Northeastern University

267 Snell Engineering
Northeastern University
Boston, MA 02115

NUMAV

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Competition: Mini-MAV & Maxi-MAV

Adult Educators

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
BS Industrial Engineering, Expected 2018
hume.j@husky.neu.edu
(402) 536-9285

Team Leader

Andrew Buggee
President, Student Chapter of AIAA
College of Science
BS Physics, Expected 2016
buggee.a@husky.neu.edu
(203) 747-4546

Mentor

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

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This proposal outlines how the Northeastern University student chapter of AIAA will successfully build, test, and operate a payload capable rocket and automated ground support equipment, as described in the competition guidelines for the 2014-2015 NASA University Student Launch Initiative. The organization was founded approximately one year ago and has since developed significant expertise in the design, construction, and flight of high-power model rockets. The organization also currently participates in educational outreach in the Boston community and will develop plans for additional outreach, alongside the Northeastern STEM center, in accordance with the requirements of the USLI competition.

A. General Information

There will be approximately 20 people committed to this project. Members are divided into groups to work on one of six subsections:

- Launch vehicle- structures
- AGSE- structures
- Simulations and modeling
- Electronics and Avionics (AGSE/launch vehicle)
- Safety

Key Managers and Technical Personnel include:

- Andrew- President
- Mary- Treasurer
- Kevin- Secretary, Electrical Group Lead
- Greg- Launch Vehicle (structures) Group Lead
- Evan- AGSE (structures) Group Lead
- Joe- Simulations and Modeling Group Lead
- John- Safety Officer
- Jonathan- Assistant Safety Officer
- Dr. Andrew Gouldstone- faculty advisor

We will work closely with NAR sections 727 and 464, MMMSC and CMASS. We will go to their scheduled launches and get feedback from their more experienced members. Scott of MMMSC, has been particularly helpful in our rocketry endeavors.

B. Facilities/Equipment

B.1. **Materials Laboratory** (For general build use)

B.1.1. Availability - 24/7 with several hours' notice.

B.1.2. Personnel - Required presence of designated team safety personnel

B.1.3. Equipment

B.1.3.1. Hand tools, cordless drill, digital scale, etc.

B.1.3.2. Soldering station

B.1.3.3. Flammable material closet for safe storage of motors and black powder

B.1.3.4. Chemical hood for safe use of epoxy and polyurethane foam

B.1.3.5. Instron tensile testing machine, and other materials testing equipment.

B.1.3.6. General use storage closet

B.2. **Student Machine Shop**

B.2.1. Availability - Tuesday and Thursday nights

B.2.2. Personnel - Requires presence of shop supervisor

B.2.3. Equipment

B.2.3.1. Bandsaw

B.2.3.2. Horizontal Bandsaw

B.2.3.3. Mill

B.2.3.4. Lathe

B.2.3.5. TIG and MIG welders

B.3. **Mechanical Engineering Department Machine Shop**

B.3.1. Availability - Accessible 9am to 5pm on weekdays

B.3.2. Personnel - Professional staff for machining assistance and supervision

B.3.3. Equipment

B.3.3.1. C&C Enabled Mills

B.3.3.2. Lathes

B.4. **Rapid Prototyping Laboratory**

B.4.1. Availability - Accessible 24/7

B.4.2. Personnel – Professional staff available 10-11am and 2-4pm Monday-Friday

B.4.3. Equipment

B.4.3.1. Epilog Laser Cutter

B.4.3.2. 3-D Printers

B.4.3.2.1. Fused Deposition Modeling

B.4.3.2.2. Stereolithography

B.4.3.2.3. Polymer-jetting

B.4.3.2.4. Powder bed

B.5. **Conference Room**

B.5.1. Availability - Weekdays 9am-5pm with one week notice

B.5.2. Equipment

B.5.2.1. High speed internet

B.5.2.2. Full Audio/visual conference capability

C. Safety

C.1. **Overview -** The following outlines our plan for the safety of the team members, facilities, and all non-team individuals involved in any aspect of the project. All team members will need to sign the NUMAV Team Member Safety Agreement shown in *Appendix 1*.

C.2. **Procedures for NAR/TRA Personnel to Perform -** To ensure safety we will comply with the rules set forth by federal, state, local and National Association of Rocketry (NAR) regulations for every rocket launch. Our rocket will be constructed out of lightweight cellulose tubing and will be modeled for stability before arriving to the launch pad. We will also model the projected altitude of flight and contact the FAA to obtain a flight waver for the desired altitude, if one hasn't already been obtained. The launch facilities which we attend have high power motor vendors, so we will buy our motors on site only if they are going to be used that day. By doing this we will avoid long-term storage of high-power motors. We are going to use an altimeter based ejection method, so we will follow the manufacturer's guidelines for removing the motors ejection charge. We will only attend launch facilities which meet the minimum diameter ratings set forth by the NAR for our impulse class.

Our rocket will be designed to use an electronic ignition system. For the small-scale and full-scale rockets, the igniter will not be inserted until the rocket is on the pad and otherwise ready to fly. The ignition system will include an independent switch which will need to be activated before the igniter can be fired, to ensure no accidental ignition occurs. When the rocket is on the launch rail, we will measure the wind speed and make sure that the wind is at an acceptable level, considering the stability of the rocket, before proceeding with the launch. Before launching we will make sure that all team members, local rocket club personnel and spectators are aware by giving a countdown over a megaphone system.

C.3. **Safety Training -** The safety officer and his assistant will give a presentation to the team members on hazard recognition and accident avoidance at the beginning of the project. A pre-launch briefing will be given before each launch.

C.3.1. Hazard Recognition and Accident Avoidance Briefing will include the following topics

C.3.1.1. General

C.3.1.1.1. If unsure about a procedure ask someone who is knowledgeable on the topic
C.3.1.1.2. Be aware of how your actions will affect yourself and individuals surrounding you
C.3.1.1.3. Wear all necessary personal safety equipment
C.3.1.1.4. Continually demonstrating ignorance of the safety rules will result in the removal of the individual from the team

C.3.1.2. Fire Safety

C.3.1.2.1. Fire prevention techniques
C.3.1.2.2. Location of fire extinguishers and fire blankets
C.3.1.2.3. Evacuation Plans

C.3.1.3. Chemical Safety

C.3.1.3.1. The following hazards are associated with chemicals
C.3.1.3.1.1. Irritation of skin, eyes, and respiratory system
C.3.1.3.1.2. Destruction of lab materials

C.3.1.3.2. How to mitigate the risks

C.3.1.3.2.1. Read the associated MSDS before handling of any chemicals
C.3.1.3.2.2. Always use the appropriate safety gear

C.3.1.3.2.3. Keep workstations clean

C.3.1.3.2.4. Use ventilation hood for materials which produce a hazardous gas

C.3.1.4. Tool Safety

C.3.1.4.1. Risks associated with improper use of equipment

C.3.1.4.2. Proper use and storage of equipment

C.3.2. Pre-Meeting/Pre-launch Briefings - As a reminder of the safety procedures the safety officer, or his appointee, will present a brief overview of the safety concerns and procedures pertaining to each day's meeting. Similarly, before a launch the safety officer will go over the correct procedure for handling motors, igniters, and black powder charges. The safety of the rocket before each launch will be reviewed by the RSO and the team understands that his/her word is the final say on the matter. To be fully prepared for a launch and the preceding safety inspection a safety and preparedness checklist will be printed out and brought to each launch and it will be filled out prior to inspection.

C.4. **Safety in Documentation -** All procedures, plans and working documents will include safety warnings above the step in which the hazard is present. These documents will include, but are not limited to, pre-launch checklist, build procedure and chemical handling procedure. To ensure all hazards are included in documentation, the safety officer will work in collaboration with the engineers writing the plans and procedures. In the situation where a chemical needs to be used, a copy of the MSDS will be attached to the end of the document.

C.5. **Legal Compliance -** We understand that any laws and regulations are in place purely for the safety of everyone involved in the launch and surrounding bystanders and their property and as such we agree to abide by all federal, state, and local regulations. We will also always be in compliance with all NAR/TRA regulations as well as specific rules set by local launch clubs. Currently the plan for testing our rockets is to attend the launches of NAR chapters CMASS and MMMSC. If the situation ever arises that we want to launch our rockets somewhere other than a scheduled launch from one of these two clubs we will make sure to go through the proper channels to acquire permits, either in the form of verbal or written permission from the FAA and the property owner. The FAA classifies the motors we will be using as Class 2. They outline the specifics of the information we need to provide and the process for obtaining permits which we plan to follow if we schedule our own launch. In doing this we will follow all guidelines including those relating to airspace regulations and fire prevention.

C.6. **Motor Storage and Transportation**-The team mentor will personally oversee the purchase, storage, and transport of any rocket motors and energetic devices including igniters and ejection charges. Our mentor, Robert DeHate, is a motor vendor and is accustomed to the protocols pertaining to the high power motors we will use. Only sufficiently NAR-certified personnel will be allowed to purchase or transport motors and other energetic devices.

C.7. **Statement of Safety Regulation Compliance**-The team recognizes the safety concerns that arise during a launch and will adhere to all the regulations of the launches we attend and to those of the competition. We also recognize the authority of the RSO and the range safety inspections. We understand that an unsafe vehicle or failure to comply with the RSO's guidelines will result in removal from the competition.

D. Technical Design

The design outline below is meant to satisfy the launch vehicle and the AGSE requirements as described in the NASA USLI 2014-2015 Handbook. The most challenging of these requirements are addressed specifically in section D.4.

D.1. **Rocket -** After many iterations of rocket design our organization has developed reliable practices for construction. We have chosen materials and construction methods in accordance with the performance requirements of a payload-capable, high-power rocket, based on significant flight heritage demonstrated by our organization. The preliminary design as simulated and discussed below has a total mass of 5.75 kilograms (~12.7 lbs) including motor and payload, an internal diameter of 9.8cm (~3.86 in), an overall length of 2.1 meters (~6.9 ft), and a fin semi-span of 10 cm (~3.94 in). A solid model of the preliminary design is shown below in *Figure 1*.

D.1.1. Airframe

D.1.1.1. The airframe body tube will be constructed of proprietary Blue Tube from Always Ready Rocketry™. Blue Tube is a vulcanized cellulose material, which is nearly as durable as a fiber glassed rocket, but is far easier to machine and assemble. This material which allows the rocket to be strong, durable, and reliable, without having the safety hazards and increased difficulty of working with fiberglass.

D.1.1.2. Laser-cut birch plywood centering rings will ensure that the force of the motor is applied coaxially to the cylindrical airframe. This will be secured to the body tube with heat resistant epoxy.

D.1.1.3. Internal, structural bulkheads will be made out of the same birch-plywood, and will be secured with the same type of heat resistant epoxy.

D.1.1.4. Steel eye-bolts, bolted through bulkheads, will provide structural attachment points for the recovery system shock cords.

D.1.1.5. The avionics bay will consist of an extra-long coupler tube, with a removable bulkhead secured to each end. The bulkheads will be secured with threaded rods, nuts, and lock washers. Each bulkhead will have an eye bolt as described above. The bay is held firmly to the airframe using stainless-steel machine screws. There will be two compartments in the avionics bay, one to house the altimeters, and another to contain a GPS tracker.

D.1.1.6. Coupled parts of the airframe where separations occur will be secured with nylon shear screws, which break at a predetermined load.

D.1.1.7. The section of the airframe forward of the main parachute chamber will serve as the payload capsule.

D.1.1.8. The forward section will have spring-loaded quick release buttons to interface with pre drilled holes in the rocket body. This is to structurally secure the nosecone of the rocket after the payload is autonomously inserted.

D.1.2. Avionics

D.1.2.1. The avionics will consist of two altimeters, for redundancy, and two BeeLine GPS Transmitters for recovery. One transmitter will be located in the payload capsule, while the altimeters and second transmitter will be located in the avionics bay, (described above).

D.1.2.2. The transmitter will be located in a separate compartment within the avionics bay. In addition, the other avionics will be shielded from any stray electromagnetic signals.

D.1.2.3. Altimeters will trigger the ejection charges to deploy the drogue chute, the payload capsule deployment, and the main parachute, and will be powered with separate 9V batteries.

D.1.2.4. The avionics bay will also contain two push-hold switches with external contacts, which will enable the altimeters to be turned on and off from the exterior of the rocket. This allows complete assembly of the rocket before arming the ejection charges on the pad, minimizing safety hazards.

D.1.2.5. Transmitters will operate in the 70cm amateur band, and will be powered with dedicated Li-ion batteries. Location data will be received with a handheld radio receiver, and decoded using a laptop computer.

D.1.2.6. All avionics will be mounted to removable plywood sleds to enable easy access and assembly.

D.1.3. Recovery System

D.1.3.1. The recovery system will consist of three nylon parachutes.

D.1.3.1.1. The drogue chute will be a relatively small (12-18 inch) parachute, and it will deploy at apogee. The drogue parachute will arrest the terminal velocity of the entire vehicle, so the main parachute can deploy safely at a lower altitude.

D.1.3.1.2. The main chute will be a larger (24-35 inches) parachute, which will deploy at approximately 1000 feet for recovery of the main vehicle.

D.1.3.1.3. The payload parachute will be a 24 inch parachute that is deployed as the payload capsule is ejected from the rocket at 1000 feet.

D.1.3.2. Black powder ejection charges will be used for airframe separation and parachute deployment. They will be ignited using electronic matches triggered by the altimeters described above.

D.1.3.3. The parachutes will be protected from hot ejection charge combustion gasses using flame-resistant Nomex wadding.

D.1.3.4. We plan to use Kevlar shock cord due to its high tensile strength and high heat resistance. We have used more elastic nylon shock cord in previous rockets, but nylon is vulnerable to damage due to high temperature ejection charge combustion. Subsequent design studies and flight tests have shown shock cord attachment points to be robust enough for the use of less-elastic Kevlar cord.

D.1.3.5. The shock cord will be secured to the eye bolts on each bulkhead by quarter inch thick, stainless steel quick links. The shock cord will be knotted to the quick links. This system allows for simple portability of the rocket.

D.1.3.6. The shock cord will be secured to the parachutes by high-capacity steel swivels. This allows the parachute to spin and rotate freely without interfering with the rest of the recovery system.

D.1.4. Fins

D.1.4.1. The four fins will be made of G-10 garolite fiberglass, a material with significant flight heritage in our organization. The G-10 is strong enough to prevent flexing during flight and landing. The G-10 fiberglass cannot be laser cut, therefore, the fins will be cut on a bandsaw.

D.1.4.2. The fins will be secured to the airframe using “through-the-wall” construction methods, and cold-weld type adhesive. Additionally, the aft airframe section that contains the fins will be filled with polyurethane foam, adding significant rigidity and strength to the fin assembly.

D.1.4.3. The fin slots will be cut on a milling machine. This ensures the accurate spacing of each slot, as well as that each slot is perfectly straight.

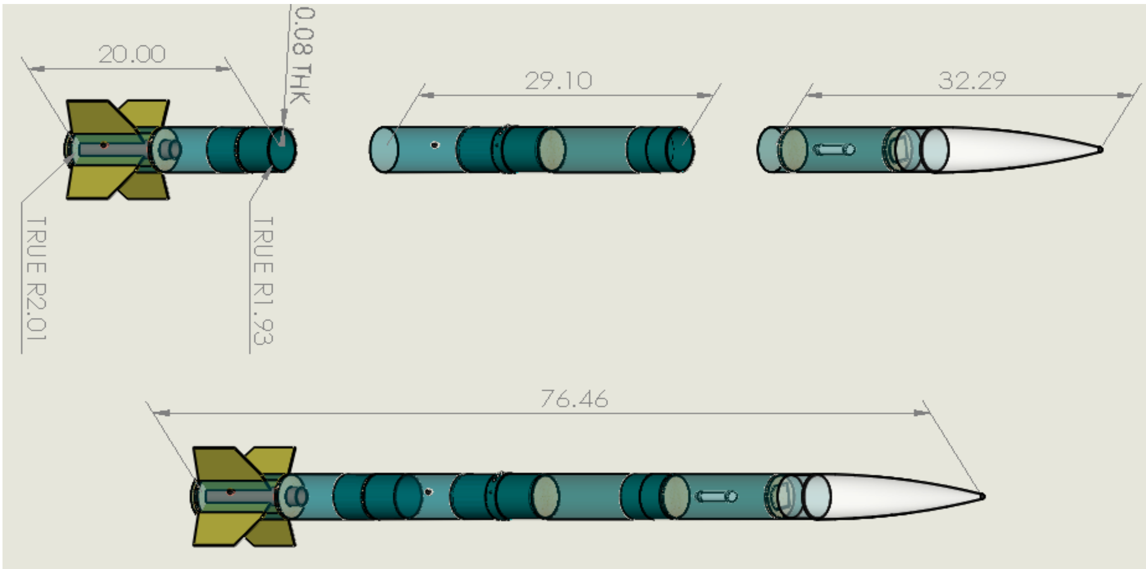

Figure 1: Our team has a lot of experience using SolidWorks to create and model high power rockets. An exploded view of the preliminary rocket design is above with all dimensions in inches.

D.1.5. Motor Selection

D.1.5.1. We are using a “J-class” motor for the rocket. The 54 millimeter “J380” motor made by Cesaroni Technology Incorporated is the ideal choice for the goal of 3000 feet in altitude. This motor provides enough thrust to allow us to design a more robust launch vehicle *(Figure 2)*. This motor was selected using the Open Rocket simulation of our rocket design (*Figure 3)*.

D.1.5.2. Motor specifications

D.1.5.2.1. Total Impulse: 1043 Ns
D.1.5.2.2. Average Thrust: 384 N
D.1.5.2.3. Peak Thrust: 435 N
D.1.5.2.4. Burn Time: 2.72 s
D.1.5.2.5. Launch mass: 1293 g
D.1.5.2.6. Empty Mass: 524 g

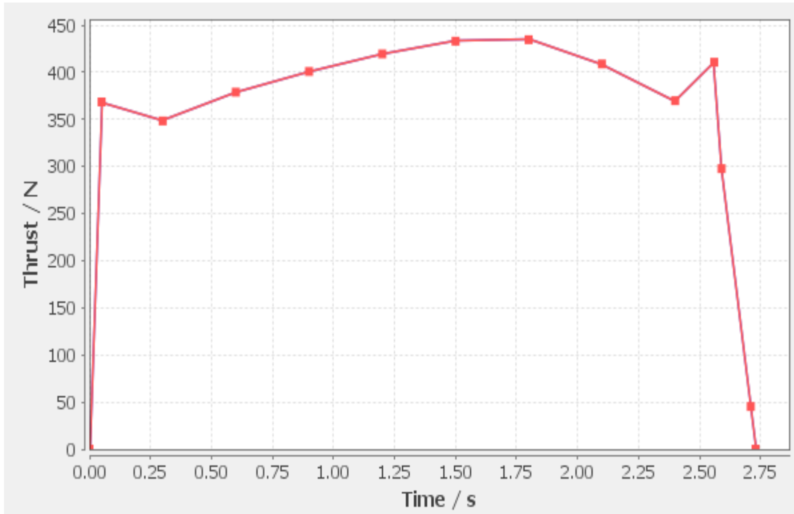

Figure 2: The J380 Motor Thrust Curve is obtained from Cesaroni Technology Inc. (Ontario, Canada)

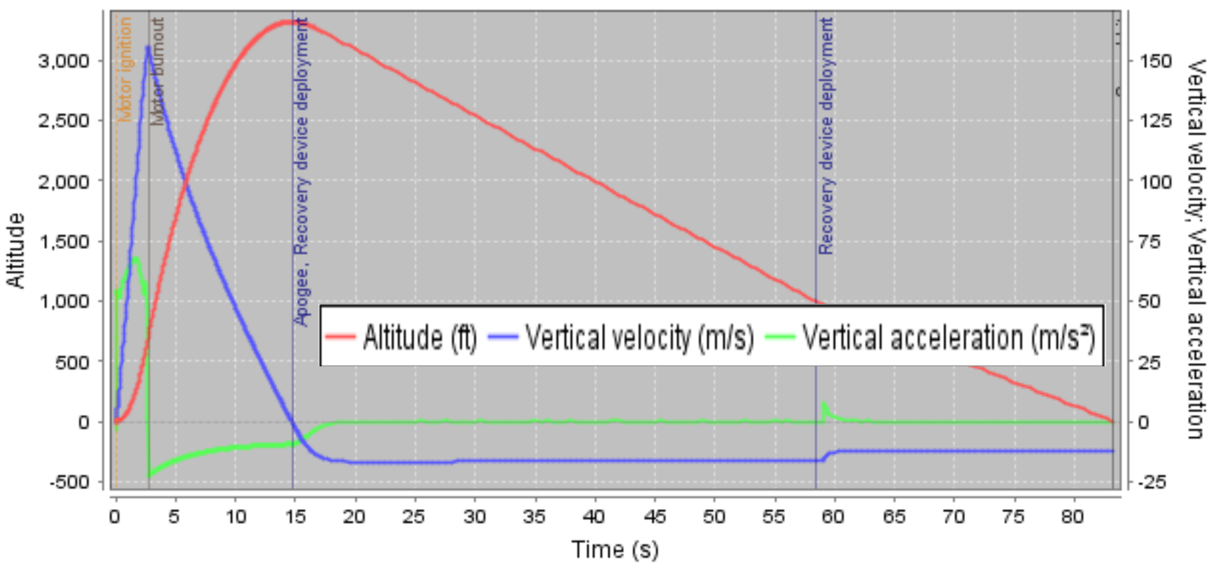

Figure 3: A plot of Open Rocket flight simulation results

D.2. **AGSE**

D.2.1. Structure

D.2.1.1. The AGSE structure will be built with 80/20 extruded Aluminum rail. It is light and can be preassembled into subsections, so that on launch day it can be put together in a timely manner.

D.2.1.2. The rocket and launch rail will start in a horizontal position, with the nosecone section removed to give access to the payload bay.

D.2.2. Subsystems

D.2.2.1. The AGSE will consist of three independent subsystems: Loader, Igniter Inserter, and Erector.

D.2.2.2. Loader- consists of three simple linear actuator mechanisms, enabling reliable loading operations

D.2.2.2.1. The payload retriever will move the payload into the elevator. It consists of a scoop that is dragged through the loading zone, using a linear actuator constructed from 80/20 rail and a stepper motor.

D.2.2.2.2. The elevator will move the payload up to loading height, coaxial to the rocket's airframe. It will consist of a set of thin curved supports that cradle the payload while allowing any debris picked up by the retriever to fall through. The platform will slide vertically on 80/20 rail, and will be actuated using stepper motors.

D.2.2.2.3. The assembler will push the nose cone onto the rocket, while simultaneously inserting the payload into its capsule. It will consist of a 3D-printed part that supports the nosecone, and a linear actuator as described above. The base of the nosecone will have a cup which mates with the end of the payload. The actuator will move the nosecone partially into position, pause to let the elevator clear the rocket's mold line, and then complete the nosecone closure, thus encapsulating the payload. The nosecone will snap into place using the mechanism described in D.1.1.8.

D.2.2.3. Igniter Inserter

D.2.2.3.1. The Motor igniter will be wrapped around an expendable material, such as a wooden dowel, and a linear actuator will insert the igniter into the motor. Rigid connection allows for maximum reliability and ease of insertion.

D.2.2.3.2. The insertion mechanism will retract after operation to allow erection and launch of the vehicle

D.2.2.4. Launch Rod Erector

D.2.2.4.1. The erector will consist of a closed-system pneumatic piston, which will be attached to the launch rail with a hinge joint, and to the AGSE structure with a fixed connection.

D.2.2.4.2. The piston will exert a torque on the launch rail, positioning it 5 degrees off of vertical.

D.3. **Mission Operations**

D.3.1. Preparation

D.3.1.1. The AGSE will retrieve the payload from the loading zone approximately one foot from the launch vehicle, which is oriented horizontally.

D.3.1.2. The AGSE will lift the payload to loading position, coaxial to the launch vehicle body, and insert it into the payload bay while structurally attaching the rocket's nosecone.

D.3.1.3. The AGSE will insert the igniter into the motor.

D.3.1.4. The AGSE will lift the rocket into position 5 degrees off vertical.

D.3.2. Flight

D.3.2.1. The rocket will launch to an apogee of 3000 feet as designed.

D.3.2.2. At apogee, the altimeters will trigger drogue parachute deployment.

D.3.2.3. At 1000 feet, the altimeters will trigger the separation of the forward portion of the airframe (constituting a payload capsule), simultaneously deploying the main launch vehicle parachute and the payload capsule parachute.

D.3.3. Recovery

D.3.3.1. The main launch vehicle section and payload capsule land separately.

D.3.3.2. GPS locator transmitters in both sections report their positions to the receiving equipment.

D.3.3.3. Team members retrieve both sections of the launch vehicle.

D.4. **Technical Challenges and Considerations**

Challenge	Approach
Maximize Payload Loading Reliability	To maximize precision, the AGSE mechanism will consist of several simple linear actuators. We will also minimize the number of individual actuations, and leverage our knowledge of rocket construction to make automated assembly as simple as possible.
Reliably Insert Motor Igniter	The igniter will be wrapped around a thin semi-rigid expendable rod, (e.g. a wooden dowel). This will then be inserted into the motor using a linear actuator. The rod will help ensure that the igniter is fully inserted into the rocket motor, and doesn't catch on the motor grains.
Aerodynamically Seal the Rocket after Payload Insertion	The nose cone will be outfitted with quick-release spring button connectors to interface with holes drilled into the body tube.
Consistent Target Altitude of 3000 feet	We will be conducting simulations to determine the exact launch altitude under variable wind conditions. We will also conduct several full-scale test launches with a dummy payload in order to dial in our altitude.
Structural Qualification of Flight Vehicle	We will perform structural component tests on bulkheads, fins, motor mount, and airframe. Combined with the significant flight heritage of our construction methods, these tests will increase confidence in the vehicle's structural integrity prior to subscale and full-scale flight tests.
Successfully Deploy Recovery System	In order to ensure the recovery system functions smoothly, we will be using 2 altimeters, each with its own e-match for redundancy. Numerous ground ejection tests will be conducted in order to ensure the payload and all parachutes deploy successfully.
Recover Rocket within Designated Landing Zone	To guarantee that both rocket sections land within the designated area, parachute size will be optimized using Open Rocket simulations and hand calculations. Kinetic energy on ground impact must also be managed. Based on preliminary simulations, we expect this to be achievable with main parachute deployment at 1000 feet, but as a contingency, an additional altimeter can be included to deploy the main parachute at a lower altitude.

E. Educational Outreach

Our outreach program is one of our highest priorities. Many of our members were first introduced to science through such events. STEM demonstrations sparked us at a young age and drove us to pursue careers in science and engineering. We hope to return the favor to Boston's youth community. Moreover, we want to help grow our community's passion for aerospace and rocketry. We believe there is a bright future in the aero/astro sector as more private companies seek to partner with government agencies. Not only do we want to be a part of this movement, but we want to help sustain it. This can only be accomplished by inspiring Boston's next generation of scientists and engineers. These two motives are the heart and soul of our outreach program.

Our team has a full schedule of STEM outreach events. In planning most of these events, we work closely with Northeastern University's Center for STEM Education. As indicated in the letter of support from Dr. Christos Zahopoulos, Executive Director of Northeastern's STEM department, *(Appendix II),* we are assisting in various education events throughout the year. Dr. Zahopoulos and the STEM center organize several annual field trips for Boston Public School students to visit the Northeastern University campus. We will be facilitating one such field trip for high school students in late October. For a middle school field trip on November 22nd, we will be designing and hosting an activity focused on rockets and Newton's third law of motion. We plan to implement an original variant of a rocket activity from the NASA Educator's Guide.

On October 25 and November 1, team members will teach a class to high school students as part of Northeastern's NEPTUN program. Students will use SOLIDWORKS 3D design software to virtually assemble the components of a car jack, a fan, a robot arm, and some other interesting machines. After creating these assemblies, students will use SOLIDWORKS to render photo-realistic images of the assemblies. The class may also make animations of some assemblies. For example, a student could take home a video of his/her virtual robot arm in action.

Another round of field trips is scheduled in early December for elementary and high school students. We will be hosting another activity as well as touring young students through our club's laboratory. They will be able to handle our past rocket and weather balloon projects and see where we work. Our thorough involvement in STEM outreach will continue past the timeframe of the USLI competition. We are working with NU's STEM center to plan a summer science camp for Boston middle school students.

In addition to Northeastern affiliated events, we have been in conversation with Boston area science teachers about conducting demonstrations and activities in local schools. We have a partnership with Curley K-8 School located in Jamaica Plain to present a STEM demonstration to 5th grade science classes. We will then engage them in an activity where they can put together an easy demonstration of their own. Currently our activity is planned to be a static electricity demonstration.

Our outreach program is something we hold in high regard, something we emphasize year-round. We revel in teaching young students about science and look forward to sharing our passion. After each event we attend, we will be posting photos in the outreach section of our new website: http://www.northeastern.edu/aiaa/

F. Project Plan

F.1. **Schedule & Milestones** – We have included the mandatory competition milestones as well as our own three voluntary milestones below. Planned project timeline targeted to meet all milestones is shown in *Figure 4.* The voluntary milestones are shown as a while required milestones are represented as a .

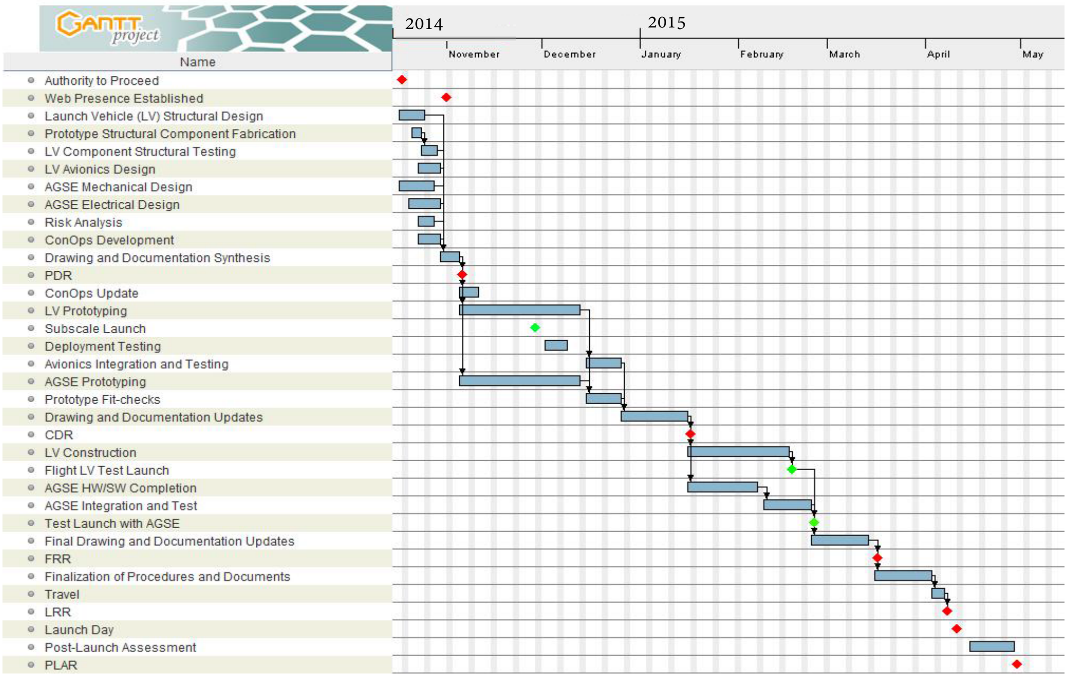

Figure 4: Project Timeline (Full Size Version in Appendix IV)

Milestone	**Date**
Awarded Proposals Announced	6 Oct. 2014
Team Web Presence Established	31 Oct. 2014
Preliminary Design Review	5 Nov. 2014
Subscale Launch *	28 Nov. 2014
Critical Design Review	16 Jan. 2015
Flight Vehicle Test Launch*	14 Feb. 2015
Test Launch with AGSE*	28 Feb. 2015
Flight Readiness Review	16 Mar. 2015
Launch Readiness Review	7 Apr. 2015
Launch Day	10 Apr. 2015
Post-Launch Assessment Review	29 Apr. 2015

* Voluntary Milestones

F.2. **Budget Summary -** The following table is a summary of our proposed budget for the competition. An Itemized budget is included in *Appendix III.*

NORTHEASTERN UNIVERSITY BUDGET SUMMARY: USLI		
System	**Sub System**	**Cost (US $)**
Launch Vehicle	Airframes/fairing	552.1
	Propulsion	618.39
	Fins	47.86
	Flight Electronics	800.1
	Recovery systems	152.06
	Miscellaneous Hardware	300
Total		2470.51
AGSE	Frame	294.12
	Electronics	217.46
	3D-printed parts	300
	Actuators	1084
	Miscellaneous Hardware	600
Total		2495.58
Total Hardware		4966.09
Support	Testing	1000
	Travel	4880
Grand Total		**$9846.09**

F.3. **Funding plan-** We have multiple partnerships with funding sources through Northeastern University, which we have utilized in the past. The Student Government Association (SGA) distributes financial support to Northeastern clubs through their Finance Board. Clubs are funded depending on their project/event and how much is required. The process requires each group submit an itemized budget and then present the purpose of their request to the Finance Board. The Finance Board will then vote on whether they believe the request falls under their donation requirements. We have been awarded funding in the past from SGA to build a weather balloon, which measured UV radiation in the Ozone layer. We plan on submitting a proposal to SGA to fund our costs for the Launch Vehicle.

In the past, we have used the Provost's Undergraduate Research Grant as a funding source. The Office of the Provost will fund undergraduates to perform research under the supervision of a faculty advisor. The application process requires submission of a written proposal and a recommendation letter from a faculty advisor. The office then reviews the proposal and decides whether funding is granted. Over the summer of 2014, we were awarded $6,000 to conduct research on new sophisticated high altitude rockets, including a rocket with payload deployment capabilities and a supersonic rocket. We plan on using this source to cover costs for the AGSE.

Other sources of funding that we have at our disposal are the Catalyst fund and the College of Engineering Scranton Fund. The Scranton fund is an endowment to be used by clubs affiliated with the College of Engineering. We plan on using this source to cover costs for testing and any miscellaneous hardware needed for completion. The Catalyst fund allows groups to create a web page to advertise their cause towards Northeastern's alumni, faculty and partners. We have previously utilized this source to raise money for our travel expenses to Virginia where we competed in the Battle of the Rockets competition. We plan on using this avenue again to raise money for our travel expenses to Huntsville.

F.4. **Community Support-** Through our previous projects we have become involved with the local divisions of the NAR, MMMSC and CMASS. Many members of these clubs have decades of rocketry experience and have been very supportive as we built more and more complicated rockets. Our relationship with these clubs is symbiotic; they provide us with information on design and safety procedures and we support the local rocketry programs and bring large rockets to show the young aerospace enthusiasts attending the launch.

As part of a large university we have many resources available to us on campus. We have worked with Northeastern's MiniBaja and NUtrons, both of which are mechanically demanding, to machine our parts in the student machine shop. The NUtrons are a robotics clubs, which we can approach when we have questions on getting the various components of our AGSE to work in sync with each other. Another club on campus which we have worked closely with is the Wireless Club. They helped us in the past with following the regulations pertaining to a radio beacon for tracking and will be of assistance for the remote tracking of our launch vehicle and payload in the competition.

We are currently in the process of sending out letters to various engineering companies in the surrounding area to garner sponsorships for additional financial support. Many of these companies such as Raytheon Company, Dassault Systems, and Sikorsky have previously employed our members. Because we have an established relationship with them, we are in a position to establish a strong partnership with these companies.

F.5. **Sustainability-** Our team is part of Northeastern's AIAA student chapter, which was founded to provide an environment for students to pursue astronautics education and projects in a University with no formal aerospace programs. In the past year since founding, the club has attracted 20 dedicated members, and is quickly growing. Since the beginning of the fall semester, we have recruited approximately 40 new, dedicated members allowing the group to split into subgroups simultaneously pursuing UAVs, weather balloons, and rockets. We believe that many new members will take interest in USLI and help with the project. The longevity of Northeastern's AIAA student chapter is promising and will provide aerospace opportunities for future classes.

We have established several methods of collecting funding to support our projects through the University, as described above. We have the opportunity to apply to the Student Government Association supplemental budget every month. We can also apply to the Provost Undergraduate Research Grant biannually and the College of Engineering Scranton Fund annually.

Through the University's STEM director, Dr. Zahopoulos, we have made plans to connect with young students in the surrounding Boston area. In addition to many outreach plans throughout the year, we plan on continuing to make connections with the community by planning a summer science camp for middle school students. We hope to branch out beyond the University and form lasting relationships with the Boston community.

Appendix I (Sample)

NUMAV Team Member Safety Agreement

As a team member I,_________________________________, understand the rules and regulations set forth by:

- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C
- Amateur Rockets, Code of Federal Regulation 27 Part 55
- NFPA1127 "Code for High Power Rocket Motors."
- NAR "High Power Rocket Safety Code"

_______I also acknowledge that I have been trained on and will follow the proper use of all production and safety/emergency equipment I may come in contact with. I have been briefed on the use of MSDS and will read the proper documentation before handling any hazardous material. I agree to work with my teammates to create a constructive and safe work environment for all individuals involved with the project.

_______I recognize the safety concerns that arise during a launch and will adhere to the regulations of the launches I attend in addition to the regulations listed above. I will recognize the authority of the Range Safety Officer (RSO) and their inspections. I understand that an unsafe vehicle, as deemed by the RSO, will not be flown until all safety concerns have been addressed to his/her satisfaction.

_______I understand that the failure to recognize any of the above safety measures will result in my removal from the rocket team and any projects pertaining to USLI.

Name:____________________ Signature:_____________________________ Date:_________

Safety Officer:_________________________ Date:_________

Team Leader:__________________________ Date:_________

NUmav Team Member Safety Agreement

As a team member I, Alexander Hersh, understand the rules and regulations set forth by:

- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C
- Amateur Rockets, Code of Federal Regulation 27 Part 55
- NFPA1127 "Code for High Power Rocket Motors."
- NAR "High Power Rocket Safety Code"

AJH I also acknowledge that I have been trained on and will follow the proper use of all production and safety/emergency equipment I may come in contact with. I have been briefed on the use of MSDS and will read the proper documentation before handling any hazardous material. I agree to work with my teammates to create a constructive and safe work environment for all individuals involved with the project.

AJH I recognize the safety concerns that arise during a launch and will adhere to the regulations of the launches I attend in addition to the regulations listed above. I will recognize the authority of the Range Safety Officer (RSO) and their inspections. I understand that an unsafe vehicle, as deemed by the RSO, will not be flown until all safety concerns have been addressed to his/her satisfaction.

AJH I understand that the failure to recognize any of the above safety measures will result in my removal from the rocket team and any projects pertaining to USLI.

Name: Alexander Hersh Signature: [signature] Date: 10/4/2014

Safety Officer: [signature] Date: 10/4/14

Team Leader: [signature] Date: 10/4/14

NUmav Team Member Safety Agreement

As a team member I, Joe Flaherty, understand the rules and regulations set forth by:

- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C
- Amateur Rockets, Code of Federal Regulation 27 Part 55
- NFPA1127 "Code for High Power Rocket Motors."
- NAR "High Power Rocket Safety Code"

JF I also acknowledge that I have been trained on and will follow the proper use of all production and safety/emergency equipment I may come in contact with. I have been briefed on the use of MSDS and will read the proper documentation before handling any hazardous material. I agree to work with my teammates to create a constructive and safe work environment for all individuals involved with the project.

JF I recognize the safety concerns that arise during a launch and will adhere to the regulations of the launches I attend in addition to the regulations listed above. I will recognize the authority of the Range Safety Officer (RSO) and their inspections. I understand that an unsafe vehicle, as deemed by the RSO, will not be flown until all safety concerns have been addressed to his/her satisfaction.

JF I understand that the failure to recognize any of the above safety measures will result in my removal from the rocket team and any projects pertaining to USLI.

Name: Joe Flaherty Signature: Joe Flaherty Date: 10/4/14

Safety Officer: [signature] Date: 10/4/14

Team Leader: [signature] Date: 10/4/14

NUmav Team Member Safety Agreement

As a team member I, Jonathan Malsan, understand the rules and regulations set forth by:

- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C
- Amateur Rockets, Code of Federal Regulation 27 Part 55
- NFPA1127 "Code for High Power Rocket Motors."
- NAR "High Power Rocket Safety Code"

JRM I also acknowledge that I have been trained on and will follow the proper use of all production and safety/emergency equipment I may come in contact with. I have been briefed on the use of MSDS and will read the proper documentation before handling any hazardous material. I agree to work with my teammates to create a constructive and safe work environment for all individuals involved with the project.

JRM I recognize the safety concerns that arise during a launch and will adhere to the regulations of the launches I attend in addition to the regulations listed above. I will recognize the authority of the Range Safety Officer (RSO) and their inspections. I understand that an unsafe vehicle, as deemed by the RSO, will not be flown until all safety concerns have been addressed to his/her satisfaction.

JRM I understand that the failure to recognize any of the above safety measures will result in my removal from the rocket team and any projects pertaining to USLI.

Name: Jonathan R. Malsan Signature: [illegible] Date: 10/4/14

Safety Officer: [illegible] Date: 10/4/14

Team Leader: [illegible] Date: 10/4/14

NUmav Team Member Safety Agreement

As a team member I, Andrew Buggee, understand the rules and regulations set forth by:

- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C
- Amateur Rockets, Code of Federal Regulation 27 Part 55
- NFPA1127 "Code for High Power Rocket Motors."
- NAR "High Power Rocket Safety Code"

AJB I also acknowledge that I have been trained on and will follow the proper use of all production and safety/emergency equipment I may come in contact with. I have been briefed on the use of MSDS and will read the proper documentation before handling any hazardous material. I agree to work with my teammates to create a constructive and safe work environment for all individuals involved with the project.

AJB I recognize the safety concerns that arise during a launch and will adhere to the regulations of the launches I attend in addition to the regulations listed above. I will recognize the authority of the Range Safety Officer (RSO) and their inspections. I understand that an unsafe vehicle, as deemed by the RSO, will not be flown until all safety concerns have been addressed to his/her satisfaction.

AJB I understand that the failure to recognize any of the above safety measures will result in my removal from the rocket team and any projects pertaining to USLI.

Name: Andrew Buggee Signature: ______ Date: 10/4/14

Safety Officer: ______ Date: 10/4/14

Team Leader: ______ Date: 10/4/14

Appendix II – Letter of Support

Northeastern University
Center for STEM Education

Center for STEM Education
Northeastern University
520 International Village
360 Huntington Avenue
Boston, MA. 02115

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" sessions which take place once each semester. They have also developed and will soon be implementing activities with high school students for the 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 fulfil 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 don't hesitate to contact me should you need any additional information!

Respectfully,

Christos Zahopoulos, PhD
Executive Director, Center for STEM Education
(617) 373-4583 | c.zahopoulos@neu.edu

Appendix III – Itemized Budget List

Item	Description	Price	Quantity	Total
Launch Vehicle				
Body Tube	Blue Tube 4 inch diameter	$38.95	8	$311.60
Coupler Tubes	2*payloads 2*coupler tubes	$10.95	8	$87.60
Nose Cone	4-inch	$21.50	2	$43.00
Bulkheads	4 inch Coupler Bulkheads	$4.05	6	$24.30
Altimeter Bay	4 inch Blue Tube Altimeter Bay	$42.95	2	$85.90
Main Chute	24 inch Fruity Chute	$62.06	1	$62.06
Drogue Chute + Payload Chute	12 inch Fruity Chute	$45.00	2	$90.00
Shock Cord	Kevlar #1500	$0.92	80	$73.60
Fin Material	G10 Fiberglass Sheet	$47.86	1	$47.86
Motor Tube	54mm Motor Mount tube	$8.09	2	$16.18
Plywood	Hobby shop Plywood	$10.00	4	$40.00
Motor Casing	54mm Pro 54 Case	$69.39	1	$69.39
Motor	J380	$91.50	6	$549.00
Retaining Ring	Aeropack	$36.38	2	$72.76
Stratologger Altimeter	Perfectflite Stratologger	$85.55	2	$171.10
GPS Tracker	The Big Red Bee GPS locater	$230.00	2	$460.00
Radio Beacon	The Big Red Bee Radio Beacon	$89.00	1	$89.00
Push Hold Switch	Apogee	$20.00	4	$80.00
Ejection Caps		$3.00	2	$6.00
AGSE				
Stepper Motor	NEMA 17 Adafruit	$14.00	6	$84.00
Sheet Metal	24*48 1/16 sheet steel	$43.80	1	$43.80
Miscellenous Hardware	Bolts, nuts, washers, tools	$350.00	1	$350.00
Pneumatics	Pneumatics	$1,000.00	1	$1,000.00
80/20 Aluminum	Mcmaster Carr	$31.29	8	$250.32
Adhesives		$250.00	1.00	$250.00
Arduino		25.23	1	$25.23
Arduino Motor Shield		25.23	1	$25.23
12V 10 aH Battery	Andymark	35	2	$70.00
Battery Charger 1 bank 6 amp	Andymark	97	1	$97.00
3-D printed parts		300	1	$300.00
Black Powder (gram)		1	50	$50.00
Igniters (40pk.)		1	41.16	$41.16
Hardware Total				$4,966.09
Support				
Testing				$1,000.00
Hotel-5 nights-4 rooms				$2,600.00
Gas-2 vans				$1,000.00
Tolls-2 cars				$280.00
Support Total				$4,880.00
GRAND TOTAL				**$9846.09**

<u>Appendix IV</u> - Project Timeline