NUSPACE

Scientific Payloads: Atmospheric-Measurement and Controlled-Descent Experiment

Northeastern University
267 Snell Engineering
Boston, MA 02115

2015-2016
NASA Student Launch
Proposal

TABLE OF CONTENTS

1. GENERAL INFORMATION

1.1. PERSONNEL INFORMATION

Faculty Advisor

Andrew Gouldstone
Ph.D. Associate Professor and Associate Chair of Mechanical Engineering
Dept. of Mechanical and Industrial Engineering, Northeastern University
a.gouldstone@neu.edu
(617) 373-3699

Safety Officer

John Hume
College of Engineering, Northeastern University
BS Industrial Engineering, Expected 2018
hume.j@husky.neu.edu
(402) 536-9285

Team Leader

Jennifer Morin
President, Northeastern Chapter of AIAA
College of Engineering, Northeastern University
BS Mechanical Engineering
morin.je@husky.neu.edu
(508) 887-662

Mentor

Robert DeHate
President AMW/ProX
NAR L3CC 75198 TRA TAP 9956
robert@amwprox.com
(978) 766-9271

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

- Controlled Descent Landing Experiment (CDLE)
- Atmospheric and Topographic Measurements Optics Suite (ATMOS)
- Payload Software
- Launch Vehicle

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

1. Evan - CDLE
2. Harry - ATMOS
3. Josh - Payload Software
4. Neel - Launch Vehicle

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

1. Jen - Team Leader
2. Dr. Andrew Gouldstone - Faculty Advisor
3. John - Safety

We intend to work closely with NAR Chapter #727, the Maine Missile Math & Science Club (MMMSC), and NAR Chapter #464, the Central Massachusetts Spacemodeling Society (CMASS). We have an arrangement with Scott Costigan, president of the MMMSC, which enables us to launch any day of our choosing so long as we provide sufficient notice to obtain the FAA waiver and secure the launch field.

1.2. FACILITIES/EQUIPMENT

1. Materials Testing Laboratory (for general build use)
   - Accessibility: 24/7 (when classes are not in session)
     - Rquired presence of designated team safety personnel
   - Available Equipment:
     - Hand tools, cordless drill, digital scale, etc.
     - Soldering station
     - Flammable material closet for safe storage of motors
     - Chemical hood for safe use of epoxy and polyurethane foam
     - Instron tensile testing machine, and other materials testing equipment.
     - General use storage closet
2. Student Machine Shop
   - Accessibility: Tuesday and Thursday nights
     - Required presence of shop supervisor
   - Available Equipment:
     - Band Saw
     - Horizontal Band Saw
     - Mill
     - Lathe
     - TIG and MIG welders
3. Mechanical Engineering Department Machine Shop
   - Accessibility: 9am to 5pm on weekdays
     - 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
  1. Objet 24
  2. ZCorp ZPrinter 450
  3. Dimension Elite
- Fused Deposition Modeling
  1. Makerbot Replicator 2
  2. Makerbot Replicator 2X
  3. Dimension Elite
- Stereolithography
  1. FormLabs Form1
- Laser Cutter
  1. Epilog Zing (30W)

5. Video Conference Room

Accessibility: Weekdays 9am to 5pm (with one week notice)
Available Equipment:

- High speed internet
- Full audio/visual conference capability

2. SAFETY

2.1. SAFETY PLAN

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 B.

The materials used by the team for this project are subject to change, however, we intend to utilize G10 Garolite, Blue Tube, PPE plastic nose cones, and wood for the launch vehicle. The quadcopter will use carbon fiber and aluminum throughout the course of its construction. When these materials are cut or sanded they can produce a fine dust, which can present a potential health hazard. Additionally, the team uses two-part epoxy as well as two-part polyurethane foam. These chemicals can also 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, which is less than ideal.

One of the controlled risks we are introducing in our project involves the descent package for the payload. A caveat to NASA approval of our design was that if the quadcopter’s descent becomes a hazard to onlookers, the system must have a passive emergency descent system.

We will be installing a parachute system to handle this possibility. In an ideal flight, this system will remain inactive; if the quadcopter presents a danger during flight, it will either activate the emergency system itself or we will activate it manually. This emergency descent system will mitigate the risk of injury from the quadcopter's descent and is discussed at length in the payload section.

2.2. PROCEDURES FOR NAR/TRA 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. This established NAR chapter conducts launches on a monthly basis. The proprietors of the launch site have partnered with the club for some time and the site 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:

1. 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 it for us.

2. The team agrees to only use the materials outlined in the safety code in the construction of our rocket. This includes lightweight materials such as paper, wood, plastic, and fiberglass.

3. The team will only use Motors that have been certified by either NAR, TRA, or CAR. These motors will be handled by the team mentor, Rob DeHate.

4. The team will only use an electrical launch system to launch the rocket. The system used for launch will have safety features to avoid accidental ignition. This system will be provided and operated by the qualified member of MMMSC acting as the LCO.

5. 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.

6. 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.

7. The team will be launching the rocket from a 10/10 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.

8. 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.

9. 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.

10. 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 field where the launches are conducted has been home to the launches for a long time and has been shown to meet all requirements of the NAR and the FAA for a flight waiver of 10,000 feet.

11. 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.

12. 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.

13. 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 officer 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 ENERGETIC DEVICES

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 STATEMENT

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.

3. TECHNICAL DESIGN

3.1. LAUNCH VEHICLE

3.1.1. Vehicle Dimensions

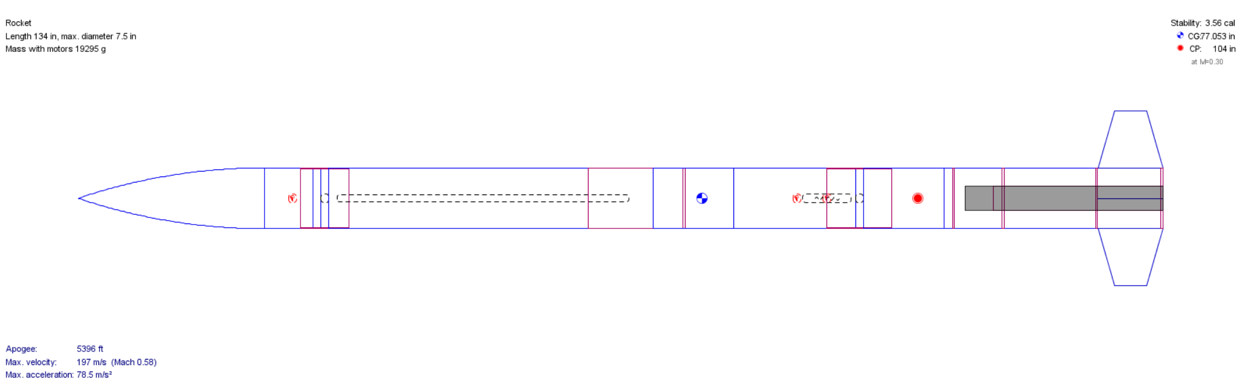

Figure 1 – Proposed Launch Vehicle

The proposed launch vehicle, seen above in Figure 1, is 7.5 inches in diameter and 134 inches long. It is divided into 4 main sections: The booster section, the recovery section, the Payload Containment Module (PCM), and the payload deployment parachute section.

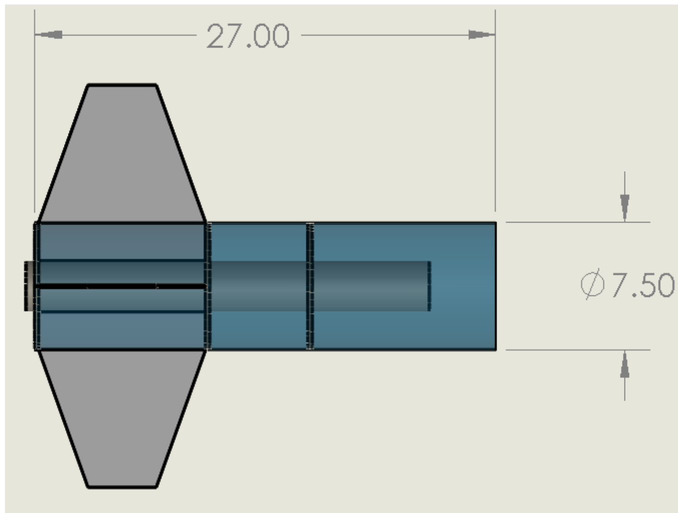

Figure 2 – Proposed Booster Section

The booster section is 27 inches long. It houses a 75 mm motor mount tube, and three centering rings to ensure that the motor stays aligned throughout launch operations. It also has fins with a root chord of 8 inches and a tip chord of 4 inches. The fins will be secured between centering rings for structural stability.

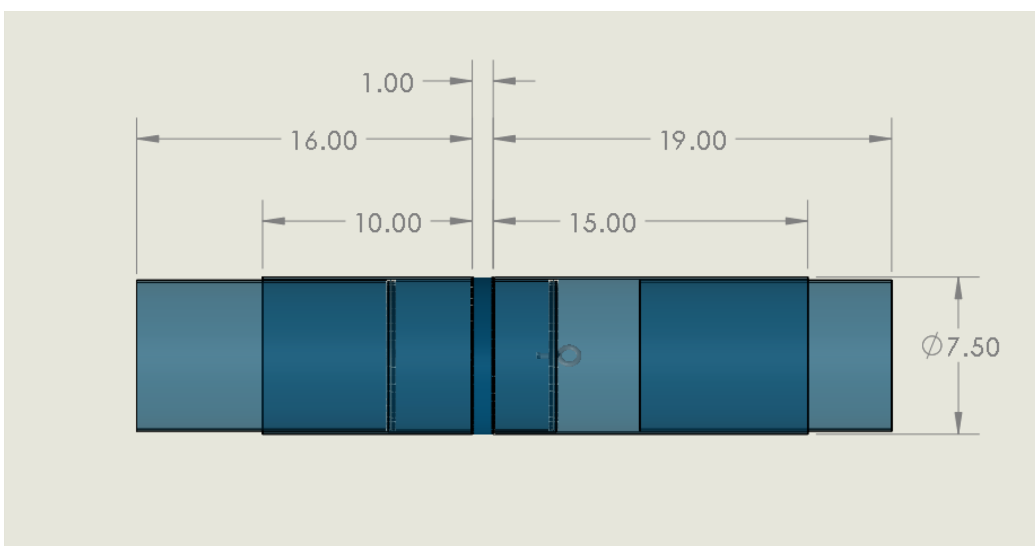

Figure 3 – Proposed Recovery Section

The recovery section is composed of 3 subsections. There is a 10 inch long interconnector section between the motor section and the electronics bay and recovery section. Above this is the electronics bay, which is sandwiched in between two bulkheads to protect the electronics. The electronics will be mounted on wooden sleds which will ride on rails created with studs.

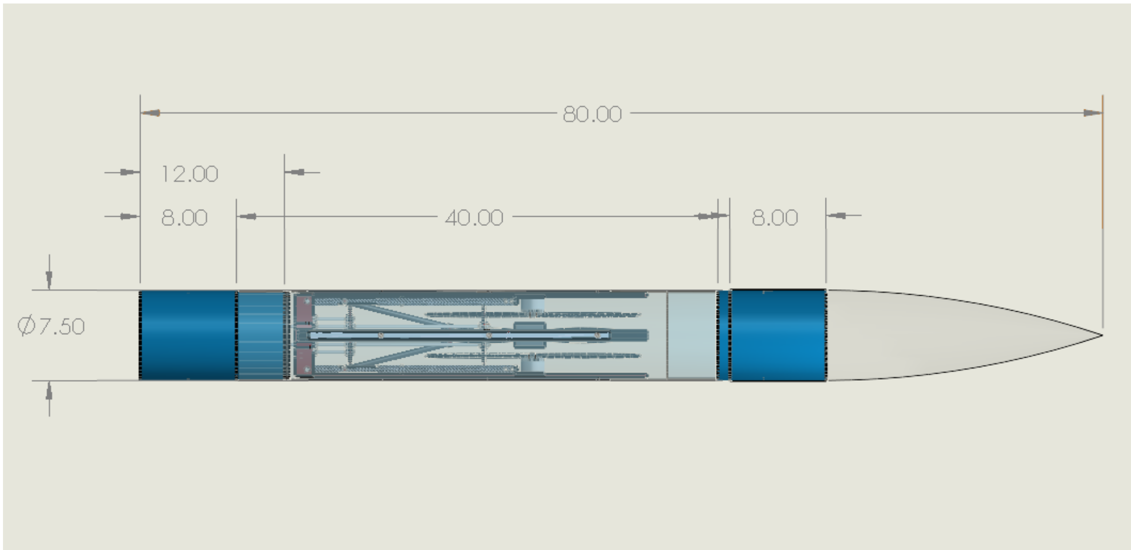

Figure 4 – Proposed Payload Containment Module

The PCM consists of a 12 inch base. This base acts as the base of the quadcopter and houses all the electronics and processing units that the Controlled Descent and Landing Experiment (CDLE) will require to fly to its target. The 40 inch quadcopter sheath will protect the quadcopter during flight and assist in deployment at apogee. Upon reaching apogee, the 18 inch parachute stored in the 8 inch section beneath the nose cone will deploy and will pull the sheath off the quadcopter to allow it to unfold.

3.1.2. Materials and Constructions

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.

However, Blue Tube's advantage 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 PPE plastic (polypropylene). PPE is fairly impact resistant and, in the past, club members have noted that PPE nose cones will survive uncontrolled landings.

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 shall 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 shall 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. Projected Altitude

The primary requirement for this project is propelling a launch vehicle to an altitude of one mile, or 5,280 ft. The Northeastern Chapter of AIAA has been using OpenRocket, a freeware modeling software, to predict the altitude of the launch vehicle. Current simulations predict that the launch vehicle will reach apogee at 5,396 ft. with a L1115 solid fuel rocket motor. This is 116 ft. over the one mile mark and, as it is likely that the mass of the launch vehicle will be greater than predicted, we will not actually reach the projected altitude. If it turns out that the projected mass of the rocket is accurate, more mass can be added to the rocket later to ensure that the launch vehicle reaches exactly 5,280 ft.

3.1.4. Projected Parachute System

Deploying the CDLE with the ATMOS will be a very complicated task - therefore a coordinated parachute system will be needed for the proper and safe recovery of the launch vehicle. At apogee, there will be two simultaneous events: A black powder charge will separate the nose cone and the PCM, releasing the 18 inch upper parachute. The force of deployment will release the PCM, and expose the quadcopter. Another charge will go off to separate the motor section and the quadcopter. This will also release a drogue parachute for the booster section, as well as the main parachute sheathed in a parachute bag. An 18 inch nylon parachute will be deployed from the upper section of the launch vehicle, between the nosecone and the blue tube covering of the quadcopter. A second 18 inch parachute will be deployed above the booster section. Simultaneous with drogue chute deployment, the booster section will also eject a parachute bag that contains the 48 inch main parachute. The main parachute will deploy via a Tender Descender rigging system. The use of a Tender Descender will allow us to release both the drogue chute and the main parachute from the motor section. The 48 inch main parachute will be deployed at 500 feet. Suspended below the quadcopter is a 12 inch long section of blue tube will contain sensors, flight electronics and a 36 inch emergency nylon parachute. If the RSO does not give permission for quadcopter deployment, the parachute will be activated so the quadcopter can be safely lowered to the ground.

3.1.5. Projected Motor

The airframe will be powered by a L1115 solid fuel motor manufactured by Cessaroni Technology. Our launch mass could be as high as 20.3 kg, so a high impulse motor would be needed in order to ensure a safe and stable flight. The L1115 provides ample trust, with 5017 N of impulse over 4.47 seconds. The L1115 is a large, heavy motor, weighing in at 4 kg before use, and measuring 0.6 meters long. However, after burnout, the empty engine is only 2 kg. This motor should propel the rocket to the one mile mark, thereby allowing for the safe deployment of the atmospheric payload at the target altitude.

The motor is one of the largest L motors available. In order to ensure that the launch vehicle hits the target altitude, the launch vehicle is being over-designed to fit a 7 kg payload. This is the maximum payload weight that our quadcopter motors would be capable of lifting while retaining maneuverability. Our target mass for the quadcopter is substantially lower than 7 kg; this gives us a margin of error with respect to altitude without increasing our motor size.

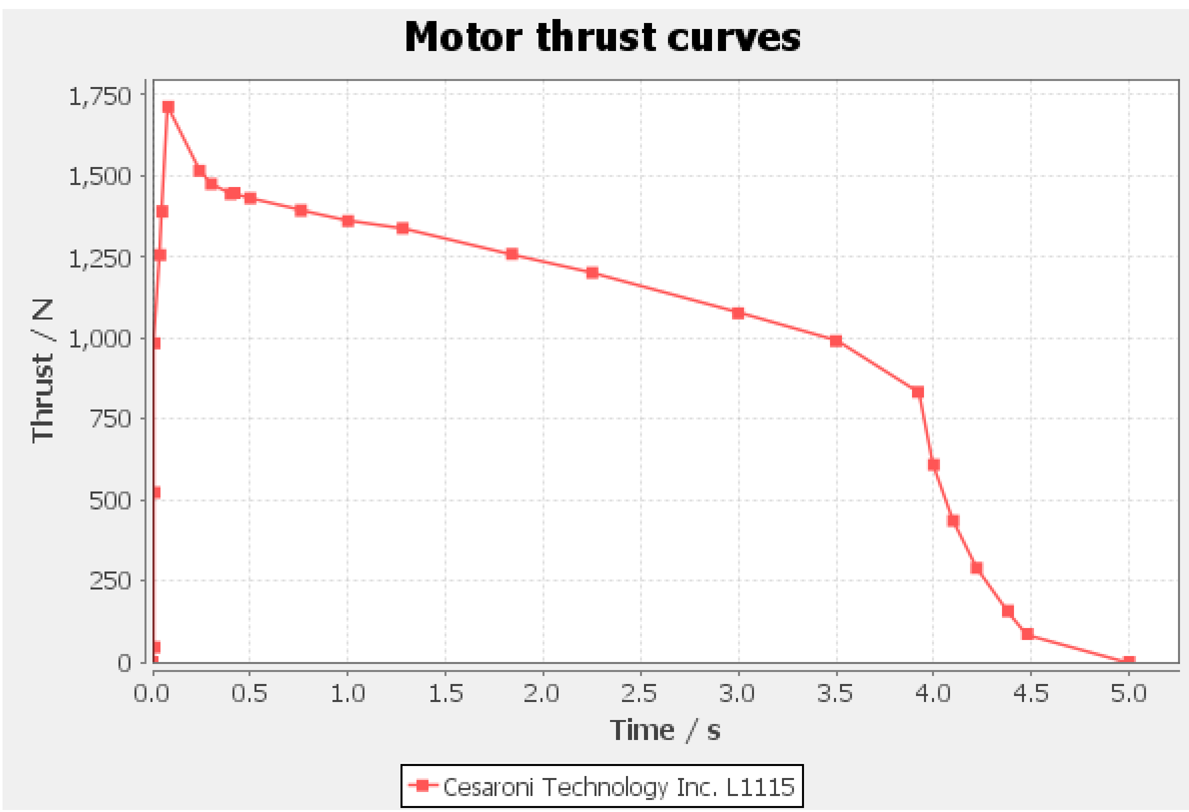

Figure 5 – L1115 Motor Thrust Curve

3.2. ATMOS

3.2.1. Proposed Objective

For our Atmospheric Measurements payload, AIAA has selected a suite of sensors to be installed aboard a quadcopter, to be deployed at the launch vehicle's apogee. Named the Atmospheric and Topographic Measurements Optics Suite (ATMOS), the payload will collect data on a number of atmospheric properties, including humidity, temperature, pressure, solar irradiance and solar radiation in the UVA and UVB range. The ATMOS will also capture images of the horizon in the visible spectrum and images of the surface in the long wave IR spectrum at 5,280 ft. above the surface of Bragg Farm in Huntsville, Alabama. The payload includes a number of additional sensors that enhance the amount, significance and relevance of data we collect. Some measurements (i.e. Photography, Solar Irradiance, IR Surface Topography) will be taken only while the quadcopter hovers at 1 mile or after it has landed. All other measurements will be taken throughout the flight.

3.2.2. Projected Design

The humidity, atmospheric pressure, and temperature will be measured using a Bosch BME280. This is a breakout board containing humidity, pressure, and temperature sensors that allows for rapid, accurate measurements while consuming little power and space in the payload (19 X 18 X 3 mm, 1g). This board will be connected to an Arduino Due which will process and store the data. The humidity sensor can detect and transmit the relative humidity of the air with an accuracy of ±3%. The pressure sensor has an accuracy of ±0.25%, and the temperature sensor has an accuracy of ±1ºC. The entire breakout board will be mounted on an interior panel of the quadcopter where it will be out of the way of other sensors but still have access to the air.

Solar irradiance is usually measured via a silicon cell pyrheliometer or pyranometer. These sensors use a small thermopile sensor encased in a glass dome. The thermopile absorbs solar radiation and heats up. The heat change is measured and then used to calculate the sunlight intensity. These tend to be extremely accurate, but are bulky, expensive, and highly dependent upon the solar zenith angle. As size and weight are major design constraints in this project, we have searched for a method to measure the solar irradiance using as lightweight a sensor as possible. Our solution is to use a Solarbotics SCC2422 monocrystalline silicon cell. This small (24 X 22 mm) cell will collect light from the sun and generate power. We will use a digital potentiometer to measure the power generated from the cell. The power of the cell divided by the surface area of the solar cell will give us a measure of the solar irradiance. However, solar cells are not 100% efficient. Therefore, we propose to do extensive experiments in order to find the ratio of solar irradiance to power generated and its temperature dependence. We can then develop an algorithm to convert the data from the potentiometer into a reading for solar irradiance. This cell will be mounted at the top of the quadcopter, exposed to the light. Because the solar flux depends upon the angle between the solar rays and the silicon cell, the ATMOS must remain stable for the duration of this measurement.

The ultraviolet radiation intensity will be measured using a ML8511 SparkFun UV Sensor Breakout. UV rays have wavelengths of 100nm to 400nm. This specific sensor detects wavelengths of 280nm to 390nm, which are considered UVA and UVB rays. Most of the remaining UV spectrum is absorbed by the atmosphere and will not reach the sensor. Images will be taken by a Raspberry Pi camera module. The camera will be able to take more than 2 pictures during descent and 3 after landing. This is a basic digital camera that will allow us to differentiate the sky from the ground and discern any other relevant features.

The payload will include a Raspberry Pi NoIR camera onboard. The camera is sensitive to near IR radiation and visible light. In order to get a reading of just the infrared contribution, a 700 nm long pass filter will be used in front of the lens. This IR camera will be mounted on the bottom of the quadcopter and will capture a picture of the ground in the IR spectrum. This data can be used to map many things including a temperature gradient or areas of high vegetation density and, subsequently, plant health. The NDVI, or Normalized Difference Vegetation Index, is an indication of whether the ground being assessed is covered with green vegetation. This index is usually taken from space with measurements of reflected visible and near IR light. Plants absorb visible light from 0.4-0.7 microns, and reflect infrared light from 0.7-1.1 microns. The more surface area a plant has (leaves), the more light is impacted. If there is more reflected IR than visible light waves, there is almost certainly vegetation in that area. However, atmospheric effects such as clouds, water vapor and aerosol particles can affect measured results from space. We will be utilizing the NDVI with our mile altitude viewpoint, Pi NoIR, and visible light camera to calculate plant density, and thus, health.

The bottom of the payload will include a Lepton FLIR camera. The Lepton is a microbolometer sensitive to the wavelengths between 8 and 14 microns. This section of the spectrum is dominated by thermal emissions of the Earth's surface because reflected radiation from the sun is almost nonexistent here. Therefore, the intensity of light leaving the surface below the payload module is a function of the surface temperature and material, both of which will remain constant over the payload's descent from 1 mile in altitude. By taking measurements of the measured intensity as a function of altitude on the way down, we will be able to determine a coefficient for the optical attenuation provided by the atmosphere in this wavelength range as a function of altitude. Using a Beer-Lambert Law type absorption to fit the data, we will be able to extract a representative optical thickness. This instrument will also be able to give the temperature of the ground within the field of view.

The sensor suite will be integrated with an Arduino. The data will be stored onboard on a micro-SD card. Upon landing, the data must be transmitted wirelessly to the ground team. The data will be transmitted via a MavLink: a radio transmission device. The MavLink will transmit the sensor data through a universal asynchronous receiver/transmitter (UART) port. The UART port will be a critical component of the quadcopter telemetry system. The data will be sorted and segregated by the microprocessor so that upon landing, various graphs and figures can be created for analysis.

Due to the imaging equipment on board, it is imperative that the ATMOS sensors maintain position and stability during the data acquisition period. In addition, an accurate measurement of solar irradiance depends on a constant solar zenith angle. To mitigate this challenge, a quad copter will support the ATMOS and maintain its stability and position. The copter will hover while the imaging and solar irradiance sensors are active. During descent, the ATMOS will continue to collect data on temperature, pressure, humidity, and UV radiation. The data from varying altitudes will be used to construct a profile of the atmosphere up to 5,280 ft. with regard to its properties and composition. After landing, the ATMOS will take final measurements every 60 seconds for a period of 10 minutes to characterize the atmosphere at ground level. The onboard camera will also take pictures of the surroundings at that time. Following completion of the data acquisition period, the ATMOS will transfer its data via a radio transmitter to a receiver at our team's home-base.

There are countless applications of high altitude sensor suites. High altitude pressure, temperature and humidity data is incredibly important for predicting weather systems such as thunderstorms, tornados and hurricanes. Moreover, humidity, pressure and temperature data is extremely important for high altitude aircraft and rockets. High humidity can affect the control surfaces on aircraft and temperature changes can cause metal expansion and contraction. Taking high altitude pictures are essential in making and validating large scale maps. Infrared cameras on board a sensor suite could be used to create an infrared map, which can be used to gauge vegetation health in rural regions. Moreover, infrared mapping data can be used to detect soil composition. One of the most pressing issues of modern times is air quality, especially industrializing countries such India and China. With absorption spectroscopy, we can detect which pollutants, such as pesticides, are in the air and validate or improve our environmental protection methods.

3.3. CDLE

3.3.1. Proposed Objective

The Controlled Descent and Landing Experiment (CDLE) will be a foldable quad-rotor aircraft. The CDLE will begin stowed inside and attached to the launch vehicle. At apogee, we will deploy the CDLE deployment parachute. This will be deployed by using a black powder charge to blow off the nose cone, and deploy an 18 inch parachute. The quadcopter arms will then unfold, and commence flight operations. It will then fly to the destination coordinates and proceed to land itself under its own power in a controlled manner.

3.3.2. Projected Design

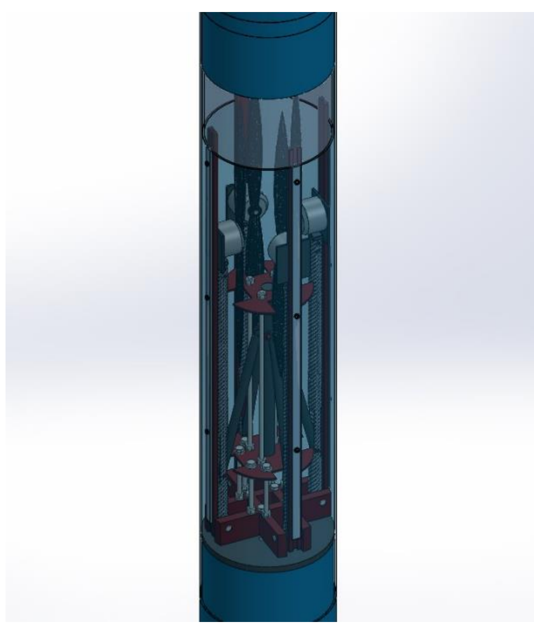

Figure 6 – Folded CDLE in Launch Vehicle

The quadcopter will be powered by 4 DC brushless motors. The KDE4014XF 380 motors is a powerful multi-rotor motor that will are made by the manufacturer KDE. The motor will output 380 revolutions per minute for every volt the motor receives. The motors will be powered by a 22 volt 6S battery providing 10,900 milliamp hours of charge. This gives the quadcopter between 3.5 (full power) and 11 minutes (constant hover) of flight time. These motors on each of the motors will be propellers that can be as big as 18” x 6.1” or as small as 13” x 4.4”. The 18 inch propellers will provide 2.4 kg of thrust per motor at 50%, and the 13 inch propellers would give us about 1 kg of thrust per motor.

The arms shall be made out of ¾ inch OD carbon fiber tubes with ⅛ inch walls. The arms will be attached to 6061 aluminum with 4 pivot points. The motors will be mounted on top of a mounting plate that fits into the quadcopter arms, and will be secured with multiple attachment points.

The quadcopter shall initially be folded into a 36 inch long cylinder with a diameter of 7 inches so it can fit into the 7.5 inch diameter body tube. There will be 36 inch long linear slides. There will be matching linear slides in the interior of body tube. A 12 inch section of blue tube will be mounted to the bottom of the quadcopter, contain the atmospheric sensor payload and the battery to power the quadcopter. This blue tube section would contain an emergency parachute. If RSO does not clear the quadcopter for flight or if the quadcopter begins an uncontrolled descent the parachute can be deployed for safe retrieval of the quadcopter.

Below is an overview of the quadcopter deployment process:

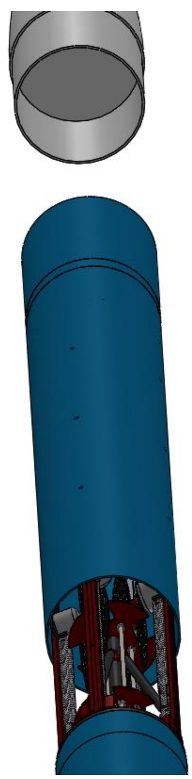

Figure 7 – PCM Removal

The jerk from deploying the first drogue parachute at apogee will cause the shear pins holding the quadcopter sheath section to break, and will expose the folded quadcopter.

Figure 8 – Linear Slides

In order to ensure a smooth and predictable unveiling, the quadcopter will ride along linear slides during the uncovering process. These slides will act as an extension of the coupler tube, which will ensure the body tube continues on a straight path and doesn't damage any essential quadcopter components.

Figure 9 – Quadcopter Deployment

The quadcopter will be jettisoned from the rest of the body. A black powder charge will pressurize the chamber, which will break the shear pins holding the quadcopter electronics section to the booster.

:

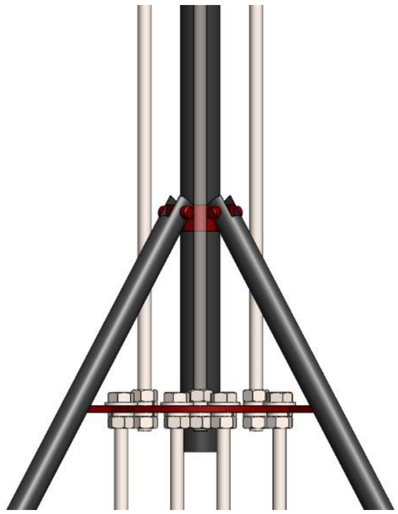

Figure 10 – Quadcopter Unfolding Mechanism

Next the quadcopter will unfold and lock its arms in place. It will do so by releasing a spring loaded bearing. The bearing will be connected to shafts with a bolt which will allow them to pivot. The other end of the shaft will be attached to the quadcopter arms in a similar manner. The actuation will cause the arms to pivot down and will deploy the quadcopter arms.

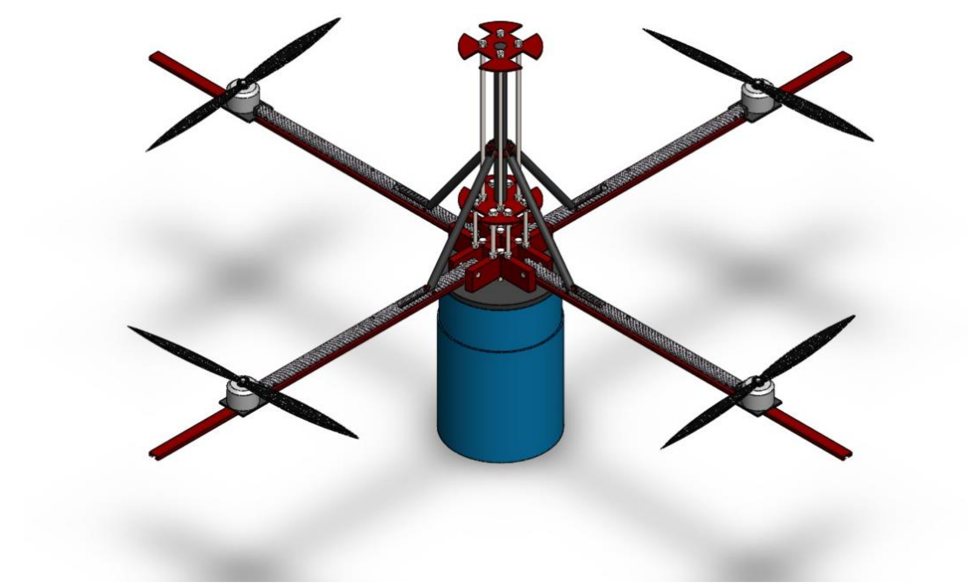

Figure 11 – Deployed Quadcopter

The quadcopter will then power up its motors and commence flight operations.

Controlled descent of a scientific payload has significant scientific and engineering value both for future space missions and terrestrial missions. The space shuttle was a great step towards reusable launch vehicles. One of the best features of the shuttle was how the boosters parachuted back to the surface, where they could be recovered and reused. However, with parachutes NASA was unable to fully control where the boosters would land, and therefore the boosters always ended up in the ocean to prevent damage. An ocean landing, while a soft one, has issues because salt water is corrosive, requiring NASA to spend millions of dollars per launch in order to refurbish the boosters. With a controlled descent mechanism, NASA could land the boosters on land at a reasonable velocity with great accuracy. With a control descent mechanism, NASA would have full control over the destination of the boosters, which would save money that would otherwise be spent sending an aircraft carrier to retrieve the hardware. Moreover, with a safe ground landing, the boosters would not spend hours in corrosive salt water, saving millions in refurbishing costs.

Controlled descent mechanisms also have great applicability for humanitarian causes. The UN and other humanitarian efforts conduct airdrops on impoverished or war torn regions inaccessible via land travel. These food drops are guided by parachutes to the ground. However, the parachutes can be knocked off course by mid-level winds or artillery on the ground. Moreover, if the food drops near a massive crowd, there might be riot or a stampede for the food, leading to further injury and deaths. A controlled descent mechanism would be able to correct for wind interference, and would be able to steer the food supplies away from areas with heavy gunfire. Moreover, with a controlled descent mechanism, the airdrop could be steered to a government building or UN depot where the food could be distributed in a safe and controlled manner.

3.4. LAUNCH SEQUENCE

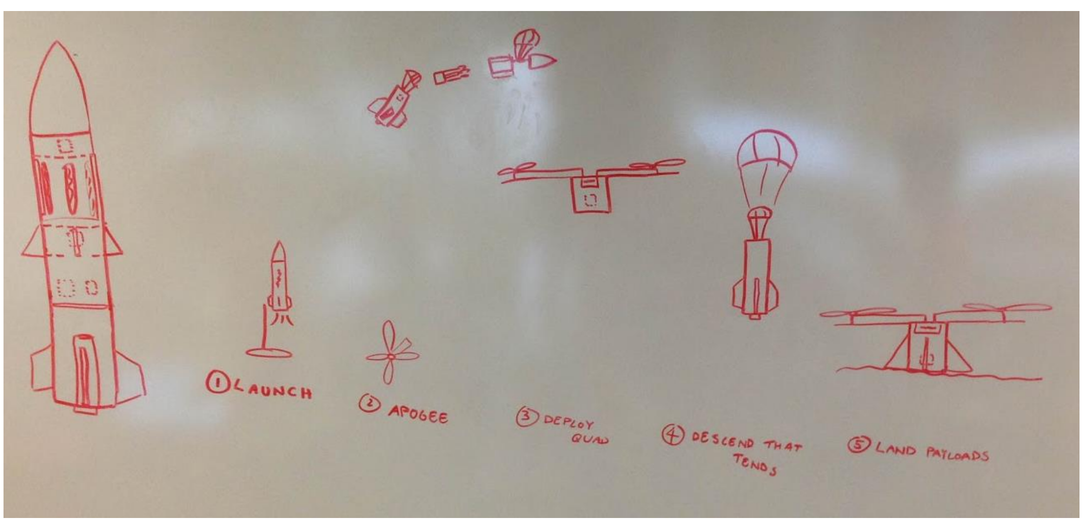

Figure 12 – Proposed Launch Sequence

The following is our detailed launch sequence, proceeding from vehicle launch through payload deployment to payload touchdown. As seen above, we have created a basic sequence of events that needs to occur. This launch sequence will most likely be adapted and altered by the preliminary design report, but it shall serve as an excellent basis for research.

1. **Launch**: The fully assembled rocket (containing the quadcopter) will be launched from the launch pad.

2. **Apogee Separation**: At apogee, a black powder charge will separate the motor stage from the quadcopter stage. A drogue chute will be deployed from the motor stage of the rocket. Simultaneously, a parachute will be deployed from the upper stage of the rocket containing the nose cone and the quadcopter. The force of deployment of the parachute should pull off the blue tube covering the quadcopter. This parachute shall return the blue tube covering and the nose cone to the ground safely.

3. **Quadcopter Deployment**: Upon RSO approval, the quadcopter deployment will be activated. The control system will initiate, unfolding the quadcopter arms and activating the electric motors, which will initiate the blades and establish a stable hover. At this point, the quadcopter will leave the vehicle and begin to take sensor readings every second. The quadcopter will then navigate to its destination and slowly descend.

    3.1. **Quadcopter Abort**: If RSO does not approve the quadcopter for flight, or if the quadcopter loses any sort of control, an emergency parachute will be deployed in order to safely return the quadcopter to the ground.

4. **Motor Stage Retrieval**: While the quadcopter payload is deploying, the motor stage will be descending. The motor stage will contain a Tender Descender, which allows for the deployment of a drogue and a main chute without the need of multiple sections of body tube. After the drogue is deployed, the main will be deployed. Once the motor section touches down, it will be retrieved by the ground team.

5. **Quadcopter Landing**: After deployment, the quadcopter will navigate autonomously to the pre-programmed destination GPS coordinates and slowly descend, taking atmospheric measurements and photos while storing them on the on-board computer system. The destination will be a sufficient distance away from the crowd for safety reasons. Upon landing, the quadcopter will wirelessly transmit the atmospheric data to the ground team, which will use the data for analysis. Upon RSO approval, the ground team will retrieve the quadcopter.

3.5. TECHNICAL REQUIREMENTS

Below is the list of the technical requirements outlined in the Student Launch Manual. The table defines how we intend to meet each requirement as well as how we intend to verify that the requirement has been met.

Table 1 – Verification Matrix

NASA Requirement	Solution Proposed	Solution Verification
Target Altitude: 1 mile = 5,280 ft (AGL)	Current design has an apogee of 5,355 ft - add mass to reduce apogee to 5,280 ft.	Record altimeter data from several test launches.
Barometric altimeter for measurement	Integrate a barometer into the additional microcontroller design	Record barometer data from several test launches.
Beeps from altimeter conveying data for altitude reached at each point in ascent	The strato-logger altimeter has an audio output that will report out its apogee with beeps (sound waves)	Transponder on ground to receive and convey beeps (sound waves) from the strato-logger altimeter
Maximum allowable altitude for vehicle: 1.061 mile = 5,600 ft (AGL)	See “Target Altitude” above.	See “Target Altitude” above.
Additional altimeters to be fitted on vehicle for electronics and payload experiments	Each electronics bay to have 2 altimeters for redundancy	Ensure extra altimeters are included in final design.
Launch vehicle has to be recoverable and reusable (being able to re-launch again without repairs/modifications)	All components will be supported by parachutes as they fall.	Test parachute system extensively for final lunch.
Launch vehicle must consist of maximum of 4 independent sections	Current design has 4 independent separations	Visual confirmation of final design
All independent sections must be tethered to the main vehicle as well as having its own parachute.	Design uses shear pins to enable proper fastening of all independent sections	Visual confirmation of final design

All independent sections must also be recovered separately from main vehicle	Parachute and GPS tracking device will be attached to each independent section	Visual confirmation and successful recovery of final design
Launch vehicle must be limited to a single stage	Current design comprises of a single rocket motor.	Visual confirmation of final design
Launch vehicle prepared for flight within 2 hours of FAA flight waiver opening	Limit launch day preparations to 2 hours.	Emulate launch day conditions by limiting tests to 2 hours.
Launch vehicle should use a 12-Volt direct current firing system	Electronic matches will set off rocket motors will be compatible with rocket	Rocket successfully launches
Launch vehicle should use a solid motor propulsion system with ammonium perchlorate [NH4ClO4] composite propellant (APCP)	Design comprises of CTI-1115 is a commercially made APCP motor	Visual confirmation of final design
Final design must be selected by Critical Design Review (CDR)	Submit design to CDR team	Team present on launch day
Total impulse of launch vehicle should not exceed 5,120 Newton-seconds (N-s) (L-class)	CTI-1115 has 4,966 N-s of impulse	N/A
Successfully launch and recover a similar subscale model to full-scale rocket (that performs similarly) prior to CDR.	Design subscale before CDR and record subscale data to submit	Team present on launch day.
Successfully launch and recover the full-scale rocket (same one as launch day) prior to Flight readiness review (FRR).	Perform a successful emulation prior to FRR.	Iterate through several tests with same conditions.

Full-scale demonstration flight must show launch vehicle's stability, structural integrity, recovery systems and the teams' ability to prepare launch vehicle for flight	Show structural rigidity based on FEA evaluation as well as degree of margin of safety, videos taken during the full scale flight will show the structural integrity and stability of the launch vehicle	Full-scale flight data to be included in the FRR. Furthermore, during test flights and full-scale launch more assessment can be passed on launch vehicle
Maximum budget for teams rocket and payloads is $7,500	Detailed ledger of the price that goes into launch vehicle	Verify pre- and post-project budgets match up.

3.6. TECHNICAL CHALLENGES

Below is the list of major challenges that the team will take on during the course of this project and the proposed solution. These are subject to change throughout the project due to unforeseen complications or iterative design changes.

Table 2 – Launch Vehicle Challenges

Challenges	**Proposed Solution**
The launch vehicle must reach the target altitude of 5,280 feet AGL	Flight data gathered through the use of simulations (such as OpenRocket), small scale models of the launch vehicle, and test flights of the complete launch vehicle will be used to lock in on the target altitude.
Design and create system to safely deploy the payload package	The payload packages will be stored inside the body on a quadcopter. The package would be stored inside the nose of the launch vehicle and be unsheathed when the nose is decoupled. The nose will release a parachute at apogee, which will break the shear pins connecting it to the motor housing. Once exposed, the payload package will glide out of the payload bay and descend.

Table 3 – Quadcopter Challenges

Challenges	**Proposed Solution**
Design and Build Controlled Descent Payload	The Controlled Descent Payload will be an autonomous quadcopter released from the launch vehicle body. The purpose of this payload package is to be deployed carrying another payload and bring it safely to the ground. The final quadcopter will be of our own design, including an emergency parachute in case of catastrophic flight failure and our own algorithms for flight instructions to arrive at a specified location.

Mechanism to Unfold Arms of the Controlled Descent Payload	The arms of the Controlled Descent Payload will be deployed using an electronically controlled mechanical release. Once the payload package has been unsheathed and released from the rocket an actuator will push a mechanical system similar to an umbrella unfolding and push the arms into place. The arms will then be locked into place with a latch.
Atmospheric Payload Integration	The Atmospheric Payload will be onboard the Controlled Descent Payload, ensuring the safe landing of the payloads. The sensors will record data and transmit it independently of the flight computer to ensure data is still received in case of catastrophic flight failure.
Backup Recovery System	In case the Controlled Descent Payload suffers a catastrophic failure the quadcopter will be equipped with an emergency parachute. The parachute will be equipped with two release options; an automatic release if it is irrecoverable and a manual release if the team or RSO deems the landing unsafe.

4. ENGAGEMENT PLAN

4.1. EDUCATIONAL ENGAGEMENT PLAN

Throughout the course of the coming year, our team will conduct (and assist with) several educational outreach programs for middle schools and high schools in our community. Our goal for these programs is to convey the sense of excitement and wonder that we all felt when introduced to rocketry and space exploration for the first time. To accomplish this, we will be continuing our partnership with Northeastern University's Center for STEM Education. Last year, we collaborated with them to reach more than 200 middle and high school students. This year, we hope to go beyond our previous year's success and reach a larger number of students.

Currently, we have four field trips planned for the fall and spring, on September 25th, October 2nd, November 6th, and April 1st. We will be hosting three middle school groups and a high school group from the Boston public school system, and facilitating the Center for STEM in running the Paper Rockets activity described in the NASA Educators' Guide. We expect to reach a total of 130-140 students with these activities. In addition, we will also be looking to host more student groups throughout the year, as soon as details with the Center for STEM are finalized.

As we did last year, we are planning to teach classes through the Northeastern Program for Teaching by Undergraduates (NEPTUN). Last year, we taught two classes on SOLIDWORKS 3D CAD software during which attendees learned to design, render, and animate mechanical devices. The members who taught the SOLIDWORKS seminars are not available this year, but we are creating a similar lesson plan based on our available expertise. While this doesn't directly relate to rocketry, 3D modeling is an important skill in engineering fields and is a skill we use in designing our rockets.

Learning Objectives

STEM Field Trips

1. **An Understanding of How Rockets Work -** Our primary goal is to give our students a beginner's understanding of how a rocket works, and a basic overview of the math and science involved. We also want to instill the same interest and passion we all have for the subject by providing them with a way to discover to excitement of rocketry

2. **The Importance of Rocketry and Space Exploration -** We want to make sure students not only understand how rockets work, but also why it's important to study and explore space. We will discuss the technological advances and benefits to society brought about by scientific investigation and how these advances relate to our daily lives.

General Objectives

3. **A General Interest in STEM Fields -** Many students perceive STEM fields as intimidating or uncool. One of our goals is to break down this reputation through fun, accessible activities.

4. **Build Lifelong Skills -** More than just information, we want to give our students skills that they will be able use for the rest of their lives. The paper rockets activity will teach students design and building skills that are applicable in many life paths. Computer modeling is a more specific skill, but is invaluable for students interested in engineering.

5. PROJECT PLAN

5.1. PROJECT TIMELINE

The Gantt chart below (Figure 13) depicts the projected schedule for the project, spanning from the date proposals are rewarded (October 2nd) to the date the PLAR is due (April 29th). The different colors classify each task into one of six categories, four of which reference the project groups discussed previously. The other categories are general tasks or documentation tasks for which the entirety of the team is responsible. Intended launch dates are indicated with the blue rhombuses and NASA milestones are indicated with red rhombuses.

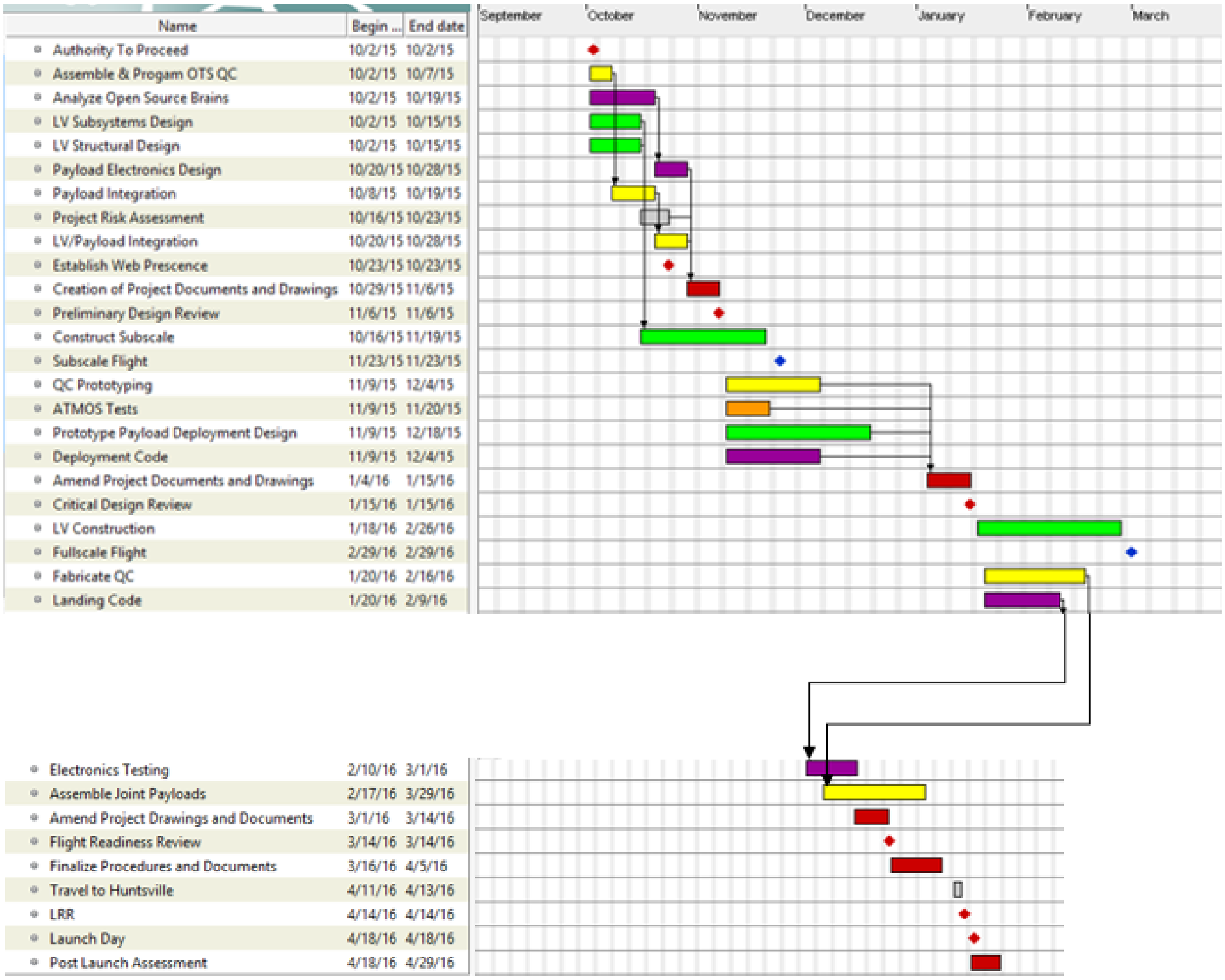

Figure 13 – Project Timeline

Payload Software   Atmospheric Measurements   Launch Vehicle   General

Controlled Descent   Documentation   NASA Deadline   Launch Date

5.2. DETAILED BUDGET

The budget below is a detailed account of all anticipated expenses for the project, including anticipated travel expenses.

Table 4 – Detailed Budget

ITEM	DESCRIPTION	QUANTITY	PRICE	TOTAL PRICE
Subscale & Full Scale Rocketry Parts				
7.5" Blue Tube	Airframe Body (full scale)	2	$139.95	$279.90

7.5" Full Length Coupler	Coupler (full scale)	1	$91.95	$91.95
7.5" Nose Cone	Nose Cone (full scale)	1	$87.95	$87.95
5.5" Blue Tube	Airframe Body (subscale)	2	$89.95	$179.90
5.5" Full Length Coupler	Coupler (subscale)	1	$55.95	$55.95
5.5" Nose Cone - 21 in.	Nose Cone (subscale)	1	$65.95	$65.95
Rail Buttons	Rail Buttons	4	$1.25	$5.00
48" Fruity Chutes Parachute	Parachute	2	$126.85	$253.70
Motor Mount Kit	Motor Mount (subscale)	1	$7.50	$7.50
Motor Retainer	Motor Retainer (subscale)	1	$26.75	$26.75
Motor Mount Kit	Motor Mount (full scale)	1	$9.95	$9.95
Motor Retainer	Motor Retainer (full scale)	1	$47.08	$47.08
75mm Motor Casing	Motor Casing (full scale)	1	$331.65	$331.65
1/8" Quick Link	Quick Link	2	$3.25	$6.50
Shear Pins	Sheer screws	8	$2.95	$23.60
Coupler Bulkhead	Coupler Bulkhead	2	$7.25	$14.50
Shock Cord	Shock Cord	200	$0.92	$184.00
9in Reusable wadding	Wadding	4	$7.44	$29.76
StratoLogger	Altimeter	4	$58.80	$235.20
Eye Bolts	Eye Bolts	2	$4.50	$9.00
G10 Fiberglass	Fins	10	$40.91	$409.10
18" Parachute	Parachute	4	$56.90	$227.60
38 mm J400 6 grain	Subscale Motor	2	$65.16	$130.32
75mm L1115 4 grain	Full scale Motor	3	$246.95	$740.85
Quadcopter Parts/Electronics				
Pixhawk	Controller	1	$199.99	$199.99
3DR uBlox GPS	GPS	1	$90.00	$90.00
3DR Radio	Radio Set (Telemetry)	1	$100.00	$100.00
Spektrum DX7s + AR8000 Receiver	Radio (Control) + Controller	1	$299.99	$299.99
Pixhawk airspeed sensor	Airspeed sensor	1	$54.99	$54.99
External USB/LED	LED/USB port for Pixhawk	1	$20.00	$20.00

Batteries	3S LIPO	6	$14.40	$86.40
Raspberry Pi	Processor	1	$69.99	$69.99
Quadcopter Kit	Prototype Kit	1	$122.87	$122.87
Drone Parachute	Parachute	1	$70	$70
Carbon Fiber Tubing	Quadcopter Frame	8	$56.99	$455.92
Pair of Rotors	Rotors	2	$109	$218
Motors to Power Rotors	Motors	4	$118	$472
Atmospheric Sensors				
Adafruit BME280	Hum, Temp, Press	1	$19.95	$19.95
Raspberry Pi Camera Module	Horizontal Pics	1	$29.95	$29.95
24x22mm Monocystalline Solar Cell	Solar Panel	1	$4.45	$4.45
DS1803 Digital Potentiometer (DIP-16)	Potentiometer	5	$3.59	$17.95
Pi NoIR	IR Mapping	1	$29.95	$29.95
IR Emitter	Abs. Spectro.	2	$1.95	$3.90
IR Receiver Diode	Abs. Spectro.	2	$9.95	$19.90
UVA UVB Sensor	Albedo UV	2	$12.95	$25.90
LWIR Sensor	IR/Albedo	1	$259.95	$259.95
9V Batteries	Power	1	$15.23	$15.23
Raspberry Pi Battery	Power	1	$49.95	$49.95
Raspberry Pi Battery Cables	Accessory to RP	2	$1.95	$3.90
Serial Cable for Board	Accessory to RP	1	$9.95	$9.95
Raspberry Pi B+ & 8GB SD Chip	Processing	2	$49.95	$99.90
Arudino Due	Processing	1	$49.95	$49.95
Data Logger	Data Storage	1	$9.95	$9.95
8 GB microSD card	Data Storage	1	$6.56	$6.56
Breadboard	Processing	1	$4.95	$4.95
6xAA Battery Holder	Power	1	$5.00	$5.00
AA batteries	Power	1	$10.14	$10.14
Support				
Hotel (4 rooms for 5 nights)				$2,600.00
Gas (2 vans)				$1,000.00
Tolls (2 cars)				$280.00
		GRAND TOTAL		$10,271.19

5.3. FUNDING PLAN

AIAA at NU proposes the following funding plan for the NASA Student Launch 2016. We plan to (1) request internal funding through Northeastern University's Student Government Association (SGA) and (2) seek external funding from corporate sponsors. The objective for our funding is to have the resources necessary to prototype and construct our launch vehicle as well as cover travel costs to all launches.

In regard to requesting internal funding through NU's SGA, we will present our sounding rocket to NU's SGA Finance Board, following their protocol and procedures to make a request for our projected budget. Their guideline includes filing paperwork and submitting an itemized budget, which details a bill of materials alongside its specific costs and vendors. After a final presentation to NU's SGA Finance Board, we will receive confirmation or rejection for our budget request. Since we have continued to maintain an excellent standing with NU's SGA, we are confident that we will be able to fund all of our sounding rocket building materials through NU's SGA. In addition to the internal funding from NU's SGA, we will also apply for NU's Provost Undergraduate Research and Creative Endeavors grant which we have successfully received in the past. Provided by the Office of the Provost, this grant enables undergraduate students to conduct research under the supervision of a faculty advisor. The process for applying to the Provost grant requires the submission of a detailed proposal and a recommendation letter from a faculty advisor. In the past, we have received $3,000 from this source and the funds would be used to cover the cost of additional supplies.

In regard to seeking external funding from corporate sponsors, we are organizing a sponsorship campaign to be carried out by the end of this semester. Compiling a list of corporate sponsors, including the corporate connections built through NU's unique six-month long cooperative education program, we intend to have our campaign plan approved by the end of September. From there, we will send out sponsorship inquiry emails alongside our sponsorship brochure. Our sponsorship brochure outlines every milestone that AIAA at NU has accomplished. A few milestones highlighted include winning the 2014 Battle of the Rockets in Culpeper, VA, our most challenging build-to-date at the NASA SL 2015, as well as various other successful rockets and weather balloons. We will follow up with our 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. Through our external funding plan we will utilize NU's expansive Empower campaign, supporting innovation in education and research. We intend to devote all of the support from this sector to cover travel expenses.

5.4. COMMUNITY SUPPORT

AIAA at NU will reach out for additional community support through a variety of methods. First, we strive to gain adequate expertise in a variety of engineering/scientific disciplines through the guidance of professors and graduate students. While we remain a diverse team of mechanical engineers, chemical engineers, electrical engineers, industrial engineers, and physicists, we are currently recruiting electrical engineers for their input on this year's avionics aspect of our UAV drone with regards to telemetry and control theory. We have a sizable community eager to aid in our endeavors for this year's competition. Second, we are currently planning for a sponsorship campaign to promote AIAA at NU to all interested corporations. The details of our plan are outlined in our detailed funding plan in the sections above. Third, through the various projects conducted over these past few years, we are now thoroughly involved with the local divisions of NAR, MMMSC, and CMASS. Through these connections, we gain more knowledge on optimal designs and proper safety procedures from members who have decades of experience. Not only that, but through these local programs, we are able to showcase our projects to the local community of students and other young scientists. We have also continued to grow and establish a strong social media presence and have had the honor of being featured in our university's online newspaper, news@Northeastern. We intend to increase community support through continuously updating our social media venues on the status of our launch vehicle as well as encourage an active community of students with a passion to learn.

5.5. SUSTAINABILITY PLAN

AIAA at NU will continue to flourish as the only aerospace/aeronautical organization on NU's campus for many years to come. First, we intend to launch annual campaigns to seek and maintain sponsorships with our partners and corporate sponsors. Second, we will continue to engage successful teams within AIAA at NU. We will divide into various project teams based on interest and technical knowledge; technical groups will include Quadcopter Payload, Atmospheric Measurements, and Launch Vehicle. In order to maintain short term and long term team goals, objectives, deadlines, we will host weekly meetings to discuss progress, questions, integration. Third, in addition to current club members and new members gained through outreach such as Northeastern's Fall Fest, we will recruit NASA SL team members with a presentation of our project plan at the first official meeting of the fall semester. We will also provide our annual Introduction to Rocketry program for all incoming members with an interest in understanding the principles behind rocketry, teaching them to build and launch a successful rocket.

Fourth is educational engagement. Our collaboration with Claire Duggan and the rest of Northeastern's Center for STEM Education has allowed us to connect with many students in the Boston public school system. We plan to continue this partnership indefinitely. Further, Northeastern's NEPTUN program will allow members of our group to teach classes of high school students. The lesson plan we develop for this will be able to be used by future members of our club for the next several years. Finally, this year, we hope to create lasting partnerships with local schools by providing educational and engaging demonstrations and activities for their students. Fifth, our funding plan for sustainability will be renewed annually. We intend on requesting a majority of our technical agenda through NU's SGA all the while seeking coverage for travel expenses through corporate sponsorships.

APPENDIX A: STEM DEPARTMENT 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
www.stem.neu.edu

APPENDIX B: RISK ASSESSMENT

Project Phase	Risk	Description	Severity-Probablility	Proposed Mitigations
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.	3D	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 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 and reduce distracitons
	Mill and Band Saw	Being improperly trained in on the mill or bandsaw can lead to destruction of equipment and personal injury.	2E	Proper training and PPE
	Dust Inhalation	Inhalation of dust or particulates from sanding or cutting operations can lead to breathing problems and injury.	3D	Use of proper PPE (mask) and fume hood
	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 chemical locked in flame cabinet when not in use, reduce distractions and crwoding in workspace
	Splinters	Improper handling of certain materials can lead to splinters.	3D	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
	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
	Full Recovery 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 or Payload Land Near Crowd	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
	Quadcopter Approaching Crowd	If the quadcopter loses control of itself or wind pushes it toward the crowd it can become a hazard.	2D	Emergency parachute deployment button installed on ground station