00	TTU
Trailer	1 Trailer	5 days	$29.99/ day	$150.00	U-Haul
Fuel	300 Gallons	5 days	$2.30/gal	$700.00	AAA
Housing	1 House	5 rooms	$165/ night	$903.00	Airbnb
Food	180 Meals	3/ day	$20/ person/ day	$1,300.00	RAS
				Total:	$3,053

Table 6.5: Travel to MSFC Budget

6.3 Finances

6.3.1 Financial Introduction

The Space Raiders function as a sub-committee of the Raider Aerospace Society (RAS) and therefore, is supported by Texas Tech University and is in affiliation with the Whitacre College of Engineering. The treasurer of Space Raiders works directly between the sub-team leads and the RAS treasurer to efficiently allocate funds to the team.

6.3.2 Current Funding Resources

Our funds currently consist of member fees, Student Government Association (SGA), fundraisers, and sponsorships. Funds allocated between
both RAS and Space Raiders finance both learning and ambitious projects in these organizations.

6.3.3 Finance Activities

The RAS Finance Team acquires funds through the following activities:
RAS membership dues, sponsorships, fundraisers, grants, TopTier Catering, and GoFundMe donations. The RAS Finance Team strives to be an active presence in the
local community, creating awareness of our mission, allowing for the acquisition of financial contributions to our projects.

6.3.4 Finance Goals

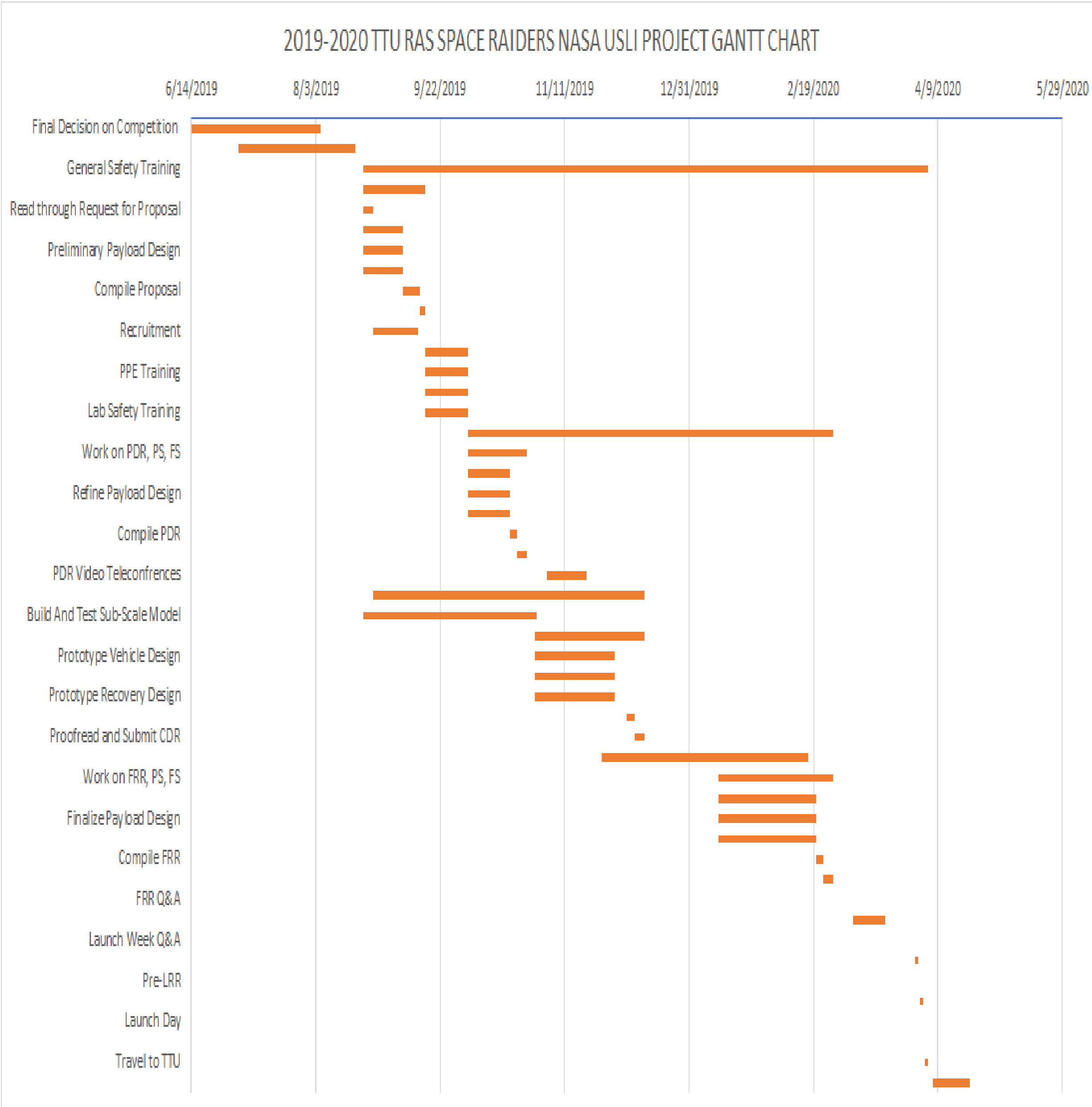
Our finance goal is to raise $20,000 to be allocated between both RAS and Space Raiders. Donors that contribute to the goal can follow our progress on both social media as well as our blog posts on our website.

6.3.4.1 Financial Mission Statement

“The Raider Aerospace Society is raising money for our High-Powered Rocketry Competitive team, the Space Raiders. After conquering our first award, the team is ready for more action. The Space Raiders are returning for their second time, to the NASA University Student Launch Initiative (USLI) competition. We would like your support to help fund our ambitious project. Help us send Texas Tech University's determined Space Raiders once again to Huntsville to launch their rocket.”

6.4 Schedule

The schedule we had developed for the 2019-2020 competition season is as follows:



TASK	START DATE	END DATE	DURATION
Final Decision on Competition	6/3/2019	8/5/2019	63
Decide Project Leads	7/3/2019	8/19/2019	47
General Safety Training	8/22/2019	4/5/2020	227
Work on Proposal	8/22/2019	9/16/2019	25
Read through Request for Proposal	8/22/2019	8/26/2019	4
Preliminary Vehicle Design	8/22/2019	9/7/2019	16
Preliminary Payload Design	8/22/2019	9/7/2019	16
Preliminary Recovery Design	8/22/2019	9/7/2019	16
Compile Proposal	9/7/2019	9/14/2019	7
Proofread and Submit Proposal	9/14/2019	9/16/2019	2
Recruitment	8/26/2019	9/13/2019	18
Training	9/16/2019	10/3/2019	17
PPE Training	9/16/2019	10/3/2019	17
Hazard Communication and Awareness Training	9/16/2019	10/3/2019	17
Lab Safety Training	9/16/2019	10/3/2019	17
STEM Engagement Activities	10/3/2019	2/27/2020	147
Work on PDR, PS, FS	10/3/2019	10/27/2019	24
Refine Vehicle Design	10/3/2019	10/20/2019	17
Refine Payload Design	10/3/2019	10/20/2019	17
Refine Recovery Design	10/3/2019	10/20/2019	17
Compile PDR	10/20/2019	10/23/2019	3
Proofread and Submit PDR	10/23/2019	10/27/2019	4
PDR Video Teleconfrences	11/4/2019	11/20/2019	16
Identify Members Attending MSFC	8/26/2019	12/13/2019	109
Build And Test Sub-Scale Model	8/22/2019	10/31/2019	70
Work on CDR, PS, FS	10/30/2019	12/13/2019	44
Prototype Vehicle Design	10/30/2019	12/1/2019	32
Prototype Payload Design	10/30/2019	12/1/2019	32
Prototype Recovery Design	10/30/2019	12/1/2019	32
Compile CDR	12/6/2019	12/9/2019	3
Proofread and Submit CDR	12/9/2019	12/13/2019	4
Full Scale Build and Test w/Payload	11/26/2019	2/17/2020	83
Work on FRR, PS, FS	1/12/2020	2/27/2020	46
Finalize Vehicle Design	1/12/2020	2/20/2020	39
Finalize Payload Design	1/12/2020	2/20/2020	39
Finalize Recovery Design	1/12/2020	2/20/2020	39
Compile FRR	2/20/2020	2/23/2020	3
Proofread and Submit FRR	2/23/2020	2/27/2020	4
FRR Q&A	1/31/2020	1/31/2020	0
FRR Video Teleconfrences	3/6/2020	3/19/2020	13
Launch Week Q&A	3/26/2020	3/26/2020	0
Travel to MSFC	3/31/2020	4/1/2020	1
Pre-LRR	4/1/2020	4/1/2020	0
Launch Week Activities	4/2/2020	4/3/2020	1
Launch Day	4/4/2020	4/4/2020	0
Awards Ceramony	4/4/2020	4/4/2020	0
Travel to TTU	4/4/2020	4/5/2020	1
Work on PLAR	4/7/2020	4/22/2020	15
Compile PLAR	4/15/2020	4/18/2020	3
Proofread and Submit PLAR	4/18/2020	4/22/2020	4

Figure 6.4.1

Appendix I

Federal Aviation Administration Guidelines

Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Amateur Rockets

Subpart C— Amateur Rockets

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§101.21 Applicability.

(a) This subpart applies to operating unmanned rockets. However, a person operating an unmanned rocket within a restricted area must comply with §101.25(b)(7)(ii) and with any additional limitations imposed by the using or controlling agency.

(b) A person operating an unmanned rocket other than an amateur rocket as defined in §1.1 of this chapter must comply with 14 CFR Chapter III.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008]

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§101.22 Definitions.

The following definitions apply to this subpart:

(a) *Class 1—Model Rocket* means an amateur rocket that:

(1) Uses no more than 125 grams (4.4 ounces) of propellant;

(2) Uses a slow-burning propellant;

(3) Is made of paper, wood, or breakable plastic;

(4) Contains no substantial metal parts; and

(5) Weighs no more than 1,500 grams (53 ounces), including the propellant.

(b) *Class 2—High-Power Rocket* means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

(c) *Class 3—Advanced High-Power Rocket* means an amateur rocket other than a model rocket or high-power rocket.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008]

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§101.23 General operating limitations.

(a) You must operate an amateur rocket in such a manner that it:

(1) Is launched on a suborbital trajectory;

(2) When launched, must not cross into the territory of a foreign country unless an agreement is in place between the United States and the country of concern;

(3) Is unmanned; and

(4) Does not create a hazard to persons, property, or other aircraft.

(b) The FAA may specify additional operating limitations necessary to ensure that air traffic is not adversely affected, and public safety is not jeopardized.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008]

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§101.25 Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets.

When operating *Class 2-High Power Rockets* or *Class 3-Advanced High Power* Rockets, you must comply with the General Operating Limitations of §101.23. In addition, you must not operate *Class 2-High Power Rockets* or *Class 3-Advanced High Power* Rockets—

(a) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails;

(b) At any altitude where the horizontal visibility is less than five miles;

(c) Into any cloud;

(d) Between sunset and sunrise without prior authorization from the FAA;

(e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA;

(f) In controlled airspace without prior authorization from the FAA;

(g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:

(1) Not less than one-quarter the maximum expected altitude;

(2) 457 meters (1,500 ft.);

(h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, and has final approval authority for initiating high-power rocket flight; and

(i) Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

[74 FR 38092, July 31, 2009, as amended by Amdt. 101-8, 74 FR 47435, Sept. 16, 2009]

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§101.27 ATC notification for all launches.

No person may operate an unmanned rocket other than a Class 1—Model Rocket unless that person gives the following information to the FAA ATC facility nearest to the place of intended operation no less than 24 hours before and no more than three days before beginning the operation:

(a) The name and address of the operator; except when there are multiple participants at a single event, the name and address of the person so designated as the event launch coordinator, whose duties include coordination of the required launch data estimates and coordinating the launch event;

(b) Date and time the activity will begin;

(c) Radius of the affected area on the ground in nautical miles;

(d) Location of the center of the affected area in latitude and longitude coordinates;

(e) Highest affected altitude;

(f) Duration of the activity;

(g) Any other pertinent information requested by the ATC facility.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008, as amended at Doc. No. FAA-2007-27390, 74 FR 31843, July 6, 2009]

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§101.29 Information requirements.

(a) *Class 2—High-Power Rockets.* When a Class 2—High-Power Rocket requires a certificate of waiver or authorization, the person planning the operation must provide the information below on each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 2 rocket expected to be flown:

(1) Estimated number of rockets,

(2) Type of propulsion (liquid or solid), fuel(s) and oxidizer(s),

(3) Description of the launcher(s) planned to be used, including any airborne platform(s),

(4) Description of recovery system,

(5) Highest altitude, above ground level, expected to be reached,

(6) Launch site latitude, longitude, and elevation, and

(7) Any additional safety procedures that will be followed.

(b) *Class 3—Advanced High-Power Rockets.* When a Class 3—Advanced High-Power Rocket requires a certificate of waiver or authorization the person planning the operation must provide the information below for each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 3 rocket expected to be flown:

(1) The information requirements of paragraph (a) of this section,

(2) Maximum possible range,

(3) The dynamic stability characteristics for the entire flight profile,

(4) A description of all major rocket systems, including structural, pneumatic, propellant, propulsion, ignition, electrical, avionics, recovery, wind-weighting, flight control, and tracking,

(5) A description of other support equipment necessary for a safe operation,

(6) The planned flight profile and sequence of events,

(7) All nominal impact areas, including those for any spent motors and other discarded hardware, within three standard deviations of the mean impact point,

(8) Launch commit criteria,

(9) Countdown procedures, and

(10) Mishap procedures.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008, as amended at Doc. No. FAA-2007-27390, 74 FR 31843, July 6, 2009]

Appendix II *

National Association of Rocketry High Powered Rocketry Safety Code

High Powered Rocketry Safety Code

1. Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
4. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a 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.
5. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will 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.
6. Launch Safety. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.

7. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
8. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
9. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.
10. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. Launcher Location. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 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.
12. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
13. Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to

recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

*The information here came from the NAR High-Powered Rocketry Safety code

Appendix III

What follows is the RAS safety contract which will be signed by every member prior to beginning any hands on work on the team.

Safety Contract:

Rules and regulations:

Behavior and Conduct:

- Horseplay or aggressive actions towards any and all persons at any fabricating or professional will not be tolerated.
- The consumption, possession and the presence of alcohol or other illicit substances will not be tolerated at any professional RAS activity.
- All food and drinks must be kept out of construction zones.
- Access to equipment other than that owned by RAS must be approved by a credible representative of ownership
- Members should NEVER run inside of the workspace building
- NEVER use equipment you are not familiar with and haven't been introduced to by an authorized RAS officer.
- Never work in poor lit areas.
- Keep yourself well balanced and never overreach.
- Never work with material that is broken or unclean.
- Always consult a RAS officer before using any special equipment or setups.
- Never stand near danger zones or close to anyone operating equipment.

General Equipment Behavior:

- Always keep hands, arms, or legs out of the cutting path of equipment.
- Position your body out of harms way while operating any equipment.
- NEVER use faulty equipment that is subject to replacement.
- NEVER test the sharpness or temperature of a tool with an appendage of a body.
- Equipment will be used solely for its functions and are not to be considered toys.
- The appropriate use of tools for a given action must be considered in order to avoid errors in equipment performance and protection.
- Only authorized members may use both the given equipment of the facility and equipment purchased by the organization.
- Equipment is not to be removed from the premises unless for club events or repairs by an approved source.

- Properly use secure support surfaces while operating any equipment in order to ensure safety to both equipment and adjacent people.
- Always store or secure tools away from potential harm to yourself, other person(s), or the equipment itself.
- Cutting edges must be sharp and within operating conditions.
- Equipment should always be adjusted and calibrated before attempting a given task.
- Always consult a RAS officer before making adjustments or performing maintenance to equipment.
- Never force or apply uneven pressure while performing any tasks with equipment.

Cleanup and Awareness:

- Keep workspaces clean and organized.
- Keep aisles clear of loose materials.
- Never use your hand or body parts to remove scraps or shavings away from the equipment operating area.
- Remove any special attachments from the equipment as well as reset both safety guards and standard settings to equipment.
- Do not leave spills or hazardous materials unattended.
- All equipment and tools will be returned to their designated storage area(s)/container(s).
- Maintain cleanliness of equipment to ensure the equipment functions properly.

Clothing Standards and PPE (Personal Protective Equipment):

- Always use proper personal protective equipment while operating any equipment.
- Closed-toe footwear is always required at RAS events.
- Hair should be secured with proper hair accessories.
- Jewelry must be removed before using any equipment.
- No baggy clothing will be worn while using the equipment.
- Non-Synthetic pants must be worn while using equipment.
- Shirts should be tucked in and long sleeves neatly rolled up.
- Do not wear gloves while operating equipment unless handling rough materials.
- Wear ear protection while around working around loud equipment.
- Use proper ventilation and wear masks to avoid breathing in harmful material debris.

Shop Maintenance:

- If you are not certain on cleaning procedures or cannot identify spilled substances, notify a RAS officer immediately.
- Always know where and how to use fire extinguishers.
- Always keep cabinet doors and drawers closed.
- If you disconnect power to a machine at the circuit breaker, use a Lockout Tag Out system or put up a sign: “DO NOT USE”

Chemical Use and Storage:

Chemicals include but are not limited to:

- Potassium Nitrate
- Ammonium Nitrate
- Potassium Chloride
- Liquid Oxygen
- Oxidizers
- Lithium
- Fluorine
- Methane
- Water
- etc.

- All chemicals must be properly secured and stored when not in use.
- Any chemicals with noxious and flammable fumes must remain in airtight containers until directly in use.
- All flammable materials must be properly stored within an approved fire cabinet.
- While handling any dangerous fumes the proper use of the fume hood, masks, goggles, lab coat, and gloves will be mandatory.
- Chemical expiration must be documented and properly disposed of.
- Disposal of chemicals must be done properly and safely according to TTU EHS standards.

Hand Tools:

Tools include but are not limited to:

Non-powered equipment such as: screwdrivers, pliers, hammers, etc.

Hand tools are to be used in a safe manner at all times and should never be used outside of their designed purpose.

Proper maintenance and replacement of hand tools should be exercised by all RAS members.

Power Tools:
Tools include but are not limited to:
- Table saw
- Band saw
- Power drill
- Drill press
- Routing tools
- Sander
- Jigsaw
- Circular saw
- Lathe
- etc.

- Electric Power tools must be grounded or double insulated to prevent electric shock. If the equipment does not meet that standard, it will not be used.
- Double check power tool as been turned off before connecting to a power source to avoid any unintended equipment actions.
- Always make sure equipment has been turned off and unplugged before any adjustments or maintenance is performed.
- Always wait for the machine to reach operating position/speed before use.
- Unplug or turn off any equipment not being used.

Specialized Machine and Equipment
Policies and procedures for any heavy equipment not listed above will be added under this given section as the need arises.

I ______________________hereby agree to all safety terms and conditions listed above as well as the terms and conditions set forth by NAR, Tripoli, Whitacre College of Engineering, and Texas Tech University's code of conduct and operating procedures. I acknowledge that failure to adhere to RAS safety guidelines or those set forth by Whitacre College of Engineering and Texas Tech University may result in my expulsion from the organization pending a review from the safety team and RAS officer board. In addition to expulsion from RAS, I may face additional review and consequences from Texas Tech University.

Printed Name:________________________ R#:__________________
Signature:________________________ Date:______________

Appendix IV

5.1

WEST SYSTEM® 105 Epoxy Resin Safety Data Sheet According to the Hazard

Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015 Date of issue: 6/1/2015 Revision date: 01/25/2019 Version: 105-2019a

Identification Product name : WEST SYSTEM® 105 Epoxy Resin Product code : 105, 105-A, 105-B, 105-C, 105-E, C 105-A, C 105-B, C 105-C, C 105-E
Relevant identified uses of the substance or mixture and uses advised against Recommended use : Resin for coatings or adhesives
Details of the supplier of the safety data sheet
Manufacturer Gougeon Brothers, Inc 100 Patterson Ave. Bay City, MI 48706 - U.S.A. T 866-937-8797 or 989-684-7286
www.westsystem.com
Emergency telephone number Emergency number : CHEMTREC 1 (800) 424-9300
CHEMTREC International +1 (703) 527-3887 24 hr

Classification of the substance or mixture Skin Irrit. 2 Eye Irrit. 2A Skin Sens. 1 Aquatic Chronic 2
Label elements Hazard pictograms (GHS) :
GHS07
GHS09 Signal word (GHS) : Warning Hazard statements (GHS) : Causes skin irritation. May cause an allergic skin reaction. Causes serious eye irritation. Toxic to aquatic life with long lasting effects Precautionary statements (GHS) : Avoid breathing dust, fume, gas, mist, vapours, spray. Wash hands thoroughly after handling. Contaminated work clothing must not be allowed out of the workplace. Avoid release to the environment. Wear protective gloves, protective clothing, eye protection. If on skin: Wash with plenty of soap and water. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If skin irritation or rash occurs: Get medical advice/attention. If eye irritation persists: Get medical advice/attention. Take off contaminated clothing and wash it before reuse. Collect spillage. Dispose of contents/container to hazardous or special waste collection point, in accordance with local, regional, national and/or international regulation
Other hazards No additional information available Unknown acute toxicity Not applicable

Substance Not applicable Mixtures
Name Product identifier HPR % Oxirane, 2,2'-[(1-methylethylidene)bis(4,1-phenyleneoxymethylene)]bis-, homopolymer (CAS No) 25085-99-8 60 - 80
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WEST SYSTEM® 105 Epoxy Resin

Safety Data Sheet

According to the Hazard Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015

Name Product identifier HPR % Benzyl alcohol (CAS No) 100-51-6 10 - 30

Phenol, polymer with formaldehyde, glycidyl ether (CAS No) 28064-14-4 5 - 10

The exact chemical identity and/or exact percentage (concentration) of each ingredient may be held as confidential business information (CBI). Any ingredient not disclosed in this section may have been determined not to be hazardous to health or the environment, or it may be present at a level below its disclosure threshold.

Description of first aid measures First-aid measures after inhalation : If breathing is difficult, remove victim to fresh air and keep at rest in a position comfortable for breathing. Get medical advice/attention if you feel unwell. First-aid measures after skin contact : In case of contact, immediately flush skin with plenty of water. Remove contaminated clothing and shoes. Wash contaminated clothing before reuse. If skin irritation or rash occurs: Get medical advice/attention. First-aid measures after eye contact : In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If easy to do, remove contact lenses, if worn. If irritation persists, get medical attention. First-aid measures after ingestion : If swallowed, do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical advice/attention if you feel unwell.

Most important symptoms and effects, both acute and delayed Symptoms/injuries after inhalation : Not a normal route of exposure. May cause respiratory tract irritation. Symptoms/injuries after skin contact : Causes skin irritation. Symptoms may include redness, edema, drying, defatting and cracking of the skin. May cause an allergic skin reaction. Symptoms/injuries after eye contact : Causes serious eye irritation. Symptoms may include discomfort or pain, excess blinking and tear production, with marked redness and swelling of the conjunctiva. Symptoms/injuries after ingestion : May be harmful if swallowed. May cause stomach distress, nausea or vomiting.

Indication of any immediate medical attention and special treatment needed Symptoms may not appear immediately. In case of accident or if you feel unwell, seek medical advice immediately (show the label or SDS where possible).

Extinguishing media Suitable extinguishing media : Foam. Carbon dioxide. Dry chemical. Unsuitable extinguishing media : Do not use a heavy water stream.

Special hazards arising from the substance or mixture Fire hazard : Products of combustion may include, and are not limited to: oxides of carbon, phenolics. Reactivity : No dangerous reaction known under conditions of normal use.

Advice for firefighters Protection during firefighting : Keep upwind of fire. Wear full fire fighting turn-out gear (full Bunker gear) and respiratory protection (SCBA). Cool closed containers exposed to fire with water spray.

Personal precautions, protective equipment and emergency procedures General measures : Use personal protection recommended in Section 8. Isolate the hazard area and deny entry to unnecessary and unprotected personnel.

For non-emergency personnel No additional information available

For emergency responders No additional information available

Environmental precautions Prevent from entering into soil, ditches, sewers, waterways and/or groundwater. See Section 12, Ecological Information.

Methods and material for containment and cleaning up For containment : Stop leak if safe to do so. Contain and/or absorb spill with inert material (e.g. sand, vermiculite), then place in a suitable container. Do not flush to sewer or allow to enter waterways. Use appropriate Personal Protective Equipment (PPE). Methods for cleaning up : Scoop up material and place in a disposal container. Provide ventilation. Clean contaminated surfaces thoroughly.

Reference to other sections See section 8 for further information on protective clothing and equipment and section 13 for advice on waste disposal.

Precautions for safe handling Precautions for safe handling : Avoid contact with skin and eyes. Avoid breathing dust, fume, gas, mist, vapours, spray. Do not swallow. Handle and open container with care. When using do not eat, drink or smoke. When mixed with epoxy curing agents this product causes an exothermic reaction, which in large masses, can produce enough heat to damage or ignite surrounding materials and emit fumes and vapors that vary widely in composition and toxicity. Hygiene measures : Contaminated work clothing should not be allowed out of the workplace. Launder contaminated clothing before reuse. Wash hands before eating, drinking, or smoking.

Conditions for safe storage, including any incompatibilities Storage conditions : Keep out of the reach of children. Keep container tightly closed. Store in a dry, cool and well- ventilated place. Storage temperature : 40°F (4°C) - 120°F (49°C). Keep away from heat and direct sunlight.

Control parameters

Oxirane, 2,2'-[(1-methylethylidene)bis(4,1-phenyleneoxymethylene)]bis-, homopolymer (25085-99-8) Not applicable

Benzyl alcohol (100-51-6) AIHA WEEL TWA (ppm) 10 ppm

Phenol, polymer with formaldehyde, glycidyl ether (28064-14-4) Not applicable

Exposure controls Appropriate engineering controls : Use ventilation adequate to keep exposures (airborne levels of dust, fume, vapor, etc.) below recommended exposure limits. Hand protection : Wear chemically resistant protective gloves. Eye protection : Wear eye/face protection. Skin and body protection : Wear suitable protective clothing. Respiratory protection : In case of insufficient ventilation, wear suitable respiratory equipment. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator. Environmental exposure controls : Maintain levels below Community environmental protection thresholds. Other information : Do not eat, smoke or drink where material is handled, processed or stored. Wash hands carefully before eating or smoking. Handle according to established industrial hygiene and safety practices.

Information on basic physical and chemical properties Physical state : Liquid Appearance : Viscous Colour : Colourless Odour : Mild Odour threshold : No data available pH : No data available Melting point : No data available

According to the Hazard Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015

Freezing point : No data available Boiling point : > 400 °F (204 °C) Flash point : > 200 °F (93 °C) (estimated based on ingredient data) Relative evaporation rate (butylacetate=1) : No data available Flammability (solid, gas) : Non flammable. Vapour pressure : No data available Relative vapour density at 20 °C : Heavier than air (estimated based on ingredient data) Relative density : 1.15 Solubility : No data available Partition coefficient n-octanol/water : No data available Auto-ignition temperature : No data available Decomposition temperature : No data available Viscosity, kinematic : 869.5 mm2/s @ 68 °F (20 °C) Viscosity, dynamic : No data available Explosive limits : No data available Explosive properties : No data available Oxidising properties : No data available

Other information Bulk density : 9.6 lb/gal (1.15 kg/L)

Reactivity : No dangerous reaction known under conditions of normal use. Chemical stability : Stable under normal storage conditions. Possibility of hazardous reactions : No dangerous reaction known under conditions of normal use. A mass of more than one pound of product plus an aliphatic amine will cause irreversible polymerization with significant heat buildup. Strong acids, bases, amines and mercaptans can cause polymerization. Conditions to avoid : Heat. Incompatible materials. Incompatible materials : Strong acids. Bases. Amines. Mercaptans. Hazardous decomposition products : May include, and are not limited to: oxides of carbon, phenolics.

Information on toxicological effects

Oxirane, 2,2'-[(1-methylethylidene)bis(4,1-phenyleneoxymethylene)]bis-, homopolymer (25085-99-8) LD50 oral rat > 15000 mg/kg LD50 dermal rabbit > 23000 mg/kg

Benzyl alcohol (100-51-6) LD50 oral rat 1620 mg/kg LC50 inhalation rat 4.18 mg/l/4h

Phenol, polymer with formaldehyde, glycidyl ether (28064-14-4) LD50 oral rat > 2000 mg/kg LD50 dermal rat 2000 mg/kg

Acute toxicity (oral) : Not classified. Acute toxicity (dermal) : Not classified. Acute toxicity (inhalation) : Not classified. Skin corrosion/irritation : Causes skin irritation. Serious eye damage/irritation : Causes serious eye irritation. Respiratory or skin sensitization : May cause an allergic skin reaction. Germ cell mutagenicity : Not classified. Carcinogenicity : Not classified. No ingredient of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA, NTP or IARC. Reproductive toxicity : Not classified. STOT-single exposure : Not classified. STOT-repeated exposure : Not classified.

Aspiration hazard : Not classified.

WEST SYSTEM® 105 Epoxy Resin Viscosity, kinematic (calculated value) (40 °C) 869.5 mm2/s @ 68 °F (20 °C)

Symptoms/injuries after inhalation : Not a normal route of exposure. May cause respiratory tract irritation. Symptoms/injuries after skin contact : Causes skin irritation. Symptoms may include redness, edema, drying, defatting and cracking of the skin. May cause an allergic skin reaction. Symptoms/injuries after eye contact : Causes serious eye irritation. Symptoms may include discomfort or pain, excess blinking and tear production, with marked redness and swelling of the conjunctiva. Symptoms/injuries after ingestion : May be harmful if swallowed. May cause stomach distress, nausea or vomiting. Other information : Likely routes of exposure: ingestion, inhalation, skin and eye.

Toxicity Ecology - general : Toxic to aquatic life with long lasting effects.

Benzyl alcohol (100-51-6) LC50 fish 1 460 mg/l (Exposure time: 96 h - Species: Pimephales promelas [static]) EC50 Daphnia 1 23 mg/l (Exposure time: 48 h - Species: water flea) LC50 fish 2 10 mg/l (Exposure time: 96 h - Species: Lepomis macrochirus [static]) Persistence and degradability

WEST SYSTEM® 105 Epoxy Resin Persistence and degradability Not established.
Bioaccumulative potential
WEST SYSTEM® 105 Epoxy Resin Bioaccumulative potential Not established.
Benzyl alcohol (100-51-6) Partition coefficient n-octanol/water 1.1
Mobility in soil No additional information available
Other adverse effects
Effect on the global warming : No known effects from this product.
Name Product identifier Ecotoxicity Classification Information Oxirane, 2,2'-[(1-methylethylidene)bis(4,1-phenyleneoxymethylene)]bis-, homopolymer (CAS No) 25085-99-8 Aquatic Chronic Cat. 2
Benzyl alcohol (CAS No) 100-51-6 Not Classified
Phenol, polymer with formaldehyde, glycidyl ether (CAS No) 28064-14-4 Aquatic Chronic Cat. 2

Waste treatment methods Product/Packaging disposal recommendations

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: This material must be disposed of in accordance with all local, state, provincial, and federal regulations. The generation of waste should be avoided or minimized wherever possible. Ecology - waste materials : Avoid release to the environment.

Department of Transportation (DOT) and Transportation of Dangerous Goods (TDG) In accordance with DOT and TDG Not regulated
Transport by sea In accordance with IMDG UN-No. (IMDG) : 3082

WEST SYSTEM® 105 Epoxy Resin Safety Data Sheet

According to the Hazard Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015

Proper Shipping Name (IMDG) : ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S. (Epoxy Resin) Class (IMDG) : 9 Packing group (IMDG) : III EmS Number : F-A, S-F Marine Pollutant : Yes
Transport by air In accordance with IATA UN-No. (IATA) : 3082 Proper Shipping Name (IATA) : Environmentally hazardous substance, liquid, n.o.s. (Epoxy Resin) Class (IATA) : 9 Packing group (IATA) : III Marine Pollutant : Yes

Federal regulations

All components of this product are listed, or excluded from listing, on the United States Environmental Protection Agency Toxic Substances Control Act (TSCA) inventory.
All components of this product are listed, or excluded from listing, on the Canadian DSL (Domestic Substances List) and NDSL (Non-Domestic Substances List) inventories.
Oxirane, 2,2'-[(1-methylethylidene)bis(4,1-phenyleneoxymethylene)]bis-, homopolymer (25085-99-8) EPA TSCA Regulatory Flag XU - XU - indicates a substance exempt from reporting under the Inventory Update Reporting
Rule, i.e, Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(C)).
Phenol, polymer with formaldehyde, glycidyl ether (28064-14-4) EPA TSCA Regulatory Flag XU - XU - indicates a substance exempt from reporting under the Inventory Update Reporting
Rule, i.e, Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(C)).
Epichlorohydrin (106-89-8) Listed on the United States SARA Section 302 Subject to reporting requirements of United States SARA Section 313 CERCLA RQ 100 lb SARA Section 302 Threshold Planning Quantity (TPQ)

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1000 lb
SARA Section 313 - Emission Reporting 0.1 %
International regulations No additional information available
US State regulations
California Proposition 65 - This product contains, or may contain, trace quantities of a substance(s) known to the state of California to cause cancer, developmental and/or reproductive harm
Epichlorohydrin (106-89-8) U.S. - California - Proposition 65 - Carcinogens List
U.S. - California - Proposition 65 - Developmental Toxicity
U.S. - California - Proposition 65 - Reproductive Toxicity - Female
U.S. - California - Proposition 65 - Reproductive Toxicity - Male
Non-significant risk level (NSRL)
Yes No No Yes 9 µg/day
Benzyl alcohol (100-51-6) U.S. - Pennsylvania - RTK (Right to Know) List
Epichlorohydrin (106-89-8) U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List U.S. - Pennsylvania - RTK (Right to Know) - Special Hazardous Substances U.S. - Pennsylvania - RTK (Right to Know) List

WEST SYSTEM® 105 Epoxy Resin

Safety Data Sheet

According to the Hazard Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015

Issue date
: 6/1/2015 Revision date : 01/25/2019 Version : 105-2019a
Other information : None.

NFPA health hazard : 2 NFPA fire hazard : 1 NFPA reactivity : 1

HMIS III Rating Health : 2 Flammability : 1 Physical : 1

WEST SYSTEM® 206 Slow Hardener Safety Data Sheet

According to the Hazard Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015 Date of issue: 08/15/2016 Revision date: 01/25/2019 Version: 206-2019a

Identification Product name : WEST SYSTEM® 206 Slow Hardener Product code : 206, 206-A, 206-B, 206-C, 206-E, C 206-A, C 206-B, C 206-C, C 206-E

Relevant identified uses of the substance or mixture and uses advised against Recommended use : Curing agent for epoxy resins

Details of the supplier of the safety data sheet Gougeon Brothers, Inc 100 Patterson Ave. Bay City, MI 48706 - U.S.A. T 866-937-8797 or 989-684-7286 www.westsystem.com

Emergency telephone number Emergency number : CHEMTREC 1 (800) 424-9300
CHEMTREC International +1 (703) 527-3887 24 hr

Classification of the substance or mixture Acute Tox. 4 (Oral) Skin Corr. 1B Eye Dam. 1 Skin Sens. 1 STOT SE 3 Aquatic Acute 3 Aquatic Chronic 2
Label elements Hazard pictograms (GHS) :
GHS05
GHS09 Signal word (GHS) : Danger Hazard statements (GHS) : Harmful if swallowed. Causes severe skin burns and eye damage. May cause an allergic skin reaction. May cause respiratory irritation. Harmful to aquatic life. Toxic to aquatic life with long lasting effects Precautionary statements (GHS) : Do not breathe dust, fume, gas, mist, vapours, spray. Wash hands thoroughly after handling. Do not eat, drink or smoke when using this product. Use only outdoors or in a well-ventilated area. Contaminated work clothing must not be allowed out of the workplace. Avoid release to the environment. Wear protective gloves, protective clothing, eye protection, face protection. If swallowed: rinse mouth. Do NOT induce vomiting. If on skin (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower. If inhaled: Remove person to fresh air and keep comfortable for breathing. If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a poison center/doctor. Wash contaminated clothing before reuse. Collect spillage. Store in a well-ventilated place. Keep container tightly closed. Store locked up. Dispose of contents/container to hazardous or special waste collection point, in accordance with local, regional, national and/or international regulation
Other hazards No additional information available Unknown acute toxicity No additional information available
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GHS07

WEST SYSTEM® 206 Slow Hardener

Safety Data Sheet

According to the Hazard Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015

Substance Not applicable Mixtures

Name Product identifier HPR % Propylene glycol diamine, 2-amino-, diether with Propylene (CAS No) 9046-10-0 30 - 60

Diethylenetriamine-bisphenol A-epichlorohydrin polymer (CAS No) 31326-29-1 10 - 30

Tetraethylenepentamine (CAS No) 112-57-2 10 - 30

Diethylenetriamine (CAS No) 111-40-0 7 - 13

1,2-Ethanediamine, N,N'-bis(2-aminoethyl)-, polymer with methyloxirane (CAS No) 26950-63-0 5 - 10

Triethylenetetramine (CAS No) 112-24-3 1 - 5

The exact chemical identity and/or exact percentage (concentration) of each ingredient may be held as confidential business information (CBI). Any ingredient not disclosed in this section may have been determined not to be hazardous to health or the environment, or it may be present at a level below its disclosure threshold.

Description of first aid measures First-aid measures after inhalation : If inhaled and if breathing is difficult, remove victim to fresh air and keep at rest in a position comfortable for breathing. Immediately call a POISON CENTER or doctor/physician. First-aid measures after skin contact : IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower. Wash contaminated clothing before reuse. Immediately call a POISON CENTER or doctor/physician. First-aid measures after eye contact : In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If easy to do, remove contact lenses, if worn. Get medical attention immediately. First-aid measures after ingestion : If swallowed, do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Immediately call a POISON CENTER or doctor/physician.

Most important symptoms and effects, both acute and delayed Symptoms/injuries after inhalation : May cause respiratory irritation. Symptoms/injuries after skin contact : Causes severe burns. Symptoms may include redness, pain, blisters. May cause an allergic skin reaction. Symptoms/injuries after eye contact : Causes serious eye damage. Symptoms may include discomfort or pain, excess blinking

and
tear production, with possible redness and swelling. May cause burns. Symptoms/injuries after ingestion : Harmful if swallowed. May cause burns or irritation of the linings of the mouth, throat, and gastrointestinal tract. May cause stomach distress, nausea or vomiting.

Indication of any immediate medical attention and special treatment needed Symptoms may not appear immediately. In case of accident or if you feel unwell, seek medical advice immediately (show the label or SDS where possible).

Extinguishing media Suitable extinguishing media : Foam. Carbon dioxide. Dry chemical. Unsuitable extinguishing media : Do not use a heavy water stream.

Special hazards arising from the substance or mixture Fire hazard : Products of combustion may include, and are not limited to: oxides of carbon, oxides of nitrogen, amines, ammonia, nitric acid, nitrosamines. When mixed with sawdust, wood chips, or other cellulosic material, spontaneous combustion can occur under certain conditions. Heat is generated as the air oxidizes the amine. If the heat is not dissipated quickly enough, it can ignite the sawdust. Reactivity : No dangerous reaction known under conditions of normal use.

Advice for firefighters Protection during firefighting : Keep upwind of fire. Wear full fire fighting turn-out gear (full Bunker gear) and respiratory protection (SCBA).

Personal precautions, protective equipment and emergency procedures General measures : Use personal protection recommended in Section 8. Isolate the hazard area and deny entry to unnecessary and unprotected personnel.

For non-emergency personnel No additional information available.

For emergency responders No additional information available.

Environmental precautions Prevent from entering into soil, ditches, sewers, waterways and/or groundwater. See Section 12, Ecological Information.

Methods and material for containment and cleaning up For containment : Stop leak if safe to do so. Contain and/or absorb spill with inert material (e.g. sand, vermiculite), then place in a suitable container. Do not flush to sewer or allow to enter waterways. Use appropriate Personal Protective Equipment (PPE). Methods for cleaning up : Scoop up material and place in a disposal container. Provide ventilation.

Reference to other sections See section 8 for further information on protective clothing and equipment and section 13 for advice on waste disposal.

Precautions for safe handling Precautions for safe handling : Do not get in eyes, on skin, or on clothing. Do not breathe vapours, mist. Do not swallow. Handle and open container with care. Do not eat, drink or smoke when using this product. Use only outdoors or in a well-ventilated area. When mixed with epoxy resin this product causes an exothermic reaction, which in large masses, can produce enough heat to damage or ignite surrounding materials and emit fumes and vapors that vary widely in composition and toxicity. Hygiene measures : Launder contaminated clothing before reuse. Wash hands before eating, drinking, or smoking.

Conditions for safe storage, including any incompatibilities Storage conditions : Keep out of the reach of children. Keep container tightly closed. Store in a dry, cool and well-ventilated place. Storage temperature : 40°F (4°C) - 90°F (32°C). Keep away from heat and direct sunlight.

Control parameters

Propylene glycol diamine, 2-amino-, diether with Propylene (9046-10-0)
Not applicable

Diethylenetriamine-bisphenol A-epichlorohydrin polymer (31326-29-1)
Not applicable

Tetraethylenepentamine (112-57-2) AIHA WEEL TWA (ppm) 1 ppm

AIHA WEEL TWA (mg/kg) 5 mg/kg (Skin)

Diethylenetriamine (111-40-0) ACGIH ACGIH TWA (ppm) 1 ppm

1,2-Ethanediamine, N,N'-bis(2-aminoethyl)-, polymer with methyloxirane (26950-63-0)
Not applicable

Triethylenetetramine (112-24-3) AIHA WEEL TWA (ppm) 1 ppm

AIHA WEEL TWA (mg/m^3) 6 mg/m^3 (Skin)

Exposure controls Appropriate engineering controls : Use ventilation adequate to keep exposures (airborne levels of dust, fume, vapor, etc.) below recommended exposure limits.

Hand protection : Wear chemically resistant protective gloves. Eye protection : Wear approved eye protection (properly fitted dust- or splash-proof chemical safety goggles) and face protection (face shield). Skin and body protection : Wear suitable protective clothing. Respiratory protection : In case of insufficient ventilation, wear suitable respiratory equipment. Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator. Environmental exposure controls : Maintain levels below Community environmental protection thresholds. Other information : Do not eat, smoke or drink where material is handled, processed or stored. Wash hands carefully before eating or smoking. Handle according to established industrial hygiene and safety practices.

Information on basic physical and chemical properties Physical state : Liquid Appearance : No data available. Colour : Colourless Odour : Ammonia Odour threshold : No data available pH : 11 Melting point : No data available Freezing point : No data available Boiling point : > 400 °F (204°C) (estimated based on similar product) Flash point : > 200 °F (93°C) (estimated based on similar product) Relative evaporation rate (butylacetate=1) : No data available Flammability (solid, gas) : Not flammable Vapour pressure : < 1 mm Hg @ 20°C (estimated based on ingredient data) Relative vapour density at 20 °C : No data available Relative density : 1.01 Solubility : No data available Partition coefficient n-octanol/water : No data available Auto-ignition temperature : No data available Decomposition temperature : No data available Viscosity, kinematic : 65.6 mm2/s @ 104 °F (40 °C) Viscosity, dynamic : No data available Explosive limits : No data available Explosive properties : No data available Oxidising properties : No data available

Other information VOC content : 9.59 g/L (0.08 lb/gal) Bulk density : 8.45 lb/gal (1.01 kg/L)

Reactivity : No dangerous reaction known under conditions of normal use. Chemical stability : Stable under normal storage conditions. Possibility of hazardous reactions : No dangerous reaction known under conditions of normal use. A mass of more than one pound

of product plus an epoxy resin will cause irreversible polymerization with significant heat buildup and pressure. Conditions to avoid : Heat. Incompatible materials. Incompatible materials : Acids. Oxidizing materials. Halogenated compounds. Hazardous decomposition products : May include, and are not limited to: oxides of carbon. Oxides of nitrogen. Amines. Ammonia.

Nitric acid. nitrosamines.
ETHYLENEDIAMINE.

Information on toxicological effects

Propylene glycol diamine, 2-amino-, diether with Propylene (9046-10-0)
LD50 oral rat 2855 mg/kg LD50 dermal rabbit 2890 mg/kg LC50 inhalation rat > 0.74 mg/l/8h

Diethylenetriamine-bisphenol A-epichlorohydrin polymer (31326-29-1)
LD50 oral rat 500 mg/kg (ATE) LD50 dermal rabbit 1100 mg/kg (ATE)

Tetraethylenepentamine (112-57-2) LD50 oral rat 1600 mg/kg LD50 dermal rabbit 1260 mg/kg

Diethylenetriamine (111-40-0) LD50 oral rat 1620 mg/kg LD50 dermal rabbit 1090 mg/kg LC50 inhalation rat *0.07 - 0.3 mg/l/4h (aerosol/mist)

1,2-Ethanediamine, N,N'-bis(2-aminoethyl)-, polymer with methyloxirane (26950-63-0)
Not applicable

Triethylenetetramine (112-24-3) LD50 oral rat 1716.2 mg/kg
LD50 dermal rabbit 805 mg/kg

* LC_{50} data has been generated for this substance by subjecting rats to an airborne aerosol/mist atmosphere in a test chamber. It has not been determined that this data directly correlates to an inherent hazard of this product as would be expected under normal, foreseeable or anticipated conditions of use.

Acute toxicity (oral) : Harmful if swallowed. Acute toxicity (dermal) : Not classified. Acute toxicity (inhalation) : Not classified. Skin corrosion/irritation : Causes severe skin burns Serious eye damage/irritation : Causes serious eye damage. Respiratory or skin sensitization : May cause an allergic skin reaction. Germ cell mutagenicity : Not classified. Carcinogenicity : Not classified. No ingredient of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA, NTP or IARC. Reproductive toxicity : Not classified. STOT-single exposure : May cause respiratory irritation. STOT-repeated exposure : Not classified. Aspiration hazard : Not classified.

WEST SYSTEM® 206 Slow Hardener Viscosity, kinematic (calculated value) (40 °C) 65.6 mm2/s @ 104 °F (40 °C)

Potential adverse human health effects and symptoms

Symptoms/injuries after inhalation : May cause respiratory irritation. Symptoms/injuries after skin contact : Causes severe burns. Symptoms may include redness, pain, blisters. May cause an allergic skin reaction. Symptoms/injuries after eye contact : Causes serious eye damage. Symptoms may include discomfort or pain, excess blinking and tear production, with possible redness and swelling. May cause burns. Symptoms/injuries after ingestion : Harmful if swallowed. May cause burns or irritation of the linings of the mouth, throat, and gastrointestinal tract. May cause stomach distress, nausea or vomiting. Other information : Likely routes of exposure: ingestion, inhalation, skin and eye.

Toxicity Ecology - general : Toxic to aquatic life with long lasting effects.

Tetraethylenepentamine (112-57-2) LC50 fish 1 420 mg/l (Exposure time: 96 h - Species: Poecilia reticulata [static]) EC50 Daphnia 1 24.1 mg/l (Exposure time: 48 h - Species: Daphnia magna)

Diethylenetriamine (111-40-0) LC50 fish 1 248 mg/l (Exposure time: 96 h - Species: Poecilia reticulata [static]) EC50 Daphnia 1 16 mg/l (Exposure time: 48 h - Species: Daphnia magna) LC50 fish 2 1014 mg/l (Exposure time: 96 h - Species: Poecilia reticulata [semi-static])

Triethylenetetramine (112-24-3) LC50 fish 1 570 mg/l (Exposure time: 96 h - Species: Poecilia reticulata [semi-static]) EC50 Daphnia 1 31.1 mg/l (Exposure time: 48 h - Species: Daphnia magna) LC50 fish 2 495 mg/l (Exposure time: 96 h - Species: Pimephales promelas)

Persistence and degradability

WEST SYSTEM® 206 Slow Hardener Persistence and degradability Not established.

Bioaccumulative potential

WEST SYSTEM® 206 Slow Hardener Bioaccumulative potential Not established.

Tetraethylenepentamine (112-57-2) BCF fish 1 (no bioaccumulation expected) Partition coefficient n-octanol/water < 1

Diethylenetriamine (111-40-0) BCF fish 1 0.3 - 1.7 Partition coefficient n-octanol/water -1.3

Triethylenetetramine (112-24-3) BCF fish 1 (no bioaccumulation expected) Partition coefficient n-octanol/water -1.4

Mobility in soil

WEST SYSTEM® 206 Slow Hardener Ecology - soil No additional information available.

Other adverse effects

Effect on the global warming : No known effects from this product.

Name Product identifier Ecotoxicity Classification Information Propylene glycol diamine, 2-amino-, diether with Propylene (CAS No) 9046-10-0

Acute Aquatic Cat. 3; Chronic Aquatic Cat. 2
Diethylenetriamine-bisphenol A-epichlorohydrin polymer (CAS No) 31326-29-1 Not classified
Tetraethylenepentamine (CAS No) 112-57-2 Acute Aquatic Cat. 2; Chronic Aquatic Cat. 2
Diethylenetriamine (CAS No) 111-40-0 Not classified
1,2-Ethanediamine, N,N'-bis(2-aminoethyl)-, polymer with methyloxirane (CAS No) 26950-63-0 Not classified
Triethylenetetramine (CAS No) 112-24-3 Acute Aquatic Cat. 2; Chronic Aquatic Cat. 2
Other information : Avoid release to the environment.

Waste treatment methods Product/Packaging disposal recommendations

: This material must be disposed of in accordance with all local, state, provincial, and federal regulations. The generation of waste should be avoided or minimized wherever possible. Avoid release to the environment.

Department of Transportation (DOT) and Transportation of Dangerous Goods (TDG) In accordance with DOT and TDG UN-No.(DOT/TDG) : UN2735

Proper Shipping Name (DOT/TDG) : Polyamines, liquid, corrosive, n.o.s. (Polyoxypropylenediamine) Class (DOT/TDG) : 8 Packing group (DOT/TDG) : II Marine pollutant : No

Transport by sea In accordance with IMDG UN-No. (IMDG) : 2735 Proper Shipping Name (IMDG) : POLYAMINES, LIQUID, CORROSIVE, N.O.S. (Polyoxypropylenediamine) Class (IMDG) : 8 Packing group (IMDG) : II EmS Number : F-A, S-B Marine pollutant : Yes

Transport by air In accordance with IATA UN-No. (IATA) : 2735 Proper Shipping Name (IATA) : Polyamines, liquid, corrosive, n.o.s. (Polyoxypropylenediamine) Class (IATA) : 8 Packing group (IATA) : II Marine pollutant : Yes

Federal regulations

All components of this product are listed, or excluded from listing, on the United States Environmental Protection Agency Toxic Substances Control Act (TSCA) inventory.

All components of this product are listed, or excluded from listing, on the Canadian DSL (Domestic Substances List) and NDSL (Non-Domestic Substances List) inventories.

Propylene glycol diamine, 2-amino-, diether with Propylene (9046-10-0) EPA TSCA Regulatory Flag XU - XU - indicates a substance exempt from reporting under the Inventory Update Reporting
Rule, i.e, Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(C)).

Diethylenetriamine-bisphenol A-epichlorohydrin polymer (31326-29-1) EPA TSCA Regulatory Flag XU - XU - indicates a substance exempt from reporting under the Inventory Update Reporting
Rule, i.e, Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(C)).

1,2-Ethanediamine, N,N'-bis(2-aminoethyl)-, polymer with methyloxirane (26950-63-0) EPA TSCA Regulatory Flag XU - XU - indicates a substance exempt from reporting under the Inventory Update Reporting
Rule, i.e, Partial Updating of the TSCA Inventory Data Base Production and Site Reports (40 CFR 710(C)).

Propylene oxide (75-56-9) Listed on the United States SARA Section 302 CERCLA RQ 100 lb SARA Section 302 Threshold Planning Quantity (TPQ)

10000 lb
SARA Section 313 - Emission Reporting 0.1 %
International regulations No additional information available

WEST SYSTEM® 206 Slow Hardener Safety Data Sheet

According to the Hazard Communication Standard (CFR29 1910.1200) HazCom 2012 and the Hazardous Products Regulations (HPR) WHMIS 2015

US State regulations
Propylene oxide (75-56-9) U.S. - California -
U.S. - California - Proposition 65 -
Proposition 65 - Carcinogens List
Developmental Toxicity

U.S. - California - Proposition 65 - Reproductive Toxicity - Female
U.S. - California - Proposition 65 - Reproductive Toxicity - Male
Non-significant risk level (NSRL)
Yes No No No
Tetraethylenepentamine (112-57-2) U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK

(Right to Know) List
Diethylenetriamine (111-40-0) U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK (Right to Know) List
Triethylenetetramine (112-24-3) U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK (Right to Know) List
Propylene oxide (75-56-9) U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List U.S. - Pennsylvania - RTK (Right to Know) - Special Hazardous Substances U.S. - Pennsylvania - RTK (Right to Know) List

Date of issue : 08/15/2016 Revision date : 01/25/2019 Version : 206-2019a Other information : None.
NFPA health hazard : 3 NFPA fire hazard : 1 NFPA reactivity : 0
HMIS III Rating Health : 3 Flammability : 1 Physical : 0

Disclaimer: We believe the statements, technical information and recommendations contained herein are reliable, but they are given without warranty or guarantee of any kind. The information contained in this document applies to this specific material as supplied. It may not be valid for this material if it is used in combination with any other materials. It is the user's responsibility to satisfy oneself as to the suitability and completeness of this information for the user's own particular use.

5.2

1 SAFETY DATA SHEET-BLACK POWDER

Section 1: Identification Product Identifier: Black Powder (includes all grades) Manufacturer's Name: GOEX Powder, Inc. Informational Telephone Number:1-(318) 382-9300 Address: P.O. Box 659
Emerg. Phone Number: 1-(800) 255-3924 (Chem Tel) Doyline, LA 71023-0659 Recommended Use: for use in competitive and recreational shooting, muzzleloading hunting and the U.S. Military .
Section 2: Hazard(s) Identification
Hazard category:
Signal Word
Hazard statement Pictogram Division 1.1
Danger
Explosive; mass explosion hazard
Target Organ Warning: Above OSHA levels, chronic exposure may cause skin irritation and damage to the respiratory system, and acute exposure can cause skin, eye, and respiratory irritation.
Section 3: Composition/information on ingredients
Component CAS-Number Weight % Charcoal
16291-96-6
8-18% Sulfur
7704-34-9 Potassium Nitrate
7757-79-1
Section 4: First-aid measures
Ingestion:
* Not a likely route of exposure. If ingested, dilute by giving two glasses of water and induce vomiting.
* Not a likely route of exposure. Flush eyes with water. * Remove patient from area to fresh air. If not breathing, give artificial respiration, preferably by mouth
* wash the affected area with copious amounts of water. Some persons may be sensitive to product. Injury from detonation: * Seek prompt medical attention immediately. Note to Physician:
* Treat symptomatically.
Section 5: Fire-fighting measures Extinguishing media: * Water may be used as the extinguishing method. DO NOT FIGHT EXPLOSIVES FIRES. Evacuate the

area according to Emergency Response Guide 112 guidelines. Isolate the area and guard against any intruders.
Special Procedures: * Black Powder is extremely flammable and may deflagrate. Get away and evacuate the area. Unusual

Hazards: * As with any pyrotechnic, if under confinement or piled in slight confinement, Black Powder can explode.

No known toxic fumes are emitted, but good ventilation should still be present.
Flash Point:
not applicable. Auto ignition Temp:

NFPA Ratings: Health=1 Flammability=3 Reactivity=1 Advice and PPE for Firefighters: * Fires involving Black Powder should not be fought unless extinguishing media can be

applied from a well protected and distant location from the point of fire. Self-contained breathing apparatus (SCBA) and protective clothing must be worn. Follow Emergency Response Guide 112. Wash all clothes prior to reuse.
9-20% 70-76% Graphite (note: not contained in all grades of black powder)
7782-42-5 <1%
Avoid, when possible and contact a Poison control center for advice on treatment, if unsure. Eye Contact: Inhalation:
Skin Contact:
to mouth. If breathing is difficult, give oxygen. Seek prompt medical attention. Avoid when possible.
Approximate range: 392º -867^{0}F /(200º-464ºC)

2 SAFETY DATA SHEET-BLACK POWDER

Section 6: Accidental release measures Personal precautions, protective equipment and emergency procedures: *
Non-flammable or flame retardant clothing should be worn when cleaning up spilled material. Material is sensitive to ignition from sources such as heat, flame, impact, friction or sparks. Therefore, non-sparking utensils should be used.
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.
Environmental precautions: * Clean up spills immediately using non-sparking utensils Do not dispose of in the ground. * Spill residues may be disposed of per guidelines under Section 13: Disposal Considerations.
Section 7: Handling and storage
Storage Conditions: * Store in a cool, dry place in accordance with requirements of 27CFR555.201-555.219 (ATF Subpart K) * Avoid heat, impact, friction and static. Protect against heat effects. Keep away from heat, open flame and ignition sources. * Absolutely no smoking around open powder or packages. Keep away from combustibles. Avoid electrostatic charges. * Store in a cool, dry place Do not store in the same area with highly combustible materials. * Keep containers closed at all times when not being used. Keep out of reach of children. Open and handle container with care. * Follow all local, state and federal laws when storing this product.
Section 8: Exposure controls/personal protection Personal protection for routine use: * Respiratory protection is not normally needed. If significant dusting occurs, a NIOSH approved dust mask should be worn. Good ventilation is recommended when working with Black Powder. Gloves may be worn to protect skin. Safety glasses with side shields are recommended for eye protection. Flame retardant outerwear such as coveralls or lab coat may be worn.

Health Hazards (Acute or chronic): * TLV is unknown for ingestion of dust.

Signs/Symptoms of Exposure: * Burning or itching of the eyes, nose or skin; shortness of breath. First Aid Procedures:
* Remove the patient from exposure and if skin contact, wash the affected area with water
Section 9: Physical and chemical properties
Physical State:
Granular powder
Solubility: Good in water pH: 6.0-8.0 Vapor Pressure/Density: not applicable Appearance:
Black in color
392º -867º F /200º -464º C Odor:
No odor detectable
Boiling Point: Not applicable
Section 10: Stability and reactivity General Information:
Section 11: Toxicological information * LD_{50} Values: unknown * TLV unknown for ingestion of dust. Some persons may be

unusually sensitive to the product. * None of the components of Black Powder are listed as a carcinogen by NTP, IARC or OSHA.
Section 12: Ecological information
* Do not dispose of powder or residues into any water streams or bodies of water. Avoid spilling powders onto any soils. Clean up any spills promptly. * No known adverse effects on marine or other aquatic organisms.
Auto-ignition Temp.:

* Loading data and the instructions for loading must be observed. Hazardous decomposition: * Detonation produces hazardous

overpressures and fragments (if confined). Gases produced may be toxic

if exposed in areas with inadequate ventilation. Conditions to Avoid: Avoid heat, impact, friction or static. Protect against heat

effects. Keep away from heat, open flame and
ignition sources. A violent burn or deflagration could occur by above mentioned items. Substances to Avoid:
Avoid contact with alkaline substances or strong acids.
* Routes of entry include Skin, Inhalation and Ingestion. (Acute Toxicity=Category 4) per Table A.1.1 of 29CFR1910.1200

3 SAFETY DATA SHEET-BLACK POWDER

Section 13: Disposal considerations * Care must be taken to prevent environmental contamination from the use of this material. The user has the responsibility to dispose of unused material, residues and containers in compliance with all relevant laws and regulations regarding treatment, storage and disposal for hazardous and non-hazardous waste. Powder can be burned in very small quantities and in very thin layer and must only be ignited from a safe distance. 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 RCRA (40CFR Parts 260-271).
* Do not dispose of the black powder container into a fire.
Section 14: Transport information Label required: Explosive
Highway:
Class or division: UN Number:
Maritime IMDG
Class or division: UN Number: Shipping Name:
1.1D or 4.1 Flam Solid-(if <100 pounds). UN0027 (NA0027 for 4.1 Flam Solid) Shipping Name: Black Powder Air Transport: Forbidden!
1.1D UN0027 Black Powder
Section 15: Regulatory information * All products related to Black Powder are reported annually as per Community Right-to Know (Tier II). Black Powder has been approved by PHMSA and copies of the approvals are on file with Environmental, Health and Safety Manager.
Section 16: Other information Prepared By: Mark Wendt, Environmental, Health and Safety Manager email: mwendt@hodgdon.com SDS Creation Date:
April 1, 2014 SDS Print Date:
April 1, 2014 Disclaimer:

The information provided on this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

5.3

Lithium Polymer Battery Safety Data Sheet

Version: 2.8

Product Name Synonyms

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: :

Li-Polymer Battery LiPo – [See APPENDIX A]
Use of the substance/preparation : Lithium polymer rechargeable cells
Company identification : Vertical Partners West
14028 North Ohio Street Rathdrum, ID 83858
Telephone number for information
24 hour emegency contact

: :

1-800-705-0620 (USA)
Chemtrec 1-800-424-9300

2.1. OSHA Regulatory Status The batteries are hermitically sealed articles under normal conditions of use. The products referenced herein are exempt articles and are not subject to OSHA's Hazard Communication Standard requirements for preparation of safety data sheets. This information is provided as a service to our customers.

2.2. Potential health effects Lithium cobalt oxide: Odorless blue-black powder - cobalt and cobalt compounds are considered to be possible human carcinogens. By International Agency for Research on Cancer (IARC): May irritate eyes, skin, nose, throat and respiratory system and may cause allergic skin sensitization.

Carbon: Odorless black powder - no cases of carbon being harmful to humans have been reported. World Health Organization (WHO), and International Labour Organization (ILO) have never verified that carbon causes irritation of the skin and mucous membrane, etc.

Electric agent: Black powder (Garlic-Like), Toxicity (Am. Conf. Of Gov. Ind. Hygienists ACGIH 2000 Edition) - Simple Asphyxiant, Flammability limits in air (STP conditions): 2.4-83vol% (The upper limit could reach 100%)

Bond: Odorless white powder - inhalation and skin contact are expected to be the primary routes of occupational exposure to this material. As a finished product, it is a synthetic, high molecular weight polymer. Due to its chemical and physical properties, this material does not require special handing other than the good industrial hygiene and safety practices employed with any industrial material of this type. Under normal processing conditions this material releases fume or vapor. Components of these releases may vary with processing time and temperature. Process releases may produce eye, skin and/respiratory tract irritation and with repeated or prolonged exposures, nausea, drowsiness, headache and weakness. Although unlikely under normal handling conditions, if this material is heated in excess of 600°F (315°C), hazardous, decomposition products will be produced. Hazardous decomposition products include hydrogen fluoride and oxides of carbon, the concentrations of which vary with temperature and heating regimens.

Electrolyte: Colorless liquid - may cause moderate to severe irritation, burning, and dryness of the skin. May cause eye irritation or burning. Breathing of the mists, vapors or fumes may irritate the nose, throat and lungs. Exposure of material with areas which contain water may generate hydrofluoric acid which can cause immediate burns on skin, severe eye burns to the mouth and gastrointestinal tract if inhaled. Direct exposure to areas of the body needs to be treated immediately to prevent injury.

2.3. Potential environmental effects No additional information available.

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Name CAS number % Carbon (C) 133-86-4 10-25 Lithium-polymer Cobalt Oxide ($LCoO_2$) 12057-24-8

1308-04-9 20-40 Lithium-Polymr Hexafluorophosphate ($LiPF_6$)

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21340-40-3 1.4

Organic Carbonates (EC/EMC/DEC) N/A 8-18 Polyvinylidene Fluoride (PVDF) 24937-79-9 1-5 PP+PE 9003-07-0

9002-8804 4-6 Copper (Cu) 7440-50-8 15-30 Aluminum (Al) 7429-50-5 10-20 Nickel 7440-02-0 0.5-1

4.1. First aid procedures First-aid measures general : The following first aid measures are required in the case of exposure to interior battery components after damage of the external battery casing. Undamaged, closed cells do not represent a danger to health. First-aid measures after inhalation : Assure fresh air breathing. If breathing difficulty or discomfort occurs and persists, see a physician. If breathing stops, give artificial respiration and see a physician immediately. First-aid measures after skin contact : Remove contaminated clothing and thoroughly wash with soap and plenty of water. If irritation persists, consult a physician. First-aid measures after eye contact : Rinse thoroughly with plenty of water for at least 15 minutes. If symptoms persist contact a physician. First-aid measures after ingestion : Contents of an open battery can cause serious chemical burns of mouth, esophagus, and gastrointestinal tract. If open battery is ingested, do not induce vomiting or give food or drink. Seek medical attention immediately.

5.1. Extinguishing media Hazardous combustion: When burned, hazardous products of combustion including fumes of carbon monoxide, carbon dioxide, and fluorine can occur.
Fire and explosion: This material does not represent an unusual fire or explosion hazard.
Flash point: N/A
Auto ignition: N/A
Flammability limits: N/A
5.2. Extinguishing media Suitable extinguishing media : Carbon dioxide, dry chemical or foam Protection during firefighting : Wear protective clothing and self-contained breathing apparatus to avoid fume inhalation.

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6.1. Personal precautions Evacuate personnel to safe areas, ventilate the area. Refer to protective measure listed in section 7 and 8.

6.1.1. For non-emergency personnel Emergency procedures : Evacuate unnecessary personnel.

6.1.2. For emergency responders Protective equipment : Inhalation of any vapor that may be emitted should be avoided. Wear self-contained breathing apparatus to avoid fume inhalation. Rubber gloves should be used to handle the contents of crushed or opened batteries.

6.2. Environmental precautions Sweep up and place in a suitable container, dispose of waste according to local, state and federal laws and regulations.

7.1. Handling Battery charge: Charge according to manufacturer’s specifications.

Battery disassembly: The batteries should never be disassembled, or mechanically abused. Should a battery unintentionally be crushed or opened, thus releasing its content, rubber gloves should be used to handle battery components. The inhalation of any vapor that may be emitted should be avoided.

Short circuiting of a battery: As with any battery, short circuit causes heating. In addition, short circuit reduces the life of the battery and can lead to ignition of surrounding materials. Physical contact with a short-circuited battery can cause skin burns.

Reverse polarity: Avoid reversing the battery polarity of a battery pack, which can cause the battery to be damaged and potentially cause a fire.

7.2. Storage Storage conditions : Store in a cool, dry and ventilated area. Do not place the battery near heating equipment, or expose to direct sunlight for long periods of time. Elevated temperatures can result in shortened battery life and degrade performance.

Personal protective equipment : None required under normal use.

Eye protection : Use ANSI approved chemical work safety goggles or face shield, when handling a leaking or ruptured battery. Skin protection : Use rubber apron and protective gloves if working with or handling a ruptured battery.

Hand protection : In case of spill use PVC, neoprene or nitrile gloves of 15 miles (0.015 inch) or thicker.

Work hygienic practice : Use good chemical hygiene practice. Wash hands after use and before drinking, eating or smoking. Wash hands thoroughly after cleaning-up a battery spill caused by leaking battery. No eating, drinking, or smoking in battery storage area. Launder contaminated cloth before re-use.

Supplementary safety and health data : If the battery case is broken or cells leaking, the main hazard is the electrolyte. The electrolyte is a solution of $LiPF_6$, EC, EMC and DEC.

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Physical state : Solid article Freezing point : N/A Boiling point : N/A
Density : N/A Vapor pressure : N/A Vapor density : N/A Flash point :
N/A Evaporation rate : N/A

10.1.
Stability Stable during normal operating conditions.

10.2. Conditions to avoid Keep away from open flames, hot surfaces, and sources of ignition. Do not puncture, crush, or incinerate.

10.3. Incompatible materials Incompatible with water, moisture, strong oxidizing agents, reducing agents, acids and bases.

10.4. Hazardous decomposition products None, under normal operating conditions. Carbon dioxide and hydrogen fluoride gas may be generated during combustion of battery.

Not applicable under normal conditions of use. Chemicals within the battery have the following properties: Cobalt in lithium cobalt oxide is considered as a class 2B carcinogen by IARC. Organic carbonated (electrolyte) vapors are categorized as corrosive, flammable and irritants.

12.1 Ecotoxicity The batteries when properly used or disposed of do not present environmental hazard. The batteries do not contain mercury, cadmium or lead.

Do not let internal components enter marine environment. Avoid release to waterways, wastewater or groundwater.

13.1. Waste treatment methods Do not incinerate. Waste disposal must be in accordance with any and all applicable regulations. Disposal of lithium rechargeable batteries should be performed by permitted, professional disposal firms knowledgeable in federal, state or local requirements. Lithium batteries should be discharged to 0.00mAh prior to disposal.

14.1.
Basic shipping description UN3480
Lithium ion batteries, Class 9

14.2 Additional information Other information : These batteries must be prepared for transportation as defined by DOT, IATA, and IMDG regulations based on the mode of transportation.

This consignment has passed UN 38.3 test report.

Customer service telephone number for information: 1-800-705-0620

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Section IA Section IB Section II Capacity of Cell/Batteries

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Cells: greater than 20 Wh
Batteries: greater than 100 Wh
Cells: no more than 20 Wh
Batteries: no more than 100 Wh
* Cell/Batteries: no more than 2.7 Wh
* Cells: more than 2.7 but no more than 20 Wh
* Batteries: more than 2.7 Wh but not more than 100 Wh Package Limitation
PAX: 5 kg
CAO: 35 kg
10 kg Gross * 2.5 kg
* 8 cells
* 2 batteries
*must not be loaded in same package

The transportation of the lithium batteries is regulated by the United Nations ”Model Regulations on Transport of Dangerous Goods”.
Exceptions from shipping requrements for lithium cells and batteries are provided in 49 CFR 173.185.
Shipping of lithium batteries in aircrafts are regulated by the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) requirements. See special provision A88.
Shipping of lithium batteries by vessel are regulated by the International Maritime Dangerous Goods (IMDG).

The information and recommendations set forth are made in good faith and are believed to be accurate at the date of preparation. Venom makes no warranty expressed or implied with respect to this information. Venom does not accept liability for any loss or damage that may occur, whether direct, incidental or consequential, from the use of this information.

Safety Data Sheet

APPENDIX A

ITEM DESCRIPTION ITEM DESCRIPTION
1549 20C 2S 8000mAh 7.4V LiPo Hard Case - UNI 15203 35C 3S 1500mAh 11.1V LiPo – UNI 2.0-L
1551 10C 3S 800mAh 11.1V LiPo - Micro/Molex 15204 50C 4S 7000mAh 14.8V LiPo – UNI 2.0-L
1552 30C 3S 7500mAh 11.1V LiPo - UNI 2.0-L 15307 15C 3S 1200mAh 11.1V LiPo Stick - Airsoft
1553 20C 2S 3200mAh 7.4V LiPo Hardcase - UNI
2.0-L 15308 30C 3S 1500mAh 11.1V LiPo - Airsoft
1554 20C 2S 4000mAh 7.4V LiPo Hardcase - UNI
2.0-L 15309 30C 2S 1200mAh 7.4V LiPo - Airsoft
1555 20C 2S 5000mAh 7.4V LiPo Hardcase - UNI

2.0-L 15310 30C 2S 1500mAh 7.4V LiPo - Airsoft
1556 25C 2S 3300mAh 7.4V LiPo Hard Case - UNI 25001X2 45C 1S 180mAh 3.7V LiPo - JST-MCX x2
1557 25C 2S 4100mAh 7.4V LiPo Hardcase - UNI
2.0-L 25001X4 45C 1S 180mAh 3.7V LiPo - JST-MCX x4
1558 25C 2S 5000mAh 7.4V LiPo Hardcase - UNI
2.0-L 25002 30C 2S 430mAh 7.4V LiPo - JST/JST-PH
1558HXT4 25C 2S 5000mAh 7.4V LiPo Hard Case - HXT4 25003 2S 4000mAh 7.4V Transmitter LiPo - Spektrum
1559 10C 2S 1600mAh 7.4V LiPo Receiver Flat Pack 25004 30C 4S 2200mAh 14.8V LiPo - UNI 2.0
1560 10C 2S 1200mAh 7.4V LiPo Receiver Pack 25005 30C 2S 1300mAh 7.4V LiPo - UNI 2.0
1577 20C 3S 2200mAh 11.1V LiPo - UNI 2.0-L 25007 30C 3S 3200mAh 11.1V LiPo - UNI 2.0
1577HXT 20C 3S 2100mAh 11.1V LiPo - HXT 3.5mm 25008 30C 1S 30mAh 3.7V LiPo - JST-MCX
1580 20C 3S 4000mAh 11.1V LiPo - UNI 2.0-L 25009 30C 1S 70mAh 3.7V LiPo - JST-MCX
1581 20C 3S 5400mAh 11.1V LiPo - UNI 2.0-L 25010 30C 1S 200mAh 3.7V LiPo - JST-MCPX
1582 20C 3S 5000mAh 11.1V LiPo - UNI 2.0-L 25011 30C 1S 250mAh 3.7V LiPo - JST-MCX
1584 25C 1S 150mAh 3.7V LiPo - Blade/MCX 25012 30C 1S 500mAh 3.7V LiPo - Mini Losi/JST
1585 15C 2S 250mAh 7.4V LiPo 25013 30C 4S 3200mAh 14.8V LiPo - UNI 2.0
1587 20C 3S 950mAh 11.1V LiPo - Micro Jet 25014 30C 2S 300mAh 7.4V LiPo - JST/JST-PH
15000 5C 2S 2400mAh 7.4V LiPo
Receiver/Transmitter Flat pack 25015 30C 6S 3200mAh 22.2V LiPo - UNI 2.0
15001 5C 2S 2100mAh 7.4V LiPo
Receiver/Transmitter Hump pack 25016 30C 4S 3600mAh 14.8V LiPo - UNI 2.0
15002 20C 2S 430mAh 7.4V LiPo - JST 25017 30C 5S 3600mAh 18.5V LiPo - UNI 2.0
15003 20C 2S 800mAh 7.4V LiPo - JST 25018 30C 6S 3600mAh 22.2V LiPo - UNI 2.0
15004 20C 4S 2100mAh 14.8V LiPo Starter Box-
Tamiya 25019 30C 4S 5000mAh 14.8V LiPo - UNI 2.0
15005 13C 2S 1320mAh 7.4V LiPo - JST 25020 30C 5S 5000mAh 18.5V LiPo - UNI 2.0
15006 13C 3S 1320mAh 11.1V LiPo - UNI 25021 30C 6S 5000mAh 22.2V LiPo - UNI 2.0
15007 20C 3S 3200mAh 11.1V LiPo - UNI 25023 30C 2S 2000mAh 7.4V LiPo - UNI 2.0
15008 20C 2S 5400mAh 7.4V LiPo - UNI 2.0-L 25024 30C 2S 800mAh 7.4V LiPo - JST
15009 20C 3S 6400mAh 11.1V LiPo - UNI 2.0-L 25025 30C 6S 2500mAh 22.2V LiPo - UNI 2.0
15010 20C 2S 8000mAh 7.4V LiPo - UNI 25026 30C 3S 450mAh 11.1V LiPo - JST
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ITEM DESCRIPTION ITEM DESCRIPTION
15011 5C 3S 3000mAh 11.1V Receiver/Transmitter
LiPo MX3 25027 70C 3S 450mAh 11.1V LiPo - JST
15012 5C 3S 2400mAh 11.1V Receiver/Transmitter
LiPo Z1/Helios 25028 30C 3S 1300mAh 11.1V LiPo - UNI 2.0
15013 30C 4S 3200mAh 14.8V LiPo 25031 50C 6S 1300mAh 22.2V LiPo - UNI 2.0
15015 30C 6S 3200mAh 22.2V LiPo 25032 30C 6S 5400mAh 22.2V LiPo - UNI 2.0
15016 25C 4S 3600mAh 14.8V LiPo 25033 50C 3S 2200mAh 11.1V LiPo - UNI 2.0
15017 25C 5S 3600mAh 18.5V LiPo 25034 25C 3S 2300mAh 11.4V LiHV - UNI 2.0
15018 25C 6S 3600mAh 22.2V LiPo 25035 25C 4S 2300mAh 15.2V LiHV - UNI 2.0
15019 25C 4S 5000mAh 14.8V LiPo 25036 25C 4S 3400mAh 15.2V LiHV - UNI 2.0
15020 25C 5S 5000mAh 18.5V LiPo 25042 50C 6S 2500mAh 22.2V LiPo - UNI 2.0
15021 25C 6S 5000mAh 22.2V LiPo 25043 50C 4S 3600mAh 14.8V LiPo - UNI 2.0
15023 20C 2S 2000mAh 7.4V LiPo - UNI 2.0-L 25045 50C 6S 3600mAh 22.2V LiPo - UNI 2.0
15024 20C 3S 1300mAh 11.1V LiPo - UNI 2.0-L 25046 50C 4S 5000mAh 14.8V LiPo - UNI 2.0

15025 25C 6S 2500mAh 22.2V LiPo 25047 50C 5S 5000mAh 18.5V LiPo - UNI 2.0
15026 35C 3S 5000mAh 11.1V LiPo - UNI 2.0-L 25048 50C 6S 5000mAh 22.2V LiPo - UNI 2.0
15027 35C 4S 5000mAh 14.8V LiPo Hardcase ROAR
- UNI 2.0-L 25049 30C 3S 2800mAh 11.1V LiPo - UNI 2.0-A
15031 50C 4S 5000mAh 14.8V LiPo Hardcase ROAR
- UNI 2.0-L 25051 30C 3S 800mAh 11.1V LiPo - JST
15032 50C 2S 4500mAh 7.4V LiPo Saddle Pack
ROAR - UNI 25052X2 45C 1S 250mAh 3.7V LiPo - JST-MCX x2
15033 40C 3S 2200mAh 11.1V LiPo - UNI 25052X4 45C 1S 250mAh 3.7V LiPo - JST-MCX x4
15036 50C 1S 5000mAh 3.7V LiPo Hard Case ROAR
- UNI 25053 30C 3S 2200mAh 11.1V Graphene LiPo - UNI 2.0-A
15037 50C 3S 2200mAh 11.1V LiPo - UNI 25054 30C 3S 3200mAh 11.1V Graphene LiPo - UNI 2.0-A
15038 30C 3S 3200mAh 11.1V LiPo Hard Case ROAR
- UNI 25055 30C 4S 2200mAh 14.8V Graphene LiPo - UNI 2.0-A
15038HXT4 30C 3S 3200mAh 11.1V LiPo Hard Case -
HXT4 25077 30C 3S 2200mAh 11.1V LiPo - UNI 2.0
15042 50C 6S 2500mAh 22.2V LiPo 25084 30C 1S 150mAh 3.7V LiPo - JST-MCX
15043 50C 4S 3600mAh 14.8V LiPo 25087 30C 3S 950mAh 11.1V LiPo - JST
15045 50C 6S 3600mAh 22.2V LiPo 25146 30C 2S 210mAh 7.4V LiPo - JST/JST-PH
15046 50C 4S 5000mAh 14.8V LiPo 25147 30C 2S 300mAh 7.4V LiPo - JST/JST-PH
15047 50C 5S 5000mAh 18.5V LiPo 25148 30C 2S 260mAh 7.4V LiPo - JST/JST-PH
15048 50C 6S 5000mAh 22.2V LiPo 25152 30C 6S 1300mAh 22.2V LiPo - UNI 2.0
15049 40C 4S 3500mAh 14.8V LiPo Hard Case - UNI 25159 30C 3S 3000mAh 11.1V LiPo - UNI 2.0
15056 40C 2S 4000mAh 7.4V LiPo Hardcase ROAR -
UNI 2.0-L 25167 30C 1S 700mAh 3.7V LiPo - Mini Losi/JST
15057 40C 2S 5000mAh 7.4V LiPo Hardcase ROAR -
UNI 2.0-L 25168 30C 1S 250mAh 3.7V LiPo - Mini Losi/JST
15058 50C 2S 5000mAh 7.4V LiPo Hardcase ROAR -
UNI 2.0-L 25169 30C 3S 2200mAh 11.1V LiPo - HXT3.5 Super Tigre
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ITEM DESCRIPTION ITEM DESCRIPTION
15059 50C 3S 5000mAh 11.1V LiPo - UNI 2.0-L 25170 30C 3S 1300mAh 11.1V LiPo - HXT3.5 Super Tigre
15060 60C 2S 5000mAh 7.4V LiPo Hard Case ROAR
- UNI 35000 15C 6S 22000mAh 22.2V LiPo
15061 60C 2S 5600mAh 7.4V LiPo Hard Case ROAR
- UNI 35000BMS 15C 6S 22Ah 22.2V LiPo Commercial BMS Battery -
XT150/AS150
15064 60C 2S 3800mAh 7.4V LiPo Hard Case Short
Pack ROAR - UNI 35001 15C 6S 16000mAh 22.2V LiPo
15067 70C 2S 7000mAh 7.4V LiPo Hard Case - UNI 35002 15C 6S 13000mAh 22.2V LiPo
15068 70C 4S 6300mAh 14.8V LiPo Hard Case ROAR

- UNI 35003 15C 6S 8000mAh 22.2V LiPo

15070 70C 2S 5300mAh 7.4V LiPo Hard Case ROAR

- UNI 35004 15C 4S 16000mAh 14.8V LiPo

15071 70C 4S 5300mAh 14.8V LiPo Hard Case ROAR

- UNI 35005 15C 4S 13000mAh 14.8V LiPo

15072 70C 2S 5800mAh 7.4V LiPo Hard Case - UNI 35006 15C 4S 8000mAh 14.8V LiPo
15075 25C 2S 10000mAh 7.4V LiPo - UNI 35007 15C 3S 16000mAh 11.1V LiPo
15079 70C 1S 6300mAh 3.7V LiPo Hard Case - UNI 35008 15C 3S 13000mAh 11.1V LiPo

15080 30C 2S 5000mAh 7.4V LiPo Hardcase - UNI

2.0-L 35009 15C 3S 8000mAh 11.1V LiPo 15081 35C 2S 3800mAh 7.4V LiPo Hard Case ROAR

- UNI 35011 3S 6000mAh 11.1V LiPo - DJI Phantom 2

15083 30C 2S 4200mAh 7.4V LiPo Saddle Pack

ROAR - UNI 35012 30C 1S 150mAh 3.7V LiPo - JST-MCX

15084 40C 2S 5000mAh 7.4V LiPo Hardcase ROAR -

UNI 2.0-L 35013 30C 1S 250mAh 3.7V LiPo

15085 20C 2S 4000mAh 7.4V LiPo - UNI 2.0-L 35014 25C 1S 250mAh 3.7V LiPo

15086 50C 2S 5000mAh 7.4V LiPo Hardcase ROAR -

UNI 2.0-L 35015 30C 1S 400mAh 3.7V LiPo

15087 50C 2S 5600mAh 7.4V LiPo Hard Case ROAR

- UNI 35016 30C 1S 500mAh 3.7V LiPo

15091 35C 2S 10000mAh 7.4V LiPo - UNI 2.0-L 35017 30C 1S 500mAh 3.7V LiPo
15092 35C 2S 5200mAh 7.4V LiPo - UNI 35018 15C 1S 600mAh 3.7V LiPo - JST
15093 35C 2S 8000mAh 7.4V LiPo - UNI 2.0-L 35019 30C 1S 600mAh 3.7V LiPo

15094 35C 3S 3300mAh 11.1V LiPo Hardcase - UNI

2.0-L 35020 30C 2S 800mAh 7.4V LiPo 15096 DJI Phantom Battery by Venom 20C 3S

2200mAh 11.1 LiPo – UNI 2.0 35021 30C 3S 1350mAh 11.1V LiPo 15099 100C 2S 5000mah 7.4v LiPo Hardcase ROAR -

UNI 35022 30C 3S 3300mAh 11.1V LiPo

15105 35C 3S 850mAh 11.1v LiPo - UNI 35023 30C 3S 1400mAh 11.1V LiPo
15106 35C 3S 1000mAh 11.1v LiPo - UNI 35024 15C 3S 2200mAh 11.1V LiPo
15107 35C 2S 2000mAh 7.4V LiPo - UNI 2.0-L 35025 15C 3S 4000mAh 11.1V LiPo
15108 35C 3S 1300mAh 11.1V LiPo - UNI 2.0-L 35026 15C 3S 5400mAh 11.1V LiPo

15112 35C 3S 5000mAh 11.1V LiPo Hardcase - UNI

2.0-L 35027 10C 3S 6000mAh 11.1V LiPo - Yuneec Q500

15113 50C 3S 5000mAh 11.1V LiPo Hardcase - UNI

2.0-L 35028 8C 3S 5100mAh 11.1V LiPo

15116 100C 2S 6000mAh 7.4v LiPo Hard Case ROAR

- UNI 35029 30C 4S 1400mAh 14.8V LiPo

15117 100C 2S 7200mAh 7.4v LiPo Hard Case ROAR

- UNI 35030 15C 4S 3200mAh 14.8V LiPo

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ITEM DESCRIPTION ITEM DESCRIPTION
15118 60C 2S 5500mAh 7.4v LiPo Saddle Pack
ROAR - UNI 35031 15C 4S 4000mAh 14.8V LiPo
15119 100C 2S 5800mAh 7.4v LiPo Saddle Pack
ROAR - UNI 35032 15C 6S 5000mAh 22.2V LiPo
15124 100C 2S 4500mAh 7.4v LiPo Shorty Pack
ROAR - UNI 35033 3S 5500mAh 11.1V LiPo - DJI Phantom 2
15125 65C 2S 4100mAh 7.4v LiPo Shorty Pack ROAR
- UNI 35034 25C 3S 5800mAh 11.1V LiPo
15126 100C 2S 5800mAh 7.4v LiPo Square Pack
ROAR - UNI 35035 20C 3S 1600mAh 11.1V LiPo - Parrot Bebop
15127 60C 2S 5200mAh 7.4v LiPo Square Pack
ROAR - UNI 35036 15C 3S 7100mAh 11.1V LiPo - Blade Chroma
15128 35C 3S 5000mAh 11.1V LiPo Hardcase - UNI
2.0-L 35037 20C 3S 2200mah 11.1V LiPo - Sensefly
15129 50C 3S 5000mAh 11.1V LiPo Hardcase - UNI
2.0-L 35038 20C 3S 5400mAh 11.1V LiPo - XT60
15135 100C 3S 5000mah 11.1v LiPo 35039 50C 3S 1000mAh 11.1V LiPo - UNI 2.0
15136 30C 3S 12000mAh 11.1V LiPo Air Pack Battery 35040 50C 3S 1300mAh 11.1V LiPo - UNI 2.0
15137 30C 3S 16000mAh 11.1V LiPo Air Pack Battery 35041 75C 3S 1300mAh 11.1V LiPo - UNI 2.0
15138 30C 4S 8000mAh 14.8V LiPo Air Pack Battery 35042 50C 4S 1000mAh 14.8V LiPo - UNI 2.0
15139 30C 4S 12000mAh 14.8V LiPo Air Pack Battery 35043 50C 4S 1300mAh 14.8V LiPo - UNI 2.0
15140 30C 4S 16000mAh 14.8V LiPo Air Pack Battery 35044 75C 4S 1300mAh 14.8V LiPo - UNI 2.0
15141 30C 6S 8000mAh 22.2V LiPo Air Pack Battery 35046X2 30C 1S 600mAh 3.8V LiHV – JST-MCPX x2
15142 30C 6S 12000mAh 22.2V LiPo Air Pack Battery 35047 10C 3S 7100mAh 11.1V LiPo - Yuneec Q500
15143 30C 6S 16000mAh 22.2V LiPo Air Pack Battery 35048 20C 3S 2800mAh 11.1V LiPo - Parrot Bebop 2
15144 45C 6S 16000mAh 22.2V LiPo Air Pack Battery 35049 4S 6700mAh 14.8V LiPo - Yuneec Typhoon H
15145 45C 6S 22000mAh 22.2V LiPo Air Pack Battery 35050 15C 3S 800mAh 11.1V LiPo - Blade Inductrix 200
15146 20C 2S 210mAh 7.4v LiPo Air Pack Battery 35051 25C 1S 800mAh 3.7V LiPo - Micro Losi/JST - Ominus
15147 20C 2S 300mAh 7.4v LiPo Air Pack Battery 35052 25C 1S 1000mAh 3.7V LiPo - Micro Losi/JST - Vista
15148 40C 2S 260mAh 7.4v LiPo Air Pack Battery -
JST 35053 50C 3S 850mAh 11.1V LiPo - UNI 2.0 15149 30C 2S 5000mAh 7.4V LiPo Hardcase ROAR -
UNI 2.0-L 35054 50C 3S 1800mAh 11.1V LiPo - UNI 2.0 15150 3S 5500mAh 11.1V Intelligent LiPo - DJI
Phantom 2 35055 75C 3S 850mAh 11.1V LiPo - UNI 2.0
15152 30C 6S 1300mAh 22.2V LiPo - EC3 35056 75C 3S 1000mAh 11.1V LiPo - UNI 2.0
15153 45C 6S 22000mAh 22.2V LiPo Air Pack Battery
- XT150/AS150 35057 75C 3S 1800mAh 11.1V LiPo - UNI 2.0
15154 10C 6S 12000mAh 22.2V LiPo Air Pack Battery 35058 50C 4S 850mAh 14.8V LiPo - UNI 2.0
15155 10C 6S 16000mAh 22.2V LiPo Air Pack Battery 35059 50C 4S 1800mAh 14.8V LiPo - UNI 2.0
15156 10C 6S 22000mAh 22.2V LiPo Air Pack Battery 35060 75C 4S 850mAh 14.8V LiPo - UNI 2.0
15157 10C 3S 6000mAh 11.1V LiPo - Yuneec Q500 35061 75C 4S 1000mAh 14.8V LiPo - UNI 2.0
15158 8C 3S 5100mAh 11.1V LiPo - XT60 35062 75C 4S 1800mAh 14.8V LiPo - UNI 2.0

15159 30C 3S 3000mAh 11.1V LiPo - EC3 35063X2 45C 1S 180mAh 3.7V LiPo - JST-MCX x2
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ITEM DESCRIPTION ITEM DESCRIPTION
15160 100C 2S 5000mAh 7.4v Water Cooled LiPo
Battery 35063X4 45C 1S 180mAh 3.7V LiPo - JST-MCX x4
15161 50C 2S 5000mAh 7.4v Water Cooled LiPo
Battery 35065X2 45C 1S 250mAh 3.7V LiPo - JST-MCX x2
15162 100C 3S 5000mAh 11.1v Water Cooled LiPo
Battery 35065X4 45C 1S 250mAh 3.7V LiPo - JST-MCX x4
15163 50C 3S 5000mAh 11.1v Water Cooled LiPo
Battery 35066 15C 6S 22000mAh 22.2V LiPo Drone Pro Battery - XT90-S
15164 100C 4S 5000mAh 14.8v Water Cooled LiPo
Battery 35068 90C 3S 1300mAh 11.1V Graphene LiPo - UNI 2.0
15165 50C 4S 5000mAh 14.8v Water Cooled LiPo
Battery 35069 90C 3S 1500mAh 11.1V Graphene LiPo - UNI 2.0
15166 3S 6000mAh 11.1V Intelligent LiPo - DJI
Phantom 2 35070 90C 4S 1300mAh 14.8V Graphene LiPo - UNI 2.0
15167 35C 1S 700mAh 3.7V LiPo - Mini Losi 35071 90C 4S 1500mAh 14.8V Graphene LiPo - UNI 2.0
15168 25C 1S 250mAh 3.7V LiPo - Mini Losi 35072 75C 4S 1500mAh 14.8V LiPo - UNI 2.0
15169 20C 3S 1800mAh 11.1V LiPo - Mini Tamiya 35073 75C 4S 850mAh 14.8V LiPo - XT30
15170 50C 2S 2400mAh 7.4V LiPo - UNI 35074X4 30C 1S 220mAh 3.8V LiHV - JST-MCPX
15171 50C 2S 4200mAh 7.4V LiPo - UNI 35075 20C 3S 4900mAh 11.1V LiPo - Sensefly SQ/Plus
15172 35C 2S 6600mAh 7.4V LiPo - UNI 35076 45C 2S 350mAh 7.4V LiPo - JST
15173 50C 3S 5200mAh 11.1V LiPo - UNI 2.0-L 35077 50C 2S 450mAh 7.4V LiPo - JST
15174 3S 6000mAh 11.1V LiPo - DJI Phantom 2 35078 50C 2S 850mAh 7.4V LiPo – JST
15185 25C 2S 5000mAh 7.6V LiHV Hard Case - UNI 35079 30C 3S 450mAh 11.1V LiPo – JST
15186 25C 3S 5000mAh 11.4V LiHV Hard Case – UNI 35080 70C 3S 450mAh 11.1V LiPo – JST
15187 50C 3S 10500mAh 11.1V LiPo - UNI 2.0-TRX 35081 75C 3S 650mAh 11.1V Graphene LiPo - XT30
15188 50C 3S 5000mAh 11.1V LiPo Hard Case –
XT90-S 35082 75C 4S 650mAh 14.8V Graphene LiPo - XT30
15189 50C 4S 9000mAh 14.8V LiPo – UNI 2.0-TRX 35083 75C 5S 1300mAh 18.5V LiPo - UNI 2.0
15190 50C 3S 2200mAh 11.1V LiPo - UNI 2.0-L 35084 90C 5S 1300mAh 18.5V Graphene LiPo - UNI 2.0
15191 30C 2S 4000mAh 7.4V LiPo - UNI 2.0-L 35085 4S 7300mAh 15.2V LiHV - Yuneec H520
15192 25C 2S 5000mAh 7.4V Graphene LiPo
Hardcase - UNI 2.0-L 45000 35C 3S 1500mAh 11.1V LiPo - EC3 15193 35C 3S 5000mAh 11.1V Graphene LiPo - UNI
2.0-L 45001 50C 3S 2200mAh 11.1V LiPo - EC3 15194 50C 3S 5000mAh 11.1V Graphene LiPo - UNI
2.0-L 45002 75C 3S 2200mAh 11.1V LiPo Battery - UNI 2.0-A
15202 50C 2S 4600mAh 7.4V LiPo Shorty Hardcase -
UNI 2.0-L 45075 75C 3S 1300mAh 11.1V LiPo - Barbwire 2
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5.4

Safety Data Sheet
Cyanoacrylate

SDS Revision Date: MAY2015

ARROWHEAD
FORENSICS

1. Identification

1.1. Product identifier Product Identity A-3202B, A-2616, A-2601 Alternate Names Cyanoacrylate Adhesive

1.2. Relevant identified uses of the substance or mixture and uses advised against Intended use See Technical Data Sheet. Application Method See Technical Data Sheet.

1.3. Details of the supplier of the safety data sheet Company Name Arrowhead Forensics

11030 Strang Line Road

Lenexa, KS 66215

Contact Telephone No. 1 (913) 894-8388 Customer Service:

2. Hazard(s) identification

2.1. Classification of the substance or mixture Combustible Liquid;H227 Combustible Liquid. Skin Irrit. 2;H315 Causes skin irritation. Eye Irrit. 2;H319 Causes serious eye irritation. Carc. 2;H351 Suspected of causing cancer. STOT SE 3;H335 May cause respiratory irritation.

2.2. Label elements Using the Toxicity Data listed in section 11 and 12 the product is labeled as follows.

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Safety Data Sheet

Cyanoacrylate

SDS Revision Date: MAY2015

H227 Combustible liquid. H315 Causes skin irritation. H319 Causes serious eye irritation. H335 May cause respiratory irritation. H351 Suspected of causing cancer.

[Prevention]:

P201 Obtain special instructions before use. P202 Do not handle until all safety precautions have been read and understood. P210 Keep away from heat / sparks / open flames / hot surfaces - No smoking. P261 Avoid breathing dust / fume / gas / mist / vapors / spray. P264 Wash thoroughly after handling. P271 Use only outdoors or in a well-ventilated area. P280 Wear protective gloves / eye protection / face protection. [Response]:

P302+352 IF ON SKIN: Wash with plenty of soap and water. P304+312 IF INHALED: Call a POISON CENTER or doctor / physician if you feel unwell. P305+351+338 IF IN EYES: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do - continue rinsing. P308+313 IF exposed or concerned: Get medical advice / attention. P321 Specific treatment (see information on this label). P332+313 If skin irritation occurs: Get medical advice / attention. P337+313 If eye irritation persists: Get medical advice / attention. P340 Remove victim to fresh air and keep at rest in a position comfortable for breathing. P362 Take off contaminated clothing and wash before reuse. [Storage]:

P403+235 Store in a well ventilated place. Keep cool. P405 Store locked up. [Disposal]:

P501 Dispose of contents / container in accordance with local / national regulations.

3. Composition/information on ingredients

This product contains the following substances that present a hazard within the meaning of the relevant State and Federal Hazardous Substances regulations.

Ingredient/Chemical Designations Weight % GHS Classification Notes

Ethyl cyanoacrylate
CAS Number: 0007085-85-0

- 75 Eye Irrit. 2;H319
STOT SE 3;H335
Skin Irrit. 2;H315

[1]
[1]

Methyl methacrylate polymer
CAS Number: 0009011-14-7
- 25 Not Classified [1]

Hydroquinone
CAS Number: 0000123-31-9
0 - 1.0 Carc. 2;H351 Muta. 2;H341 Acute
. 4;H302 Eye Dam. 1;H318 Skin Sens.
l317 Aquatic Acute 1;H400

[1][2]
[1][2]

In accordance with paragraph (i) of §1910.1200, the specific chemical identity and/or exact percentage (concentration) of composition has been withheld as a trade secret. [1] Substance classified with a health or environmental hazard. [2] Substance with a workplace exposure limit. [3] PBT-substance or vPvB-substance. *The full texts of the phrases are shown in Section 16.

4. First aid measures

4.1. Description of first aid measures General In all cases of doubt, or when symptoms persist, seek medical attention.

Never give anything by mouth to an unconscious person. Inhalation Remove to fresh air, keep patient warm and at rest. If breathing is irregular or stopped, give artificial respiration. If unconscious place in the recovery position and obtain immediate medical attention. Give nothing by mouth. Eyes Immediately flush with plenty of water for at least 15 minutes. Get medical attention. If eyelids are bonded closed, release eyelashes with warm water by covering with a wet pad. Do not force eye open. Cyanoacrylate will bond to eye protein and will cause lachrymatory effect which will help to debond the adhesive. Keep eye covered until debonding is complete, usually within 1-3 days. Medical attention should be sought in case solid particles of polymerized cyanoacrylate may have been trapped behind the eyelid causing abrasive damage. Skin Do not pull bonded skin apart. Soak in warm soapy water. Gently peel apart using a blunt instrument. If skin is burned due to the rapid generation of heat by a large drop, seek medical attention. If lips are bonded, apply warm water to the lips and encourage wetting and pressure from saliva in the mouth. Peal or roll lips apart. Do not pull lips apart with direct opposing force.

Ingestion Ensure breathing passages are not obstructed. The product will polymerize rapidly and bond to the mouth making it almost impossible to swallow. Saliva will separate any solidified product in several hours. Prevent the patient from swallowing any separated mass. 4.2. Most important symptoms and effects, both acute and delayed Overview Skin contact may cause burns. Bonds skin rapidly. Skin and eye irritant. Vapor is irritating to eyes and mucous membranes. When above TLV. Prolonged overexposure to vapors may produce allergic reactions with asthma like symptoms in sensitive individuals. Possible cancer hazard. Contains an ingredient which may cause cancer based on animal data (See Section 3 and Section 15 for each ingredient). Risk of cancer depends on duration and level of exposure. See section 2 for further details.

Eyes Causes serious eye irritation. Skin Causes skin irritation.

5. Fire-fighting measures

5.1. Extinguishing media Carbon Dioxide, Dry Chemicals, Foam 5.2. Special hazards arising from the substance or mixture Hazardous decomposition: Irritating organic vapors may be released. Use of a SCBA is recommended. Keep away from heat / sparks / open flames / hot surfaces - No smoking. Avoid breathing dust / fume / gas / mist / vapors / spray. 5.3. Advice for fire-fighters A self-contained breathing apparatus is required. ERG Guide No. 128

6. Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures Put on appropriate personal protective equipment (see section 8). 6.2. Environmental precautions Do not allow spills to enter drains or waterways. Use good personal hygiene practices. Wash hands before eating, drinking, smoking or using toilet. Promptly remove soiled clothing and wash thoroughly before reuse. 6.3. Methods and material for containment and cleaning up DO NOT use cloth materials. In case of a leak or spill, flood area with water to polymerize the material. Soak up with inert absorbent. Ventilate area. Prevent product from entering drains.

7. Handling and storage

7.1. Precautions for safe handling Avoid contact with skin and eyes. Avoid breathing vapors. See section 2 for further details. - [Prevention]: 7.2. Conditions for safe storage, including any incompatibilities Handle containers carefully to prevent damage and spillage. Store in a cool dry area, away from heat, sparks and open flame. Keep containers sealed when not in use. Store out of direct sunlight. Incompatible materials: Polymerized by water, alcohol, amines and alkalis. Store below 72 F. See section 2 for further details. - [Storage]: 7.3. Specific end use(s) No data available.

8. Exposure controls and personal protection

8.1. Control parameters

Exposure

CAS No. Ingredient Source Value

A: 1 mg/m3S, Revised 2008,

9-13-321000
0

NIOSH C 2 mg/m

Supplier No Established Limit

0-58-5807000 lyhtE etalyrcaonayc AHSO oN hsilbatsE ed Limit

ACGIH TWA: 0.2 ppm

NIOSH No Established Limit

Supplier No Established Limit

0009011-14-7 Methyl methacrylate polymer OSHA No Established Limit

ACGIH No Established Limit

NIOSH No Established Limit

Supplier No Established Limit

Carcinogen Data

CAS No. Ingredient Source Value

0000123-31-9 Hydroquinone OSHA Select Carcinogen: No

NTP Known: No; Suspected: No

IARC Group 1: No; Group 2a: No; Group 2b: No; Group 3: Yes; Group 4: No;

0007085-85-0 Ethyl cyanoacrylate OSHA Select Carcinogen: No

NTP Known: No; Suspected: No

IARC Group 1: No; Group 2a: No; Group 2b: No; Group 3: No; Group 4: No;

0009011-14-7 Methyl methacrylate polymer OSHA Select Carcinogen: No

NTP Known: No; Suspected: No

IARC Group 1: No; Group 2a: No; Group 2b: No; Group 3: Yes; Group 4: No;

8.2. Exposure controls Respiratory If workers are exposed to concentrations above the exposure limit they must use the appropriate, certified respirators. Eyes
Protective safety glasses recommended

Skin Use polyethylene gloves and aprons. DO NOT use cotton/cloth gloves. Engineering Controls Positive draft exhaust ventilation should be provided to maintain vapor concentration levels below TLV. Use NIOSH approved respirator if there is potential to exceed exposure limit(s). Other Work Practices Use good personal hygiene practices. Wash hands before eating, drinking, smoking or using toilet. Promptly remove soiled clothing and wash thoroughly before reuse. See section 2 for further details. - [Prevention]:

9. Physical and chemical properties

Appearance Clear Liquid Odor Sharp Odor threshold Not Measured pH Not Measured Melting point / freezing point Not Measured Initial boiling point and boiling range Greater than 300 F Flash Point 160 - 200 F (TCC) Evaporation rate (Ether = 1) Not Measured Flammability (solid, gas) Not Applicable Upper/lower flammability or explosive limits Lower Explosive Limit: Not Measured Upper Explosive Limit: Not Measured Vapor pressure (Pa) Not Measured

Vapor Density Not Measured Specific Gravity 1.1 Solubility in Water deziremyloP yb retaw Partition coefficient n-octanol/water (Log Kow) Not Measured Auto-ignition temperature Not Measured Decomposition temperature Not Measured Viscosity (cSt) Not Measured 9.2. Other information
No other relevant information.

10. Stability and reactivity

10.1. Reactivity Hazardous Polymerization will not occur. 10.2. Chemical stability Stable under normal circumstances. 10.3. Possibility of hazardous reactions No data available. 10.4. Conditions to avoid No data available. 10.5. Incompatible materials Polymerized by water, alcohol, amines and alkalis. 10.6. Hazardous decomposition products Irritating organic vapors may be released. Use of a SCBA is recommended.

11. Toxicological information

Acute toxicity

Ingredient Oral LD50,

mg/kg

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Inhalation Gas LC50, ppm

lyhtE
etalyrcaonayc -)0-58-5807(,00.005,4 taR - Category: 5

Skin LD50, mg/kg
Inhalation Vapor LC50, mg/L/4hr
Inhalation Dust/Mist LC50, mg/L/4hr

No data available
Methyl methacrylate polymer - (9011-14-7) No data
available
2,000.10,
No data
No data Rabbit -
available
available Category: 5
No data available
enoniuqordyH
-)9-13-321(,00.023 taR - Category: 4
No data
No data
No data available
available
available
4,800.00, Rat -
No data
No data
No data Category: 5
available
available
available

Safety Data Sheet

Cyanoacrylate

SDS Revision Date: MAY2015

ARROWHEAD FORENSICS

Note: When no route specific LD50 data is available for an acute toxin, the converted acute toxicity point estimate was used in the calculation of the product's ATE (Acute Toxicity Estimate).

Classification Category Hazard Description etucA yticixot)laro(--- toN elbacilppA etucA yticixot)lamred(--- toN elbacilppA etucA yticixot)noitalahni(--- toN elbacilppA nikS noitatirri/noisorroc 2 sesuaC niks noitatirri . Serious eye damage/irritation 2 Causes serious eye irritation. yrotaripseR noitazitisnes --- toN elbacilppA nikS noitazitisnes --- toN elbacilppA mreG llec yticinegatum --- toN elbacilppA yticinegonicraC 2 detcepsuS fo gnisuac .recnac evitcudorpeR yticixot --- toN elbacilppA elgnis-TOTS erusopxe --- toN elbacilppA detaeper-TOTS erusopxe --- toN elbacilppA noitaripsA drazah --- toN elbacilppA 12.

Ecological information

12.1. Toxicity Toxic to aquatic life Aquatic Ecotoxicity

Ingredient 96 hr LC50 fish,
mg/l

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48 hr EC50 crustacea, mg/l
ErC50 algae, mg/l

lyhtE etalyrcaonayc -)0-58-5807(toN elbaliavA Not Available Not Available
Methyl methacrylate polymer - (9011-14-7) Not Available Not Available Not Available
enoniuqordyH
-)9-13-321(,440.0 suhcnyhrocnO mykiss
0.13, Daphnia magna
0.335 (72 hr), Pseudokirchneriella
subcapitata

12.2. Persistence and degradability There is no data available on the preparation itself. 12.3. Bioaccumulative potential Not Measured 12.4. Mobility in soil No data available.

12.5. Results of PBT and vPvB assessment This product contains no PBT/vPvB chemicals. 12.6. Other adverse effects No data available.

13. Disposal considerations

13.1. Waste treatment methods Observe all federal, state and local regulations when disposing of this substance.

14. Transport information

DOT (Domestic Surface Transportation)

ICAO/IATA

14.1. UN number 3991AN toN detaluger 4333NU 14.2. UN proper shipping name

IMO / IMDG (Ocean Transportation)

Not regulated Aviation regulated liquids N.O.S.

(Cyanoacrylate ester) 14.3. Transport hazard class(es)

Combustible liquid, n.o.s., (Cyanoacrylate ester)

Air Class: 9

14.4. Packing group III

toN elbacilppA III EXCEPTIONS: (Not more than

500ml). Unrestricted 14.5. Environmental hazards IMDG Marine Pollutant: No 14.6. Special precautions for user

oN rehtruf noitamrofni Please note that Cyanoacrylates are not restricted for domestic ground transportation in non bulk containers (The DOT defines a bulk container as a “Package” containing more than 450 liters. The “Package” is the individual bottle, tube or drum, not a carton containing many bottles.

15. Regulatory information

Regulatory Overview The regulatory data in Section 15 is not intended to be all-inclusive, only selected regulations are represented. Toxic Substance Control Act (TSCA)

DOT Hazard Class: Combustible

IMDG: Not Applicable liquid

Sub Class: Not Applicable

All components of this material are either listed or exempt from listing on the TSCA Inventory. WHMIS Classification B3 D2A

US EPA Tier II Hazards Fire: Yes

Sudden Release of Pressure: No Reactive: No Immediate (Acute): Yes Delayed (Chronic): Yes EPCRA 311/312 Chemicals and RQs: To the best of our knowledge, there are no chemicals at levels which require reporting under this statute. EPCRA 302 Extremely Hazardous:

Hydroquinone EPCRA 313 Toxic Chemicals: To the best of our knowledge, there are no chemicals at levels which require reporting under this statute. Proposition 65 - Carcinogens (>0.0%): To the best of our knowledge, there are no chemicals at levels which require reporting under this statute. Proposition 65 - Developmental Toxins (>0.0%): To the best of our knowledge, there are no chemicals at levels which require reporting under this statute. Proposition 65 - Female Repro Toxins (>0.0%): To the best of our knowledge, there are no chemicals at levels which require reporting under this statute. Proposition 65 - Male Repro Toxins (>0.0%): To the best of our knowledge, there are no chemicals at levels which require reporting under this statute. New Jersey RTK Substances (>1%):

Ethyl cyanoacrylate Pennsylvania RTK Substances (>1%) : To the best of our knowledge, there are no chemicals at levels which require reporting under this statute.

16. Other information

The information and recommendations contained herein are based upon data believed to be correct. However, no guarantee or warranty of any kind, expressed or implied, is made with respect to the information contained herein. We accept no responsibility and disclaim all liability for any harmful effects which may be caused by exposure to our products. Customers/users of this product must comply with all applicable health and safety laws, regulations, and orders. The full text of the phrases appearing in section 3 is: H302 Harmful if swallowed. H315 Causes skin irritation. H317 May cause an allergic skin reaction. H318 Causes serious eye damage.

ARROWHEAD
FORENSICS

H319 Causes serious eye irritation. H335
May cause respiratory irritation. H341
Suspected of causing genetic defects.
H351 Suspected of causing cancer. H400
Very toxic to aquatic life.

This is the first version in the GHS SDS format. Listings of changes from previous versions in other formats are not applicable. IMPORTANT: The information presented herein, while not guaranteed, was prepared in good faith and is known to be true and accurate to the best of our knowledge. NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR PURPOSE, OR OF ANY OTHER KIND, EXPRESSED OR IMPLIED, IS MADE REGARDING PERFORMANCE, STABILITY OR OTHERWISE. This information is not intended to be all-inclusive as to the manner and conditions of use, handling and storage. Other factors may involve other or additional safety or performance considerations. While our technical personnel will be happy to respond to questions regarding safe handling and use procedures, safe handling and use remains the responsibility of the customer. No suggestions for use are intended as, and nothing herein shall be construed as a recommendation to infringe any existing patents or violate any federal, state or local laws, rules, regulations or ordinances.

End of
Document

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SAFETY DATA SHEET NEMA Grade G-10 / G11

Current,
Incorporated

Product Name: NEMA Grade G10 / G11

Manufacturer: Current, Incorporated
30 Tyler Street
Extension East
Haven, CT 06512

Emergency Phone: 203-469-1337
877-436-6542 (Toll Free)

Description: Fully cured solid composite of epoxy/glass cloth

Product Use: Used for electrical insulation in sensitive electronic equipment

GHS Classification: Not applicable. This material, as sold, is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29CFR 1910.1200

GHS Signal Words with Hazard and Precautionary Statements:
Warning!

Dust generated during machining, grinding or sanding may cause eye irritation. Fumes from decomposition or burning may irritate eyes, nose and respiratory system. Dust generated by secondary operations can be explosive. Avoid eye exposure to dust and fumes. Avoid skin exposure to dust and fumes.

GHS Pictograms: Warning! This product may form combustible dust during processing.

Route of Entry: None for this product as sold. For dust or chips generated during fabrication operations:

eye contact, skin contact, and
inhalation.

Section 2. Hazard Identification

Section 1. Identification

Target Organs: None

Skin Contact: Solid sheet may be abrasive to, or cut the skin. Operations such as milling, cutting, grinding, etc. may produce dust or fines that may be irritating.

Eye Contact: No hazard for product as sold. Operations such as milling, cutting, grinding, etc. may produce dust or fines that may be irritating.

Respiratory Contact: Not an expected route of entry. Operations such as milling, cutting, grinding, etc. may produce dust or fines that may be irritating.

Ingestion: Not an expected route of entry.

HMIS (United States) NFPA (United States) WHMIS (Canada): Not classified as hazardous

Health 1

Flammability 0

Reactivity 0

PPE B

Section 3. Composition / Information on Ingredients

Fully cured solid composite of epoxy/glass:

Name CAS #

Fiberglass 65997-17-3

Epoxy Resin 25036-25-3

Section 4. First – Aid Measures

For dust or fumes produced by machining, grinding or sanding:

Skin: Wash skin with soap and water. If redness or itching develops seek medical attention.

Eye: Flush with large amounts of cool water for 15 minutes. If irritation persists, seek medical attentio n.

Respiratory: Remove to fresh air. Call a physician if necessary.

Ingestion: Not an expected route of entry with normal product use. If large amounts of dust swallowed seek medical attention.

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Section 5. Fire-Fighting Measures

Flammability: Not Flammable under normal conditions. Flash Pt.: N/A, Class: Sol id

Extinguishing Media: Water, foam, carbon dioxide or dry chemical

Special Fire and Explosion Hazard: None as sold. (Accumulated dust may be explosive. Heat from fire can generate decomposition products that may cause a health hazard.)

Special Firefighting Procedures: Fire fighters should wear positive-pressure self-contained breathing apparatus (SCUBA) and protective clothing.

Section 6. Accidental Release Measures

Personal Precautions, Protective Equipment and Emergency Procedures:

Material is non-hazardous as sold.

Environmental Precautions: None

Spills: Material is solid as sold. Contain and manage dust during secondary operations. Sweep up accumulated dust using water spray to suppress. Eliminate all ignition sources.

Section 7. Handling and Storage

Handling Precautions: No specific usage precautions required as sold. Follow normal good hygiene practices.

Storage Precautions: Store in a cool, dry well-ventilated area.

Section 8. Exposure Controls / Personal Protection

Machining, cutting, grinding or sanding fiber glass plastic produces respirable fibrous glass dust regulated by OSHA as noted below. Respirable fiberglass dust may cause cancer.

Component Information Exposure limits

Component Name CAS # TLV, TWA, ACGIH OSHA PEL, TWA

Fiberglass 65997-17-3 10mg/m3 (dust) 15 mg/m3 (total dust)

5 mg/m3 (respirable)

Epoxy Resin 25036-25-3 10mg/m3 (dust) 10mg/m3 (dust)

Eye Protection: Minimize dust generating activities. Wear safety goggles. Do not wear contact lenses.

Skin Protection: Wear gloves to protect from sharp edges and protective clothing.

Respiratory Protection: If personal exposure cannot be controlled by ventilation, wear a particulate respirator approved by NIOSH/MSHA to protect against dust.

Other: Emergency eye wash stations should be available if cutting or producing dust.

Section 9. Physical and Chemical Properties

Appearance: Light Green / Light Brown Lower Explosion Limit: Not Available

Odor: Odorless Solid Upper Explosion Limit: Not Available

Odor Threshold: Not Applicable Vapor Pressure: Not Applicable

pH: Not Applicable Vapor Density: Not Applicable

Melting Point: Not Available Relative Density: Not Available

Freezing Point: Not Applicable Solubility: Not Soluble

Boiling Point and Range: Not Applicable Auto-Ignition Temperature: Not Available

Flash Point and Method: Not Applicable Decomposition Temperature: Not Available

Evaporation Rate: Not Applicable Viscosity: Not Applicable

Flammability: Not Flammable Specific Gravity; ~ 1.93

Partition Coefficient (n-Octanol / Water): Not Applicable

Section 10. Stability and Reactivity

Reactivity: Product is non-reactive

Chemical Stability: Stable under normal conditions

Possibility of Hazardous Reactions: Thermal decomposition may produce oxides of carbon.

Conditions to Avoid: Protect from heat, sparks and flame

Materials to Avoid: Avoid contact with strong acids and bases.

Hazardous Decomposition Products: Carbon dioxide, carbon monoxide, bromine and other hazardous gases

may be generated under normal processing conditions.

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Hazardous Polymerization: Will not occur.

Section 11. Toxicological Information

Component Oral LD50 (rat) Dermal LD50 (rabbit) Inhalation LC50 4hr (rat)

Glass Fiber: Not determined Not determined Not determined

Section 12. Ecological Information

As sold, this material is not classified as hazardous.

This material is not
biodegradable.

Particulates generated during machining may be subject to Federal and State air pollution control laws.

Section 13. Disposal Considerations

Disposal
Methods:

This material (as sold) is not classified as hazardous waste. Dispose of only by methods approved by and used in accordance with local, state and federal regulations for non-hazardous waste.

Particulates generated during machining and fabrication operations may be subject to Federal and State Air Pollution Control Laws.

Section 14. Transport Information

This product, as offered for shipment, is not regulated as a Hazardous Material.

UN Number: Not Applicable

UN Proper Shipping Name: Not Applicable

Transport Hazard Class: Not Applicable

DOT Classification: Not Applicable

Special Provision for Transport: Not Applicable

IMDG Code: Not Applicable. Not expected to be a marine pollutant

Transport Canada: Not Applicable.

Section 15. Regulatory Information

OSHA Hazard Communication Standard: This product is considered non-hazardous under OSHA Hazard Communication Standard (29CFR 1910.1200)

California (Proposition 65): No components exceeding levels listed in “No significant Risk Levels” (NSRLs) for carcinogens or “Maximum Allowable Doses Levels (MADLs), as established in regulation title 27, California code of regulations.

Superfund Amendments and Reauthorization Act of 1986 Title III: This product is not a hazardous chemical under 29CFR 1910.12000, and therefore is not covered by Title III of SARA.

Toxic Substance Control Act (TSCA): All components of this product are on the TSCA inventory or are exempt from TSCA inventory requirements.

HMIS Codes:
Health 1
Flammability 0
Reactivity 0
PPE B

Section 16. Other Information

Revision Information: Revision 2 (May 19, 2015), Complete, to comply with HCS Standard 29 CFR 1910.1200(g). Update to new “SDS” format.

Additional information on this product may be obtained by calling
203-469-1337.

Notice to
Reader:

To the best of our knowledge, the information contained herein is accurate. However, this should not be accepted as a guarantee of accuracy without confirming tests at your own facility. The above named manufacturer assumes no liability for accuracy or completeness of the information contained herein. The data relates only to the material as supplied and does not relate to combinations with other materials or processes.

End of SDS
Document

5.6

Material Safety Data Sheet

Section 1: PRODUCT AND COMPANY IDENTIFICATION

MSDS Identification: Carbon Fabric, Sized or Unsized MSDS Number: 439-3227-00SU-C000-12 Date: October 1, 2002 Page: 1 of 6 Supersedes MSDS: 439-3227-00SU-C000-11

Manufacturer: Emergency Telephone Number: Hexcel Schwebel 800-433-5072 (24-Hour) 2200 South Murray Avenue P.O. Box 2627 Information Telephone Number: Anderson, SC 29621 864-260-5799 (Normal Business Hours-ET)

Product Identification: Carbon Fabric: Sized or Unsized

Chemical Family: Woven Carbon Fabric with various types of Sized and Unsized Carbon Fibers.

Section 2: COMPOSITION/INFORMATION ON INGREDIENTS

Component CAS® % by OSHA(PEL) ACGIH®(TLV®)

Number Weight Carbon fiber, 7440-44-0 98.5-100 15 mg/m^3(Total) 10 mg/m^3(Total) synthetic 5 mg/m^3(Respirable) 3 mg/m^3(Respirable)

This product is not classified as a Hazardous Chemical as defined by the OSHA Hazard

Communication Standard, 29 CFR 1910.1200.

Where specific exposure limits for component dusts are not established, the levels provided for (Total/Inhalable) dust and (Respirable) fraction reflect the classification of Particulates Not Otherwise Regulated (PNOR) by OSHA or Specified (PNOS) by ACGIH®.

Section 3: HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW: Appearance and Odor: Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor.

Statement of Hazard: Warning! May cause temporary mechanical irritation of the eyes, skin or upper respiratory tract.

If sized, vapor or fumes generated from heating or curing this product may cause eye and respiratory tract irritation.

Carbon fibers or dust are electrically conductive and may create electrical short-circuits which could result in damage to and malfunction of electrical equipment and/or personal injury.
MSDS Number: 439-3227-00SU-C000-12 Date: October 1, 2002 Page: 2 of 6

Section 3: HAZARDS IDENTIFICATION (Continued)

EMERGENCY OVERVIEW (continued): Primary Routes of Exposure: Eye--Yes
Skin--Yes Inhalation--Yes Ingestion--No

HMIS® Rating: Health--1 Flammability--0 Reactivity--0 Special--None

Potential Health Effects: Eye: Contact may cause mechanical irritation to the eyes. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the eyes. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Skin: Contact may cause mechanical irritation to the skin and possible dermatitis. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Inhalation: May cause mechanical irritation to the upper respiratory tract. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the respiratory tract. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Ingestion: Ingestion unlikely under normal conditions of use. If any of this product or the cured product dust is swallowed, seek medical attention immediately.

Medical Conditions Aggravated by Exposure: Preexisting eye, skin or respiratory disorders may be aggravated by exposure to this product or to the dust from machining, grinding or sawing the cured product.

Carcinogenic Information: None of the components present in this material at concentrations equal to or greater than 0.1 % are listed or regulated by IARC, NTP, OSHA or ACGIH® as a carcinogen.

Other: OSHA(PEL) ACGIH®(TLV®)

Exposure limits for cured product dust as [Particulates Not Otherwise 15 mg/m^3(Total) 10 mg/m^3(Inhalable) Regulated (PNOR) by OSHA or 5 mg/m^3(Respirable) 3 mg/m^3(Respirable) Specified (PNOS) by ACGIH®]:

Section 4: FIRST AID MEASURES

Eye: In case of eye contact, immediately flush eyes with large amounts of water for at least 15 minutes, keeping the eyelids open. Get medical attention immediately.

Skin: In case of contact that causes irritation, immediately wash skin with soap and room temperature to cool running water. Use a washcloth to help remove the fibers. To avoid further irritation, do not rub or scratch irritated areas. Rubbing or scratching may force fibers into the skin. Get medical attention immediately, if the irritation persists.

Inhalation: If large amounts of dust, fiber, fumes or vapor are inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, qualified personnel may administer oxygen. Get medical attention immediately.
MSDS Number: 439-3227-00SU-C000-12 Date: October 1, 2002 Page: 3 of 6

Section 4: FIRST AID MEASURES (Continued)

Ingestion: Ingestion of this product or the dust from it is unlikely. If swallowed, get medical attention immediately.

Section 5: FIRE FIGHTING MEASURES

Flash Point/Method of Determination: Not determined

Means of Extinction: Use water spray, dry chemical or CO_2 to extinguish fires. Special Fire Hazards: Avoid exposure through use of a self-contained, positive-pressure breathing apparatus. Section 6:

ACCIDENTAL RELEASE MEASURES

Procedures in case of Accidental Release or Leakage: Avoid contact with skin, eyes or clothing (See Section 8). Clean up material, put into a suitable container and dispose of properly (See Section 13).

Section 7: HANDLING AND STORAGE

Precautions to be taken in Handling and Storage: Store in a cool, dry place. Maintain sealed against contamination from dirt and moisture.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Eye/Face Protection: Avoid eye contact. Wear safety glasses with side shields, as necessary, when using this product or when machining, grinding or sawing the cured product.

Skin Protection: Protective clothing such as a loose fitting long sleeved shirt that covers to the base of the neck, long pants and gloves, as necessary to prevent irritation. Skin irritation is known to occur primarily at pressure points such as around the neck, wrist, waist and between the fingers.

Respiratory Protection: Not ordinarily required. If sized and sufficient vapor or fumes are being generated during heating or curing of this product, use a NIOSH approved organic vapor respirator. If sufficient dust or fibers are generated during use or when machining, grinding or sawing the cured product, use a NIOSH approved dust respirator.

Ventilation: Use local exhaust sufficient to control vapor, fumes, fibers or dust generated. If exhaust ventilation is not available or is inadequate, use a NIOSH approved respirator, as appropriate.

General Hygiene Recommendations: Before eating, drinking, smoking or using toilet facilities, wash face and hands thoroughly with soap and water. Remove any contaminated clothing and launder before reuse. Use vacuum equipment to remove fibers and dust from clothing and work areas. Compressed air is not recommended.

MSDS Number: 439-3227-00SU-C000-12 Date: October 1, 2002 Page: 4 of 6

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Odor...Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor. Melting Point ($^oF/^oC$)......................... 6512^{o}F/3600^{o}C Specific Gravity (Water=1)................ 1.5-1.9 pH of Undiluted Product.................... Not determined Volatile [Percent (%) by Weight]....... 0 Percent (%) VOC.............................. Not determined Solubility in Water............................ Negligible

Section 10: STABILITY AND REACTIVITY

Stability: Stable under proper handling and storage conditions

Incompatible Materials: None

Products evolved from Heat of Combustion or Decomposition: The products of combustion and decomposition depend on other materials present in the fire and the actual conditions of the fire. Burning will decompose the sizing system, if appropriate, and produce carbon and nitrogen oxides, phenols, aldehydes, acrolein, carboxylic acid, traces of incompletely burned carbon products and other unidentified gases and vapors that may be toxic. Avoid inhalation.

Hazardous Polymerization: Will not occur under proper conditions of use. Rapid heating of the product in bulk may produce an uncontrolled exothermic reaction that may char and decompose the sizing system, if appropriate, generating unidentified gases and vapors that may be toxic. Avoid inhalation.

Section 11: TOXICOLOGICAL INFORMATION

Component Toxicity Data: Median Lethal Dose (Species):

Oral (LD_{50})...Not determined Inhalation (LC_{50})...Not determined Dermal (LD_{50})...Not determined Irritation Index, Estimation of Irritation (Species): Skin...Not determined Eyes...Not determined Inhalation...Not determined

Section 12: ECOLOGICAL INFORMATION

No ecological data has been determined.
MSDS Number: 439-3227-00SU-C000-12 Date: October 1, 2002 Page: 5 of 6

Section 13: DISPOSAL CONSIDERATIONS

Waste Disposal Methods: Material for disposal should be placed in appropriate sealed containers to avoid potential human and environmental exposure. It is the responsibility of the generator to comply with all federal, state, provincial and local laws and regulations. We recommend that you contact an appropriate waste disposal contractor and environmental agency for relevant laws and regulations. Under the U.S., Resource Conservation and Recovery Act (RCRA), it is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification.

Section 14: TRANSPORT INFORMATION

DOT: Proper Shipping Name.... Not
regulated Hazard Class................... Not
regulated Identification Number..... Not
regulated Packing Group................ Not
regulated Label Required................ None

Section 15: REGULATORY INFORMATION

SARA Title III: Section 302/304 Extremely
Hazardous Substance: None

Section 311 Hazardous Categorization:
None

Section 313 Toxic Chemicals:
None

CERCLA Section 102(a) Hazardous Substance: None

RCRA Information: Currently, the product is not listed in federal hazardous waste regulations 40 CFR, Part 261.33, paragraphs (e) or (f), i.e. chemical products that are considered hazardous if they become wastes. State or local hazardous waste regulations may also apply if they are different from the federal regulation. It is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification and to assure proper disposal.

WHMIS (Canada):
Classification: None

This product has been classified in accordance with hazard criteria of the "Controlled Products Regulations" and this MSDS contains all the information required by the "Controlled Products Regulations."

Ingredient Disclosure List:
None
MSDS Number: 439-3227-00SU-C000-12 Date: October 1, 2002 Page: 6 of 6

Section 15: REGULATORY INFORMATION (Continued)

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): Warning! The state of California has determined that the following listed component chemicals in this product may cause cancer, birth defects or other reproductive harm: None

U.S., EPA, TSCA Information: This product is an article as defined by TSCA and is not required to be listed in the TSCA inventory.

Ozone Depletion Information: This product does not contain or is not manufactured with ozone depleting substances as identified in Title VI, Clean Air Act "Stratospheric Ozone Protection" and the regulations set forth in 40 CFR, Part 82.

Section 16: OTHER INFORMATION

Special Precautions: Airborne carbon fibers or dust are electrically conductive and may create electrical short-circuits that could result in damage to and malfunction of electrical equipment and/or personal injury.

Explanation and Disclaimer: Wherever such words or phrases as "hazardous," "toxic," "carcinogen," etc. appear herein, they are used as defined or described under state employee right-to-know laws, Federal OSHA laws or the direct sources for these laws such as the International Agency for

Research on Cancer (IARC), the National Toxicology Program (NTP), etc. The use of such words or phrases should not be taken to mean that we deem or imply any substance or exposure to be toxic, hazardous or otherwise harmful. Any exposure can only be understood within the entire context of its occurrence, which includes such factors as the substance's characteristics as defined in the MSDS, amount and duration of exposures, other chemicals present and preexisting individual differences in response to the exposure.

The data provided in this MSDS is based on the information received from our raw material suppliers and other sources believed to be reliable. We are supplying you this data solely in compliance with the Federal OSHA Hazard Communication Standard, 29 CFR 1910.1200 and other Federal and state laws as described in Section 15: Regulatory Information.

The information contained in this MSDS is proprietary and confidential to Hexcel Corporation. This MSDS and the information in it are not to be used for purposes other than compliance with the Federal OSHA Hazard Communication Standard. If you have received this MSDS from any source other than Hexcel Corporation or its authorized agent, the information contained in it may have been modified from the original document and it may not be the most current revision.

Liability, if any, for use of this product is limited to the terms contained in our sale terms and conditions. We do not in any way warrant (expressed or implied, including any implied warranty for merchantability or fitness for a particular purpose) the data contained or the product described in this MSDS. Additionally, we do not warrant that the product will not infringe any patent or other proprietary or property rights of others.

Contact: David M. Rubin,
Hexcel Schwebel Environmental, Health and Safety Manager

5.7

SDS – Pro-X® Rocket Motor Reload Kits Page 1/7 Version 4.00 Revision Date. 2015-06-01

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SAFETY DATA SHEET

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Pro-X® Rocket Motor Reload Kits & Fuel Grains

-- 1.0 PRODUCT / COMPANY IDENTIFICATION

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Product Name: Pro24, Pro29, Pro38, Pro54, Pro75, and Pro98 Rocket Motor Reload Kits Synonyms: Rocket Motor, Hobby Rocket Motor, HPR Reload Kit Part Numbers: Reload kits: P24R-Y-#G-XX, P29R-Y-#G-XX, P38R-Y-#G-XX,

P54R-Y-#G-XX, P24R-Y-#GXL-XX, P29R-Y-#GXL-XX, P38R-Y-#GXL-XX, P54R-Y-#GXL-XX, Propellant grains: P75AC-PG-XX, P98AC-PG-XX, P98AC-MB-PG-XX

Where: Y = reload type (A = adjustable delay, C = C-slot)
= number of grains
& XX = propellant type

Product Use: Solid fuel motor for propelling hobby rockets

Manufacturer / Supplier: Cesaroni Technology Inc.
P.O. Box 246 2561 Stouffville Rd. Gormley, Ont. Canada
L0H 1G0 Telephone Numbers:
Product Information: Tel: +1-905-887-2370 Fax: +1-905-887-2375 24 Hour Emergency Telephone Number: Tel: +1-613-996-6666 (CANUTEC)

-- 2.0 HAZARDS IDENTIFICATION

-- Signal Word: Warning GHS Pictogram: Hazard Statement: H204 Fire or Projection Hazard

Precautionary Statements

P210 Keep away from heat/sparks/open flames/hot surfaces. No smoking P250 Do not subject to grinding/shock/friction. P370+P380 In case of fire: Evacuate Area. P372 Explosion risk in case of fire. P373 DO NOT fight fire when fire reaches explosives. P401 Store in accordance with local/regional/national regulations. P501 Dispose of in accordance with local/regional/national regulations.

Emergency Overview:

There articles contain cylinders of ammonium perchlorate composite propellant, encased in inert plastic parts. The forward closure also contains a few grams of black powder. ProX Rocket motor reload kits are classified as explosives, and may cause serious injury, including death if used improperly. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced personnel in accordance with all applicable federal, state and local laws and regulations. Avoid inhaling exhaust products. General Appearance:

Cardboard tubes contain various plastic parts. Inside the plastic tube are cylinders of composite propellant (rocket fuel). The forward closure also contains a small quantity of black powder. All parts are odourless solids.

Potential Health Effects:

Ey
e:

Not a likely route of exposure. May cause eye irritation. Skin:

Not a likely route of exposure. Low hazard for usual industrial/hobby handling.

Ingestion:

SDS – Pro-X® Rocket Motor Reload Kits Page 2/7 Version 4.00 Revision Date. 2015-06-01

Not a likely route of exposure.

Inhalation:

Not a likely route of exposure. May cause respiratory tract irritation. Do not inhale exhaust products.

-- 3.0 COMPOSITION / INFORMATION ON INGREDIENTS

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Propellan
t

Ingredient Name CAS Number Percentage ---
------------------ ---------------- -----------------

Ammonium Perchlorate .... 7790-98-9 40-85 % Metal
Powders .... 1-45 % Synthetic Rubber
.... 10-30 %

Black Powder Ignition pellet

Ingredient Name CAS Number Percentage ---
------------------ ---------------- -----------------

Potassium Nitrate .... 7757-79-1 70-76 % Charcoal
.... n/a 8-18 % Sulphur
.... 7704-34-9 9-20 % Graphite
.... 7782-42-5 trace

-- 4.0 FIRST AID MEASURES

--

Eye
s:

Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids.
Get medical aid. Skin:

Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

Ingestion: Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cupfuls of milk or water.

Inhalation: Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing

is

difficult, give oxygen. Get medical
aid.

Burns: Burns can be treated as per normal first aid procedures.

-- 5.0 FIRE FIGHTING MEASURES

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Extinguishing Media:

In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam to contain surrounding fire.

Exposure Hazards During Fire:

Exposure to extreme heat may cause ignition.

Combustion Products from Fire:

During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

Fire Fighting Procedures:

Keep all persons and hazardous materials away. Allow material to burn itself out. As in any fire, wear a self- contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Special Instructions / Notes:

These articles burn rapidly and generate a significant flame for a short period of time. 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. Do not inhale exhaust products.

-- 6.0 ACCIDENTAL RELEASE MEASURES

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Safeguards (Personnel): Spills: Clean up spills immediately. Replace articles in packaging and boxes and seal securely. Sweep or scoop up using non-sparking tools.

-- 7.0 HANDLING AND STORAGE

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Handling: Keep away from heat, sparks and flame. Avoid contamination. Do not get in eyes, on skin or on clothing. Do not taste or swallow. Avoid prolonged or repeated contact with skin. Follow manufacturer’s instructions for use.

Storage: Store in a cool, dry place away from sources of heat, spark or flame. Keep in shipping packaging when not in use.

-- 8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

--

Engineering Controls:

Use adequate explosion proof ventilation to keep airborne concentrations low. All equipment and working surfaces must be grounded. Personal Protective Equipment:

Eye
s:

Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166. Skin:

Clothing should be appropriate for handling pyrotechnic substances. Clothing:

Clothing should be appropriate for handling pyrotechnic substances. Respirators:

A respirator is not typically necessary. Follow the OSHA respirator regulations found in 29CFR1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN

149 approved respirator when necessary.

-- 9.0 PHYSICAL AND CHEMICAL PROPERTIES

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Physical State: solid Appearance: rubber cylinders inside plastic parts Odour: none Odour Threshold: Not available. pH: Not available. Vapour Pressure: Not available. Vapour Density: Not available. Viscosity: Not available. Evaporation Rate: Not available. Boiling Point: Not available. Freezing/Melting Point: Not available. Coefficient of water/oil distribution: Not available. Autoignition Temperature: 280°C Flash Point: Not available. Explosion Limits, lower (LEL): Not available. Explosion Limits, upper (UEL): Not available. Sensitivity to Mechanical Impact: unprotected black powder can be ignited by impact Sensitivity to Static Discharge: unprotected black powder can be ignited by static discharge Decomposition Temperature: > 400°C Solubility in water: black powder is soluble in water Specific Gravity/Density: black powder = 1.7-2.1

Propellant = not available

Molecular Formula: Not applicable Molecular Weight: Not applicable.

-- 10.0 STABILITY AND REACTIVITY

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SDS – Pro-X® Rocket Motor Reload Kits Page 4/7 Version 4.00 Revision Date. 2015-06-01

Chemical Stability:

Stable under normal temperatures and pressures.

Conditions to Avoid:

Heat, static electricity, friction, impact

Incompatibilities with Other Materials:

Combustible or flammable materials, explosive materials

Hazardous Products Of Decomposition:

Oxides of nitrogen

Hazardous Polymerization:

Will not occur.

SDS – Pro-X® Rocket Motor Reload Kits Page 5/7 Version 4.00 Revision Date. 2015-06-01

-- 11.0 TOXICOLOGICAL INFORMATION

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Routes of Entry: Skin contact – not likely

Skin absorption – not likely Eye contact – not likely Inhalation – not likely Ingestion – not likely Effects of Acute Exposure to Product:

No data available

Effects of Chronic Exposure to Product:

No data available

Exposure Limits:

Black Powder

Pellets

Ingredient Name CAS Number OSHA PEL ACGIH TLV
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Potassium Nitrate 7757-79-1 not established not established Charcoal n/a not established not established Sulphur 7704-34-9 not established not established Graphite 7782-42-5 2.5 mg/m^3 15 mmpct (TWA)

Propella
nt

Ingredient Name CAS Number OSHA PEL ACGIH TLV
-- ------------------ ---------------- ------------------

Ammonium Perchlorate 7790-98-9 not established not established metal powder varies varies
Synthetic Rubber not established not established

Irritancy of the Product:
No data available

Sensitization to the Product: No data available

Carcinogenicity:
Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA

Reproductive Toxicity:
No data available

Teratogenicity:
No data available

Mutagenicity:
No data available

Toxically Synergistic Products:
No data available

LD50:
No data available

-- 12.0 ECOLOGICAL INFORMATION

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Environmental Data:

Ecotoxicity Data:
Not determined.

EcoFaTE Data:
Not determined.

-- 13.0 DISPOSAL CONSIDERATIONS

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Product As Sold: Pack firmly in hole in ground with nozzle pointing up. Ignite motor electrically from a safe distance and wait 5 minutes before approaching. Dispose of spent components in inert trash. Product Packaging: Dispose of used packaging materials in inert trash. Special Considerations: Consult local regulations about disposal of explosive materials.

SDS – Pro-X® Rocket Motor Reload Kits Page 6/7 Version 4.00 Revision Date. 2015-06-01

-- 14.0 TRANSPORT INFORMATION

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Shipping Information – Canada

TDG Classification: Class 1.4 Explosive Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors) UN Number: 0351 UN Classification Code: 1.4 C Packing Group: II UN Packing Instruction: 101

Shipping Information - USA / IMO

Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors) UN Number: 0351 UN Classification Code: 1.4 C DOT / IMO Label: Class 1 – Explosive – Division 1.4C

Shipping Information - IATA

Proper Shipping Name: Articles, Explosive, N.O.S. (Model Rocket Motors) UN Number: 0351 UN Classification Code: 1.4 C IATA Labels: Class 1 – Explosive – Division 1.4C

Cargo Aircraft Only

-- 15.0 REGULATORY INFORMATION

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Canad
a

This product has been classified according to the hazard criteria of the Canadian Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

WHMIS Classification: Not Controlled (explosive)

Domestic Substance List (DSL)
Status:

All ingredients are listed on Canada's DSL List.

Canadian Explosives Classification: Rocket Motors - R2, PE3 This products are authorized explosives in Canada.

These products are not considered “Controlled Goods” in Canada under the Controlled Goods Regulations.

United States of America

TSCA Inventory
Status:

All ingredients are listed on the TSCA inventory.

Hazardous Chemical
Lists

CERCLA Hazardous Substance (40 CFR 302.4) No SARA Extremely Hazardous Substance (40CFR 355) No SARA Toxic Chemical (40CFR 372.65) No European/International Regulations

The product on this MSDS, or all its components, is included on the following countries' chemical inventories: EINECS – European Inventory of Existing Commercial Chemical Substances

European Labelling in Accordance with EC Directives

Hazard Symbols:
Explosive. Risk Phrases:

R 2 Risk of explosion by shock, friction, fire or other sources of ignition. R 11 Highly flammable R 44 Risk of explosion if heated under confinement. Safety Phrases:

S 1/2 Keep locked up and out of the reach of children. S 8 Keep container dry. S 15 Keep away from heat. S 16 Keep away from sources of ignition -- No smoking.

S 17 Keep away from combustible material. S 18 Handle and open container with care. S 33 Take precautionary measures against static discharges. S 41 In case of fire and/or explosion do not breathe fumes.

-- 16.0 OTHER INFORMATION

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MSDS Prepared by: Regulatory Affairs Department

Cesaroni Technology Inc. P.O. Box 246 2561 Stouffville Rd. Gormley, ON Canada L0H 1G0

Telephone: 905-887-2370 x239 Fax: 905-887-2375 Web Sites:
www.cesaronitech.com

www.Pro38.com

5.8

DUPONT -- KEVLAR BRAND FIBER

=== MSDS Safety Information

=== MSDS Date: 11/19/1999

MSDS Num: CKSQM Product ID: KEVLAR BRAND FIBER MFN: 01 Responsible Party Cage: TO822 Name: DUPONT Address: 1007 MARKET STREET City: WILMINGTON DE 19898 Info Phone Number: 1-800-441-3637; 800-453-8527 Emergency Phone Number: 800-424-9300 Resp. Party Other MSDS No.: SP1889 Preparer's Name: EDMUND MERRIMAN Chemtrec IND/Phone: (800)424-9300 Review Ind: Y Published: Y === Contractor Summary === Cage: TO822 Name: DUPONT Address: 1007 MARKET STREET City: WILMINGTON DE 19898 Phone: 1-800-441-3637; 800-453-8527 Cage: TO979 Name: DUPONT ADVANCED FIBERS SYSTEMS Box: 27001 City: RICHMOND VA 23261 Phone: 800-453-8527

=== Ingredients

=== Cas: 26125-61-1 Name: POLY(TEREPHTHALOYLCHLORIDE/P-PHENYLENEDIAMINE) (PARA-ARAMID POLYMER) > Wt: 89. ----------------------------- Cas: 7732-18-5 RTECS #: ZC0110000 Name: WATER, ABSORBED % low Wt: 0. % high Wt: 7. ----------------------------- Name: PULP WET-LAP % low Wt: 35. % high Wt: 70. ----------------------------- Cas: 7757-82-6 RTECS #: WE1650000 Name: SODIUM SULFATE IN KAVLAR PULP < Wt: .1 ----------------------------- Name: SODIUM SULFATE IN OTHER FORMS < Wt: 2. ----------------------------- Name: FINISH < Wt: 2.

< Wt: 2. === Health Hazards Data

=== Carcinogenicity Inds - NTP: NO IARC: NO OSHA: NO Effects of Exposure: EYE: FIBER FLY & DUST MAY CAUSE IRRITATION. SKIN: CONTINUAL RUBBING OF FIBERS & FIBER PIECES ON THE SKIN MAY CAUSE IRRITATION. INGESTION: KEVLAR IS NONTOXIC WHEN EATEN. INHALATION: KEVLAR IS TOO BIG TO INHALE INTO THE LUNGS, BUT FIBER DUST & FLY FROM PROCESSING MAY BE BREATHED INTO THE NOSE

& THROAT. WORKING UNPROTECTED IN DUSTY CONDITIONS MAY CAUSE UPPER RESPIRATORY IRRITATION & COLD-LIKE SYMPTO MS. CHRONIC: PROCESSING KEVLAR OR MACHINING MATERIALS CONTAINING KEVLAR MAY CREATE FIBER DUST IN THE AIR SMALL ENOUGH TO BE BREATHED INTO THE LUNGS. BREATHING HIGH CONCENTRATIONS OF DUST FOR LONG PERI ODS MAY CAUSE LUNG INJURY. Explanation Of Carcinogenicity: NONE OF THE COMPONENTS PRESENT IN THIS MATERIAL AT CONCENTRATIONS EQUAL TO OR GREATER THAN 0.1% ARE LISTED BY AIRC, NTP, OSHA, OR ACGIH AS A CARCINOGEN. Signs And Symptions Of Overexposure: EYE: IRRITATION. SKIN: IRRITATION. INHALATION: UPPER RESPIRATORY IRRITATION AND COLD-LIKE SYMPTOMS. First Aid: EYE: IN CASE OF CONTACT IMMEDIATELY FLUSH EYES WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES. CALL A PHYSICIAN IF IRRITATION PERSISTS OR DEVELOPS. INHALATION: IF LARGE AMOUNTS OF FUMES, DUST OR FIBERS ARE INHALED, REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN & CALL PHYSICIAN. IF PERSISTENT COUGH OR OTHER SYMPTOMS DEVELOP, GET MEDICAL ATTENTION. SKIN: WASH WITH SOAP & WATER. USE HAND CREAMS TO SOOTH & MOISTEN IRRITATED SKIN. GET MEDICAL ATTENTION IF IRRITATION PERSISTS AFTER CONTACT STOPS. INGESTION: IN CASE OF GASTRO-INTESTINAL DISTRESS FOLLOWING ACCIDENTAL INGESTION, CALL PHYSIC IAN.

=== Handling and Disposal

=== Spill Release Procedures: WASH, SHOVEL OR MOP UP AND PLACE IN SOLID WASTE CONTAINERS. FIBER IS NOT BIODEGRADABLE; DO NOT FLUSH TO DRAINS. CLEAN UP DUSTS AND PULP WITH HIGH EFFICIENCY PARTICULATE AIR(HEPA) FILTERED VACUUM EQUIP MENT, OR BY WET CLEANING. AVOID THE USE OF DRY SWEEPING OR AIR JET BLOWING OF FIBERS AND DUST, WHICH CAN RE-SUSPEND RESPIRABLE DUST IN THE AIR. Waste Disposal Methods: KEVLAR FIBER IS NOT A HAZARDOUS WASTE AS DEFINED BY REGULATIONS IMPLEMENTING THE RESOURCE CONSERVATION AND RECOVERY ACT(RCRA). WASTE MATERIALS OF KEVLAR MAY BE TREATED, STORED, TRANSPORTED AND DISPOSE D OF IN

ACCORDANCE WITH STATE AND LOCAL REGULATIONS GOVERNING THE DISPOSAL OF OTHER COMMON OR NON-RC RA REGULATED WASTE MATERIALS. Handling And Storage Precautions: DO NOT TOUCH MOVING THREADLINES OF KEVLAR FIBER. ENTAGLEMENT WITH THIS HIGH STRENGTH FIBER CAN SEVERELY CUT OR EVEN SEVER FINGERS. KEVLAR IS DEGRADED BY ULTRAVIOLET LIGHT. DO NOT STORE IN DIRECT SUN L IGHT. FLUORESCENT LIGHTING WILL CAUSE DISCOLORATION, BUT WILL NOT AFFECT FIBER MECHANICAL PROPERTIES Other Precautions: USE ONLY WITH ADEQUATE VENTILATION. AVOID DUST GENERATION. DO NOT CONSUME FOOD, DRINK OR TOBACCO IN AREAS WHERE THEY MAY BECOME CONTAMINATED WITH THIS MATERIAL. === Fire and Explosion Hazard Information === Extinguishing Media: WATER, FOAM, DRY CHEMICAL, CARBON DIOXIDE (CO2). Fire Fighting Procedures: WEAR SELF-CONTAINED BREATHING APPARATUS. KEEP PERSONNEL REMOVED AND UPWIND OF FIRE. WEAR FULL PROTECTIVE EQUIPMENT (FULL BUNKER GEAR). Unusual Fire/Explosion Hazard: KEVLAR FIBER DUST DOES NOT PRESENT AN EXPLOSION HAZARD.

HAZARD. === Control Measures === Respiratory Protection: RESPIRATOR USE MUST BE IN COMPLIANCE WITH OSHA STANDARD 29 CFR 1910.134(THE RESPIRATOR STANDARD). AN AIR PURIFYING RESPIRATOR WITH A DUST/MIST/FUME CARTRIDGE OR CANISTER MAY BE USED UNDER CIRCUMSTANC ES MEETING RESPIRATOR STANDARD. DISPOSABLE DUST MASKS EQUIVALENT TO 3M MODEL N95 8210 MAY ALSO BE USED. Ventilation: IF FUMES, FIBER FLY OR DUSTS ARE GENERATED, USE ENGINEERING CONTROLS (WHERE TECHNICALLY FEASIBLE) WHENEVER NECESSARY TO CONTROL EXPOSURES BELOW LIMITS. Protective Gloves: WEAR PROTECTIVE GLOVES AND SLEEVES. Eye Protection: SAFETY GLASSESOR COVERALL GOGGLES. Other Protective Equipment: ISOLATION, ENCLOSURES, EXHAUSTS AND VENTILATION, WETTING AND DUST COLLECTION SYSTEMS MAY BE USED. USE NON-GREASY MOISTURIZING SKIN CREAM TO

PREVENT DRYING. Work Hygienic Practices: WASH CONTAMINATED CLOTHING BEFORE REUSE. Supplemental Safety and Health: *DRY AND WET KEVLAR PULP IS PACKAGED IN MOSITURE-PROOF BAGS/BALES TO PREVENT DRYING TO LESS THAN 4% MOISTURE AND POSSIBLE PICKUP OF ELECTROSTATIC CHARGE. IF PACKAGE IS PUNCTURED, RE-MOISTURIZE PULP T O AT LEAST 4% MOSITURE BEFORE USING. === Physical/Chemical Properties === HCC: N1 M.P/F.P Text: DOES NOT MELT Spec Gravity: 1.45G/CC Solubility in Water: INSOLUBLE Appearance and Odor: ODORLESS, GOLDEN, SOLID: YARN, FELT, FABRIC, PAPER, PULP, FLOC, STAPLES === Reactivity Data === Stability Indicator: YES Materials To Avoid: NONE REASONABLY FORESEEABLE. Hazardous Decomposition Products: FIBER DECOMPOSITION TEMPERATURE >400C. AT LOWER TEMPERATURES FINISH MAY BOIL OFF AS A FUME, WHICH SHOULD BE VENTED. Hazardous Polymerization Indicator: NO === Toxicological Information === Toxicological Information: EYE EFFECTS: KEVLAR IS UNTESTED FOR EYE INJURY. SKIN EFFECTS: KEVLAR FIBER IS NOT A SKIN IRRITANT OR A SKIN SENSITIZER IN ANIMALS. SKIN SENSITIZTION HAS NOT BEEN OBSERVED IN HUMAN SKIN PATCH TESTS OR IN INDUSTRIAL EXPERIENCE. ACUTE ORAL EFFECTS: KEVLAR POLYMER HAS VERY LOW TOXICITY BY INGESTION. ORAL ALD > 7500 MG/KG IN RATS. ACUTE INHALATION EFFECTS: INDUSTRIAL EXPERIENCE SHOWS THE INHALATION OF KEVLAR FIBROUS DUST & FLY MAY CAUSE MECHANICAL IRRITATION OF THE MUCOUS MEMBRANES OF NOSE & THROAT.CHRONIC INHALATION EFFECTS: A 2 YEAR INHALATION STUDY PRODUCED PULMONARY FIBROSIS AT 25, 100 & 400 F/ CC. === Ecological Information === Ecological: KEVLAR FIBERS ARE NON-BIO-DEGRADABLE IN THE ENVIRONMENT & DO NOT LEACH MATERIAL

TOXIC TO FLORA OR FAUNA. FINISHES & ADDITIVES USED WITH KEVLAR ARE TESTED FOR THEIR POTENTIAL EFFECTS ON MANUFACTURING W ASTEWATER TREATMENT SYSTEMS. BIOCOMPATIBILITY & AQUATIC TOXICITY TESTS GIVE THE FOLLOWING RESULTS: FINISHES DO NOT APPEAR TO BE INHIBITORY OR TOXIC TO MICROBES COMMONLY FOUND IN BIOLOGICAL TREATMENT S YSTEMS. BIODEGRADATION & NORMAL ANTI-FOAM TREATMENTS SHOULD CONTROL FOAMING. DEGRADATION OF

& NORMAL ANTI-FOAM TREATMENTS SHOULD CONTROL FOAMING. DEGRADATION OF

SCOURED FINISHES SHOULD NOT RESULT IN INCREASED EFFLUENT TOXICITY. MOST FINISHES ARE SUBSTANTIALLY OR COMPLE TELY BIODEGRADABLE, BUT A FEW ARE NOT.

=== MSDS Transport Information === Transport Information: NOT REGULATED. === Regulatory Information === Sara Title III Information: SECTION 313: NOT REPORTABLE. Federal Regulatory Information: TSCA: KEVLAR FIBER PRODUCTS ARE LISTED ON THE TSCA INVENTORY. CLEAN AIR ACT AMENDMENTS OF 1990: KEVLAR FIBER PRODUCTS AND THEIR PACKAGING DO NOT CONTAIN NOR ARE THEY MANUFACTURED WITH ANY OF THE OZONE -DEPLETING SUBSTANCES LITEDD IN EITHER XLASS I (CHLOROFLUOROCARBONS, HALONS, CARBON TETRACHLORIDE AND METHYL CHLOROFORM OR CLASS II (HYDROCHLOROFLUOROCARBONS). FDA: SOME BUT NOT ALL, KEVLAR FIBER PROD UCTS ARE APPROVED FOR USE AS ARTICLES OR COMPONENTS OF ARTICLES INTENDED FOR REPEATED CONTACT WITH F OOD (CFR 21 PART 177.1732, 4/92 EDITION). State Regulatory Information: CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT OF 1986 (PROPOSITION 65): KEVLAR FIBER CONTAINS NONE OF THE SUBSTANCES KNOWN TO THE STATE OF CALIFORNIA TO CAUSE CANCER OR REPRODUCTIVE TOXICIT Y. PENNSYLVANIA AND NEW JERSEY RIGHT-TO-KNOW LAWS: KEVLAR FIBER IS CONSIDERED AN ARTICLE AND IS NOT SUBJECT TO THE PROVISIONS OF THE PENNSYLVANIA AND NEW JERSEY RIGHT-TO-KNOW LAWS.

=== Other Information

=== Other Information: CANADA: KEVLAR IS NOT WHIMIS CONTROLLED. THIS MATERIAL IS NOT TDG REGULATED. NFPA RATINGS: HEALTH-0, FLAMMABILITY-1, REACTIVITY-0. NPCA RATINGS: HEALTH-0 * (CHRONIC HEALTH EFFECTS), FLAMMABILITY-1, RE ACTIVITY-0.

=== Transportation Information

=== Responsible Party Cage: TO822 Trans ID NO: 154525 Product ID: KEVLAR BRAND FIBER MSDS Prepared Date: 11/19/1999 Review Date: 08/24/2000 MFN: 1 Net Unit Weight: UNKNOWN Multiple KIT Number: 0 Unit Of Issue: CY Type Of Container: CYLINDER

=== Detail DOT Information

=== DOT PSN Code: ZZZ DOT Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION

=== Detail IMO Information

=== IMO PSN Code: ZZZ IMO Proper Shipping Name: NOT REGULATED FOR THIS MODE OF TRANSPORTATION

=== Detail IATA Information

=== IATA PSN Code: ZZZ IATA Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION

=== Detail AFI Information

Detail AFI Information ____ AFI PSN Code: ZZZ AFI Proper Shipping Name: NOT REGULATED BY THIS MODE OF TRANSPORTATION

=== HAZCOM Label

=== Product ID: KEVLAR BRAND FIBER Cage: TO822 Assigned IND: Y Company Name: DUPONT Street: 1007 MARKET STREET City: WILMINGTON DE Zipcode: 19898 Health Emergency Phone: 800-424-9300 Date Of Label Review: 08/24/2000

Status Code: A Origination Code: F Eye Protection IND: NO Skin Protection IND: NO Signal Word: NONE Respiratory Protection IND: NO Health Hazard: None Contact Hazard: None Fire Hazard: None Reactivity Hazard: None === Disclaimer (provided with this information by the compiling agencies): This information is formulated for use by elements of the Department of Defense. The United States of America in no manner whatsoever expressly or implied warrants, states, or intends said information to have any application, use or viability by or to any person or persons outside the Department of Defense nor any person or persons contracting with any instrumentality of the United States of America and disclaims all liability for such use. Any person utilizing this instruction who is not a military or civilian employee of the United States of America should seek competent professional advice to verify and assume responsibility for the suitability of this information to their particular situation regardless of similarity to a corresponding Department of Defense or other government situation.