Northeastern

University
Student
Launch
Initiative

University

2016 - 2017
Proposal

Northeastern University
267 Snell Engineering
Boston, MA 02115

NU*HOPE*

Northeastern
University
High altitude
Object
Protection
Experiment

September 30, 2016

Table of Contents

1. General Information 3
1.1. Personnel Information 3
1.2. Facilities and Equipment 5
2. Safety Plan 7
2.1. Safety Plan Summary 7
2.3. Briefing Plan (Hazards, Accidents, and Pre-Launch) 9
2.4. Caution Statements 9
2.5. Compliance with the Law 9
2.6. Handling of Rocket Motors and Energetics 10
2.7. Safety Statements 10
2.8. Hazard Analysis 10
3. Technical Information 11
3.1. Launch Vehicle Information 11
3.1.1. Launch Vehicle Technical Info 11
3.1.2. Materials and Construction 14
3.1.3. Avionics 15
3.1.4. Motor Brand and Designation: 15
3.2. Payload Information: Fragile Material Protection 17
3.2.1. Payload Option Selection Process 17
3.2.2. Choosing Option 3: Fragile Material Protection 19
3.2.3. Approach to Payload Design 20
3.2.4. Payload Description and General Dimensions 24

3.2.5. Materials and Construction 25

3.2.6. Testing Plan 26

3.2.7 Sensor Suite / Telemetry 26

4. Educational Engagement 28

4.1. Educational Engagement Summary 28

4.2. Evaluation Criteria for Activities 28

5. Project Plan 29

5.1. Project Plan Summary 29

5.2. Team Leadership 29

5.3. Day to Day Operations 30

5.4. Project Launch Operations 31

5.5. NASA Required Milestones 32

5.6. Internal Team Milestones 33

5.7. Funding Plan 36

5.8. Budget 36

5.9. Sustainability 40

6. Conclusion 41

6.1. Concluding Remarks 41

Appendix A: Risk Assessment 42

Appendix B: Center for STEM Education Letter of Support 45

Appendix C: Gantt Chart 46

1. General Information

1.1. Personnel Information

1. Faculty Advisor:

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4. Mentor

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Approximately 25 members will be involved in the project. All tasks assigned to members will fall under the jurisdiction of one of the two project groups:

- Launch Vehicle
- Experimental Payload: Fragile Material Protection (Referred to as "The Payload")

The following members will be responsible for overseeing project groups and will be considered our key technical personnel:

1. Payload Lead – Sam

- Leads in design, building, and testing of the experimental payload.
- Assures payload integrates with LV.
- Coordinates creation of testing procedure and criteria for payload.
- Heads the creation of the payload content for reports; assures that it is completed by the draft deadlines.
- Completes final payload section review for all reports.

2. Launch Vehicle - Evan

- Leads in design, building, and testing of the launch vehicle.
- Assures LV is ready for Design Safety Committee check before each launch.
- Heads the creation of the LV content for reports; assures that it is completed by the draft deadlines.
- Completes final LV section review of all reports.

The following individuals will be responsible for overseeing the logistics and management of the project and will be considered our key managers:

1. Team Leaders - Evan and Sam

    - Point of contact for NASA
    - Oversee the planning of meetings (send emails)
    - Create and enforce deadlines
    - Coordinate with AIAA board

2. Head Safety Officer - David

    - Team who will create and implement the safety plan
    - Researching and writing the safety section of each NASA report
    - Present Safety presentation to team members prior to building

3. Assistant Safety Officer - Katherine

    - Assist safety officer in completing safety requirements

4. Treasurer - Geoffrey

    - Maintains team's budget.
    - Update NU AIAA Treasurer (Lauren Bell) with spending.
    - Organizing fundraising (ex: Provost).
    - Coordinates purchasing through specified buyers.

5. STEM Engagement Officers - Alyssa and Ben

    - Plan and coordinate STEM outreach for the team
    - Fulfill the engagement requirements and complete the final Educational Engagement Activity Report (due within 2 weeks of the event end date).

6. Faculty Advisor - Dr. Andrew Gouldstone

We intend to work closely with NAR Chapter #727, the Maine Missile Math & Science Club (MMMSC), and NAR Chapter #464, the Central Massachusetts Space modeling Society (CMASS).

1.2. Facilities and Equipment

1. Materials Testing Laboratory (for general build use)
    - Accessibility: 24/7 (when classes are not in session)
    - Necessary Personnel: Designated team safety personnel
    - Equipment:
        - Hand tools, cordless drill, digital scale, etc.
        - Soldering station
        - Flammable material closet
        - Chemical hood for safe use of epoxy and polyurethane foam
        - Instron tensile testing machine, and other materials testing equipment.
        - General use storage closet
        - MakerGear M2
        - Full Spectrum Laser

2. Student Machine Shop
    - Accessibility: Tuesday and Thursday nights
    - Necessary Personnel: Shop supervisor
    - Equipment:
        - Band saw
        - Horizontal band saw
        - Mill
        - Lathe
        - TIG and MIG welders

3. Mechanical Engineering Department Machine Shop

- Accessibility: 9am to 5pm on weekdays
- Necessary Personnel: Professional staff for machining assistance and supervision
- Equipment:
    - CNC Enabled Mills
    - Lathes

4. 3D Printing Studio
- Accessibility: Weekdays 9am to 5pm for consultations and printing
- Equipment:
    - Powder Printing
        - Objet 24
        - ZCorp ZPrinter 450
        - Dimension Elite
    - Fused Deposition Modeling
        - Makerbot Replicator 2
        - Makerbot Replicator 2X
        - Dimension Elite
    - Stereolithography
        - FormLabs Form1
    - Laser Cutter
        - Epilog Zing (30W)

5. Video Conference Room
- Accessibility: Weekdays 9am to 5pm (with one week notice)
- Equipment:
    - High speed internet
    - Audio/Visual conference capability

2. Safety Plan

2.1. Safety Plan Summary

NU HOPE makes safety a priority and have developed this safety plan to keep group members and any bystanders safe during this competition.

The main facility used by the team is an on-campus materials science lab to which key personnel have access. This lab is where the majority of basic assembly occurs that does not require machine tooling. As the lab is also used for classes, it contains chemicals and equipment associated with materials testing. We do not have permission or training to handle these chemicals or operate this equipment and will not be using either for the purposes of this project. The potential risks for the lab equipment are detailed in the risk assessment table in Appendix A.

The materials used by the team for this project are subject to change, however, we intend to utilize Blue Tube, PPE plastic nose cones, and wood for the launch vehicle. Additionally, the team uses two-part epoxy as well as two-part polyurethane foam. These chemicals have the potential to be dangerous if they come in contact with the skin or are accidentally ingested. These risks, while low, are evaluated in the risk assessment table.

The launch motor is one of the highest risks in a rocket project. As a club, we purchase our motors at the launch site instead of storing our own, usually from our team mentor (a certified motor vendor). We do this because storing energetics (such as rocket motors, black powder, etc.) ourselves introduces substantial risk of fires or personal injury. In addition, the storage area would be a university owned building, and is therefore not an adequate storage facility for these products.

2.2. Procedures for NAR/TRA Personnel to Perform

The team agrees to abide by all points outlined in the NAR High Power Safety Code. During the test phase of the project, our team will attend launches with the MMMSC in Berwick, ME. There is also a possibility of attending launches with the MDRA in Gaithersburg, MD. These are both established NAR chapters and conduct launches on a monthly basis. The proprietors of these launch sites have partnered with the club before and the sites meets all requirements to accommodate a waiver of 10,000 feet.

The team will abide by all of the points outlined in the NAR High Power Safety code as follows:

2.2.1. Certification. The team will only launch rockets using motors we are certified to use. This will be verified internally by team leaders as well as the RSO of MMMSC. There are multiple team members that are Level 1 NAR certified and some that are Level 2 certified. If larger motors must be launched we will either obtain certification to launch them or our mentor will launch them for us.

2.2.2. Materials. The team will comply with the materials requirement and will only use materials outlined in the safety code for constructing the rocket. This includes lightweight materials such as paper, wood, plastic, fiberglass, or when necessary ductile metal.

2.2.3. Motors. The team will only use motors that have been certified by either NAR, TRA, or CAR. The motor will be used to the manufacturer's recommendations and will not be modified. There will be no smoking, open flames, or heat sources within 25 feet of the motor. The motors will be handled by the team mentor, Rob DeHate.

2.2.4. Ignition System. An electrical launch system will be used exclusively to launch the rocket. This system will be provided and operated by the qualified member of MMMSC acting as the LCO.

2.2.5. Misfires. In the event of a misfire we will follow the explicit instructions of RSO. This generally involves waiting at least 60 seconds to approach the rocket. This rule will be enforced by team leadership as well as the RSO of MMMSC.

2.2.6. Launch Safety. The team will use a five second countdown before launching the rocket. This countdown will be broadcast over a loudspeaker system that is owned and operated by MMMSC. We will abide by the safe distance table and ensure that when arming the energetics no one except for safety personnel are within the minimum safe distance from the rocket. We will determine that the stability of the rocket is sufficient for a safe flight using the open source rocket simulation software, OpenRocket. We will not fly more than one High Power Rocket at a time.

2.2.7. Launcher. The team will be launching the rocket from a 15/15 rail provided by MMMSC equipped with a stable base, metal blast deflector, and fire resistant tarp positioned underneath the launch vehicle. The rod will be of a sufficient length to attain a safe velocity before separation of the rocket and the launch rail.

2.2.8. Size. The launch vehicle will not use a motor or motors with more than 40960 Newton-seconds of combined impulse and the vehicle will have a thrust-to-weight ratio greater than three. This will be ensured by measuring the weight of the launch vehicle prior to launch and comparing to the maximum weight outlined by this rule.

2.2.9. Flight Safety. The team will exercise flight safety by not launching at targets, into clouds, or near airplanes. In addition the team will comply with the rule by not launching any flammable or explosive payloads. We will not launch in wind speeds greater than 20 mph, due to the effect that weather cocking will have on the vehicle.

2.2.10. Launch Site. The launch site will comply with all points outlined by the safety code. This will be ensured by the team upon arrival at the site as well as members of MMMSC. The fields where the launches are conducted have been home to the launches for a long time and have been shown to meet all requirements of the NAR and the FAA for a flight waiver of 10,000 feet.

2.2.11. Launcher Location. The launch pad will be a safe distance from any and all residences, roads, highways, and power lines. The pad will be placed by members of MMMSC during setup, and will be verified by the RSO, as they are ultimately responsible for all launch operations that occur at MMMSC launches.

2.2.12. Recovery System. The launch vehicle will be fully recoverable. This will be ensured by using a dual deployment parachute system for the main body. At apogee, the booster will deploy a drogue parachute, and deploy a larger main parachute at a lower altitude using a Tender Descender. This will reduce drift while maintaining safety. To protect the parachutes during deployment, we will use Nomex flame retardant wadding.

2.2.13. Recovery Safety. The team agrees to only recover the rocket when it is safe to do so. This includes not attempting to recover it from power lines, trees, or anywhere where the actions of the recovery team will endanger the onlookers or personal property.

2.3. Briefing Plan (Hazards, Accidents, and Pre-Launch)

Each team member will be required to participate in a safety presentation run by the safety officers before being allowed to participate in building projects. This presentation will include information about safe operating procedures in the lab as well as information about Personal Protective Equipment location and usage. This presentation will also include emergency response training including fire response and first aid.

The purpose of the safety presentation is to give each member a good understanding of workshop operations and safety to minimize the chance of accidents. Pre-launch briefings will be given by the safety officer before launch. These briefings will communicate the safe operating procedures for the day. All team members will be expected to adhere to the safety plan set by the team as well as all rules set by MMMSC. The word of the RSO is final and the vehicle will not fly without RSO approval.

2.4. Caution Statements

The importance of Personal Protective Equipment (PPE) and safe operating procedures will be communicated to team members in the pre-building safety presentation as well as in all relevant documentation. Signs posted around the lab will remind students of the necessary PPE for specific activities. In addition to the signs, we will keep a quick reference guide that dictates the PPE that must be worn for specific activates. Material Safety Data Sheets, and the newer Safety Data Sheets will be kept readily available and accessible in the lab for all materials. Safety procedures will be emphasized in all pre-meetings and all pre-launch briefings.

2.5. Compliance with the Law

The team agrees to comply with all points laid out by the NFPA and the FAA concerning the launching of rockets and sale and transportation of commercial rocket motors and explosives.

This will be accomplished by working with MMMSC as well as our mentor. MMMSC already has steps in place to comply with the FAA and has already obtained a waiver to launch to 10,000 feet. The team will ensure the compliance of the NFPA rules for sale and transportation of motors by only buying certified motors from licensed motor vendors.

2.6. Handling of Rocket Motors and Energetics

We plan to purchase the vehicle motor from our team mentor, a certified motor vendor. He will transport the motor (and other energetics) to the launch site, and we will purchase them from him there. As discussed previously, by operating in this manner we avoid storing and transporting the energetics and the risks associated with these actions.

2.7. Safety Statements

All team members understand and agree to abide by the following points:

- The launch vehicle will undergo an inspection before each flight by the Range Safety Officer.
- The decision as to whether or not the rocket is safe to launch made by the RSO is the final word on the matter and if he/she determines it is unsafe to fly it will not fly until the hazards are addressed.
- Every team member will comply with all safety regulations set by the FAA, NFPA, NAR, NASA, the RSO, and any club that we launch with.
- Any failure to abide by these points will result in not being allowed to launch our rocket and can result in removal from the program.

2.8. Hazard Analysis

Please find our team's hazard analysis table in Appendix A.

3. Technical Information

3.1. Launch Vehicle Information

3.1.1. Launch Vehicle Technical Info

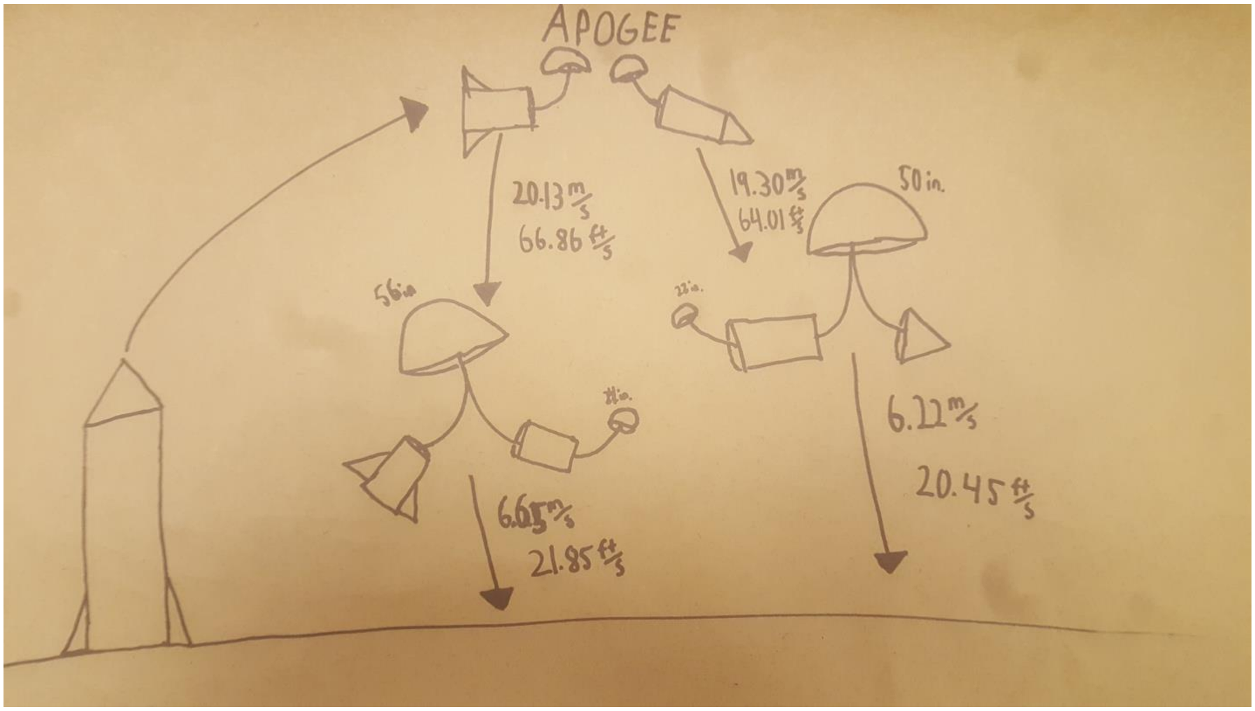


Figure 1: Concept of Operations

After launch, the rocket will ascend until it reaches an apogee of 5393.701 ft. Upon reaching apogee, the rocket will split. The booster section will deploy a drogue parachute 24 in. in diameter, and the payload section will deploy a drogue chute 22 in. in diameter. The booster section will fall with a velocity of 66.86 ft/s and the nose cone section will fall with a velocity of 64.01 ft/s. At about 1000 ft above the ground, each section will split again, and deploy a main parachute. The booster section will deploy a parachute 56 in. in diameter and will slow to a velocity of 21.85 ft/s. The payload sections will deploy a parachute 50 in. in diameter and will slow to a velocity of 20.45 ft/s. They will fall at this velocity until they touch down.

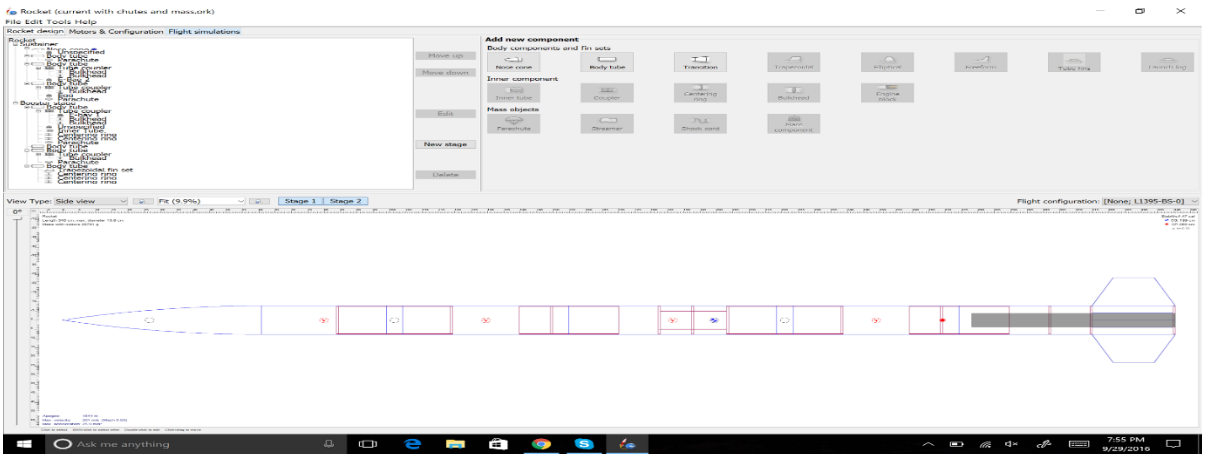


Figure 2: Open Rocket Simulation

Our proposed rocket, displayed in Figure 2 above, has a length of 134 inches and a diameter of 6.16 inches. It is comprised of two main sections, each of which are divided into two subsections. The rocket has a projected apogee of 5393.701 feet, which has been calculated via simulations utilizing the open source software Open Rocket. The first main section, the payload, is divided into the Nose and the Fragile Object Containment Unit (FROCU). The second main section, the Booster Section, is divided into the Aft Parachute Section (APS) and Motor Section.

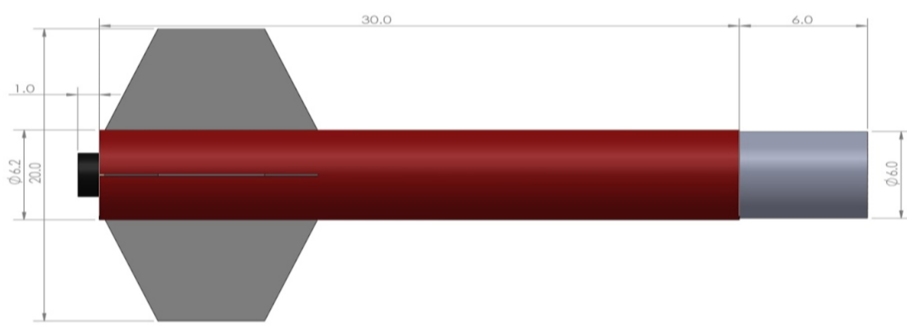


Figure 3: The Motor Section

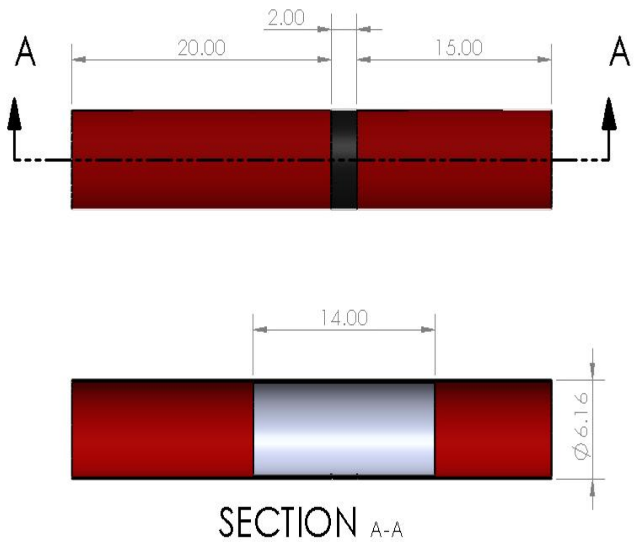


Figure 4: The Aft Parachute Section

Figures 3 and 4 are the two pieces of the vehicle's "booster section". Figure 3 is the motor section, and Figure 4 is the Aft Parachute Section. The booster section is 73 inches long, with a 26 inch-long Motor Section, and the APS being 47 inches. The APS houses an electronics bay between two bulkheads in order to protect the sensitive instruments cased inside. The Motor Section houses a 75 mm motor mount tube, and three centering to ensure that the motor remains stable and aligned during preparation and launch. There will be four trapezoidal fins attached to the Motor Section of the rocket, with a root chord of 10 inches and a tip chord of 5 inches. These four fins will be secured between two of the centering rings to further increase the structural stability of the vehicle.

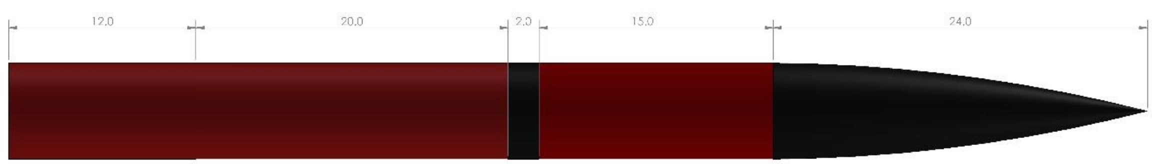


Figure 5: The Payload Section

The payload section will be 61 inches long, the Nose will be 24 inches long, and the FROCU will be 37 inches long. The Nose is conical nose cone made of carbon fiber to vastly reduce air friction during flight. The FROCU will house the payload in a protective compartment, and will also contain an additional electronics bay, and be secured by two bulkheads to protect the instruments.

3.1.2. Materials and Construction

The airframe body tube will be constructed of proprietary Blue Tube, a vulcanized cellulose material, from Always Ready Rocketry™. During the brainstorming phase, three airframe materials were considered: carbon fiber, fiberglass, and Blue Tube. Out of these three materials, carbon fiber is the most durable, while Blue Tube and fiberglass have approximately equal durability. In the Northeastern AIAA experience, Blue Tube body tubes have been able to sustain heavy impacts with minimal damage.

Furthermore, Blue Tube's advantage also lies in its cost-effectiveness. Both carbon fiber and fiberglass body tubes are more expensive than Blue Tube. Carbon fiber is about 5 times as expensive as Blue Tube. In terms of performance, fiberglass only offers an advantage at supersonic speeds, and for the purpose of this project, the launch vehicle will be subsonic. Moreover, since Blue Tube is the cheapest material out of the three, should errors occur during the construction phase of the launch vehicle, it would be easy to cheaply procure replacement material. The Northeastern AIAA chapter has had a long working history with Blue Tube, and members have made over 30 rockets using this material. Since club members are experienced with Blue Tube, it is an ideal candidate for the airframe material.

The fins will be made out of Garolite G10. Garolite G10 is a glass cloth laminated with epoxy, essentially making it a specialized version of fiberglass. Fiberglass is extremely impact resistant and durable. The epoxy layers also make the Garolite highly flame resistant, making Garolite an ideal choice for the fins since the launch vehicle will need to be launched multiple times. The nose cone will be made out of carbon fiber. Using carbon fiber for the cone keeps the cone incredibly light as well as durable.

There are four essential tasks for constructing the launch vehicle: cutting the Blue Tube into pieces for the various sections of the rocket; creating bulkheads; creating fin slots in the body tube; and creating fins. Most of the work will take place in the Northeastern machine shop. A band saw will be used to slice the Blue Tube into appropriate lengths for construction. The band saw will also be used to cut out fins from fiberglass sheets. The band saw is commonly used because of its ease of use and its versatility. Centering rings and bulkheads will be laser cut from quarter inch plywood sheets. The laser cutter is an ideal machine to create bulkheads and centering rings due to its precision and speed. The nose cone will be cut down to size if needed and will be sanded down. It is likely that weight will be added to the nose cone to counterbalance the weight of the motor. In order to create fin slots, a mill will be used in the machine shop. The constituent components of the rocket will be put together using epoxy. Epoxy is an incredibly strong and cheap adhesive that is also fairly heat resistant. After putting the components together, the rocket will be sanded and painted

3.1.3. Avionics

There will be two avionics bays in this rocket, one inside the motor half of the rocket and one inside the payload section of the rocket, since the two sections will separate from each other completely at apogee. Each section will have an identical set of avionics components: two PerfectFlite Stratologger altimeters, each powered by a separate 9V battery. Each section will also contain a Big Red Bee 2 meter APRS GPS for tracking. All information will be sent to an XBee radio telemetry device to be sent back to a ground station in real-time. The diagram shown in Figure 4 below is a schematic of how these components will be connected. In each e-bay, the components will be mounted on a plywood sled that has a bulkhead connected on either end; an aluminum foil cage will surround everything to ensure proper performance of components. The batteries will be mounted on plastic battery holders in order to ensure easy replacement, and all other elements will be mounted directly onto the plywood using screws and washers. One of the Stratologgers will be used as a redundant system in case the main one does not work. Each Stratologger will be connected to two e-matches, one for the drogue parachute and one for the main. The Stratologger will send a charge to ignite each e-match at specified altitudes: apogee for the drogue and 700ft for the main parachute.

Once launched, the rocket will be tracked online using the aprs.fi site and the live information sent from the XBee, and once it lands, a 2M Yagi antenna will be used to find its exact location to retrieve it.

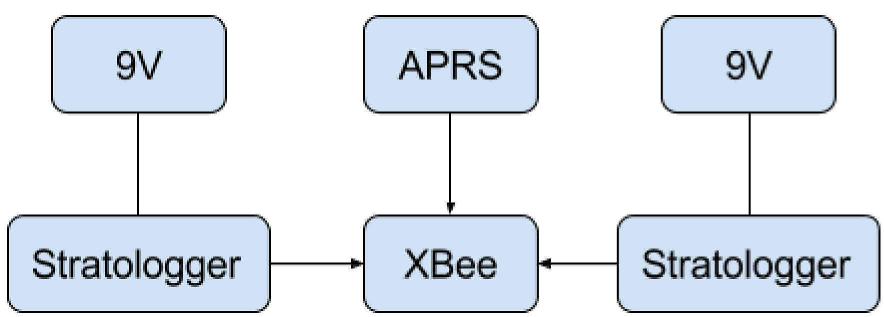


Figure 6: Avionics Flowchart

3.1.4. Motor Brand and Designation:

The rocket will employ a Cesaroni Technology L class rocket motor.

Table 1: Pro75 4895L1395-P

Loaded Weight	4323.0 grams	Total Impulse	4895.4 N-s
Propellant Weight	2364.9 grams	Avg Thrust	1395.7 N
Burnout Weight	1848.0 grams	Thrust to Weight Ratio (assuming our weight)	6.94

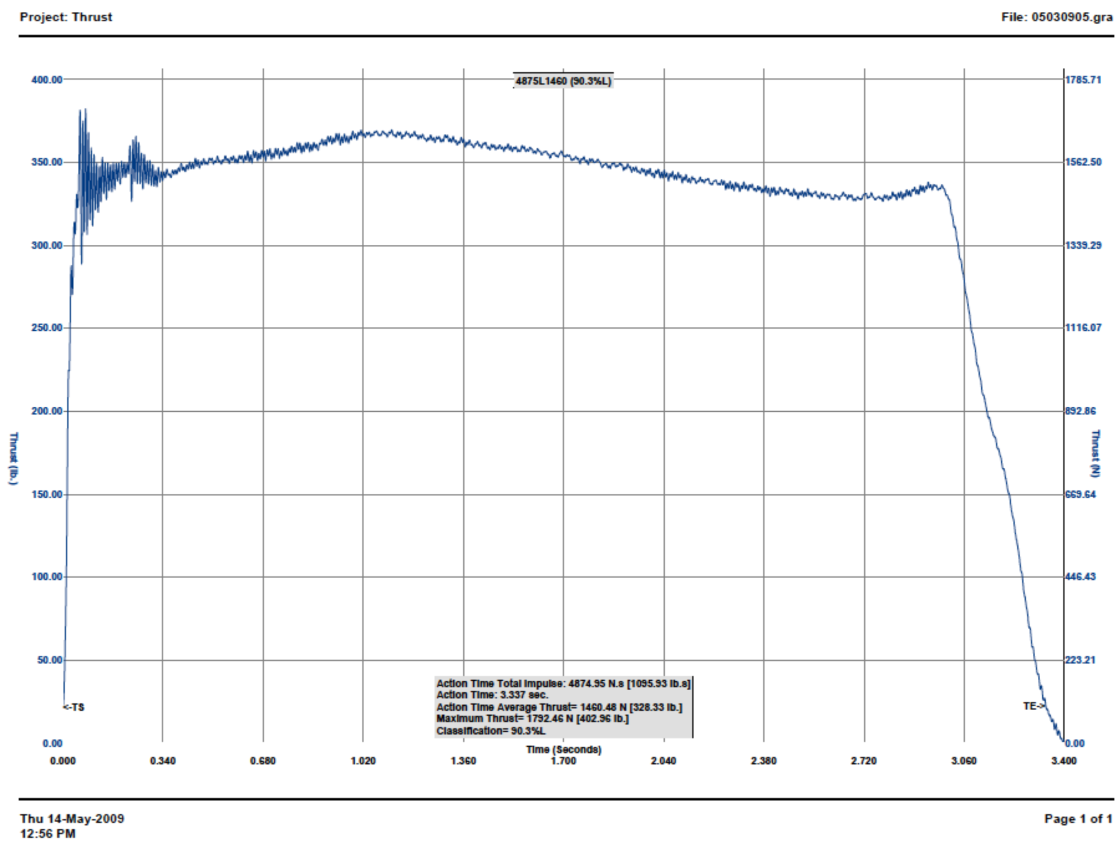


Figure 7: L1395 Thrust Curve

This rocket motor was chosen by our team because of its reasonable size, and its impulse. Its 75 mm diameter and 621 mm length allows our motor tube to be a comfortable size. The L1395-P also creates about 4895.4 N-s that puts us well within the target range of the challenge, with enough power to get to an altitude that is both close to and above a mile. This will allow our payload to change mass without significantly affecting the ability of the rocket to reach target altitude.

We chose a Cesaroni Technologies motor due to the reliability of their rocket motors, and the team's familiarity with Cesaroni Technologies motors.

3.2. Payload Information: Fragile Material Protection

3.2.1. Payload Option Selection Process

The payload team kicked off the semester by meeting to initially discuss all of the payload options, to brainstorm the pros and cons of each, and to give us a good jumping off point to start deciding on a payload to pursue for the competition. After thoroughly reviewing the requirements for each option, we also broadly discussed how we thought we should create a system to choose our experiment in order to utilize our team's prospective members with diverse majors and skills. We also wanted to assure that we would choose a payload option that would thoroughly engage the whole team throughout the entire 8-month process. Finally, we took a quick poll of those in attendance and found that we had a preference of either Fragile Material Protection (option 3) or Roll Induction and Counter Roll (option 2), the former having slightly more votes; there was a weaker interest in Landing Detection and Controlled Landing (option 1).

We challenged everyone from the first meeting to spend the weekend mulling over the options and investigating the pros and cons of each for themselves, even brainstorming some possible avenues each could explore. In addition, we sent out an email to the 48 people who responded to our initial feeler email and requested they read the payload options and complete a poll ranking their preference. This poll combined with the votes from the previous meeting resulted in 21 participants. Again there was a preference toward options 2 and 3, though this time the former received a slightly higher favor.

To achieve our deadline of selecting a payload by *Monday, September 5th* we met and utilized the option preference data we gained from our polls along with a weighted decision matrix to decide on which payload to pursue this year. The major goals we identified that we wanted the payload options to fulfil are outlined in Table 2.

Table 2: Project Goals Table

Goal	Description
Learning	Expand team knowledge about rocketry, physics, etc.
Achievability	Can we complete the project well? Do we have the background knowledge needed to anticipate success?
Skillsets Engaged	Incorporate multiple majors/skills such as mechanical, electrical, software, etc.
Creativity	Ability to be creative in interpreting the experiment criteria.

Next, we created a pairwise comparison chart in Table 3 to compare the importance of each goal in relation to each other and come up with an overall ranking for the goals.

Table 3: Pairwise Comparison Chart

Goals	Learning	Achievability	Skillsets Engaged	Creativity	Total	Rank (Importance)
Learning	--	0	1	1	2	2nd
Achievability	1	--	1	1	3	1st
Skillsets Engaged	0	0	--	1	1	3rd
Creativity	0	0	0	--	0	4th

Then, we started our weighted decision matrix by assigning a weight for each objective through rigorous discussion, shown in Table 4.

Table 4: Weighted Decision Matrix – Part 1

Objective	Rank (from Pairwise Comparison)	Weight (Determined through discussion)
Learning	2	25%
Achievability	1	50%
Skillsets Engaged	3	15%
Creativity	4	10%
Total		100%

Next, we went through each objective and attributed a percentage to how much we thought it achieved each goal, seen in Table 5. To make this process easier, we would find a general consensus among the group about which option best fulfilled each goal and we would give it the highest percentage. Then, we assigned lower percentages to the other two options depending on how they respectively fulfilled each goal

Table 5: Weighted Decision Matrix – Part 2

Objective	Option 1	Option 2	Option 3

Learning	60%	90%	90%
Achievability	40%	70%	80%
Skillsets Engaged	90%	80%	60%
Creativity	75%	60%	90%

Finally, we multiplied the percentages each option received from part 2 by the weight we designated each goal in part one and then added these percentages up to get an overall total percentage score for each option, as seen in Table 6.

Table 6: Weighted Decision Matrix – Part 3

Objective	Option 1	Option 2	Option 3
Learning	15%	23%	23%
Achievability	20%	35%	40%
Skillsets Engaged	14%	12%	9%
Creativity	8%	6%	9%
TOTALS	49%	70%	72%

Once again option 3 and 2 were in the lead, this time option 3 got a slightly higher percentage, while option 1 was lagging behind. Using this decision matrix result and factoring in the member's preference from our poll we ultimately decided on pursuing payload option 3.

3.2.2. Choosing Option 3: Fragile Material Protection

The following are the main four reasons we ultimately decided to journey into utilizing option 3, fragile material protection, for our experimental payload:

1. ***High Achievability***

After reviewing our team's strengths, focusing on our current knowledge and skill sets, we believe that option 3 best fits the capabilities of the team. Overall, we believe that option three presents an opportunity for the team to apply a wide variety of our talent effectively and successfully. Ideally, this will be a positive competitive experience, allowing for the team to apply their existing knowledge of payload protection, as well as learn new skills to be applied towards a successful payload module. While our last NASA USLI launch saw an unfortunate "rapid unplanned disassembly", we believe that this current project is achievable and practical enough that they can tackle it with a level of high confidence and make for a much more successful launch attempt.

2. ***Opportunity to be Creative and Original***

We believe that option 3 will allow our members to utilize their creativity and develop a unique, functional, and challenging design to complete the objective. The flexibility of the project's goals will allow us to utilize the team's engineering and scientific talent to generate original idea that successfully completes the task while being sufficiently different from other engineering teams. Since the core requirement is simply to protect the payload within the parameters set, we have a great deal of freedom to decide exactly how this will be accomplished.

3. ***Accessible to All Members – Everyone Learns***

Option 3 greatly resembles the classic "egg drop" challenge that most undergraduate engineering students have encountered at some point. The egg drop provides a great commonality for the payload team, allowing for everyone to have some sort of ground knowledge of the concept upon which we can build and brainstorm. We aim to encourage new members to feel comfortable with participating in design sessions, as it makes members feel at ease and confident in contributing to the design discussion. This common starting ground also allows for our more experienced members to engage newer members to teach them about the engineering and calculations behind designing, building, and testing a successful payload.

4. ***Payload and Launch Vehicle Independence***

By having a payload that is carried to apogee by the launch vehicle, without interfere during powered flight, we have the freedom to isolate the launch vehicle from the payload, and vice versa. This allows us to work on the two sections in tandem. This way, delays in one section will not severely impact the timeline of the other. In option two, the launch vehicle's success would tie in heavily with the payload, due to the unavoidable level of integration between the two. In this case, a failure of the payload system would jeopardize the launch vehicle itself, possibly creating a safety hazard.

The independence of option 3 allows for flexible testing opportunities, in which the launch vehicle can use an equivalent payload mass with some sensors to gather data, and then the payload can be separately tested and the maximum forces measured. This promotes working on the segments in more dedicated, independent teams, which have to depend less upon cross team integration to guarantee success.

3.2.3. Approach to Payload Design

Upon deciding to pursue the third payload experiment option, Fragile Material Protection, we wanted to hold a fun activity to get engage all of our team members. We decided to run an impromptu fragile payload protection competition of our own, in the form of an egg drop competition. We split up into five teams, each with the same fixed amount of materials ranging from paper to Play-doh^{TM}; each team had 45 minutes to design and build their payload to encase and protect a raw egg. The activity culminated in a friendly competition where we first dropped the fragile material protection systems from one story, and then two stories to see which team's creations could survive.

Figure 8 and Figure 9: Intro Team Egg Drop Competition

This team icebreaker allowed members to start thinking creatively and practically about what kind of methods you can use to lessen forces on an object. Next, we were able to run a giant brainstorming session where all ideas were encouraged. After going through the basic payload requirements from the SL handbook, we made lists spanning all of the blackboards in the room: how to best protect an unknown payload; what types of materials we could use; what sensors we might want; how we could test our system; any questions we wanted answered; and what to think about and research before our next meeting.

We continued brainstorming in the next meeting, but tried to focus in on the ideas we liked more and began to think about how those payload protection systems could actually work. We created a list of the main concepts we thought would best be able to aid us in protecting the unknown object(s). In addition, we honed in on compiling a more complete list of requirements for the payload, taking into consideration both the competition enforced requirements and general restrictions we had in terms of being integrated with the launch vehicle. From this we created a set of design criteria.

Figure 10: Experiment Protection Brainstorming Session

The following is a list of criteria the payload design must fulfil in order to successfully comply with the regulations put forward by NASA, and the requirements identified by our team to assure a successful recovery of the unknown fragile material.

List of Payload Experiment Requirements:

- Must protect object(s) that fit within a cylinder 3.5” in diameter and 6” tall.
- Mass calculations must account for the object(s) weighing a maximum of 4 ounces.
- Object(s) must be sealed in their containment apparatus until after the completion of the launch.
    - Must meet size, shape, and weight requirements of launch vehicle in order for successful integration.
    - Payload system takes up its own section of launch vehicle
- Use passive protection system that does not need to be actuated to reduce the risk of failure
    - Plan to hit ground vertically, but must be able to deal with hitting bottom corners
    - Supplementary material cannot be added to the payload protection system once receiving the object(s) on launch day.
    - Need to be able to accommodate for the possibility of multiple objects.
- Payload protection system has to be able to be repeatedly tested.
    - Should incorporate modularity in order to allow for heightened flexibility in adaptation for testing.

    - Must have electronic infrastructure to facilitate data collection of forces similar to what we anticipate the object(s) will undergo.

- Live telemetry for testing and launched to update acting forces.

    - Used to verify if we are accomplishing goal of having object(s) survive anticipated forces.
    - Have less than 75ft/lbs of kinetic energy when it hits the ground.

- Maximum drift of 2500 feet at 25 mph winds.

Now that we had brainstormed a lot of protection system methods, and a system to rate our designs, we had another team meeting where we broke up into six teams and had each team come up with their version of what they thought our payload system should work. This generated more thought out ideas with corresponding preliminary designs. The meeting concluded with each team presenting their designs to the larger group, and answering any questions about why they made the design decisions they did.

Next, we could do a large review of all of our previous brainstorming and focus on looking at our six designs from the previous meeting. We found that a lot of our group designs had things in common, and so we went back over each design and picked out the main ideas. We now had a list of the major design concepts we had identified. Going back over our design criteria, we went through the list and did a vote to either incorporate the concept in our initial design or to exclude it from the design for now and possibly investigate it further later. The payload subsection finally culminated in a payload concept that had a design that focused on encompassing three major ideas:

1. An adjustable plate system to be able to adapt to the unknown object(s) taking up any volume up to the maximum ⅗" diameter by 6" long imaginary cylinder. This plate system would also incorporate a multiple plate design which would allow for the creation of subsections to space out multiple objects if they are given.
2. The inclusion of an inner sub-container for the payload that is suspending within the larger launch vehicle payload section.
3. This inner section would have a split damping strategy where we split up the vertical and horizontal forces and had some sort of system to combat both.

We also generated a basic design scheme that incorporated all of these general design ideas. Also, we designated the exact space in the rocket for the payload by declaring the max dimensions it would take up: a height of 18" in the 6" diameter launch vehicle and a weight of 10lbs. We also decided on some general types of dampening and cushioning materials to test in our prototyping phase, including springs, foam, and segmented compression materials.

Now that we had thoroughly created design criteria and major design concepts to abide by, we began to work on our initial payload protection system design. This encompassed generating initial paper designs before moving into SolidWorks to make our computer aided design (CAD). In addition, we had to start finding what materials we wanted to purchase to construct a prototype of our fragile material protection system.

3.2.4. Payload Description and General Dimensions

The payload system will consist of an outer and inner cylinder. The inner section has multiple disks in it that can be moved up and down into notches created along the insides of the cylinder in order to partition the unknown payload, if it comes in multiple parts. The disks will be padded with a compressive material to further cushion the object(s); this material will be chosen after we test out a variety of options during our prototyping phase. The open volume of this inner section is adaptable using an adjustable payload bulkhead that can be moved vertically in the inner section and locked into place with a bulkhead adjustment pin. Outside of the cylinder on the sides is additional foam to cushion the x-axis, which we assume will have the weakest force exerted on it throughout the launch and the landing. The y-axis, which we assume will require the most force dampening, is a system consisting of springs on the bottom and either a foam section or reusable honeycomb structure on the top. The foam or honeycomb on top, instead of additional springs, is to prevent the inside cylinder from oscillating. The springs on the bottom are in two layers extending down from the interior cylinder with a layer of wood separating the two layers.

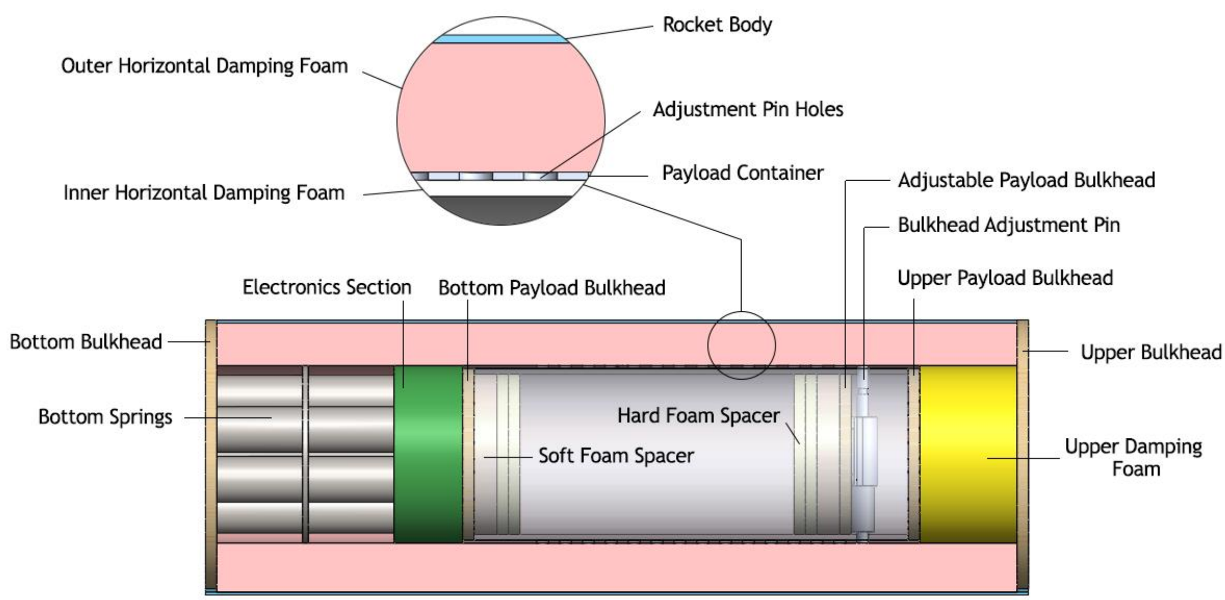
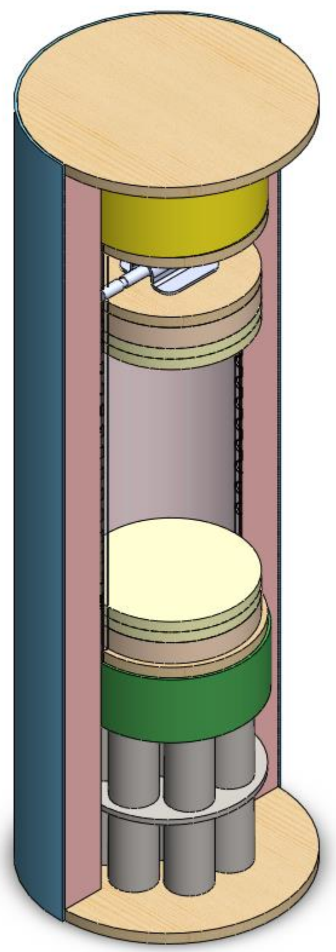


Figure 11: Payload Design – Protection System Components Labeled

In conjunction with the launch vehicle team, we created a set of maximum size requirements for our payload to integrate with the launch vehicle. The maximum dimensions of our payload dedicated launch vehicle section is 6” diameter tube that is

18” long. Our inner section must fit within this body tube, with enough room for substantial padding and compression methods, and must also be able to house a maximum volume of an imaginary 3.5” diameter, 6” long cylinder to be able to encompass the maximum dimensions of the unknown object(s). Taking into consideration the 4oz maximum mass of the unknown object(s), our entire payload section should weigh a maximum of 10lbs.



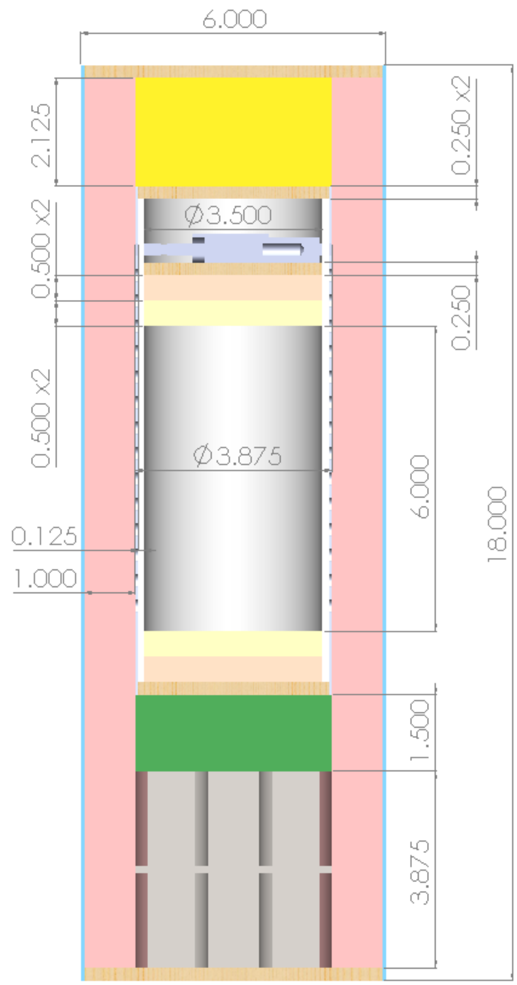


Figure 12 and Figure 13: Payload Isometric View and Dimensions

3.2.5. Materials and Construction

After reviewing many methods of dampening force, we have decided to test four different padding options that will cushion the outside of the payload. One of the options is Super-Cushioning High Strength EVA Foam Sheets. We chose these foam sheets because they lessen impact force and resist tearing better than other types of foam. We will also be considering Purple™ Cushion, which is a hyper elastic polymer, as another method of cushioning. This technology is created in a grid format which allows pressure to be passed from wall to wall. In addition, we will be testing shredded Latex and Ionomer

Foam Sheets. Shredded Latex is a heavier option with inherent elasticity and compression, while Ionomer Foam Sheets have the unique ability to bond ionically to neighboring molecular chains with the same bond as the polymer chain itself, allowing them to be molded into different shapes and thicknesses with relative ease.

We are testing Chemical-Resistant Nylon foam sheets and High Temperature Silicone foam sheets for the moveable discs inside of the payload. We have chosen these sheets because they have a close celled structure, which increases the density and structural integrity of the foam. We have chosen three different firmnesses and two different thicknesses of foam so we can test multiple combinations of disks, and find the optimal protection system. To cushion the interior wall of the cylinder that is holding the payload, we are using an ionomer foam sheet, which is highly resistant to impact tearing. The characteristics of these foams should provide optimal protection for the payload.

We have decided to test three different types of springs within the K65 series. They will be on the underside of the inner payload container in order to dampen the force exerted on the payload during the flight and the landing. They all have an individual total length of 1.75 inches. We chose 1.75 inches because we plan to use two layers of springs working together separated by a layer of wood. We have 3.875 inches of total space underneath the internal payload container, so that leaves us with .375 inches of wood in between. The three different types of springs we chose are all compression springs, ranging from 1.5” diameter to 2.2”. This allows us to use about 10 springs, all in parallel with each other, on each layer. The spring rates range from 2.86lbs/inch to 16.2 lbs/inch. These ranges will allow us to find the most optimal spring rate to dampen the force.

A possible material to dampen acceleration force on the precious cargo, we plan to use a Negative Stiffness (NS) Honeycomb design. It is superior to normal honeycomb as it can absorb multiple impacts without losing structural integrity. This structure would be used in the upper level of the payload protection system and functions by absorbing energy from the payload (Correa). We do not know how this structure will perform under large acceleration forces, and we have to determine how to scale down this design. We plan to produce the NS Honeycomb using PLA filament and 3D printing using CURA.

3.2.6. Testing Plan

We plan to have a system of sensors in our subscale launch vehicle, to get a better grasp of the forces that our payload protection system must withstand. Our prototype will ideally be completed by the end of fall. Once complete, we will put it through extensive testing, including dropping the prototype from high elevations and slingshotting the prototype at high velocity into the ground. As we perform the tests, we’ll continuously make revisions to the prototype model until we reach our finalized version, which will be ready to be utilized in the full scale launch vehicle. If there is still any late revisions or improvements to be made to the payload for use in full scale, adjustments to the model and timeline accordingly in preparation for the competition.

3.2.7 Sensor Suite / Telemetry

The sensors onboard the payload section will be used to measure and gather data on the forces the payload undergoes during its flight. We are focusing on collecting acceleration data over the course of the payload's flight. The accelerometer will be accompanied by a selection of other sensors, so as to get supplemental data about what happens to the payload (gyroscope data, temperature, etc.). We are looking to use the 10 DOF IMU Breakout board to do this. The data collected by these sensors will be sent via radio to the ground station. It will provide live data, including the position of the payload, throughout the flight. We want to have a telemetry system in our launch vehicle that will gather data about what forces the payload sustains during flight and be able to both save the information to local memory in the launch vehicle, and be able to radio it down to the ground station in real time. To do this, we will be using XBees to transmit and receive the data. Since we are using Xbees, we will not need certification to use radio. Also, we will be trying to configure a system which would give us the ability to send a signal to the radio (the XBee) on launch pad right before the launch. This will start the data collection process and radio transmission. It will then continue to collect data throughout the entire launch and landing. The sensors will be tested in the subscale and eventually a final sensor configuration will be used in the final launch.

4. Educational Engagement

4.1. Educational Engagement Summary

For this year, we have several STEM outreach events already planned. We have already participated in one STEM event this year, the Cambridge Science Festival's Science on the Street event, where we helped run a booth showing children how to construct stomp rockets and paper kites. In the future, we plan to run the following events:

1. STEM Field Trips for the Northeastern University Center for Stem Education: We will be running egg drop and catapult activities on November 18th and February 3rd, and we are currently in the preliminary stages of planning more activities for January 13th, February 17th, March 31st, and April 7th.
2. NEPTUN: We will be running a seminar for the Northeastern Program for Teaching by Undergraduates. In total we will run four 2 hour long courses spread between October 22nd and 29th.
3. Cambridge Science Festival: We will be running our own booth at the festival's Science Carnival and hosting our own event at Northeastern as a part of the weeklong festival in April.
4. MathMovesU: We will be participating in this day-long event for over 200 middle school-age Girl Scouts, in collaboration with engineers from Raytheon.
5. Building Bridges: A biannual Center for Stem Education event for high school students, where they are introduced to the NEU College of Engineering, and participate in engineering activities run by Northeastern students and faculty.

See Appendix A for our letter of support from the Center for STEM Education.

4.2. Evaluation Criteria for Activities

The event will be considered successful if:

- Kids participate in STEM themed, team activities
- Children get hands on experience trying to solve a problem by going through the scientific/engineering design process
- Students learn a little about what our club is and why we love STEM so much, exposing them to what exciting possibilities STEM offers
- Students learn something new (ex: basics of rocketry)
- The kids have fun and enjoy the activity

We want to educate and get students interested in rockets. We plan to do this by showing students in what our club is about by showcasing our awesome past projects, teaching them about the basics of rocket science, and overall getting them excited about STEM!

5. Project Plan

5.1. Project Plan Summary

NASA Student Launch is a challenge which requires an aggressive initial timeline. Last year in the fall, the team sat back and coasted to a start. This year, there will be no such coast phase. We will set deadlines for key milestones much earlier than in previous years. We are looking at targeting the **October MMMSC launch** for our subscale launch test. This early deadline will require a lot of development work up front, and a lot of time and personnel management, but gives three distinct advantages:

1. In case of an inflight anomaly that results in catastrophic vehicle failure, we will have a timeframe to conduct backup launches, should the team desire to.

2. In the likely case of a successful launch, we will have a lot of time to review the data, and make improvements to the vehicle, as well as the flight plan

3. Finally, this early deadline would give us much needed time to conduct an internal critical design review in November.

Table 8 gives an outline of the launch days that we have at our disposal this fall. Note that some NAR clubs do not have an adequate ceiling to conduct subscale test launches.
This plan will require a minimum of two days per week of meetings of 1-1.5 hours in length, with the expectation that the leaders of the development teams will be putting in an extra hour or so per week for organizational purposes. Please see section 5.3. “Day to Day Operations” for more information on specific meeting times.

5.2. Team Leadership

In order to efficiently undertake the workload involved in participating in this challenge we chose to create a board centered leadership. One benefit of this style of leadership is that by having multiple leaders with clearly identified responsibilities the work load for each person is lessened. In addition, regularly scheduled board meetings allows for a reliable system for the leaders to meet and update each other on their progress, to assure that everyone is meeting their deadlines and the team as a whole is making good progress.

Table 7: Leadership Positions & Responsibilities

Position	**Responsibilities**
Team Leaders (2)	• Point of contact for NASA. • Oversee the planning of meetings (send emails). • Create and enforce deadlines. • Coordinate with AIAA Executive Board.

Launch Vehicle Lead	• Leads in design, building, and testing of the launch vehicle. • Assures LV is ready for Design Safety Committee check before each launch. • Heads the creation of the LV content for reports; assures that it is completed by the draft deadlines. • Completes final LV section review of all reports.
Payload Lead	• Leads in design, building, and testing of the experimental payload. • Assures payload integrates with LV. • Coordinates creation of testing procedure and criteria for payload. • Heads the creation of the payload content for reports; assures that it is completed by the draft deadlines. • Completes final payload section review for all reports.
Treasurer	• Maintains team's budget. • Update NU AIAA Treasurer with spending. • Organizing fundraising (ex: Provost). • Coordinates purchasing through specified buyers. • Make sure we purchase everything through one account so we accrue points.
Safety Officers	• Team who will create and implement the safety plan. • Researching and writing the safety section of each NASA report.
STEM Engagement	• Fulfill the 200 minimum engagement and complete the final Educational Engagement Activity Report (due within 2 weeks of the event end date).

Additional leadership positions will open in the spring in preparation for and at the competition. These spring positions will include a person in charge of the logistics for the trip to Huntsville, an official spokesperson for the team for when we get to the competition, and a public relations coordinator to organize and publish media for the competition.

5.3. Day to Day Operations

The NASA student launch team will meet twice a week, however, this schedule may be adjusted as necessary due to increased/decreased workload at specific points during the project. In order to ensure that every meeting has clear organizational goals, the team leaders will meet with each other each weekend for approximately ½ hour. During these meetings, an excel spreadsheet of current tasks and action items will be compiled. This spreadsheet will then be printed out, and hung on the wall of the lab, so that all members of the NASA project can see it. Tasks that are currently assigned to someone will have that person's name in the field next to the task. Tasks that are open will have no name next to the task, and will be able to be rapidly assigned to members waiting for work. This will allow us to give longer and more detailed tasks to the more dedicated members of the project, while having a constantly updated quick reference sheet for those members that wish to help, but cannot commit to working on the project full time.

5.4. Project Launch Operations

At a minimum, this project requires three launches:

1. A subscale test launch of the launch vehicle and recovery systems.
2. A full scale test launch of the launch vehicle and recovery systems.
3. A full scale launch of the launch vehicle, recovery systems, and experiment at Huntsville Alabama.

For the purposes of this proposal, we will only focus on the first subscale test launch, as there are no launch dates set in stone for 2017. As the 2017 launch dates become available, the project leadership will sit down and knock out a plan for the full scale vehicle launch.

As stated above, for the subscale test launch, we are targeting the October 22, 2016 launch at the Maine Missile Math and Science Club in Berwick, Maine. This means that we will conduct our design safety committee (an AIAA internal quality assurance team) review by at October 19, 2016 at the latest. If we find that we are unprepared to launch by the October launch day, we will target our backup launch day of December 3, 2016. There is a launch on November 26, 2016, however, this launch day is undesirable, as it takes place over the Thanksgiving holiday. These launch days assume that no other MMMSC launches are announced. In order to provide transportation to the launch, we will see if there are members on the team with access to cars. Furthermore, we will ensure to make sure that members that are eligible to drive the COE vans get the proper certifications to do so.

The logistics of moving a team to a launch are very complicated, so for each launch we will ask a group of people in the project to oversee them. This will have a two-fold benefit, as we are providing members in the team a leadership opportunity, and we are also ensuring that the logistics of getting ourselves to and from the launches are actively managed.

Table 8: List of Nearby Fall Launches

NAR Club	Location	Available Launch Dates
MMMSC	Berwick, ME	10/1/16 10/22/16 (Subscale Launch) 11/26/16 12/3/16
CMASS	Amesbury, MA	10/15/16 11/5/16 11/19/16
MDRA	Various locations, MD	10/8/16 – RIMRA 11/12/16 – RIMRA 12/10/16 - RIMRA

To ensure that we do not only focus on the launch vehicle, we will also be expecting drastic progress from the experiment team at each internal milestone. Please see section 5.6. for a list of the internal milestones for both the launch vehicle and the experiment.

5.5. NASA Required Milestones

In addition to the required physical deliverables, NASA also requires that teams thoroughly document the process of designing, testing, building, and validating their launch vehicles and experiments. NASA does this by requiring reports at various milestone points throughout the project. Table 9 gives a summary of the required milestones, due dates, and the deliverables due at each.

Table 9: NASA Required Milestones

Milestone	Deliverables	Due Date
Proposal	• Full proposal of project, with concept outline, budget, STEM plan, and project plan	9/30/2016
Preliminary Design Review	• Preliminary Design Review Report: Document with details of preliminary design and project progress so far • Preliminary Design Review Presentation: Presentation presented to NASA engineers and SME's. Must contain preliminary design, emphasis on launch vehicle and recovery system. Must also contain experiment preliminary design and analysis. • Preliminary Design Review Flysheet: An overview of the launch vehicle so far.	10/31/2016
Critical Design Review	• Critical Design Review Report: Document detailing final design and project progress. • Critical Design Review Presentation: Presentation presented to NASA engineers and SME's with details of the final design of the launch vehicle and final experiment design. • Critical Design Review Flysheet: A final overview of the launch vehicle design "as designed" details. • Subscale Flight Data	1/13/2017
Flight Readiness Review	• Flight Readiness Review Report: Document detailing final design "as built" and justifying flight readiness of launch vehicle and experiment.	3/6/2017

	• Flight Readiness Review Presentation: Presentation discussing the "as built" details of the launch vehicle and experiment, and justifying both of their safety to the NASA team of safety experts. • Flight Readiness Review Flysheet: Overview of the final "as built" launch vehicle • Full Scale Flight Data	
Launch Readiness Review	• Conducted at Huntsville by a team of NAR experts, this is a full review and justification of the launch vehicle and experiment. The NAR team is focused on ensuring that the vehicle is safe for flight.	4/5/2017
Launch Day	• Final Launch Vehicle • Final experiment • Launch checklist	4/8/16
Post-Launch Assessment Review	• The PLAR is an assessment of system in-flight performance.	4/24/16

Most of the milestones require written reports and formal presentations. These reports are one of the key aspects of the project, as in the greater engineering world, it is important to understand how to organize and compile a large technical report. Due to the nature of the project, these deadlines come up very rapidly, so it will be necessary to always ensure that the team is always aware of the next deadline, and continuously making progress towards completing it. At some points in the project, this may require a certain group to accomplish multiple things in parallel, for example, building the subscale vehicle in addition to writing the PDR.

5.6. Internal Team Milestones

In addition to NASA's mandated milestones, we feel it is necessary to set internal team milestones. These internal development milestones will help keep the team focused in between design reviews, and allow for team leaders to plan for set dates to ensure the entire team is up to speed on the current design, and plan. Due to the nature of the project, the dates behind these internal team milestones are very fluid, and more will be added over time. Table 10 covers the absolute minimum team milestones that we feel are necessary. Please see Appendix C for our team's GANTT chart that encompasses these milestones.

Table 10: Internal Team Goals and Milestones (Fall 2016)

Milestone	**Deliverables**	**Due Date**

Payload Selection	• Decide on a payload option from the three possible experiments using member votes and a weighted decision matrix.	9/5/2016
First Meeting	• Officially introduce the challenge to members, layout the plan for this year's competition, and welcome new members.	9/7/2016
AIAA Proposal	• Written proposal due on Friday @ 10PM. • Oral presentation on Saturday @ 4PM. • Fall budget due Sunday.	9/9-11/2016
Payload LV Space Claim	• Payload has to give LV the dimensions of space it requires in the launch vehicle. • Payload needs to communicate what sort of recovery system is wants to be integrated into the LV. • Payload needs to request from LV what kind of data, using what kind of sensors (ex: accelerometers) it wants collected from the subscale launch.	9/15/16
Payload Concept	• Payload experimental concept must be nailed down for the method of protecting the unknown fragile material.	9/21/2016
LV Design	• Complete design of the launch vehicle is due, including *Open Rocket* simulations.	9/22/2016
Payload Design	• Completed *SolidWorks* CAD for the payload.	9/23/2016
Proposal Rough Draft	• Written sections from each group will be collected to compile a rough draft for the proposal. • Rough draft will go through a series of reviews and will ultimately be formatted in *Word* for final submission.	9/25/2016
Submit Proposal	• Submit completed electronic copy of proposal to NASA SL project office.	9/30/2016
Supply Order	• LV must have completed orders of all required materials for subscale. • Payload must have completed orders of all required materials for prototype.	10/1/2016
Post-Proposal Reflection	• Meeting with the whole team to review major points of the proposal and address next steps for the project.	10/3/2016
Shipping Deadline	• All parts for the LV subscale and payload prototype must be shipped to us.	10/6/2016
Awarded Proposals Announced	• Check and assure we were are one of the approved proposals.	10/12/2016

Kickoff and PDR Q&A	• PDR questions due. • Participate in kickoff and PDR Q&A.	10/14/2016
LV Build Deadline	• The subscale LV must be completed. • Subscale ready to be reviewed by the Design Safety Committee to approve it to be launched.	10/19/2016
LV Subscale Launch	• Subscale launch of LV. • Collect data for payload about forces involves in flight; focusing on launch, apogee, deployment, and landing to find the highest forces experienced.	10/22/2016
Payload Prototype/Testing Plan	• Payload prototype must be completed. • Testing plan must be completed that has a place holder for the maximum force data gathered from LV subscale launch.	10/22/2016
PDR Rough Draft	• Written sections from each group will be collected to compile a rough draft for the Preliminary Design Review. • PDR will go through a series of reviews and will ultimately be formatted in *Word* for final submission. • Rough draft of presentation slides and selection of speakers.	10/23/2016
Preliminary Payload Testing	• Preliminary payload testing must be completed utilizing data from LV subscale; test results should be incorporated into final revision of PDR. • Initial suggestions for design improvements based off of results should be compiled along with a plan for moving forward and building the final payload.	10/26/2016
PROVOST	• Deadline to submit for PROVOST funding (up to $3000).	10/28/2016
Submit PDR	• Post PDR reports, presentation, slides, and flysheet on team website. • Establish team web presence.	10/31/2016
PDR Teleconference	• Meeting of presenters beforehand to prep for presentation. • Completion of teleconference with NASA, followed by an internal meeting to discuss how it went and take notes on anything learned.	TBD 11/2-18/2016
Post-PDR Reflection	• Meeting with the whole team to review major points of the proposal and address next steps for the project.	11/7/2016

5.7. Funding Plan

The AIAA club at NU in preparation for the NASA Student Launch 2017 proposes to secure funding in the following ways. We will request funding from (1) Northeastern's Student Government Association (SGA), (2) Northeastern's Provost Grant, (3) Northeastern's Catalyst Fund and (4) seek external funding from corporate sponsors.

Regarding our plan to apply for funding through Northeastern University's SGA, we will present our rocket to SGA's finance board and follow their specified protocol in order to request funding for our expected budget. This protocol involves filing paperwork and submitting an itemized budget, which features a list of materials along with their specific costs and vendors. We will have one more final presentation to the finance board, after which we will be notified if we have been allotted funding for our proposed budget. Although this procedure suggests the possibility of a rejection, we are confident that this will not be the case, as we maintain an excellent standing with NU's SGA and are expected to fund all of our rocket building materials through NU's SGA. In addition to this, we will also apply for NU's Provost Undergraduate Research and Creative Endeavors Grant which is provided by the office of the Provost and enables undergraduate students to conduct research under the supervision of a faculty advisor. The application for the Provost Grant requires the submission of a detailed proposal and a recommendation letter from a faculty advisor. We have received $3000 from this grant in the past and are expected to receive funding again. The funds would be used to cover the costs of additional supplies. Lastly, we will be participating in Catalyst, Northeastern's crowd-funding program. Catalyst enables projects to be exposed to thousands of potential donors within Northeastern and generate interest within the community. We will have to submit an online application, after which we will present a video or photo presentation to potential donors as well as document the progress of our ongoing project.

In regard to seeking outside funding from corporate sponsors, we are organizing a sponsorship campaign that will be carried out by the end of the semester. We are in the process of compiling a list of corporate sponsors, including the corporate connections built through NU's unique six-month long cooperative education program, and we intend to have it approved by the end of early October. Afterwards, we will send out sponsorship inquiry emails as well as our sponsorship brochure, which outlines every milestone that AIAA at NU has accomplished. A few achievements outlined was our win at the 2014 Battle of the Rockets in Culpeper, VA, our performance at both NASA SL 2015 and 2016, which featured our most challenging build-to-date, as well as various other successful rockets and weather balloons. We will follow up with any potential corporate sponsors through telephone calls and, if requested, presentations to a corporate board. This external funding will offer the opportunity to contribute online or by mail. We intend to devote all of the support from this sector to cover travel expenses.

5.8. Budget

Table 11: Budget

ITEM	QUANTITY	VENDOR	PRICE	TOTAL PRICE

Subscale & Full Scale Rocketry Parts				
98mm Blue Tube	3	Apogee Rockets	38.95	116.85
98mm Full Length Coupler	2	Apogee Rockets	39.95	79.9
4 inch 98mm Fiberglass Nosecone	2	Apogee Rockets	39.95	79.9
54 mm blue tube mmt	2	Apogee Rockets	23.95	47.9
54mm 3-Grain Motor Case	1	Animal Motor Works	65	69.39
54mm end closure	1	Apogee Rockets	42.75	42.75
54mm aeropack retainer	1	Apogee Rockets	31.03	31.03
Shock Cord	150	Apogee Rockets	0.97	145.5
Perfectflite Stratologger	5	Perfectflite	46.99	234.95
18x18 Black Nomex Parachute Protector	4	Apogee Rockets	10.49	41.96
60" Frutiy Chute	2	Fruity Chutes	275	550
Tracking Powder	1	Apogee Rockets	6.25	6.25
18" Fruity Chute	2	Fruity Chutes	53	106
G10 Garolite	2	Mcmaster	56.69	113.38
Quick Links	4	Mcmaster	11.2	44.8
J355-Red Lightning	2	Animal Motor Works	93	186
SMS GPS	3	Animal Motor Works	100	300
Rail Buttons for 1010 rail	2	Apogee Rockets	3.22	6.44
2-56 Nylon Shear Screws	2	Mcmaster	5.5	11
3/8-16 Flex lock Nuts	2	Mcmaster	7.29	14.58
3/8 Washers	1	Mcmaster	12.36	12.36
808 Keychain Camera	1	Apogee Rockets	41.35	41.35
Limit Switches	10	Mcmaster	3.81	38.1
3/8-16 U bolt	4	Mcmaster	2.16	8.64
Spring Pin	4	Mcmaster	2.37	9.48
Remove before flight tags	1	Amazon	9.95	9.95
Insert Before Flight Tags	1	Amazon	5.95	5.95
6in body tube (Blue Tube)	2	Apogee	66.95	133.9
6 in coupler tube (blue tube)	1	Apogee	66.95	66.95

75mm motor mount tube (75mm Blue tube)	1	Apogee	29.95	29.95
Perfectflite Stratologgers	3	Apogee	58.8	176.4
U-Bolt	4	Mcmaster	2.86	11.44
Parachute 24" (TAC Drouge)	1	Giant Leap Rocketry	31.1	31.1
TAC 9-C parachute	1	Giant Leap Rocketry	267.9	267.9
Recovery Harness (1 inch Tubular Nylon	1	Apogee	60.99	60.99
Shock Cord 1500 Kevlar	30	Apogee	0.97	29.1
L995 Red Lightning Motor	1	Animal Motor Works	190	190
5/16 Quicklinks	4	Giant Leap Rocketry	3.51	14.04
Nomex Parachute Protection	2	Giant Leap Rocketry	12.45	24.9
G10 Fiberglass Fin Stock	2	Giant Leap Rocketry	52.49	104.98
JB Weld	2	Giant Leap Rocketry	6.29	12.58
6inch Fiber glass nosecone	1	Public Missiles	104.99	104.99
Pneumatic Air Cylinders	4	Andymark	48	192
Pneumatic Base Kit	2	AndyMark	263	526
Air Resovoir	2	Andymark	17	34
808 Keychain Camera	1	Apogee Rockets	41.35	41.35
Beaglebone Black 1Ghz Proccesor	1	Adafruit	55	55
Payload Parts				
Polycarb Tube	6	McMaster-Carr	21.78	130.68
Super-Cushioning High-Strength EVA Foam Sheets	2	McMaster-Carr	86.05	172.10
Purple cushion	2	Purple	39.99	79.98
Shredded Latex	2	Diynaturalbedding	8.00	16.00
PLA Filament	2	Makergear	35.00	70.00
Chemical-Resistant Nylon Foam Sheets	2	McMaster-Carr	13.32	26.64

High-Temperature Silicone Foam Sheets	2	McMaster-Carr	28.47	56.94
High-Temperature Silicone Foam Sheets	2	McMaster-Carr	28.47	56.94
High-Temperature Silicone Foam Sheets	2	McMaster-Carr	23.05	46.10
High-Temperature Silicone Foam Sheets	2	McMaster-Carr	23.05	46.10
Ultra-Strength Wear- and Weather-Resistant Ionomer Foam Sheets	2	McMaster-Carr	5.71	11.42
1/4" dia. AL6061 rod, 12" length	2	McMaster-Carr	2.00	4.00
1/2" dia. AL6061 rod, 12" length	2	McMaster-Carr	3.08	6.16
Steel bracket	2 pkg of 50	McMaster-Carr	4.64	9.28
Spring	2 pgk of 12	McMaster-Carr	7.26	14.52
Springs	2 pkg of 12	McMaster-Carr	7.26	14.52
Springs	2 pkg of 12	McMaster-Carr	7.26	14.52
Springs	2 pkg of 12	McMaster-Carr	7.26	14.52
10-DOF IMU	6	Adafruit	29.95	179.7
Instant Expanding Package Foam	4	McMaster-Carr	5.59	22.36
Xbee Pro SC3	4	Digikey	42.00	168.00
Xbee breakout board	4	Sparkfun	2.95	11.80
Xbee FTDI breakout board	2	Adafruit	10.00	40.00
2mm female headers	4	Adafruit	0.95	3.80
Extra long male headers	10	Adafruit	3.00	30.00
Xbee antennas	8	Digikey	7.63	61.04
Teensy	4	PJRC	19.80	79.20
Sd cards	4	newegg	19.75	79.00
Micro SD card breakout	4	adafruit	7.50	30.00
SD card reader	2	newegg	14.99	29.98
Support				
Hotel (4 rooms for 5 nights)				2600.00
Gas (2 vans)				1000.00
Tolls (2 cars)				2800.00
Grand Total				$9867.28

5.9. Sustainability

AIAA at NU will continue to succeed as Northeastern's primary aerospace/aeronautic organization for many years to come. In order to maintain this notion, we will continue our annual campaigns to seek and secure sponsorships with our corporate partners. We will also divide into two project groups, Launch Vehicle and Payload, depending on interest and technical knowledge, in order to maximize cohesion and propensity for success. In order to maintain short and long term goals and be proactive in our efforts, we will host weekly meetings to discuss progress, objectives, and deadlines. As well, along with the new members recruited through outreach in events such as fall fest, we will recruit more NASA SL team members with a presentation of our project plan at the first official meeting of the fall semester. In addition, we will continue providing our annual Introduction to Rocketry program for all incoming members with an interest in understanding the principles behind rocketry, in an attempt to teach them to build and launch successful rockets.

Additionally, we will continue our focus on educational involvement. Through our collaboration with Claire Duggan and the rest of Northeastern's Center for STEM Engagement, we've been able to connect with countless students in the Boston public school system and we plan to continue this indefinitely. Furthermore, we will continue our NEPTUN program, which allows members of our group to teach classes to high school students. Using lesson plans refined from years of engagement in this program, we are able to efficiently and consistently deliver our core message and teachings. Also, we plan to connect with students by providing educational and engaging demonstrations and activities. Moreover, our funding plan for sustainability will be renewed annually through Northeastern's SGA, which provides the majority of AIAA's funding. Other expenses, such as travel, will be covered through corporate sponsorships.

6. Conclusion

6.1. Concluding Remarks

For the past two years, we have competed in NASA's student launch competition, and it has done some amazing things for our club. In addition to creating our initial relationship with Northeastern University College of Engineering's Center for STEM Education in 2015 (we are very happy to say that our partnership with them has now grown into one of the largest partnerships of any Northeastern COE club), this project also provides an opportunity for our members to gain some invaluable real-world design experience, which gives them a large competitive edge when searching for co-ops, internships, and full-time job opportunities, especially within the product development field.

One of the things that makes Student Launch such a great event is the enthusiasm and energy that comes from the volunteers, as well as the organization and planning that goes into it that ensures everything runs smoothly. Everyone from Northeastern University who has had the opportunity to go down to Huntsville, Alabama has had a fantastic experience. On behalf of everyone from Northeastern University that has competed in Student Launch before, thank you all so much for your time and dedication to making this competition such a great experience for us in years past, and on behalf of everyone on the 2016-2017 Northeastern University Student Launch Proposal team, we would like to sincerely thank you for taking the time to consider us again for this fantastic opportunity, and we very much look forward to competing again this year!

Thank you very much for your time and consideration,

Evan Kuritzkes and Samantha Glassner
Co-Team Leaders, NU-HOPE

Appendix A: Risk Assessment

Phase	Risk	Description	Severity-Probability	Mitigation
Building Phase	Epoxy	Contact with epoxy resin can cause skin irritation. Accidental ingestion or contact with eyes can be more severe.	4B	Proper PPE-gloves, mask, and safety glasses
	Two-Part Foam	Contact with the foam can cause skin irritation. Accidental ingestion or contact with eyes can be more severe.	4D	Proper PPE-gloves, mask, and safety glasses
	Motor Handling	Improper motor handling can cause accidental motor ignition.	2D	Mentor will handle all motor transportation and storage
	Burns	Contact with hot tools such as the soldering iron or heat gun can cause burns.	3D	Proper training for operators and reduce distractions
	Fire	Improper use of hot tools can lead to fires.	1E	Be aware of fire hazards and know how to use extinguisher
	Cuts	Improper use of sharp tools can lead to injury.	3D	Proper training for operators and reduce distractions
	Mill and Band Saw	Being improperly trained in on the mill or bandsaw can lead to destruction of equipment and personal injury.	2D	Proper training and PPE-safety glasses
	Dust Inhalation	Inhalation of dust or particulates from	3D	Use of proper PPE (mask)

		sanding or cutting operations can lead to breathing problems and injury.		
	Paint Fumes	**Inhalation of fumes during painting can be hazardous to the health of team members.**	**4B**	**Use of proper PPE (mask) and fume hood**
	Chemical Burns	**Improper handling of chemicals can lead to spills and possible chemical burns.**	**2E**	**Keep chemicals locked in flame cabinet when not in use, use proper PPE**
	Splinters	**Improper handling of certain materials can lead to splinters.**	**4D**	**Use gloves while handling carbon fiber, fiberglass, and wood.**
Launch Phase	**Accidental Motor Ignition**	**Improper handling or storage of motor can lead to igntion.**	**1E**	**Proper training on motor handling and proper storage, mentor will handle all motor transportation and storage**
	Motor Failure at Takeoff	**Faulty motor or incorrect installation of e-match can lead to a bad motor ignition.**	**2E**	**Maintain a safe distance from launchpad and have team mentor inspect rocket on pad**
	Drogue Failure	**Improper installation of ejection charge or parachute can lead to a failure to deploy the parachute.**	**2D**	**Follow checklist to ensure correct install**
	Main Parachute Failure	**Improper installation of ejection charge or parachute can lead to a failure to deploy the parachute.**	**2D**	**Follow checklist to ensure correct install**

	Vehicle Land Near Spectators	**Failure to account for wind or improper aiming of launch rail can lead to the descent path of the rocket to be in line with the crowd.**	**2D**	**Angle launch rod away from the crowd and account for wind**

Appendix B: Center for STEM Education Letter of Support

Northeastern University
Center for STEM Education

To Whom It May Concern,

This letter is intended to recognize and express support for the Northeastern University Student Chapter of the American Institute of Aeronautics and Astronautics (NU AIAA) in their application to the NASA Student Launch program.

The NU AIAA student group has shown a passion and dedication for supporting K-12 initiatives relating to rocketry and aeronautical engineering, and we are excited to have the group participating in several outreach events. Members of the NU AIAA group are spearheading efforts to introduce aerospace topics to both middle school and high school students, through various programs and initiatives run or supported by the Center for STEM Education.

The NU AIAA group supports the K-12 school field trips programs, wherein Boston Public Schools students visit Northeastern University and participate in hands-on science and engineering activities. This program leverages a variety of activities including several units from the NASA Educators Guide, in addition to an activity developed around a space suit design challenge. Creating and sustaining expanded learning opportunities on Northeastern's campus regarding aerospace, and integration of learning experiences back into the K-12 classroom are key objectives that the group is addressing. In addition to the field trips programs, the NU AIAA group supports the Middle School Summer STEM Program run at Northeastern each summer, and the supplemental "Callback" session, which takes place once each semester. They have also developed and will soon be implementing activities with high school students for NEPTUN event hosted in late October, and for additional groups of high school students who visit for program-related events and introductions to engineering fields.

I appreciate your consideration of their application, and look forward to continued partnership with the NU AIAA group. Their dedication and capacity to fulfill on their mission provide us with great confidence that the group will be successful in supporting K-12 educational efforts while also advancing their own knowledge and understanding of the aerospace industry.

Please do not hesitate to contact me should you need any additional information!

Claire J. Duggan

Claire J. Duggan
Director for Programs
The Center for STEM Education
Northeastern University

The Center for STEM Education
Northeastern University
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Appendix C: Gantt Chart