NASA Student Launch

2014-2015 Proposal for Maxi-MAV

October 6, 2014

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Section 1. General Information

1) School Information/Project Title

School Name: University of Louisville
Organization: *River City Rocketry*
Location: J.B. Speed School of Engineering
132 Eastern Parkway
Louisville, KY 40292
Project Title: Project Free the Bird

2) Team Officials

Advisor Name: Dr. Yongsheng Lian
Contact Information: y0lian05@louisville.edu **or** (502) 852-0804

Dr. Yongsheng serves as a faculty at the Department of Mechanical Engineering at the University of Louisville. He worked at the Ohio Aerospace Institute as a Senior Researcher from 2003 to 2005 and as a Research Scientist at the Aerospace Engineering Department of the University of Michigan from 2005 to 2008. He joined the University of Louisville in 2008. He has 17 years of experience in computational fluid dynamics. He developed algorithms to study fluid/structure interaction, laminar-to-turbulent flow transition, low Reynolds number aerodynamics, and its application to micro air vehicle, two-phase flow, and design optimization.

Team Captain/Safety Officer Name: Emily Robison
Contact Information: emrobi07@louisville.edu **or** (502) 758-0487

Emily is currently a fourth year mechanical engineering student at the University of Louisville's J.B. Speed School of Engineering. After helping the team take home the safety award during the 2013-2014 season, she will be returning as safety officer and captain. She has spent three semesters on co-op working on various programs with Raytheon Missile Systems. Through this experience, she gained valuable knowledge in design, testing, assembly processes, and safety. Emily hopes to pursue a career in the aerospace industry after graduation.

Team Captain Name: Gregg Blincoe
Contact Information: GLBlincoe@gmail.com **or** (502) 640-9305

Gregg is currently a fourth year mechanical engineering student at the University of Louisville's J.B. Speed School of Engineering. He learned a lot through his involvement in the 2012-2013 competition year and while helping the team take a 3rd place overall finish in last year's competition. He successfully obtained both Level 1 and Level 2 certifications through Tripoli using both commercial and scratch built kits respectively. Gregg plans to apply his engineering knowledge and skills in the aerospace industry upon graduation from UofL.

3) Tripoli Rocketry Association Mentor

Name: Darryl Hankes
Certification: Level 3 Tripoli Rocketry Association
Contact Information: nocturnalknightrocketry@yahoo.com **or** (270) 823-4225

Darryl Hankes engaged himself in rocketry in February of 2003. In 2004, he joined Tripoli Indiana and where he received his Level 1 TRA certification. In 2006 at Southern Thunder, Hankes received his Level 2 TRA certification. A year later, in 2007, Hankes successfully attempted his Level 3 TRA Certification at Mid-West Power. Over the years, Hankes has flown an R10,000 twice in a team project along with countless M-R projects with clusters, staging, and air starts. He is also the prefect for the Tripoli Rocketry Association, Bluegrass Rocket Society, which provides launch support during test launches. Hankes has mentored the team through all three seasons that River City Rocketry has participated in NASA's student launch competitions. The team is pleased to see his return for this year's competition.

4) Team Members and Organization

The University of Louisville's team this year will consist of 22 students from several different engineering majors. The team includes students from electrical and computer engineering, computer engineering and computer science, and mechanical engineering. Resumes for each team member can be found in Appendix I. The team seeks to branch out to majors beyond engineering, such as education to help support our outreach program. As the competition year is young, new members may be added to the team hierarchy throughout the season. NASA will be notified of any changes.

In order to improve organizational efforts, a team hierarchy has been established. This hierarchy is displayed below in Figure 1. A larger version of this may be found in

Appendix I – Supplemental Documentation.

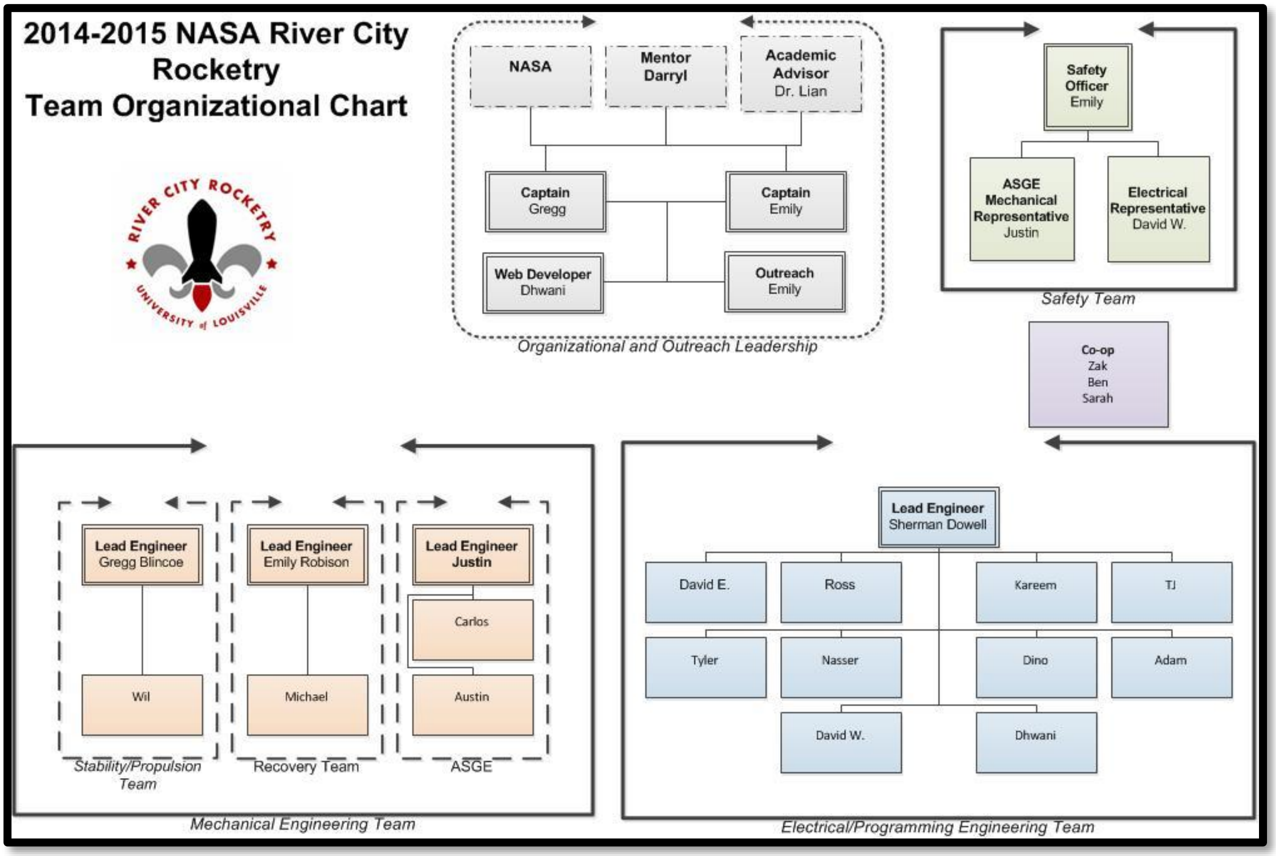


Figure 1: 2014-2015 team hierarchy.

The goal behind the structure of this hierarchy is to improve interdepartmental communication.

Section 2. Facilities and Equipment

1) Facilities/Equipment

Mechanical Engineering Project Support Laboratory

The Mechanical Engineering Project Support Laboratory is a facility used for the support of student design and research projects. Research prototypes, experimental test fixtures, and student design prototypes are fabricated in the facility. This facility is available 24 hours a day. Major equipment items include:

- Sharp 13" × 40" lathe
- Radial drill press
- MIG welder
- Thermal dynamic plasma cutter
- 15" drill press
- Air compressor
- Horizontal band saw
- 55 ton shop press
- 5000 lb. hoist
- Bench grinder
- Power hand tools
- Hand tools

FirstBuild

Figure 2: Part of FirstBuild's open workspace shown here (right).

Formed by GE Appliances, Local Motors, and the University of Louisville, FirstBuild, a microfactory, is a place for builders, makers and hackers to come together to bring their ideas to life. Having ties with the University, FirstBuild is excited to engage the team members in professional manufacturing practices and allowing them to use their equipment to build any necessary components. One team member is currently employed there and will be the point of access to the machine shop for the team. Major equipment items include:

- 3-axis Haas CNC Mill
- OMAX Abrasive Waterjet
- Media Blaster
- Horizontal Band Saw
- Vertical Band Saw
- Haas CNC Lathe
- Sheet Metal Brakes
- Various Hand Tools
- 24”x48” Universal Laser Cutter
- 50 Ton Press

- 2 Metal Lathes
- Miter Saw
- Drill Press
- Surface Grinders
- 4 MakerBot 3D Printers
- Various Hand Tools
- Drills
- Soldering Equipment
- Air Compressor
- Objet 3D Printer

Samtec, Inc. Machine Shop:

As a team sponsor last year, Samtec Inc. has agreed to allow the team to use their extensive machine shop resources. One team member is currently employed there and will have 24 hour access to these facilities. A full staff of professional machinists is also available for advice, help, and advanced machining that is unable to be performed by students. Major equipment items include:

- 6 Bridge Port Mills
- Vertical Band Saw
- 2 Metal Lathes
- Miter Saw
- Drill Press
- 4 Surface Grinders
- Horizontal Band Saw
- 50 Ton Press
- Various Hand Tools
- Drills
- Soldering Equipment
- Air Compressor

Figure 3: From left to right: Bridgeport mill, surface grinder, and a metal lathe.

LVL1

LVL1 (pronounced “level one”) is a hackerspace. This is an open community lab and workshop located in Louisville, Kentucky that is democratically operated by its membership. LVL1 is accessible to the public at large as long as an official member is present at the space. Members can access LVL1 24 hours a day using a building key. The team will maintain a membership at LVL1 throughout the build phase of the season. This allows the team unlimited access to LVL1 any time. Major equipment items include:

- CNC Table
- Table Saw
- 40W CO_2 Laser Cutter
- MakerBot 3D Extruder Printer
- Pneumatic Tool System
- Router
- Chop Saw
- Wood Lathe
- Welder
- Soldering Irons
- Anti-Static Mat
- Miter Saw

Rapid Prototyping Facility

The Rapid Prototyping Facility is used in support of our sponsoring industrial consortium and student design projects. The facility creates prototypes and moldings from nylon, glass-filled nylon, polycarbonate, and varying metals using scanning lasers in a material layering process. Access is only granted to official university personnel upon request.

Lutz Micro/Nano Technology Center

The Lutz Micro/Nano Technology Center (MNTC) is composed of three core facilities:

- State-of-the-art class 100/1000 cleanroom for prototyping miniature devices and systems divided into 7 dedicated bays with advanced micro/nano fabrication equipment.
- MEMS Modeling and TCAD Lab for the design, layout, and simulation of micro/nano devices.
- Micro/Nano Post-Processing Lab for packaging and testing of completed components

All three micro/nanotechnology core facilities are utilized for both research and instructional purposes. They provide a state-of-the-art environment for the fundamental and current fabrication techniques used to manufacture integrated circuits (ICs), discrete microelectronic devises, MEMS devices such as sensors and actuators, and various electro-optic devices. Access is only granted to official university personnel upon request.

Supporting Airfields

The surrounding NAR and TRA chapters have given permission to River City Rocketry team to utilize their airfields which are all located within 1.5 hours from the university. The local chapters also have monthly launches at their fields with FAA clearance to fly at or above Level 2 altitudes.

2) Computer Software

Dahlem Supercomputer Laboratory

This laboratory was provided by the Vogt Engineering Center to support the research and instructional missions of the Speed Scientific School. The main feature of this facility is Adelie, a supercomputer available to all Speed School engineering students. Adelie is a 64 bit Linux cluster parallel system based on the Opteron processor. The system currently consists of 28 nodes with a total of 94 processor cores, 192 Gigabytes of memory, 2.2 Terabytes of disk storage, and 329 Gigaflops of aggregate processor speed.

Another part of the facility is the Access Grid Node, which is an internet-based system for world-wide video conferencing developed by Argonne National Laboratories. The laboratory also hosts 30 computers with similar software as that is used in the Kurz Laboratory, accommodation for individual laptops, and printing equipment.

Students are able to access this laboratory from 8am-5pm on weekdays or by request.

Speed School Software Bundle

Any enrolled engineering students have access to an external website where they may download several software packages for personal use. The software available for students includes:

- Microsoft Office 2010 Suite
- Maple
- Matlab
- Minitab
- Mathcad
- SolidWorks with Simulation and Flow Simulation
- MS Project and MS Visio
- Microsoft Visual Studio
- NI Circuit Design Suite
- LabVIEW
- ANSYS 12 with Workbench 2.0
- Engineering Equations Solver

References

"Dahlem Supercomputer Laboratory." *J.B. Speed School of Engineering*. N.p., n.d. Web. 9 Aug 2012. <http://louisville.edu/speed/research/centers-and-labs/dahlem-supercomputer-laboratory.html>.

"Vogt Engineering Center ." *Department of Industrial Engineering* . N.p., n.d. Web. 9 Aug 2012. <http://louisville.edu/speed/industrial/facilities/cooperative-facilities.html>.

Web Conferencing Capabilities

Conference and lecture rooms are open to students, upon reservation, for conference calls, and/or presentations. Each room comes equipped with a desktop computer with internet access, a conference telephone with speaker phone, and a projector or large screen TV. A webcam can be obtained from an engineering department or borrowed from the team's advisor. Software to run WebEx can easily be installed on any computer without special permissions.

3) Website Compliance

The website that will be corresponding to our rocketry club will be www.rivercityrocketry.org. The instillation of the website is currently in process, but will be completely done by the web-presence deadline. The website will encompass all of the documents from this year and previous years. It will also include information about all of our outreach events we have hosted and/or participated in. The site will also have other relevant information including detailed reporting of our project progress, funding, media, and even blog posts from our current team. We will also have any supporting members name or logo on the site, whether it be a company or an individual backer.

Figure 4: RiverCityRocketry.org's home page.

The backend coding of the website will be completed using PHP with MySQL as a backend. The front end will just encompass the basic HTML/CSS/JQuery model. The hosting of the website will be done on University of Louisville - JB Speed School of Engineering servers that we gained access to from the computer science department.

Section 3. Safety

1) Safety Plan

Safety Officer Responsibilities

Emily is the safety officer for the River City Rocketry team for the 2014-2015 season. She is responsible for ensuring the overall safety of the team, students, and public throughout all team activities as well as assuring compliance with all laws and regulations. The following are the Safety Officer's specific responsibilities.

- Provide a written team safety manual that includes hazards, safety plans and procedures, PPE requirements, MSDS sheets, operator manuals, FAA laws and NAR regulations.
- Confirm that all team members have read and comply with all regulations set forth by the team safety manual.
- Identify safety violations and take appropriate action to mitigate the hazard.
- Establish and brief the team on a safety plan for various environments, materials used, and test procedures.
- Establish a risk matrix that determines the risk level of each hazard based off of the probability of the occurrence and the severity of the event. Ensure that this type of analysis is done for each possible hazard.
- Oversee testing being performed to ensure that risks are mitigated.
- Remain active in the design, construction, testing and flight of the rocket in order to quickly identify any new potential safety hazards and to ensure the team complies with the team safety plan.
- Enforce proper use of Personal Protective Equipment (PPE) during construction, ground tests, and test flights of the rocket.
- Make MSDS sheets and operator manuals available and easily accessible to the team at all times.
- Provide plan for proper purchase, storing, transporting, and use of all energetic devices.
- Ensure compliance with all local, state, and federal laws.
- Ensure compliance with all NAR and Tripoli regulations
- Ensure the safety of all participants in educational outreach activities, providing PPE as necessary.

Emily has written a team safety manual that each team member was required to review and sign indicating compliance. The document includes hazards, proper safety plans and procedures, PPE requirements, MSDS sheets, FAA laws, and NAR regulations. The manual will be revised throughout the year as a need arises. Emily is responsible for making sure that each team member has read and acknowledged the safety manual and will continue to enforce all statements in the safety manual. The manual can be found on the team website so that it is easily accessible for all team members at all times.

Hazard Analysis

Risk Assessment Matrix

By methodically examining each human interaction, environment, rocket system and component, hazards have been identified and will continue to be brought to the team's attention. Each hazard has been assigned a risk level through the use of a risk assessment matrix, found in Table 3, by evaluating the severity of the hazard and the probability that the hazard will occur.

A severity value between 1 and 4 has been assigned to each hazard with a value of 1 being the most severe. In order to determine the severity of each hazard, the outcome of the mishap was compared to an established set of criteria based on the severity of personal injury, environmental impact, and damage to the rocket and/or equipment. This criteria is outlined below in Table 1.

Severity		
Description	**Value**	**Criteria**
Catastrophic	1	Could result in death, significant irreversible environmental effects, complete mission failure, monetary loss of $5k or more.
Critical	2	Could result in severe injuries, significant reversible environmental effects, partial mission failure, monetary loss of $500 or more but less than $5k.
Marginal	3	Could result in minor injuries, moderate environmental effects, complete failure of non-mission critical system, monetary loss of $100 or more but less than $500.
Negligible	4	Could result in insignificant injuries, minor environmental effects, partial failure of non-mission critical system, monetary loss of less than $100.

Table 1: Severity criteria.

A probability value between 1 and 5 has been assigned to each hazard with a value of 1 being most likely. The probability value was determined for each hazard based on an estimated percentage chance that the mishap will occur given the following:

- All personnel involved have undergone proper training on the equipment being used or processes being performed.
- All personnel have read and acknowledged that they have a clear understanding of all rules and regulations set forth by the latest version of the safety manual.

- Personal Protective Equipment is used as indicated by the safety lab manual and MSDS.
- All procedures were correctly followed during construction of the rocket, testing, pre-launch preparations, and the launch.
- All components were thoroughly inspected for damage or fatigue prior to any test or launch.

The criteria for the selection of the probability value is outlined below in Table 2.

Probability		
Description	**Value**	**Criteria**
Almost Certain	1	Greater than a 90% chance that the mishap will occur.
Likely	2	Between 50% and 90% chance that the mishap will occur.
Moderate	3	Between 25% and 50% chance that the mishap will occur.
Unlikely	4	Between 1% and 25% chance that the mishap will occur.
Improbable	5	Less than a 1% chance that mishap will occur.

Table 2: Probability criteria.

Through the combination of the severity value and probability value, an appropriate risk level has been assigned using the risk assessment matrix found in Table 3. The matrix identifies each combination of severity and probability values as either a high, moderate, or low risk. The team's goal is to have every hazard to a low risk level by the time of the competition launch. Those that are not currently at a low risk level will be brought down through redesign, new safety regulations, or any other measures seen fit to reduce risk. Risk levels will also be reduced through verification of systems.

Risk Assessment Matrix				
Probability Value	**Severity Value**			
	Catastrophic-(1)	Critical-(2)	Marginal-(3)	Negligible-(4)
Almost Certain- (1)	2-High	3-High	4-Moderate	5-Moderate
Likely-(2)	3-High	4-Moderate	5-Moderate	6-Low
Moderate-(3)	4-Moderate	5-Moderate	6-Low	7-Low
Unlikely-(4)	5-Moderate	6-Low	7-Low	8-Low
Improbable-(5)	6-Low	7-Low	8-Low	9-Low

Table 3: Risk assessment matrix.

Preliminary risk assessments have been completed for possible hazards that have been identified at this stage in the design. Acknowledging the hazards now brings attention to these particular failure mechanisms. As the design continues to move forward, the team can design with these possible failures in mind. The team will work to mitigate the hazards during the design phase. The identified hazards can be found in the hazard matrices located in the appendix.

Some risks are currently unacceptably high. This is because all risk mitigation has been implemented in through concept design work and some hand calculations. No testing has been done on any of the systems to support the risk mitigation. Risk levels will only be lowered once physical testing has been performed to support the design.

Lab and Machine Shop Risk Assessment

Construction and manufacturing of parts for the rocket will be performed in both on-campus and off-campus labs. The hazards assessed in Table 21 are risks present from working with machinery, tools, and chemicals in the lab.

AGSE Launch Pad Functionality Risk Assessment

The hazards outlined in Table 22 are risks linked to the launch pad functionalities of the AGSE. Due to the high importance of a stable launch tower, the system will be rigorously tested prior to any launches.

Stability and Propulsion Risk Assessment

The hazards outlined in Table 23 are risks associated with stability and propulsion. The team has multiple members of the team with certifications supporting that they can safely handle motors and design stable rockets of the size that the team will be working with. This area is considered a low risk for the team, but it is still important to address any potential problems that the team may face throughout the project.

Recovery Risk Assessment

The hazards outlined in Table 24 are risks associated with the recovery. Since there are three recovery systems onboard, many of the failure modes and results will apply to all of the systems but will be stated only once for conciseness.

Cache Capsule Risk Assessment

The hazards outlined in Table 25 are risks that are related to the cache capsule. This includes potential risks during assembly, operation, launch, and recovery of the capsule.

Vehicle Assembly Risk Assessment

The hazards outlined in Table 26 are risks that could potentially be encountered throughout the assembly phase and during launch preparation.

Environmental Hazards to Rocket Risk Assessment

The hazards outlined in Table 27 are risks from the environment that could affect the rocket or a component of the rocket. Several of these hazards resulted in a moderate risk level and will remain that way for the remainder of the season. These hazards are the exception for needing to achieve a low risk level. This is because several of these hazards are out of the team's control, such as the weather. In the case that environmental hazards present themselves on launch day, putting the team at a moderate risk, the launch will be delayed until a low risk level can be achieved. The hazards that the team can control will be mitigated to attain a low risk level.

Hazards to Environment Risk Assessment

The hazards outlined in Table 28 are risks that construction, testing or launching of the rocket can pose to the environment.

2) NAR/TRA Procedures

NAR Safety Code

The below table describes each component of the NAR High Power Rocket Safety Code, effective August 2012, and how the team will comply with each component. This table has also been included in the team safety manual that all team members are required to review and acknowledge compliance.

NAR Code	Compliance
1. **Certification**. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.	Only Darryl, the team mentor, and certified team members are permitted to handle the rocket motors.
2. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.	The Mechanical Engineering team will be responsible for selecting the appropriate materials for construction of the rocket.
3. **Motors.** I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.	Motors will be purchased through Wildman Rocketry and will only be handled by certified members of the team who are responsible for understanding how to properly store and handle the motors. Additionally there is a portion on motor safety in the team lab manual that the entire team is responsible for understanding.
4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the	All launches will be at NAR/TRA certified events. The Range Safety Officer will have the final say over any safety issues.

launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.	
5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its batter and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.	The team will comply with this rule and any additional precautions that the Range Safety Officer makes on launch day.
6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.	The team will comply with this rule and any determination the Range Safety Officer makes on launch day.
7. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table,	The teams AGSE will function as the launch pad for the rocket. The AGSE will be rigorously tested for stability before a launch will be allowed. The length of the tower will be designed to ensure that in any allowable wind condition, the rocket will be able to attain a rail exit velocity that will ensure a stable flight. The AGSE will have a blast deflector integrated into the design. The team will be familiar with and comply with the minimum distance table at all launches.

and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.	
8. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.	The team will comply with this rule and any determination the Range Safety Officer makes on launch day.
9. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams and a maximum expected altitude of less than 610 meters (2000 feet).	All team launches will be at NAR/TRA certified events. The Range Safety Officer will have the final say over any rocketry safety issues.
10. **Launcher Location.** My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.	The team will comply with this rule and any determination the Range safety Officer makes on launch day.
11. **Recovery System.** I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-	The Recovery team will be responsible for designing and constructing a safe recovery system for the rocket. A safety checklist will be used on launch day to ensure that all critical steps in preparing

resistant or fireproof recovery system wadding in my rocket.	and packing the recovery system and all necessary components into the rocket are completed.
12. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.	The team will comply with this rule and any determination the Range Safety Officer makes on launch day.

Table 4: NAR safety code compliance.

3) Team Safety

A team safety meeting will be held prior to any construction, tests. or launches in order to ensure that every team member is fully aware of all team safety regulations as detailed in the team safety manual. Each team member is required to review and acknowledge the safety manual. As revisions are made and released, team members are responsible for remaining up to date with team safety regulations. The team safety manual covers the following topics:

- Lab Workshop Safety
- Material Safety
- Personal Protective Equipment regulations
- Launch Safety Procedures
- Educational Engagement Safety
- MSDS sheets
- Lab specific rules.

Should a violation to the contract occur, the violator will be revoked of his or her eligibility to access to the lab and attend launches until having a meeting with the safety officer. The violator must review and reconfirm compliance with the safety rules prior to regaining eligibility.

Prior to each launch, a briefing will be held to review potential hazards and accident avoidance strategies. In order to prevent an accident, a thorough safety checklist will be created and will be reviewed on launch day. Individual checklists will be created for each subsystem. The checklists include the following information:

- Required tools
- Required hardware
- Required PPE
- Explicit step-by-step instructions to be checked off after completion
- Caution statements indicating steps where specific PPE is required.

- Danger statements indicating steps there is a particular hazard to personnel involved and what should be done to mitigate that hazard.
- Warning statements indicating importance in a procedure. Describe if a certain procedure is not followed completely, then a particular event will happen, resulting in the occurrence of a particular hazard.
- Signatures required from two representatives that all steps have been completed.

Throughout preparations, it will be the responsibility of the safety officer to confirm that each of the necessary tasks for a successful launch are completed. Two team members are required to sign off, verifying that each required task has been completed in order to ensure a safe launch. Once all subsystem checklists are completed, a final checklist must be completed and final approval granted by the safety officer and captain. The safety officer has the right to call off a launch at any time if she determines anything to be unsafe or at a high risk level.

4) Local/State/Federal Law Compliance

The team has reviewed and acknowledged regulations regarding unmanned rocket launches and motor handling. Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C, Code of Federal Regulation 27 Part 55: Commerce in Explosives; and fire prevention, and NFPA 1127 "Code for High Power Rocket Motors" documentation is available to all members of the team in the team safety manual.

5) Motor Safety

Darryl, the team mentor, who has obtained his Level 3 TRA certification, will be responsible for acquiring, storing, and handling the teams rocket motors at all times. Team members that have attained a minimum their Level 2 certification, are also permitted to assist in this responsibility. By having obtained a Level 2 certification, the individual has demonstrated that he or she understands the safety guidelines regarding motors. Any certified member of the team that handles or stores the team's motors is responsible for following the appropriate measures. The motors for both test and competition launches will be transported by car to the launch site.

6) Safety Compliance Agreement

The University of Louisville River City Rocketry team understands and will abide by the following safety regulations declared by NASA. The following rules will be included in the team safety contract that all team members are required to sign in order to participate in any builds or launches with the team.

1. Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.

2. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
3. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

Section 4. Technical Design: Vehicle

1) Applicable Formulations

Three core values must be calculated to assess the stability and success of the rocket: peak altitude, center of gravity, and center of pressure. The peak altitude is found through a precise sequence of equations. The average mass is first calculated using

$$m_a = m_r + m_e - \frac{m_p}{2} \quad (1)$$

where m_r is the rocket mass, m_e is the motor mass, and m_p is the propellant mass. The aerodynamic drag coefficient (kg/m) is then computed by

$$k = \frac{1}{2}\rho C_D A \quad (2)$$

where ρ is the air density (1.22 kg/m^3), C_D is the drag coefficient, and A is the rocket cross-sectional area (m^2). Equations 1 and 2 are utilized to calculate the burnout velocity coefficient (m/s) using

$$q_1 = \sqrt{\frac{T - m_a g}{k}} \quad (3)$$

where T is the motor thrust , and g is the gravitational constant (9.81 m/s^2). Equations 1, 2, and 3 are then used to compute the burnout velocity decay coefficient (1/s) using

$$x_1 = \frac{2kq_1}{m_a} \quad (4)$$

Equations 3 and 4 are used to calculate the burnout velocity (m/s) using

$$v_1 = q_1 \frac{1 - e^{-x_1 t}}{1 + e^{-x_1 t}} \quad (5)$$

where *t* is motor burnout time (s). The altitude at burnout can then be computed by

$$y_1 = \frac{-m_a}{2k} \ln\left(\frac{T - m_a g - k v_1^2}{T - m_a g}\right) \quad (6)$$

Once the burnout altitude is calculated, the coasting distance must be determined beginning with the calculation of the coasting mass using

$$m_c = m_r + m_e - m_p \quad (7)$$

The coasting mass replaces the average mass in equations 3 and 4; this results in equations 8 and 9 for the coasting velocity coefficient and coasting velocity decay coefficient, respectively:

$$q_c = \sqrt{\frac{T - m_c g}{k}} \tag{8}$$

$$x_c = \frac{2kq_c}{m_c} \tag{9}$$

Equations 8 and 9 can then be utilized to determine the coasting velocity (m/s) using

$$v_c = q_c \frac{1 - e^{-x_c t}}{1 + e^{-x_c t}} \tag{10}$$

The coasting distance can then be computed using

$$y_c = \frac{m_c}{2k} \ln\left(\frac{m_c g + kv^2}{T - m_c g}\right) \tag{11}$$

The peak altitude is then determined using

$$PA = y_1 + y_c \tag{12}$$

The center of gravity location is calculated using

$$cg = \frac{d_n w_n + d_r w_r + d_b w_b + d_e w_e + d_f w_f}{W} \tag{13}$$

where *W* is the total weight, *d* is the distance between the denoted rocket section center of gravity (nose, rocket, body, engine, and fins, respectively) and the aft end. The center of pressure measured from the nose tip is calculated using

$$X = \frac{(C_N)_N X_N + (C_N)_F X_F}{(C_N)_N + (C_N)_F} \tag{14}$$

where C_{NN} is the nose cone center of pressure coefficient (2 for conical nose cones), X_N is the computed by

$$X_N = \frac{2}{3} L_N \tag{15}$$

where L_N is the nose cone length. C_{NF} in equation 14 is the fin center of pressure coefficient calculated using

$$(C_N)_F = \left[1 + \frac{R}{S+R}\right]\left[\frac{4N\left(\frac{S}{d}\right)^2}{1 + \sqrt{1 + \left(\frac{2L_f}{C_R + C_T}\right)^2}}\right] \tag{16}$$

where *R* is the radius of the body at the aft end , *S* is the fin semispan , *N* is the number of fins, L_F is the length of the fin mid-chord line, C_R is the fin root chord length, and C_T is the fin tip chord length . X_F in equation 14 is calculated using

$$X_F = X_B + \frac{X_R(C_R+2C_T)}{3(C_R+C_T)} + \frac{1}{6}\left[(C_R + C_T) - \frac{(C_R C_T)}{(C_R+C_T)}\right] \qquad (17)$$

where X_B is the distance from the nose tip to the fin root chord leading edge. X_R is the distance between the fin root leading edge and the fin tip leading edge measured parallel to body. Equations 14 through 17 are also known as the Barrowman Equations (The Theoretical Prediction of the Center of Pressure, 1966). Note that Equation 14 is a simplified form because the rocket has no transition in diameter in the body; thus, the transitional terms have been omitted.

2) Stability and Construction

The launch vehicle and its internal structure will be constructed primarily of carbon fiber, fiberglass, plywood, ABS plastic, and aluminum. The vehicle is designed to house a cache capsule payload within its airframe. To ensure an efficient design, the launch vehicle is designed to host the cache capsule system as high up in the rocket as is reasonably possible.

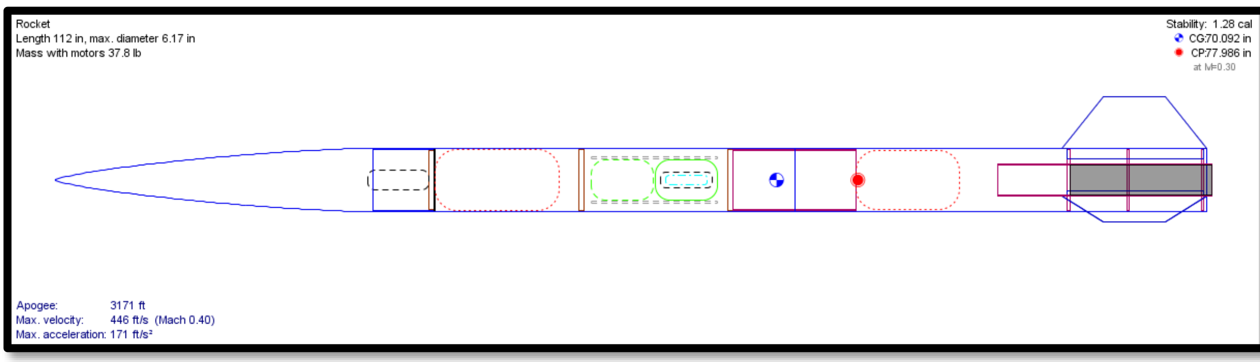


Figure 5: Preliminary OpenRocket simulation of 2014-2015 launch vehicle.

Figure 5 shows the preliminary layout of the launch vehicle. The vehicle is designed such that the cache capsule system will be located directly beneath the main recovery system. This allows the one of the heaviest systems in the vehicle to sit high up in the rocket, thus raising the center of gravity and in return, the stability. The figure also shows the joint between the propulsion bay and the section of airframe containing the cache. The secondary recovery system sits within this section of the rocket.

For stability, the rocket will host 3 trapezoidal fins, as seen in Figure 6. The fins have top and root chord lengths of 5 inches and 14 inches respectively. The decision for this was based on the design of the Autonomous Ground Support Equipment (AGSE).

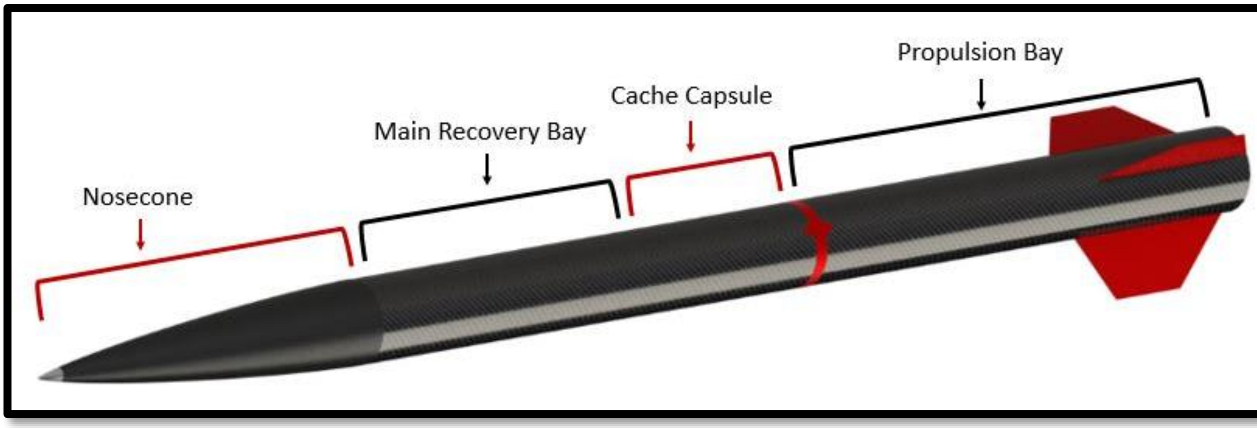
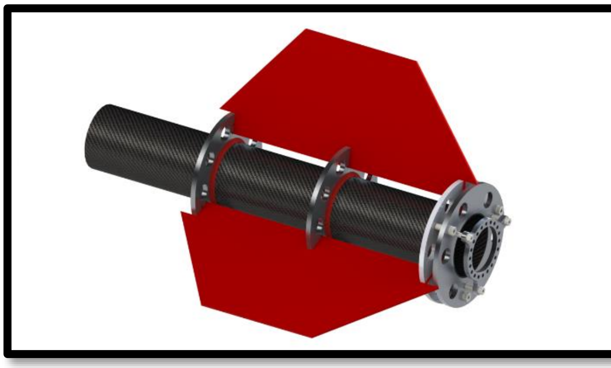


Figure 6: Full scale launch vehicle showing the 3 fin setup.

Furthermore, the launch vehicle will host a removable fin system. The team has incorporated a system like this in the past and it was proven reliable. By building upon the pros and cons of the old system, the team will have a reliable way of incorporating a precise removable fin system. By incorporating this system the launch vehicle can be transported easily, and in the event of a fin breaking, the team would simply be able to replace the fin on the fly. This would completely eliminate the risk of having a rocket incapable of flying in the unlikely event of a fin breaking.



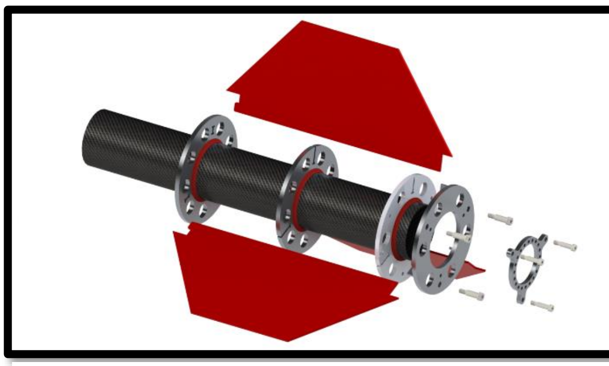


Figure 7: Exploded representation of removable fin system.

The vehicle is composed of four primary sections: nosecone, main recovery bay, cache containment bay, and the propulsion bay. Table 5 lays out the general dimensions of the launch vehicle.

Section of Launch Vehicle	Material	Diameter	Length
5:1 Von Karman Nosecone	Fiberglass	6"	30"
Main Recovery Bay	Carbon Fiber	6"	21"
Cache Containment Bay	Carbon Fiber	6"	21"
Propulsion Bay	Carbon Fiber	6"	40"
		Total Launch Vehicle Length	112"

Table 5: Dimensions of primary launch vehicle sections.

The bay lengths were chosen in the most realistic manor and will likely change based upon the needs of the systems as the project progresses. Carbon fiber was chosen as the choice material for most of the vehicle's section due to its weight saving attributes. The Von Karman Nosecone, seen in Figure 8, was chosen due to its performance at subsonic speeds.

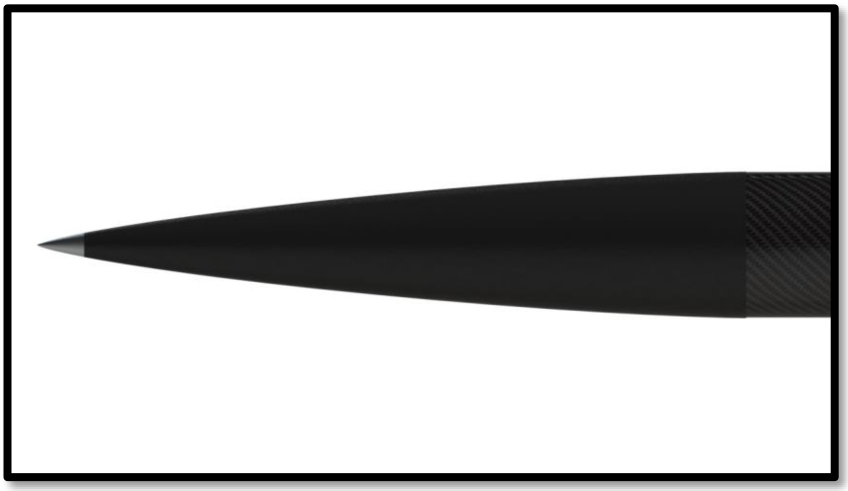


Figure 8: Von Karman nosecone.

The overall internal dimensions of the Von Karman nosecone also allows for the containment of an avionics bay, thus allowing an efficient use of space.

The launch vehicle will be constructed by adhering to proven manufacturing processes. All sections of the vehicle that are to separate at an event will be joined to their respective coupler with 4-40 nylon shear pins. Those section that are to stay intact throughout the course of the entire flight and descent will be joined with the appropriate metal fasteners. All bulk plates, centering rings, and permanently secured sections of the rocket will be epoxied using Glenmarc's G5000 two component filled epoxy. This epoxy was chosen for its superior strength, as seen in Table 6.

Glenmarc's G500 Epoxy	
Tensile Strength	7,600 psi
Compression Strength	14,800 psi
Shore "D" Hardness	85
Elongation at break %	6.30%

Table 6: G500 epoxy data.

3) Propulsion

Utilizing the open source software, OpenRocket, the team was able to simulate a number of motor configurations. The motor configuration chosen for the current configuration is a Cesaroni Technology Inc. reloadable two grain L910 C-Star. The team will use the available Cesaroni two grain 75mm aluminum reloading case in conjunction with this motor. This motor configuration, as shown in Table 5 has a total impulse of 2,856.1 Ns and a maximum and average thrust of 1,086.1 N and 907.1 N, respectively.

Manufacturer	Cesaroni Technology
Classification	L910
Diameter	75 mm
Length	35 cm
Total Weight	2,616 g
Propellant	1,270 g
Average Thrust	907.1 N
Maximum Thrust	1086.1 N
Total Impulse	2856.1 Ns
Burn Time	3.2 s
Isp	229 s

Table 7: Data related to motor selection.

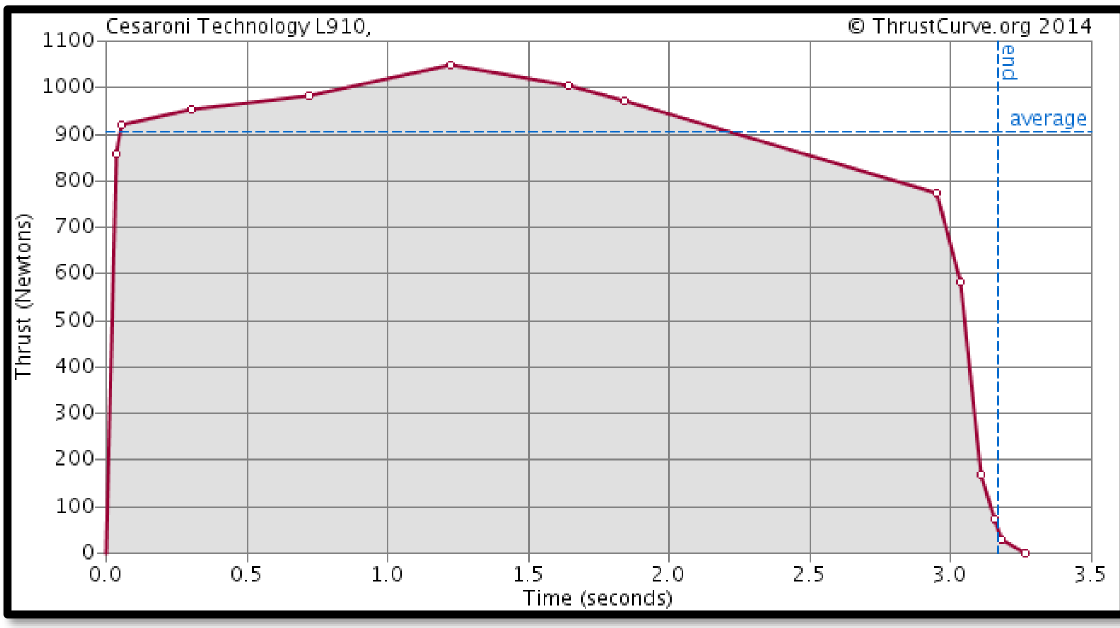


Figure 9: Thrust curve of L910 motor.

4) Cache Capsule

The cache capsule must fulfill the following requirements in order for the mission to be considered a success.

1. Provide a location for the cache to be placed by the arm.
2. Secure the cache inside the capsule during flight.
3. Be ejected from the rocket at a designated altitude.

Design

The cache capsule consists of two primary enclosures which are shown in Figure 10. The upper enclosure is the electrical bay. The electrical bay contains all of the electronics, batteries, and servos required for the cache capsule to perform all required operations. The cache capsule is designed to be a completely independent system that can function without any dependence on the rocket. The lower section is designated for the retention and storage of the cache during flight.

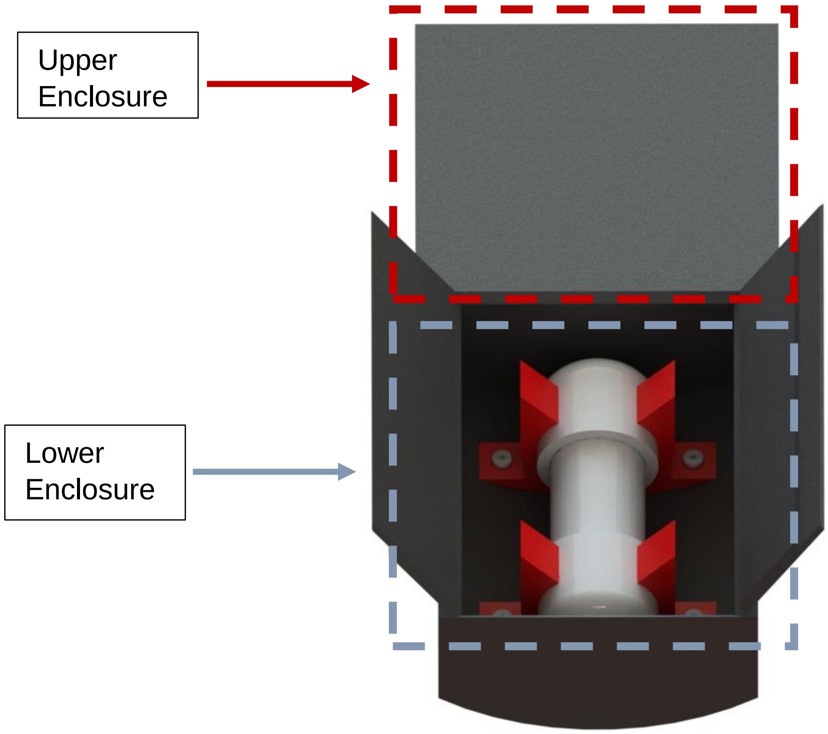


Figure 10: Cache capsule.

The lower section contains two retaining clips, shown in

Figure 11. The clips are sized to fit around the PVC caps of the cache. This allows for the gripper on the robotic arm to have room to grip the cache until it is fully inserted into the clips.

Figure 11: Retaining clip.

The two angled faces serve as a guide for the robotic arm if the alignment is not precisely in the middle of the clip. The angles guide the cache to the centered location. When a force is applied by the robotic arm, the retaining clip will flex, allowing the cache to slide into place. Once the cache has been pushed into place, the clips will snap back to their original position, forming a compression fit. This compression fit will secure the cache during the remainder of the ground operations and throughout launch and recovery.

A benefit to the retaining clips is that the system can function no matter what orientation the rocket is at. This will protect the cache from moving around during flight. This also gives the team the flexibility to rotate the system and install the cache from any angle.

At the beginning of the launch sequence, the doors to the lower section of the capsule will be open. Contact switches are to be placed in the clips to communicate to the system when the cache has been secured. Once both switches have been activated, servos will be actuated on a time delay, giving the arm time to move out of the way before the doors close. This process is detailed in Figure 12.

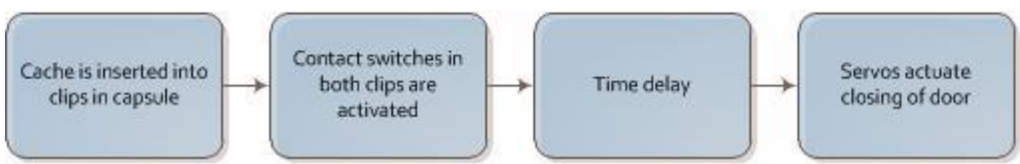


Figure 12: Cache capsule process.

Once the doors are closed, they will be locked into place. The doors will have to be manually opened in order to retrieve the cache. The closed doors sit directly on top of the retaining clips, serving as a secondary retention system for the cache. If the retaining clips should fail, the capsule doors will prevent the cache from falling out.

Challenges

The primary challenges are shown in Table 8.

Challenge	Solution
Secure cache in place.	Clips allow for easy insertion and retention of cache. Analysis will be performed to optimize the dimensions of clips to apply a sufficient force to retain the cache while minimizing the force applied by arm to insert cache.
Close doors of capsule autonomously after the arm is out of the way.	Servos to close doors are activated by a switch on a time delay. Testing will be performed to ensure the necessary timing of events.

Table 8: Cache capsule challenges.

5) Retractable Door for Payload Insertion

Overview

To keep the ground station and launch vehicle systematically autonomous, a retractable door will be incorporated into the launch vehicle. The door, when activated via on-board electronics, will be opened by a servo motor. With the door opened, the payload can be inserted into the cache containment. Once the payload is in place, the door will be told to close, at which point the servo motor will actuate the door closed.

Design

There are two primary criteria that were taken into account when designing the door assembly.

1. The door has to be big enough to allow both the arm and the payload to fit through it when open.
2. The door, when closed, has to have a proper seal around its edges so as to ensure air will not enter the airframe and cause flight instability.

Once the design of the arm device was finalized, the overall dimensions necessary for the launch vehicle's door could be justified. Knowing this information, the door is designed to be 7 inches in length, with an arc length of 4.5 inches. Having worked with wound fiber filaments in the past, the cutout in the airframe necessary for proper fitment of the door was deemed acceptable for structural stability.

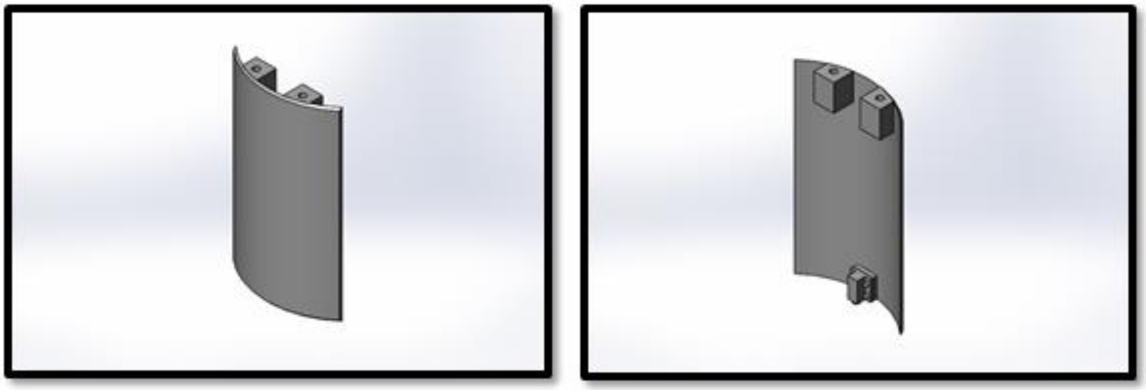


Figure 13: Front and rear view of the preliminary door design.

The door is designed to be 3D printed out of ABS plastic. By increasing the density of the 3D print job, the door will be sufficiently strong enough to withstand the launch and recovery of the vehicle. A silicone gasket will be custom cut on a Universal laser cutter to mate with the door and airframe of the rocket. This will ensure an airtight fitment between both components.

The door is designed so that its rotational path is constrained by an aluminum guide. Shoulder pins will be installed into the standoffs attached to the inside of the door. These pins will run along the track of the guides, thus allowing smooth movement within the airframe of the launch vehicle, as seen in Figure 14 below.

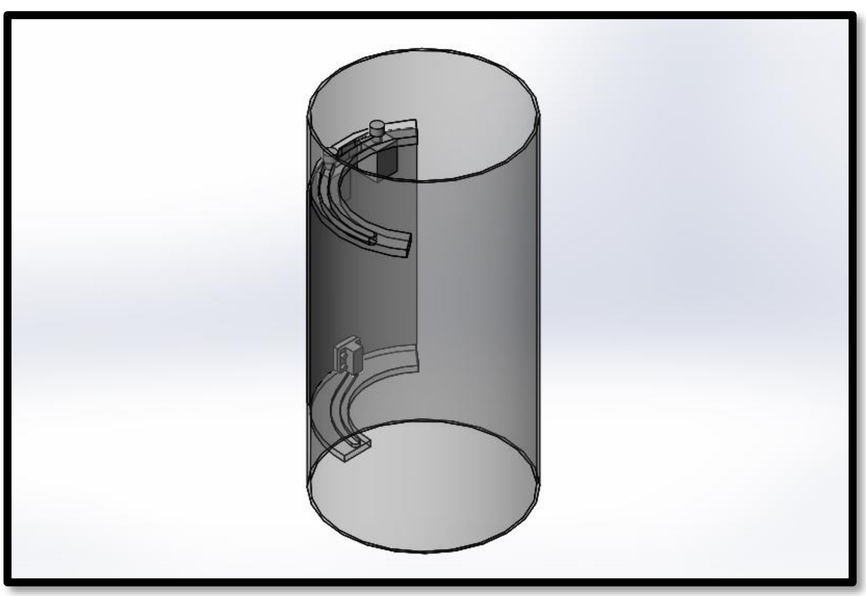


Figure 14. Transparent view of a section of airframe showing the integration of the door into the guides.

Challenges

To make sure the door system integrates with the rocket and functions as intended certain solutions were sought for various design challenges, as seen in Table 9.

Challenges	Solutions
Design the door such that the cache payload and arm device will fit during payload insertion.	Proper dimensional analysis will be conducted to ensure there are no clearance issues throughout the design and revision of any payload containment and insertion systems.
The door will be autonomously opened and closed.	On-board computer electronics will work hand in hand with ASGE systems to synchronize payload insertion and door actuation movements.
The door shall remain airtight when closed.	A custom silicone gasket will be designed and integrated into the door system to create an airtight seal around the edges of the door.
The door shall not be allowed to open during flight.	Using the proper servo motor, the door system can be "locked" shut to be certain the door will not back itself through the guides during flight.

Table 9. Solutions to various door design challenges.

6) Statement of Work Verifications

Designing an efficient high powered launch vehicle has its own inherent challenges. To ensure safety and vehicle performance the team will focus on tackling various design challenges with various solutions. Furthermore, the team must make sure their overall design stays within the constraints laid out by the Statement of Work. Table 10, below details the various challenges and their related solutions.

Challenges	Solutions
The vehicle shall deliver the payload to, but not exceeding, an apogee altitude of 3,000 feet above ground level (AGL).	Efficiently document and record all material and component weights throughout the design and manufacturing of the launch vehicle. Maintain accurate OpenRocket simulations and hand calculations to ensure correct motor selections.

The vehicle shall carry one commercially available, barometric altimeter for recording the official altitude used in the competition scoring.	Each section of the launch vehicle that falls under its own parachute, including the cache containment section, will have its own barometric altimeter. For complete redundancy, each section will have a secondary backup altimeter as well.
The launch vehicle shall be designed to be recoverable and reusable.	Each parachute will be designed to ensure sections of the launch vehicle land with a kinetic energy below the maximum kinetic energy laid out in the Statement of Work. Landing within these constraints will leave our launch vehicle in a reusable state.
The launch vehicle shall have a maximum of four (4) independent sections.	Our launch vehicle will be comprised of 4 independent sections: the nosecone, the main recovery bay, the payload containment bay, and the propulsion bay. Each section will either fall under their own parachute or will be tethered to another section's recovery.
The launch vehicle shall be limited to a single stage.	Having a limited altitude of 3,000' eliminates any need for staging of our launch vehicle. Motor selections have been made to accomplish all necessary altitude requirements on a single stage launch vehicle.
The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.	A comprehensive launch procedure checklist will be constructed by the team to allow for accurate and expedited vehicle assembly while preparing for flight.
The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board component.	The power supplies for all AGSE components, altimeters, and flight event devices have been chosen to eliminate the chances of power failure for an extended period of time.
The launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system.	The launch vehicle will utilize the provided and proven launch igniters provided with the Cesaroni motors. The igniters are designed to ignite the vehicle's motor by use of a standard 12 volt direct current firing system.

The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	The team will be using a Cesaroni L910 two grain C-Star motor for its full scale launch vehicle. The team has never had a motor failure in the past while using Cesaroni motors.
The total impulse provided by a launch vehicle shall not exceed 5,120 Newton-seconds (L-class).	The total impulse of the Cesaroni L910 two grain C-Star motor is 2,856.1 Newton-seconds.
Any team participating in Maxi-MAV will be required to provide an inert or replicated version of their motor matching in both size and weight to their launch day motor. This motor will be used during the LRR to ensure the igniter installer will work with the competition motor on launch day.	The team will be 3D printing an exact replica of the motor used in the full scale flight for the LRR. It will be custom weighted to ensure the inert replica matches the launch day motor in both size and weight.
Pressure vessels on the vehicle shall be approved by the RSO and shall meet the criteria laid out in the Statement of Work.	The current design of the launch vehicle and AGSE does not require the use of any pressure vessels. If the design changes to include such a system, NASA and the RSO will be notified, and the criteria mentioned in the Statement of Work will be met.
All teams shall successfully launch and recover a subscale model of their full-scale rocket prior to CDR. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale shall not be used as the subscale model.	The team will design a 1:2 scaled model of the full scale launch vehicle. The subscale launch vehicle will be used to test stability and integration of various systems seen in the full scale launch vehicle.

Table 10: Solutions to various challenges set out by the statement of work.

Section 5. Technical Design: Recovery

The recovery system must fulfill the following requirements in order for the mission to be considered a success.

1. The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude.
2. All independent sections must have a maximum kinetic energy of 75 ft-lb_f at landing.
3. The recovery system electrical circuits shall be completely independent of any payload electrical circuits.
4. The recovery system shall contain redundant, commercially available altimeters, each with an independent arming switch that is accessible from the exterior of the rocket airframe.
5. Each altimeter shall have a dedicated power supply.
6. Each arming switch shall be capable of being locked in the ON position for launch.
7. Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.
8. An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.
9. The recovery systems electronics shall not be adversely affected by any other on-board electronic devices during flight.

The details on how these requirements are to be met are discussed in the following section.

Design

In order to eject the cache capsule, the rocket will be recovered in three independent sections. The sequence of recovery events is described in Table 11.

Event	Altitude (ft.)	Description
1	3,000	Apogee. Nose cone ejection. Entire rocket under main parachute acting as drogue.
2	1,250	Eject lower airframe. Both upper and lower airframes now falling under main.
3	1,000	Lower sustainer ejection. Lower sustainer under parachute. Fairing payload and nose cone under pilot parachute.

Table 11: Recovery events and descriptions.

The main parachute for the upper airframe will be sized appropriately in order to ensure that the upper airframe and nosecone land with a minimum kinetic energy of 75 ft-lb_f. Prior to the lower airframe and cache capsule detaching, the main parachute will function more like a drogue parachute due to the additional weight. The main will provide stability while still allowing the section to fall rapidly until the lower two sections separate, eliminating significant drift.

The lower airframe will be secured to the upper airframe using shear pins. Calculations will be made to ensure that the shock of the opening of the main parachute will not prematurely shear the pins. At 1,250 ft, a second charge will be blown, separating the lower airframe from the upper airframe. The lower airframe will fall under its own independent recovery system.

With the detachment of the lower airframe, the section of the upper airframe that houses the cache capsule will be exposed. The cache capsule will be mounted to a bulkplate using a non-explosive actuator release such as the one pictured in Figure 15.

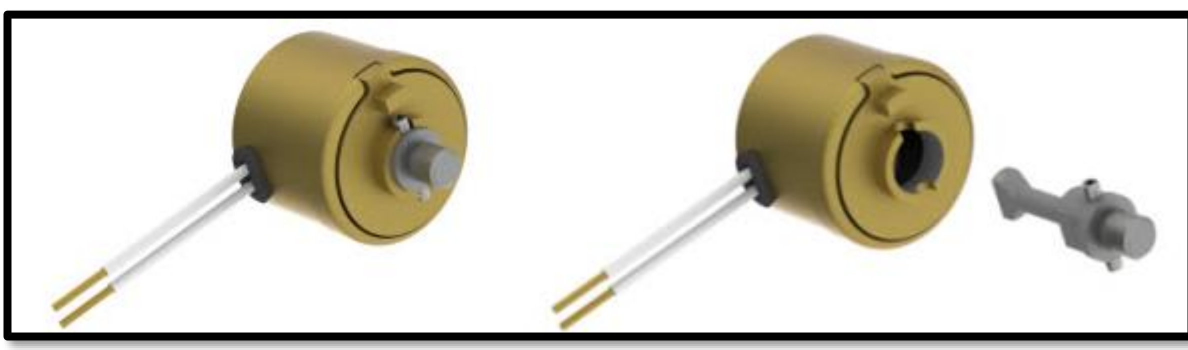


Figure 15: Non-explosive actuator release.

The actuator will release at 1,000 ft, deploying the cache capsule which is recovered under a small parachute. The actuator operates without generating any external fragmentation or debris, making this a safe system to operate near the parachute for the cache capsule.

For the first two recovery events, there will be a designated avionics bay that will be completely independent of all other systems. Due to the past success with PerfectFlite Stratologger, pictured in Figure 16, two units will be placed in each avionics bay. These will be used to trigger black powder ejection charges.

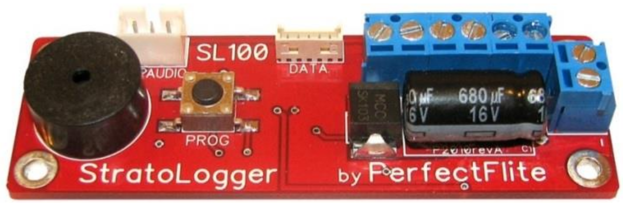


Figure 16: PerfectFlite Stratologger.

The PerfectFlite Stratologger altimeter records its altitude at a rate of 20Hz with a 0.1% accuracy. In previous testing, the altimeter was found to be accurate to ±1 foot. The StratoLogger can be configured to provide a constant serial (UART) stream (9600 baud rate ASCII characters) of the device's current altitude over ground. Each StratoLogger will be powered by an individual Duracell 9V battery. Duracell batteries have been selected due to their reliability and the feature that their leads are internally soldered.

Each altimeter will be locked into the on position through use of a Featherweight screw switch, shown in Figure 17. The switches allow for easy arming of altimeters while the rocket is upright in the AGSE. Access holes will be drilled and marked to allow for arming.

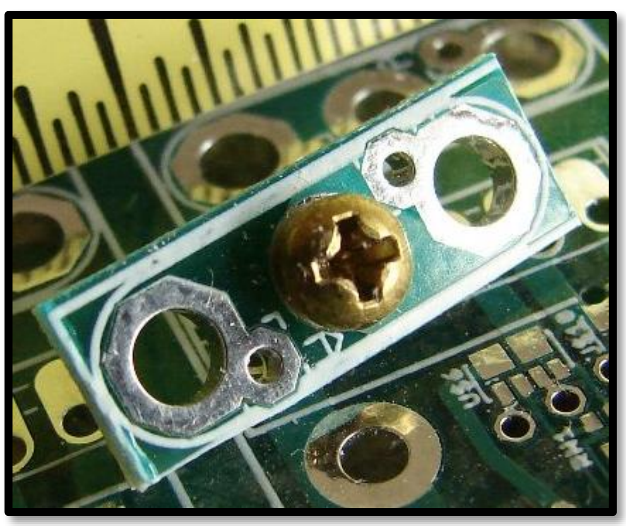


Figure 17: Featherweight screw switch.

To satisfy the GPS requirement, both of the avionics bays will use a Garmin Astro DC 40. There will be a wooden bulkplate dividing the GPS units and altimeters in the avionics bay. The bulkplate will be covered in aluminum tape in order to shield the altimeters from the GPS unit.

Since the cache capsule is a self-contained unit, all required avionics will be located in the electronics enclosure. Due to the size constraints, the avionics setup will be different. The capsule will have redundant altimeters located in the electrical bay to initiate the capsules ejection from the upper airframe. One altimeter will be a TeleMetrum v2.0, pictured in Figure 18. The TeleMetrum is a recording dual-deploy altimeter with an integrated GPS and telemetry link. The GPS feature on the TeleMetrum satisfies the requirement for the payload container to contain a GPS locator.

Figure 18: TeleMetrum v2.0 altimeter.

Since it is unnecessary to have a redundant GPS locator, the secondary altimeter will be a Stratologger. This selection was made because the Stratologger provides the same dual-deploy altimeter functionalities as a TeleMetrum for half the cost.

Challenges

The primary recovery challenges are shown in Table 8.

Challenge	Solution
Avoiding parachute tangling during ejection.	All parachutes will be stored in a deployment bag which will be custom made and tailored to each individual parachute.
Custom made parachute with unknown drag coefficient.	A parachute will be tested to determine the drag coefficient which will be used in sizing and construction of the remaining parachutes.
Eject cache capsule without damaging the parachute for the capsule.	A non-explosive actuator release will be used to release the cache capsule from the upper airframe. The system does not produce any fragmentation or debris making it safe to operate near a parachute.

Table 12: Recovery challenges.

Section 6. Technical Design: AGSE

1) Autonomous Ground Support Equipment

Overview

To be considered a success, the AGSE must meet the following requirements:

1. Teams will position their launch vehicle horizontally on the AGSE.
2. A master switch will be activated to power on all autonomous procedures and subroutines.
3. After the master switch is turned on, a pause switch will be activated, temporarily halting all AGSE procedure and subroutines. This will allow the other teams at the pads to set up, and do the same.
4. Once the launch services official has inspected the launch vehicle and declares that the system is eligible for launch, he/she will activate a master arming switch to enable ignition procedures.
5. The Launch Control Officer (LCO) will activate a hard switch, and then provide a 5-second countdown.
6. At the end of the countdown, the LCO will push the final launch button to initiate launch.
7. All AGSE systems shall be fully autonomous.
8. The system must suffer no setbacks when the pause button is initiated.
9. The system must complete all tasks within 10 minutes.
10. The capture and containment system must be able to retrieve the payload from outside of the vehicle MOLD line and from the ground.
11. No forbidden technologies will be utilized. The forbidden technologies are as follows
    a. Sensors that rely on Earth's magnetic field
    b. Ultrasonic or other sound-based sensors
    c. Earth-based or Earth-orbit-based radio aids (e.g. EGPS, VOR, cell phone, etc…)
    d. Open Circuit pneumatics
    e. Air breathing systems

In addition to the above requirements, the following controls parameters must be met to be considered a success.

1. A master switch to power all parts of the AGSE, the switch must be easily accessible and hardwired into the AGSE
2. A pause switch to temporarily terminate all actions performed by the AGSE. The switch must be easily accessible and hardwired into the AGSE

3. A safety light that indicates that the AGSE is powered on. The light must be amber/orange in color. It will flash at a frequency of 1 Hz when the AGSE is powered on, and will be solid in color when the AGSE is paused while power is still supplied.
4. An all systems go light to verify all systems have passed safety verifications and the rocket system is ready to launch.

To accomplish the above requirements, the AGSE has been broken up into sub-stations shown in Table 13.

Sub-Station	Responsibility
Payload Capture and Containment	Locate, capture, and place the payload inside the launch vehicle. The containment responsibility has been placed with the launch vehicle.
Ground Station	House all control electronics in addition to all prerequisite switches and indicator lights.
Launch Platform	Support and guide vehicle during launch procedures and launch.
Vehicle Erector	Raise vehicle from horizontal position to 5 degrees of vertical.
Igniter Installer	Install electronic match after vehicle has been safely erected.

Table 13: AGSE sub-stations.

Figure 19: AGSE

System Timeline

Per the Statement of Work (SOW) the ground station has 10 minutes to complete its tasks. Shown in Figure 20 is the proposed timeline for the events during competition.

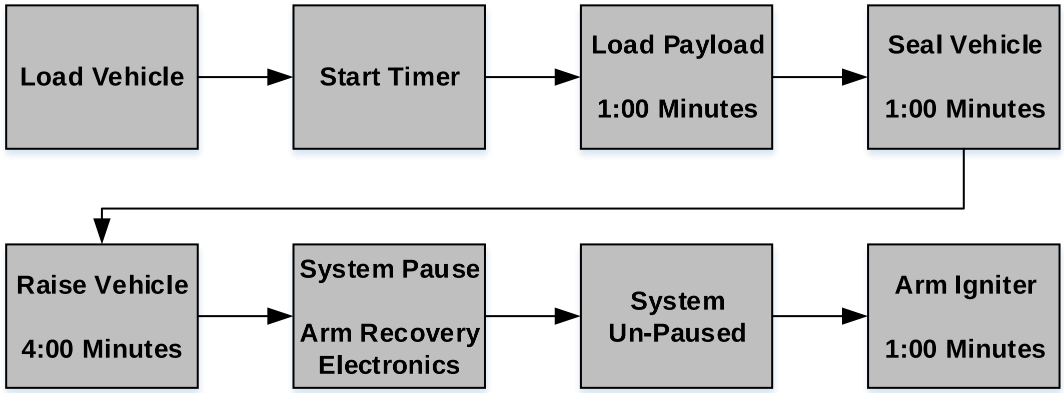


Figure 20: AGSE Timeline.

We have budgeted a total of 7 minutes for all systems, this was done in the event that the team needed to be able to perform a reset that there would be enough left over time.

2) Payload Capture and Containment

Payload Arm

To raise the payload from the ground and place it inside the rocket, an arm mechanism was devised that will only move in two dimensions, up or down and left or right. A slider will be the only part moving besides the payload gripper. The parts for the payload arm are mostly made with off-the-shelve 6061 aluminum components. A full isometric view of the arm can be seen in Figure 21 with the slider in its vertical and horizontal positions.

Figure 21: Payload arm with slider in vertical position (left), and slider in horizontal position (right).

Payload Arm Location

The payload arm will screw into the horizontal 80/20 rail on the right side of the launch platform. The arm will face inwards such that the payload will be placed underneath the launch platform. The reason for doing so is that it removes the need to rotate the arm 180 degrees to face the rocket. The height from the ground to the payload containment section in the rocket will be 4 feet and the horizontal distance from the launch pad side rail to the rocket will be 12 inches. A front view of the Payload Arm mounted on the Launch Platform and an isometric view are shown in Figure 22 and Figure 23 respectively.

Figure 22: Front view of launch platform with payload arm completely extended vertically.

Figure 23: Isometric view of launch platform with payload arm.

The payload arm will have a 1/8inch thick base plate that will have two 6061 aluminum towers attached to it via L-brackets on each side. The towers and the L-brackets will be bought off-the-shelve. The towers are U-channels with attachments holes along it that will allow the team to easily attach other components onto it. The towers are currently planned to be 15 inches tall but can be bought at longer or shorter lengths if necessary. The L-brackets and towers will connect with 6-32 screws and nuts. Almost all of the components on the payload arm will use 6-32 screws but they're not shown in any of the models. The base plate will have two brackets underneath it that will be used to attach it onto the 80/20 rail with screws. Figure 24 shows the attachment point of the payload arm structure to the side of the 80/20 rail on the launch platform.

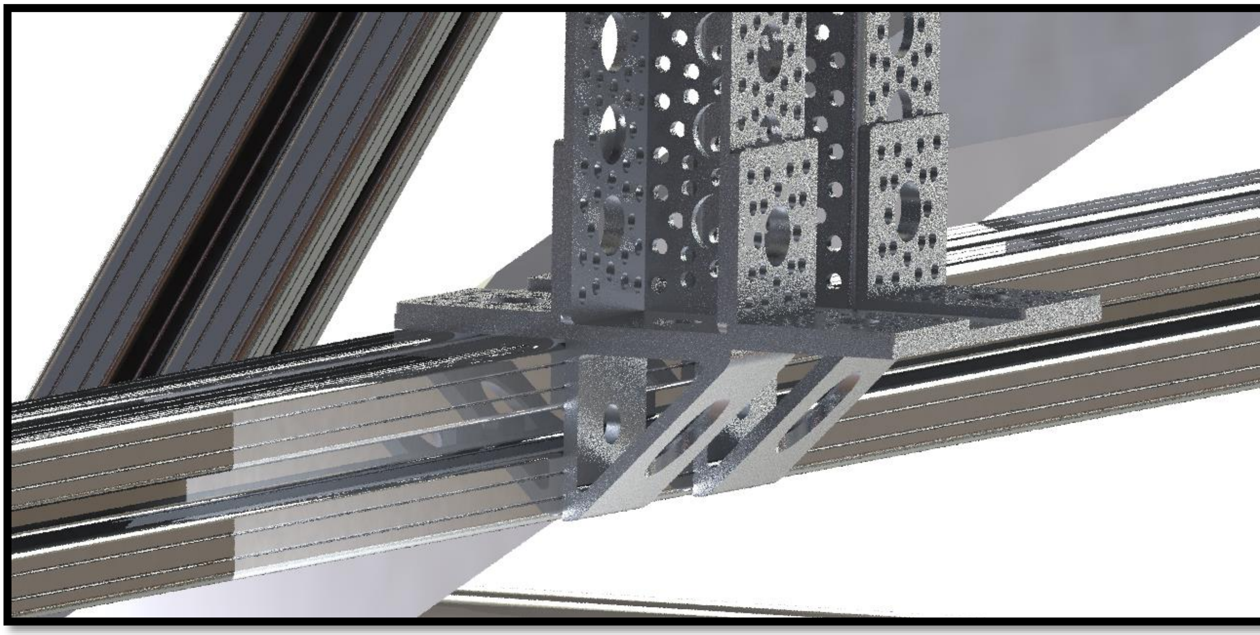


Figure 24: Payload arm attachment to 80/20 rail.

Payload Gripper

The payload arm will start fully extended in the vertical direction with the payload gripper hovering above the payload and the arms open as shown in Figure 25. Once the system has been activated, a servo with a gear attached to it will move a gear rack upwards. The rack will interface with another gear that is attached to the gripper arms. By moving the gear rack upwards, the arms will close around the payload and hold it in place. The arms will be made out of 3D printed ABS plastic. If the arms do not provide enough force to hold the payload, a different servo will be chosen and/or a rubber strip will be attached to the ends to provide more friction.

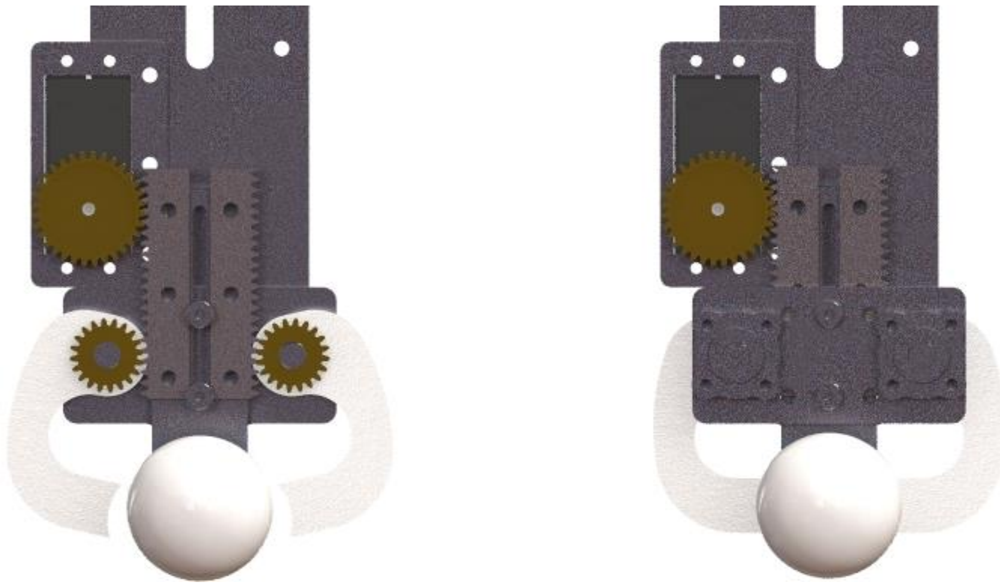


Figure 25: Payload gripper open with gears shown (left), payload gripper closed (right).

To insure that the rack only slides in one dimension, two shoulder screws will be used to align the racks via a slot that attaches to the plate that connects both of them. Besides connecting both racks, the plate will be used to push the payload onto the clips that secure it inside the rocket since it moves forwards whenever the gripper arms open up and backwards as they close. A touch sensor will probably be put on the end of the plate to let the system know if it is contact with the payload. The end of the plate will be shaped to have to same radius of the payload's midsection and will probably be machined out of 6060 aluminum. Figure 26 shows a better view of this plate's shape.

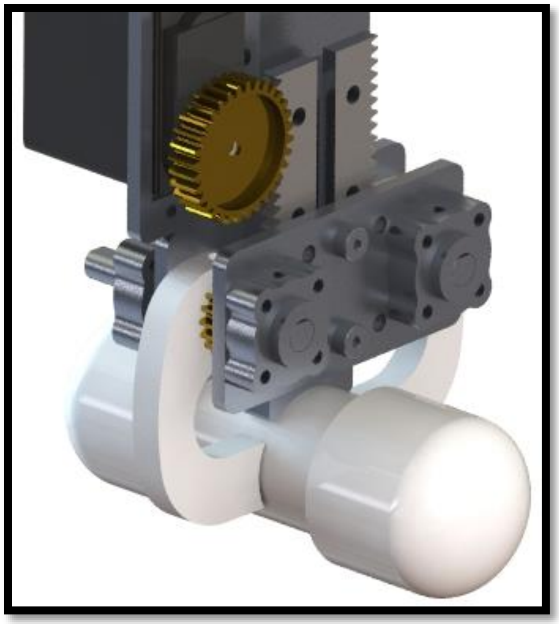


Figure 26: Gripper isometric view with arms closed.

A D-shaft will be used on each side to attach the gears and gripper arms using a set screw. The gripper arms will slide over the base of their corresponding gears and will be held in place using the same set screw. To constrain the D-shafts, a set-screw hub will be used on each end. Each of the gears used are off-the-shelve brass gears with a pitch of 32 and a pressure angle of 20 degrees. The rack is made out of Delrin plastic and will be cut to length.

Payload Slider

To raise the payload, a 48 inch 6061 aluminum plate will be used. This plate will have a 36 inch slot in the middle so that it is constrained while moving up. Four gear racks similar to those used in the gripper will be lined up along the length of the slot. The racks will interface with a gear near the top of the arm where horizontal plates will be located that attach to two towers. The horizontal plates will be made out of aluminum as well and will be custom machined. L-brackets will be used to attach the plates to the towers. Figure 27 illustrates the interface just described.

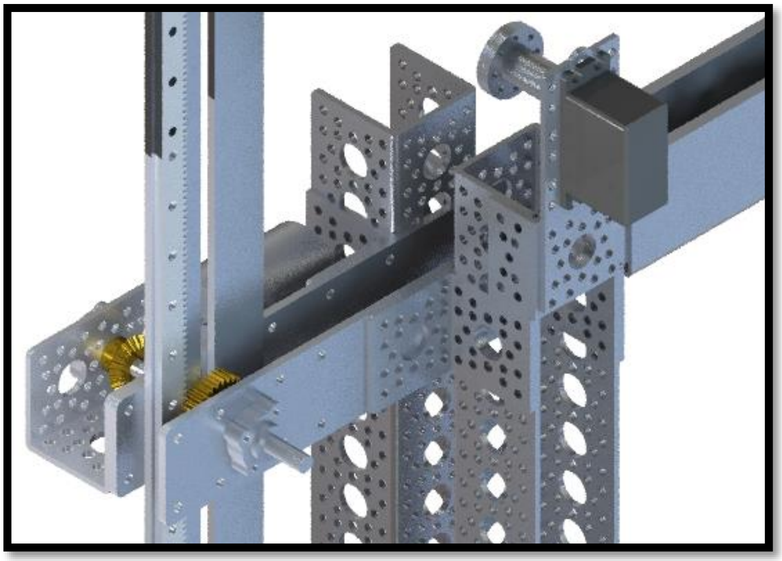


Figure 27: Slider interface with horizontal plates.

A 10 RPM motor with a torque of 368 oz-in will be used to drive two bevel gears that will in turn drive the gear attached to the racks on the payload slider. The reason for using bevel gears is that the motor will be placed parallel to the horizontal plates to save space. A U-channel will attach to one of the horizontal plates and the motor and bevel gears will be mounted in this channel. A 0.25 inch D-shaft will attach the bevel gear and gear that are moving the slider. The shaft will be constrained using the same set screw hubs used for the payload gripper. The bevel gears are made out of brass and have a 45 degree angle, a pitch of 32, and 24 teeth. Figure 28 shows the location of the bevel gears and their mounting location.

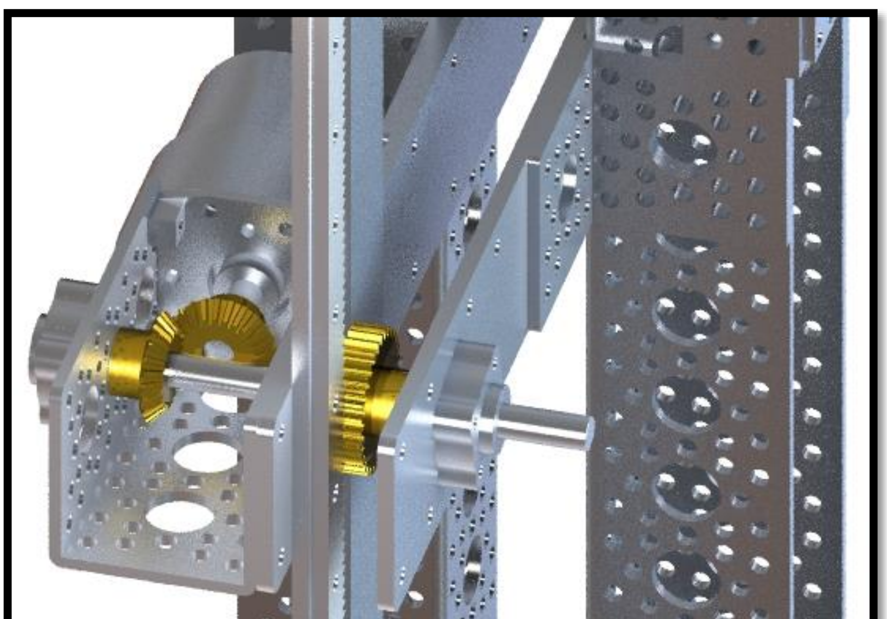
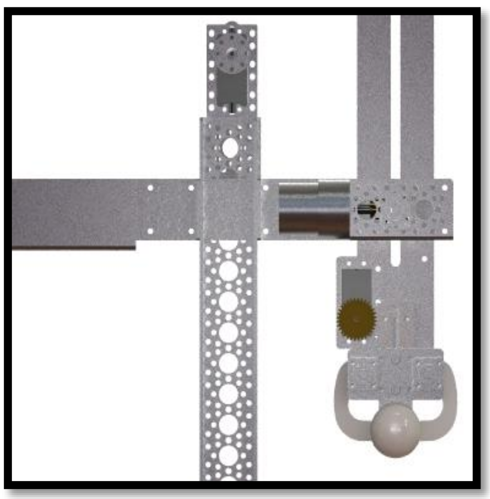


Figure 28: Isometric view of mounted bevel gears.

Once the payload gripper is near the horizontal plates, the slider will transition from being vertical to horizontal. This process will occur using a continuous rotation servo with a spool attached to it. A cable will be wound around the spool and the other end of the cable will be attached to the top of the slider. The servo will be constantly spinning to release cable while the slider is moving upwards. Once the system detects the gripper is near the top, the servo will start spinning the opposite direction and the cable will begin to wind around the spool. This action will cause the slider to pivot around the gear that was moving it up. The horizontal plates attached to the tower will have a custom sheet metal U-shaped bracket connecting them at the back that will act as a support for the slider while it's horizontal and to prevent the slider from continuing to fall over. Figure 29 and Figure 30 show the slider in its horizontal position after falling over. The servo will be place on the top of the right tower for now. Further work will be done to optimize its location or even find a better method to transition the slider's orientation.



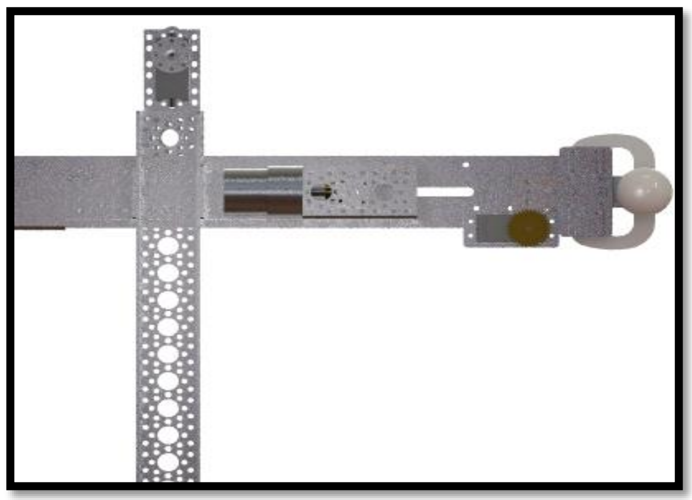


Figure 29: Slider in vertical position (left), slider in horizontal position (right) with gripper retracted near towers.

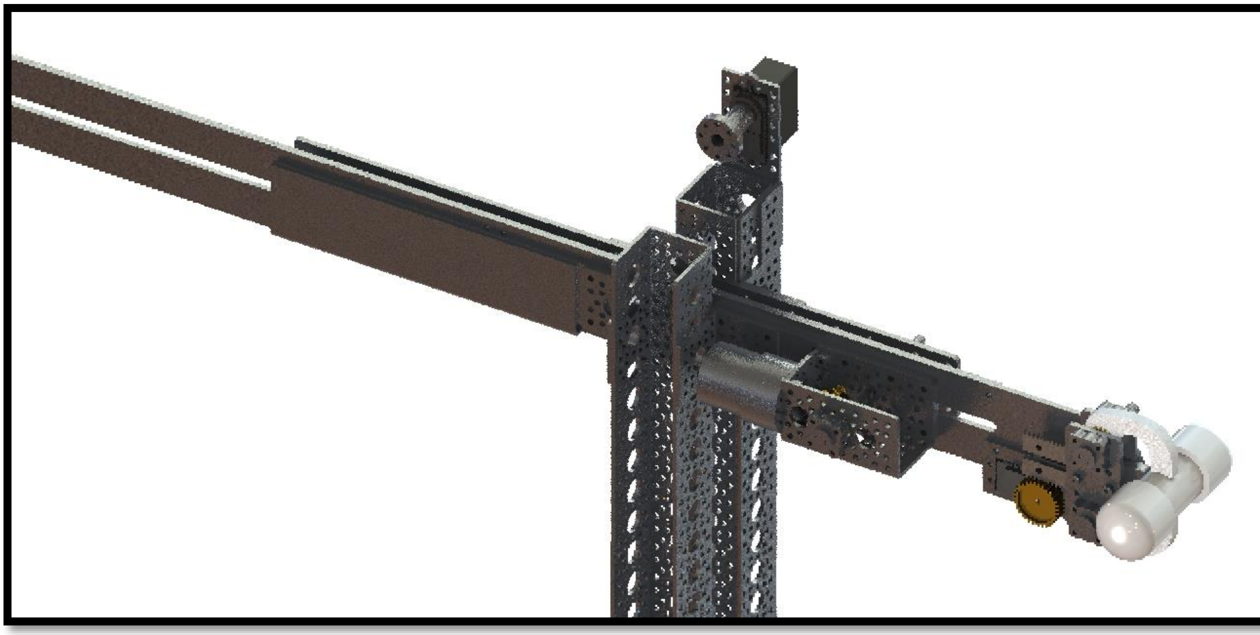


Figure 30: Isometric view of payload arm with slider in horizontal position.

Since the gear used to move the slider up and down was the pivot point, the slider will be able to move horizontally using the same motor just by changing its rotational direction. The slider will only have to move 12inches horizontally to place the payload inside of the rocket. The long length of the slider on the opposite side will act as its own counter weight to prevent it from falling over. Clips will be added later on to lock the slider from rotating if it's determined necessary during testing.

Once horizontal, the slider will move forward into the rocket until it reaches the clips that will secure the payload. The gripper arms will then open up and the rack plate will push the payload into the clips as mentioned previously. Once this is done, the gripper arms will close and the slider will be retracted all the way back to the support towers. When the slider is back, the system will stop any more movement of the payload arm as its task will be done.

Further evaluation will be done to determine the specifications required for the motor and servos. A static analysis will also be done to insure the structure will be functional. The computer ground station will require few outputs to control the payload arm due to the simple structure only requiring two servos, a motor, and possibly a touch sensor.

Challenges

The challenges for the payload arm are shown in Table 14.

Challenge	Solution
Insuring the payload stays in the gripper until its placement in the rocket.	Servo with enough torque to hold the payload will be used. Rubber strips will be added later on if payload keeps sliding out.
Making sure the slider can move upwards.	A motor with enough torque will be chosen to insure it can move the slider up as well out horizontally.
Rotating the slider horizontally.	Currently a servo will pull the slider down but a better method will be devised in the future.
Knowing when the arm is in contact with the payload.	A touch sensor might be used to let the system know when it's in contact with the payload.
Keeping the structure stable on the 80/20 rail.	Two brackets will be used to attach the base plate to the 80/20 rail. If this is not enough, a different structure will be designed.
The rocket is 4 feet off the ground.	A 48in slider will be used to reach the ground.

Table 14: Payload arm challenges and potential solutions.

3) Ground Station

The ground station must be capable of meeting the following requirements to be consider a success.

1. Provide a stable platform for all AGSE sub systems to mount to.
2. House all necessary electronics for AGSE sub systems.
3. Provide protection for critical systems.
4. Maintain stability prior to, during, and post launch.
5. Be reusable.

Design

The design ground station will consist of a primary frame, electronics area, articulation anchors, and outrigger assembly. The station will be comprised of 80/20 extrusions as the primary structural element. The structure of the ground station is shown in Figure 31.

Figure 31: Ground station frame.

The electronics area will be positioned directly below the carriage track. Placing the electronics below the track is an optimal location because the electronics will be clear of the articulating launch platform and motor exhaust.

The articulation anchors will be comprised of custom manufactured parts and commercial components. The anchors will provide a solid connection between the launch platform and the ground station.

The outriggers will be made out of 80/20 extrusions with power screws for actuation. The outriggers will be positioned at the rear of the ground station near the launch platform. The outriggers will deploy outwards to provide a triangular footprint at the base of the launch platform. This outrigger layout is similar to the footprint of launch towers that the team has used previously.

Construction

The primary components in the ground station will be made form 80/20 extrusions. The 80/20 components will be cut using the station shown in Figure 37.

Challenges

The primary construction and operational challenges are shown in Table 15.

Challenge	Solution
Maintain stability during launch.	Ground station will include actuating outriggers.
Protect electronics from sub systems and motor exhaust	Electronics will be located away from motor exhaust and other systems.

Table 15: Ground station design challenges.

4) Launch Platform

Overview

The launch pad must perform the following functions to be considered a success.

1. Hold the rocket steady during payload installation.
2. Raise the vehicle within a four minute window.
3. House the ignition instillation station and the pivot point for the vehicle erection system.
4. House and protect all required sensors involved in raising the vehicle.
5. Be reusable.
6. Be able to come apart to be transported in a passenger vehicle.

Design

The launch platform is to be of a guide tower design similar to what the team has used in previous years. There will be three 80/20 aluminum extrusions that will guide the vehicle until it has reached the required minimum velocity. There is a 0.125 inch gap between the vehicle and the guide towers.

Figure 32: Launch platform.

At the base of the platform will be three triangular plates with each plate serving a specific purpose. The base plate is the mounting plate for the igniter installation station and three 24 inch 80/20 extrusions that stabilize the three primary guide extrusions. The secondary plate is where the primary guide rails are mounted to and acts as a blast deflector. The third plate provides torsional support to the guide rails and where the vehicle rests before ignition. All three plates have central holes to allow for the igniter to feed through and be installed in the vehicle. Figure 33 shows the base of the launch platform.

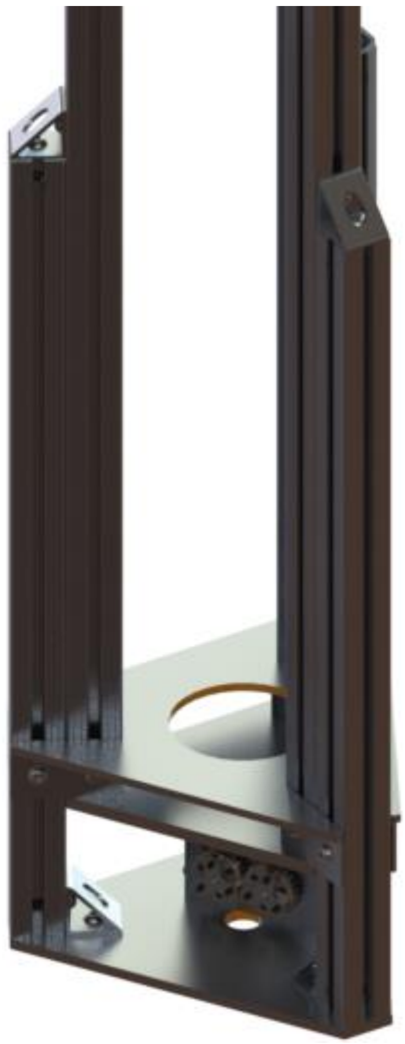


Figure 33: Launch platform base.

For transportation purposes the launch tower will split in half into two sections. To ensure structural rigidity when fully assembled points of disassembly have additional features. A 10 inch long half threaded rod will be incorporated. The threaded half will thread into the lower half of the assembly. The non-threaded half is a 5/16” dowel pin that will be encapsulated within the upper rod giving support as shown in Figure 34.

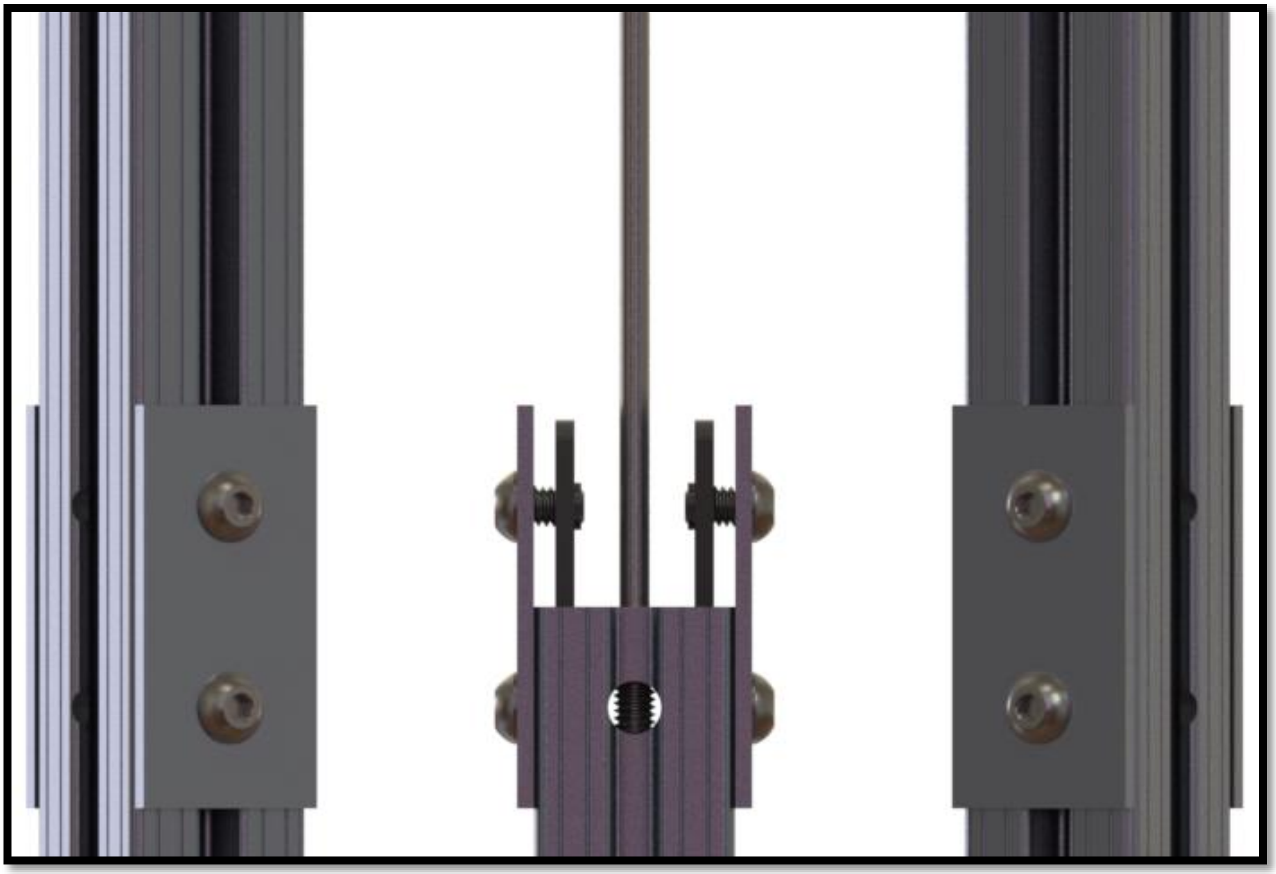


Figure 34: Tower Separation Joint.

Also shown in

Figure 35 are mounting plates. These plates act as fasteners to keep rigidity in the joint. These configuration was used in previous years as well which adds to the confidence level of the design.

Figure 35: Stability ring assembly.

There will be two assemblies to keep the guide rails from bending away from each other. These stations will consist of three 80/20 extrusions and an aluminum ring with enough clearance for the vehicles fins. One assembly will be at the top of the platform. The other station will be mounted below the separation joint.

The height of the launch rail is to be kept to a minimum to reduce the overall mass of the system and lower the amount of friction that the vehicle sees during takeoff. A minimum takeoff velocity was determined using a N.A.R. rule of thumb. “Best practice would indicate that rockets should be guided by launch rods, rails, or towers until they have attained a forward velocity of at least 4 times the velocity at which the wind is blowing (or gusting) at the launch site.” from "Launching Safely in the 21st Century." Oct. 2005. Web. 14 Sept. 2014.

The height of the launch tower is to be determined using

$$h = \int_0^{t_e} V dt \qquad (17)$$

where V is the velocity at any time, and t_e is the time at which the vehicle has hit the required exit velocity. To determine t_e the following free body diagram (F.B.D.) was constructed and shown in Figure 36.

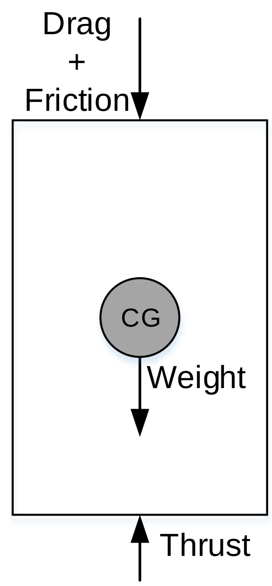


Figure 36: Vehicle takeoff F.B.D.

The sum of forces was calculated to determine the acceleration as a function of time using

$$+\uparrow \sum \mathrm{F} = \mathrm{ma} \tag{18}$$

where m is the total mass of the vehicle and a is the acceleration of the vehicle. The sum of forces is determined using

$$+\uparrow \sum \mathrm{F} = \mathrm{T} - \mathrm{mg} - \mathrm{F_d} - \mathrm{F_f} \tag{19}$$

where T is the motor thrust, g is the acceleration due to gravity, $\mathrm{F_d}$ is the force due to drag, and $\mathrm{F_f}$ is the frictional force due to the guide tower. $\mathrm{F_d}$ was determined using

$$\mathrm{F_d} = \frac{1}{2}\rho \mathrm{C_d} \mathrm{A} \mathrm{V}^2 \tag{20}$$

where ρ is the air density, $\mathrm{C_d}$ is the drag coefficient (taken from the OpenRocket simulation), A is the reference area, and V is the vehicle velocity. Due to the mass of the propellant being time dependent the mass of the vehicle is determined using

$$\mathrm{m} = \mathrm{m_w} - \mathrm{b_r t} \tag{21}$$

where m_w is the “wet” mass of the vehicle with a full motor, b_r is the burn rate of the motor propellant, and t is time after ignition. Equations 18-21 can be combined to determine the acceleration of the vehicle and the resulting equation is shown below.

$$a_i = \frac{T_i - (m_w - b_r t)g - F_f - \frac{1}{2}\rho C_d A V_{i-1}^2}{m_w - b_r t} \tag{22}$$

Euler’s method will be used to calculate the vehicles velocity as a function of time using

$$V_i = V_{i-1} + a_i t \tag{23}$$

These calculations have not been performed due to the need to test for the friction coefficient and thrust values from a static test so for the purposes of the proposal the launch platform is to be 10 feet tall. The estimated mass of the platform is 70.88 lbs. This mass is directly from the SolidWorks model with all parts and materials added.

Construction

All 80/20 parts will be cut using the station shown in Figure 37.

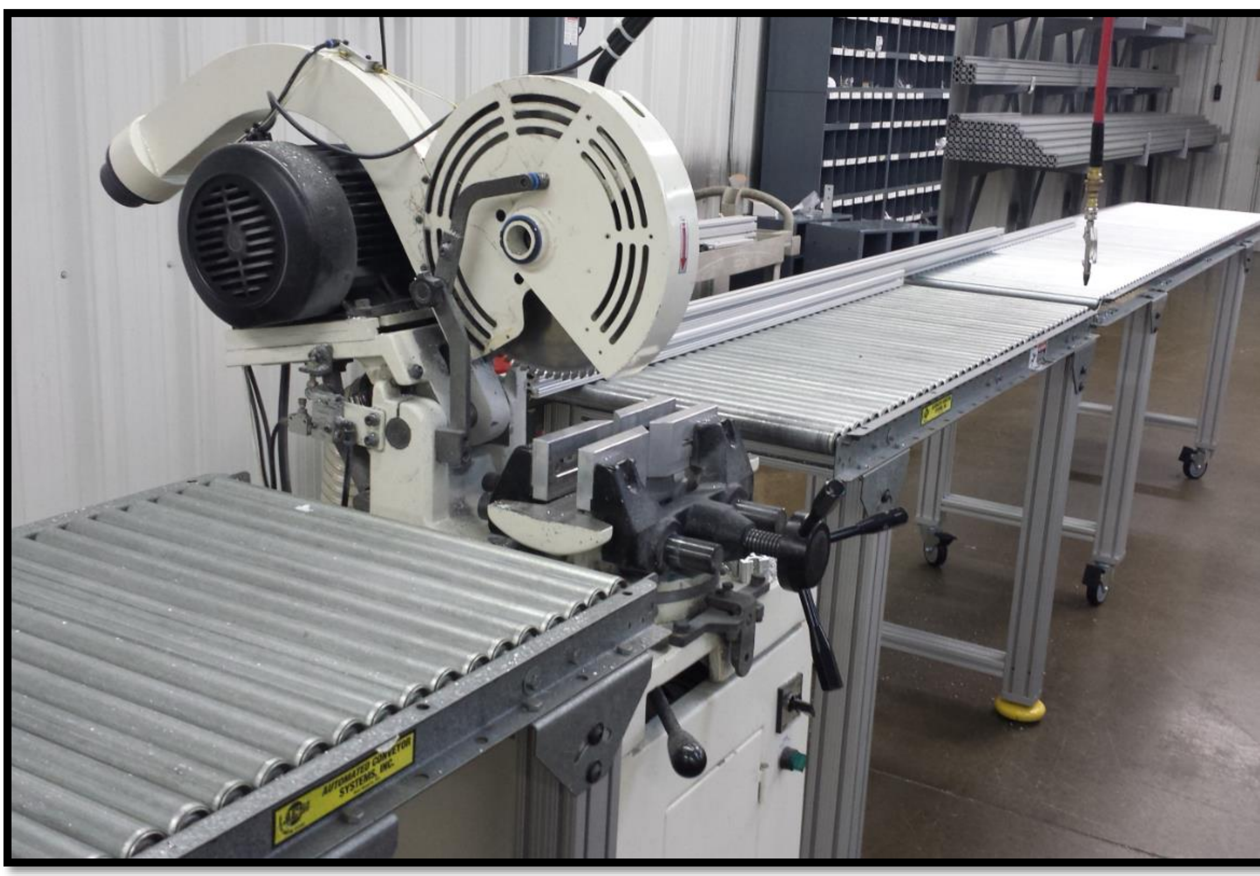


Figure 37: 80/20 cutting station.

The anti-torsion rings will be made from 0.125 inch 6061 aluminum. They will be cut using a waterjet cutter at FirstBuild. The screw holes within the parts will then be made using an end mill for increased accuracy.

The triangular base plates will be constructed using CNC end mills for tolerances within 0.001 inches. To ensure proper placement of all fasteners, the fastening option chosen has a set screw as part of the fastener as shown in Figure 38, fastening plate removed for clarity.

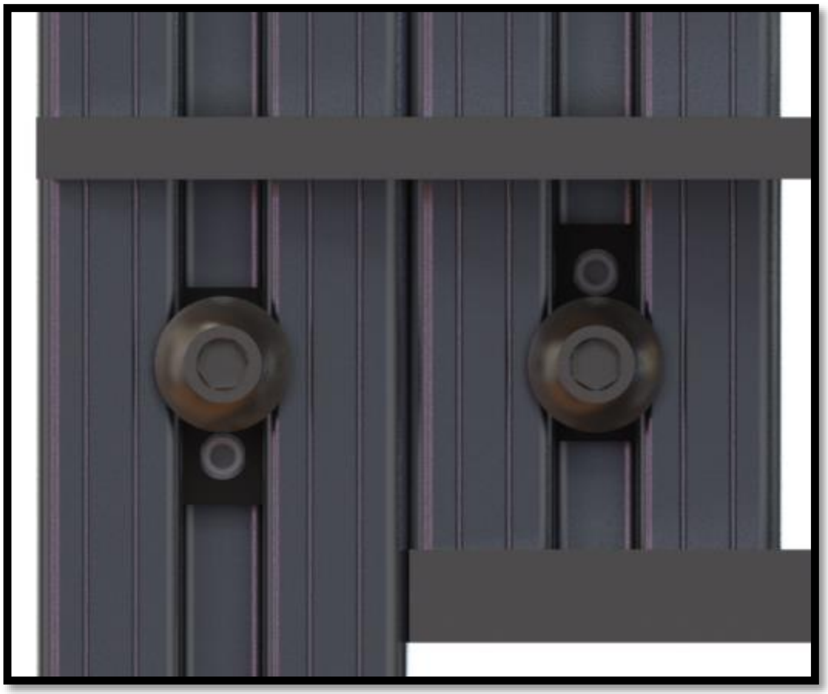


Figure 38: Accurate fastening option.

Design Challenges

The design challenges for the vehicle and solutions are shown in Table 16.

Design Challenge	Solution
Determining the minimum safe guide tower height	Analysis has been performed to determine height and tests will be performed for the needed values.
Accurate construction	Fasteners which can be permanently placed in the optimum location will be used.
Transportation	The station breaks into halves and the rings are removable.
Deflecting exhaust heat away from ignition station	The exhaust won't be deflected from the ignition station but instead the ignition station will be constructed in a way that it

	can take the exhaust heat for a short amount of time.
Ensuring alignment between ignition station and vehicle	The ignition station is attached to the platform.
Remain stable during vehicle erection	The joints that split the platform in half will be staggered so that the load is spread out more evenly.

Table 16: Launch platform design challenges.

5) Vehicle Erector

The vehicle erector must be capable of meeting the following requirements to be consider a success.

1. Erect the vehicle from a horizontal position to a position 5 degrees from vertical.
2. Hold vehicle steady during pre-launch procedures including erection of the vehicle, installation of igniter, and arming of recovery systems.
3. Lock vehicle in current position upon power failure, system pause, or other motion halting action.
4. Hold vehicle steady during launch.
5. Be reusable

Design

The design of the vehicle erector with consist of a track and carriage linkage system. The track will consist of two parallel 80/20 extrusions that will provide linear guides for the carriage as shown in Figure 39.

Figure 39: Vehicle erector track assembly.

The carriage will be actuated by a pair of power screws. The power screws will be sized such that a single screw can handle the load of the entire loaded launch platform. The power screws will be powered through a single transfer-case. The transfer-case will be driven by two separate motors to add redundancy to the system.

The carriage assembly is shown in Figure 40.

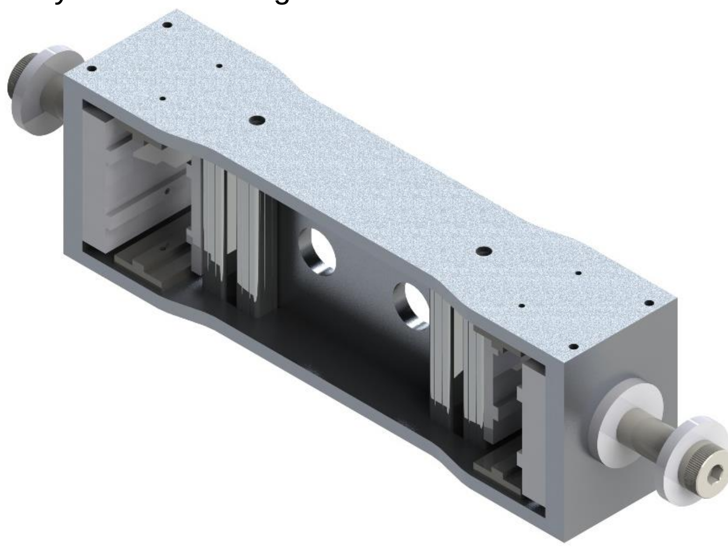


Figure 40: Vehicle erector carriage assembly.

The carriage will be made of out a collection of 80/20 and custom machined components. The geometry of the carriage was selected to reduce the possibly for the carriage to jam inside the track system. The loads on the carriage are all centralized on a neutral axis to prevent rotational load from being applied to carriage. A rotational load could potentially jam the carriage. The width of the carriage also allows for a wide articulating connection between the vehicle erector and the launch platform. This wide articulation connection will provide more stability for the launch platform prior to, during, and post launch.

Controls

In this system, the following items are used to take care of different tasks:

1. Microcontroller unit
2. Motor controller and batteries
3. Motor and gearbox
4. Sensory system

A block diagram of the system is shown in Figure 41. In this schematic, the laptop computer is responsible for the high-level decisions for the whole system including the arm, rocket erector, and vision system. Decisions are made by commanding the different units in order and making changes in the whole scenario, if necessary, in an online manner. The rest of the items for this specific unit are briefly described below.

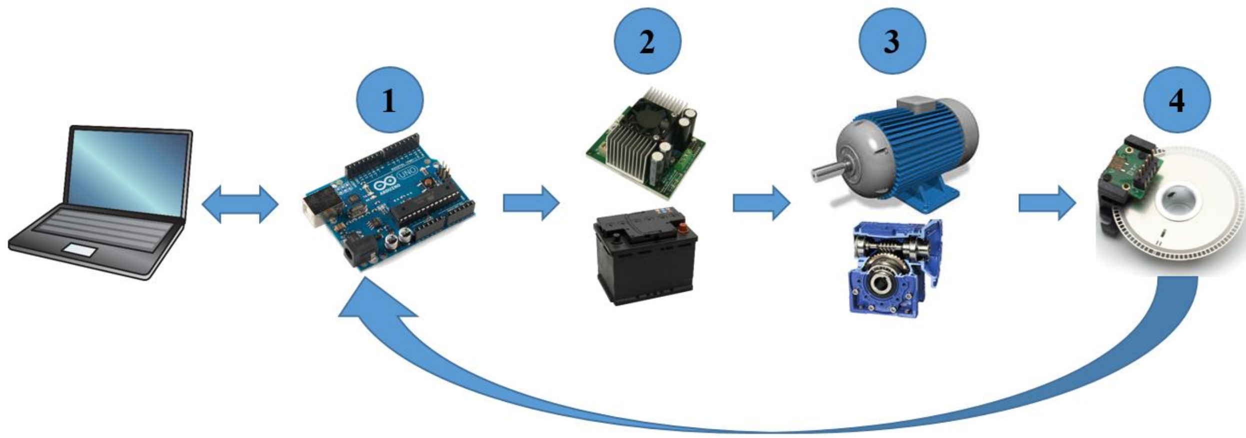


Figure 41: Control elements.

1. Microcontroller:

The microcontroller will be used as an interface between the laptop computer and the rest of the unit. It receives high-level decisions from the laptop when it is time to erect the rocket (i.e., after the previous steps like payload containment are complete).

When the microcontroller is commanded by the laptop to initiate the process, the microcontroller will send the corresponding commands to the motor controller to start tilting the rocket to a perpendicular position. For this goal, the microcontroller is in real-time communication with the sensor. This closed-loop system implements a simple PI (proportional-integral) control strategy for command tracking, noise rejection, and disturbance reduction.

It is noteworthy that the communication between the laptop and microcontroller is a two-way path. The laptop provides high-level decision for the microcontroller, and the microcontroller provides sensory information back for the laptop in real time so a software (e.g., a virtual reality) can be designed on the laptop for monitoring/visualization purposes. It also enables the whole system to make dynamic decisions in case of unexpected situations for improved safety reasons.

2. Motor controller and battery:

The motor controller, in turn, translates the digital commands from the microcontroller to applicable voltages and currents for the motors. The motor controller is, in effect, an interface between the microcontroller (which is able to provide low-power signals) and the battery (which is capable of propelling the rocket, but instead is not able to provide varying voltages).

For this item, DC motors used in electric wheelchairs are a good option as they can be purchased for cheap from broken wheelchairs. They are capable of providing enough torque for this project and contain a built-in self-lock gearbox.

For this item, Sabertooth motor controllers (from Dimension Engineering) are a good option as they are relatively cheap and they can, out of the box, supply DC brushed motors. They also implement soft current limiting and thermal protection and we will not have to worry about killing the driver.

3. Motor and gearbox

The motor is responsible for erecting the rocket and launch pad. The motor will be interfaced with a self-lock gearbox (e.g., worm-gear) to account for the rocket weight at the equilibrium point. Because the dynamics of the system, it is intrinsically unstable. Using a self-lock gear box simplifies the task immensely. It also preserves battery life in case the rocket needs to remain in the erection state for long periods of time.

For this item, DC motors used in electric wheelchairs are a good option as they can be purchased for cheap from broken wheelchairs. They are capable of providing enough torque for this project and contain a built-in self-lock gearbox. They, also, have built-in electrical brakes that can be utilized in a dynamic automatic manner to improve safety. Besides, they have a handle that can be used to manually disengage the motor from the gearbox.

Figure 42: Motor and gearbox.

4. Sensory system

Since the rocket must reach a certain tilt before the launch occurs, a simple accelerometer will be used to provide this information for the system. An Arduino Esplora, shown in Figure 43, has been selected to use. It has a three-axis accelerometer which can be used to measure the board's relation to gravity on three axes. Using this approach, the whole microcontroller-sensor collaboration and its implementation are simplified substantially.

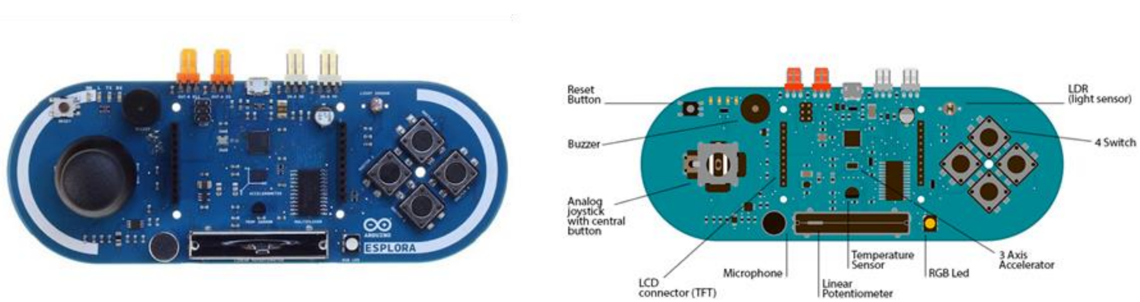


Figure 43: Arduino Esplora.

Construction

The custom components on the carriage will be manufactured using 6061-T6 aluminum and will be machined using CNC technology. The 80/20 components will be cut using the station shown in Figure 37.

Challenges

The design challenges for vehicle erection system are shown in Table 17.

Design Challenge	Solution
Launch platform stability	The system will hold the platform up sufficiently high enough such that there will be minimum sway
Safety	If there is a power loss or the pause button is initiated the vehicle must not crash to the ground. The lead screw design does not allow for the carriage to back out if power is lost.
Adequate power screw selection	Tooth stress analysis, buckling analysis, and tensile stress analysis will be performed and the screws sized accordingly.
Adequate torque	The geometry of the system will be analyzed for the required torque and a custom transmission will be designed and paired with a motor so that adequate power and torque are provided.

Table 17: Vehicle erector design challenges.

6) Ignition Station

The ignition station must be capable of meeting the following requirements to be considered a success.

1. Move the igniter up to the top of the interior of the motor assembly.
2. Hold the igniter until motor ignition.
3. House the igniter without damage while the vehicle is being rotated from the horizontal to vertical position.
4. Be reusable.

The igniter is going to be augmented by a 1/32 inch wooden dowel rod. Immediately under the igniter head will be a 6 inch section of dowel followed by a 1/8 inch gap then a series of 3 inch long dowel rods spaced by 1/8 inch. The gaps allow the igniter cable to be spooled away from the ignition station.

Design

The design of the ignition station mimics that of a cable extruder. Two extrusion wheels will grip the dowel augmented igniter and push it up the motor assembly. To allow for the gaps between the dowel sections, two motors and two sets of extrusion wheels will be used as seen in Figure 44.

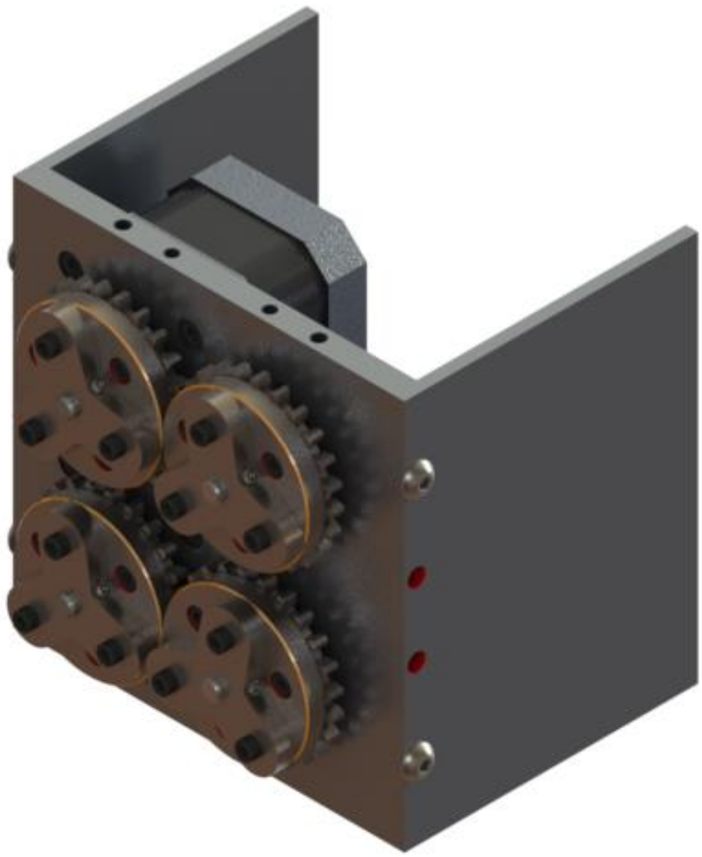


Figure 44: Ignition sub-station.

The station consists of a mounting plate which houses the two stepper motors, two blast shield plates which mount to the side of the assembly, four extrusion wheel assemblies, shown in Figure 45 (exploded view in Figure 46), and two shafts. The secondary shaft assemblies will be held in place by custom nylon bushings shown in Figure 47.

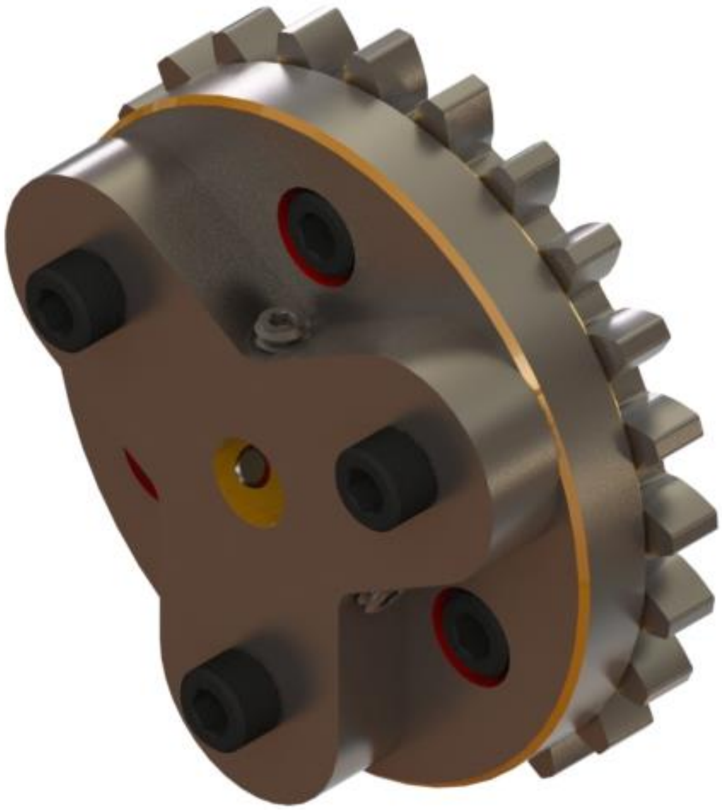


Figure 45: Extrusion wheel.

Figure 46: Exploded extrusion wheel assembly.

Figure 47: Custom nylon bushing

The extrusion wheel assembly consists of a 24 toothed gear, wheel, and shaft collar. The wheel is fastened to the gear using three #4-40 screws, the shaft collar then connects to the wheel via three #4-40 screws. The shaft collar connects to the shaft via three #4-40 set screws. A secondary set of shaft will connect the driven gears to the driving gears. This shaft will have an extrusion wheel assembly, a custom nylon bushing, and snap ring for alignment.

A cutaway of the entire assembly is shown in Figure 48.

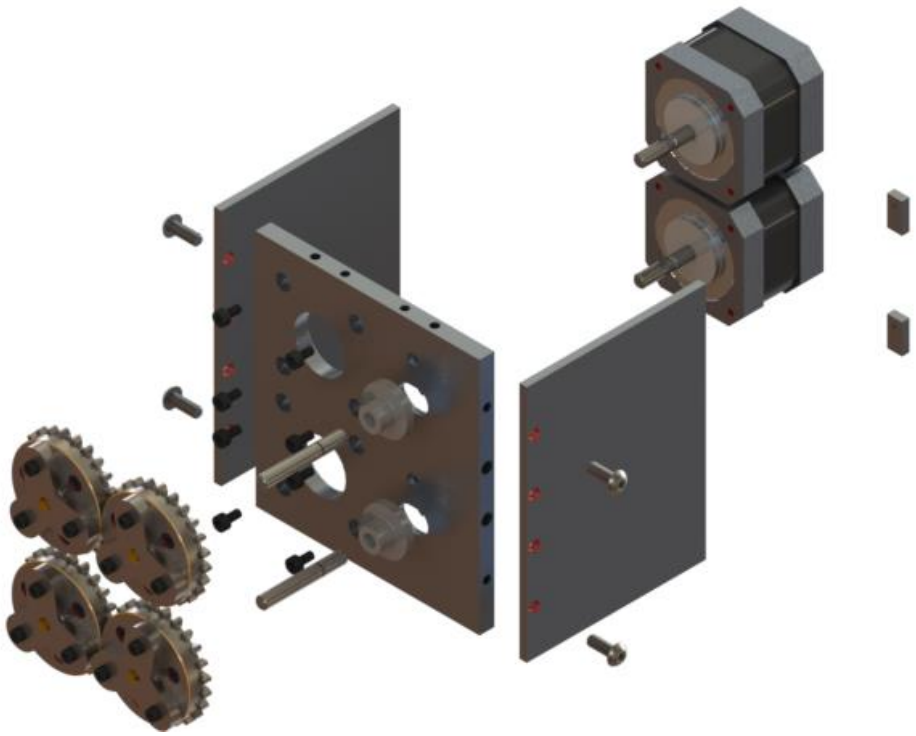


Figure 48: Exploded ignition station.

Controls Overview

A PC running Matlab will send an activation signal to an Arduino micro controller. Upon this activation, the Arduino will then run a simple program sending a signal to the motor shield turning the steppers a set amount of distance. This will accurately place the e-match into the rocket motor.

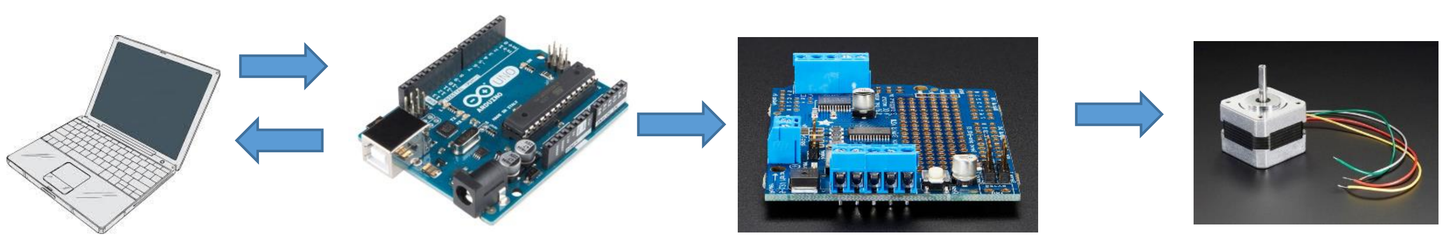


Figure 49: Controls schematic.

PC to/from Arduino Uno:

The Arduino will only execute the program when the input pin connected to the PC goes Hi. At the end of the program the Arduino Board will set an output pin Hi signifying that the e-match has successfully been installed. For safety purposes if the input pin coming from the PC ever goes low before the end of the program the stepper will return to its starting position.

Arduino Uno to Motor Shield:
The chosen motor shield has a dedicated PWM driver chip onboard that is fully compatiable with the output of the Arduino. The driver will be able to interpret the signal coming from the Arduino Uno and supply the necessary power to the stepper motor.

Motor Shield to Stepper:
The stepper will receive power and a signal from the motor shield and turn a set amount of times inserting the E-match into the correct position inside the rocket.

Design Challenges
The design challenges for the ignition station are shown in Table 18.

Design Challenge	Solution
Survive ignition	Ignition station will act as its own blast shield. The gears, extrusion wheels, and shaft mounts will be printed out of Titanium. The mounting plates will be aluminum and will encapsulate the motors.
Raise igniter wire	Chain linked dowel rods will allow.
Hold igniter wire in place	Motor tension will be kept constant.
Ensure straight placement of wire	Two wheels will ensure proper alignment of igniter wire upon installation.

Table 18: Ignition station design challenges.

7) Statement of Work Verification

Table 19 shows the requirements set forth by the statement of work and the teams proposed method of completion.

Requirement	Method of Completion
Teams will position their launch vehicle horizontally on the AGSE	The platform will start in a horizontal position.
A master switch will be activated to power on all autonomous procedures and subroutines	There will be a toggle switch wired into the AGSE supply line. "Golden Rule" interrupt will be assigned in software to ensure enable/disable has priority in system execution.
After the master switch is turned on, a pause switch will be activated, temporarily halting all AGSE procedure and subroutines. This will allow the other teams at the pads to set up, and do the same.	A secondary toggle switch will be implemented on the AGSE to halt all operations for safety and setup. The second toggle having all e-stop priority aside from the master switch.
Once the launch services official has inspected the launch vehicle and declares	A third toggle switch will be implemented as a master arming switch. Once payload

that the system is eligible for launch, he/she will activate a master arming switch to enable ignition procedures.	is stored/rocket raised, the system will enter a scheduled halt status. Power will be supplied to ignition station microcontroller, but not to actuating motors. This will ensure the highest safety margin for rocket ignition. The master arming switch activation will allow the microcontroller to continue with automated igniter instillation. The master arming switch shall have possibility of arming a TBD distance away from AGSE to further ensure safety of arming staff.
The Launch Control Officer (LCO) will activate a hard switch, and then provide a 5-second countdown	Power supply for the igniter is electrically isolated and supplied by LCO and team. This will ensure LCO's have complete control of abort process.
All AGSE systems shall be fully autonomous	All AGSE systems will be controlled autonomously by PC/Microcontroller systems. All launch processes will be automated, except the processes ensuring safety of go/no-go toggle switch actuation which be controlled by appropriate launch staff.
The system must suffer no setbacks when the pause button is initiated	All components and procedures will fail safely in a recoverable state if pause sequence is initiated. Specific fail-safe implementation will be outlined in future failure mode evaluations. Communication will exist between AGSE and vehicle to ensure vehicle does not close while arm is inside the vehicle.
The system must complete all tasks within 10 minutes	The time requirement has been separated by sub-station and the amount of time will be factored into the detailed design.
The capture and containment system must be able to retrieve the payload from outside of the vehicle MOLD line and from the ground	Capture and containment system has been designed with remote payload retrieval in mind. Payload capture will be able to reach pre-determined area below ground station and outside vehicle mold line.
No forbidden technologies will be utilized	No forbidden technologies will be used.
A master switch to power all parts of the AGSE, the switch must be easily accessible and hardwired into the AGSE	A fused power block will isolate all devices from power supply.

A pause switch to temporarily terminate all actions performed by the AGSE. The switch must be easily accessible and hardwired into the AGSE	The secondary toggle switch will be implemented on the AGSE to halt all operations for safety and setup. The second toggle having all e-stop priority aside from the master switch.
A safety light that indicates that the AGSE is powered on. The light must be amber/orange in color. It will flash at a frequency of 1 Hz when the AGSE is powered on, and will be solid in color when the AGSE is paused while power is still supplied	The central PC/microcontroller will have control of indicating power/pause status through an Amber LED panel indicator. The LED flashing will be implemented through PWM control from microcontroller with inputs from both power switch and pause switch.
An all systems go light to verify all systems have passed safety verifications and the rocket system is ready to launch	"All Systems Go" LED indicator will be implemented on launch station to verify LCO's approval.

Table 19: AGSE SOW verification.

Section 7. Educational Engagement

In previous years, the University of Louisville River City Rocketry Team has managed to reach out to many students and adults in the local community. Schools from across the state of Kentucky were able to get a hands on experience with engineering and rocketry working side-by-side with members of the team. The team strove to maintain relationships built with organizations in the community while continuing to reach people in new ways. The focus was not on how many people were could reached, but the quality of education that was brought to each and every individual.

Figure 50: A student loads an Estes rocket he build onto the launch pad.

Curriculum

The University of Louisville River City Rocketry Team has developed a variety of programs that are to be incorporated in this year's outreach program. Included is a list of the different activities in which the team has participated in the past and will continue to do this year.

<u>6 Day Program Curriculum</u>

Last year the team added a six week aerospace program that was a huge success. Due to the high demand by schools to have the program offered at their schools, the team will continue to offer this program. With the incorporation of robotics into NASA's competition and the large increase in the electrical and programming team, the team is looking to offer a similar program for robotics and basic programming. The details are still being worked out but we look to have this program released by January. The curriculum for the aerospace program is detailed below.

Figure 51: A young engineer building a paper rocket at E-Expo.

Day 1: The Space Race and Mercury and Gemini Program History:
This lesson introduces the cold war, the relationship between the United States and the U.S.S.R. and how it propagated the space race. The beginning of space history is discussed, including the missions and objectives from the Mercury and Gemini programs. America's achievements are highlighted such as Alan Shepard becoming the first American in space and John Glenn becoming the first American to orbit the Earth. Rocketry concepts are taught including rocket stability, principles of aerodynamics, Newton's Laws, and basic rocket building techniques. The day concludes with the building and launching of paper rockets.

Day Two: Apollo Program History:
This lesson examines in detail the most monumental program in the history of manned spaceflight. The students will learn about the 17 Apollo missions, from the fatal fire of Apollo 1, mankind's giant leap of Apollo 11, the "successful failure" of Apollo 13, and the rest of the historic moon landings. Core concepts taught during this lesson are:

- Thrust-to-weight ratio.
- Improved rocket building techniques (Advanced paper rocket activity).


Figure 52: Dhwani assisting in the launch of a paper rocket at E-Expo.

Day Three: Shuttle Program, ISS, and Curiosity Rover History:
This lesson examines in detail the movement of NASA from making deep space missions, to mastering low-earth-orbital techniques. The space shuttle was also analyzed from a standpoint of reusability. The International Space Station is followed with a look into what it takes to sustain life in low earth orbit. Finally, a brief look at the Curiosity Rover mission demonstrates how we land a probe on another planet. Students had the opportunity to do the following:

- Understand the use of composites vs. metals in aerospace applications.

- Design a payload that would fit inside the space shuttle cargo bay.
- Design a space station with the fundamental elements for sustaining life.
- See simulations of extra-terrestrial landing techniques for unmanned missions.
- See videos from inside the International Space Station.

Day Four: OpenRocket Simulation:

The class had the opportunity to model the Estes rocket that they built in the fifth day of the program. A worksheet is prepared with all of the parameters to accurately simulate the rocket. The simulation software allows the students to learn how to use the same program that the University of Louisville River City Rocketry Team uses to simulate their rocket. This stresses the importance of precisely predicting flight trajectories and altitudes. The following concepts are discussed:

- Understanding how math is applied through software simulations.
- Mass balance.
- Stability margin acceptability.
- The relationship between position, velocity, and acceleration curves and flight events.

Day Five: Rocket Construction:

Each student has the opportunity to construct and launch their own rocket. Rockets are small Estes model rockets using black powder motors. Each student is be carefully supervised. The students are led through a visual walkthrough of rocket assembly. The following concepts are taught:

- Proper measurement and construction techniques.
- Fin installation.
- Launch lug mounting.
- Shock cable and parachute organization.

Figure 53: One of many fellow students at the Academy at Shawnee working to construct a rocket.

Day Six: Final Construction/Rocket Launch:

The students are taken through a safety briefing by a member of the University of Louisville River City Rocketry Team. Any remaining construction work on the rockets is completed during this session. The students are taught how to pack parachutes, load motors, install igniters and develop a pre-launch checklist. Finally, the students launched their rockets.

Outreach Opportunities

Figure 54: Carlos helping a student prep her rocket for launch.

Figure 55: A student at the Academy at Shawnee launching her rocket.

Engineering Exposition (E-Expo)

Since 2006, the J.B. Speed School of Engineering Student Council has hosted the larges student-run event on the University of Louisville's campus called Engineering Exposition. The event is geared towards celebrating strides in engineering as well as getting the local youth interested in the field. During the event, the professional engineering societies on UofL's campus set up educational games and scientific demonstrations for the elementary and middle school students to participate in.

The University of Louisville River City Rocketry Team will host its third annual water bottle rocket competition for middle school students. Teams from local middle schools can participate in teams of up to three students to design and build their own water bottle rockets out of two liter bottles and other allowable materials. Workshops will be held with schools interested to teach the students about the components of a rocket and aerodynamics in preparation for the competition. The students will get to show off their rockets at the E-Expo event throughout the day and will conclude the day with the competition. Teams will compete for awards in highest altitude, best constructed rocket, and landing closest to the launch pad. This event has been a huge success in the past and many schools have voice interest in continuing their involvement so we are looking for our best turn out yet this year.

Figure 56: Three students launch a water bottle rocket that they built themselves while at the annual E-Expo.

In addition to the water rocket competition, the team will host a paper rocket station for people of all ages. This has been the most popular station at the exposition in the past and are looking to continue to build up that reputation.

<u>Boy Scouts and Cub Scouts:</u>

In the past, the University of Louisville River City Rocketry Team has worked with local Boy Scout and Cub Scout troops to assist the earning of the Space Exploration merit badge. The team has assisted in developing a program that meets the requirements to earn the merit badge. The scouts get to learn about the history of space, current space endeavors, and build and launch an Estes rocket. The team has plans to continue to work with these groups throughout the year.

Louisville Science Center Partnership:

In the Louisville metropolitan area, the Louisville Science Center has heavily promoted STEM topics. The University of Louisville River City Rocketry Team plans to participate in Engineering Week at the science center for the third year running. The team will set up an interactive booth to discuss rocketry and to build and launch paper rockets with any visitors.

Big Brothers Big Sisters Partnership:

Big Brothers Big Sisters is active in the Louisville community and is constantly striving to bring opportunities to underprivileged kids. The team recently put on a program with a group of kids that had not yet been paired with a mentor through the program. Through this event, we have established a relationship with Big Brothers Big Sisters and are looking forward to bringing more programming to the students involved in this organization.

Figure 57: A thought provoking "little brother" grills the team on the fundamentals of rocketry.

Louisville Mini-Maker Faire

Every year Louisville hosts a mini-maker faire. The team took the project out to show off to anyone attending the event. We worked with small children as well as adults with experience in the field. This gave us an opportunity to talk to the community about our project and what our rocket does. People were given the opportunity to ask questions about anything about the rocket, what it does, and how it works.

Section 8. Project Plan

1) Timeline

Reference Appendix III.

2) Comprehensive Budget

Full Scale Vehicle Budget			
Description	**Quantity**	**Per Unit Cost**	**Total Cost**
6" FG Von Karman Nosecone	1	$122.55	$122.55
6" CF Airframe Tubing (4 feet in length)	4	$404.80	$1,619.20
6" CF Coupler Tubing (1 foot in length)	5	$109.25	$546.25
1/8" Thick 24" x 36" Fiberglass	4	$35.78	$143.12
6" Plywood Bulkplate - 1/2" thick (Coupler)	6	$5.90	$35.40
6" Plywood Bulkplate - 1/2" thick (Airframe)	6	$5.90	$35.40
Cesaroni L910 - 2G CS	6	$199.66	$1,197.96
Pro 75 2G Hardware Set	1	$242.96	$242.96
1/4"-20 x 4' Threaded Rod (Aluminum)	4	$4.46	$17.84
1/4"-20 Hex Nuts (Aluminum) (pkg of 100)	1	$4.46	$4.46
4-40 Black Nylon Shear Pins (pkg of 100)	1	$5.42	$5.42
3/8"-16 for 2.5" OD Black-Oxide U-Bolt (Steel)	5	$1.55	$7.75
3/8"-16 Hex Nuts Black-Oxide (18-8 SS) (pkg of 25)	1	$7.11	$7.11
1/4" Flat Washer (Aluminum) (pkg of 100)	1	$6.80	$6.80
3/8" Flat Washer Black-Oxide (18-8 SS) (pkg of 100)	1	$8.49	$8.49
Servo	1	$40.00	$40.00
Hinges	2	$10.00	$20.00
Neodymium Magnets (1/8" x 1/16")	1	$8.99	$8.99
Momentary Contact Switch	2	$0.98	$1.96
Professional Paint Job for Competition	1	$250.00	$250.00
		Overall Cost	**$4,321.66**

Recovery Budget			
Description	**Quantity**	**Per Unit Cost**	**Total Cost**
Ripstop Nylon (59"x36")	13	$7.99	$103.87
1" Tubular Nylon (1 yard)	10	$1.25	$12.50
Nomex Cloth (1 ft)	3	$19.99	$59.97
TeleMetrum GPS Payload	1	$321.00	$321.00
Perfect Flight StratoLogger	4	$79.95	$319.80
Electric Matches	50	$1.25	$62.50
4FA Black Pow der (1lb)	1	$24.40	$24.40
9V Duracell Batteries (x4)	3	$12.73	$38.19
Garmin Astro 320 GPS Unit	2	$189.99	$379.98
		Overall Cost	**$1,322.21**

Subscale Vehicle Budget			
Description	**Quantity**	**Per Unit Cost**	**Total Cost**
3" FG Von Karman Nosecone	1	$46.01	$46.01
3" FG Airframe Tubing (4 feet in length)	3	$77.92	$233.76
3" FG Coupler Tubing (1 foot in length)	5	$13.16	$65.80
1/8" Thick 24" x 36" Fiberglass	3	$35.78	$107.34
3" Plyw ood Bulkplate - 3/16" thick (Coupler)	5	$1.64	$8.20
3" Plyw ood Bulkplate - 3/16" thick (Airframe)	5	$1.66	$8.30
1/4"-20 x 4' Threaded Rod (Aluminum)	2	$4.46	$8.92
1/4"-20 Hex Nuts (Aluminum) (pkg of 100)	1	$4.46	$4.46
4-40 Black Nylon Shear Pins (pkg of 100)	1	$5.42	$5.42
1/4"-20 for 1.5" OD Black-Oxide U-Bolt (Steel)	5	$0.85	$4.25
1/4"-20 Hex Nuts Black-Oxide (18-8 SS) (pkg of 50)	1	$7.07	$7.07
1/4" Flat Washer (Aluminum) (pkg of 100)	1	$6.80	$6.80
1/4" Flat Washer Black-Oxide (18-8 SS) (pkg of 100)	1	$6.11	$6.11
Standard Parachute Large	1	$25.00	$25.00
Standard Parachute Small	1	$7.50	$7.50
Perfect Flight StratoLogger	4	$79.95	$319.80
Electric Matches	15	$1.25	$18.75
4FA Black Pow der (1lb)	1	$24.40	$24.40
9V Duracell Batteries (x4)	3	$12.73	$38.19
		Overall Cost	**$946.08**

Payload "Arm" Budget			
Description	**Quantity**	**Per Unit Cost**	**Total Cost**
15" Aluminum Channel	2	$11.99	$23.98
90deg Channel Bracket	6	$1.59	$9.54
10 RPM Gear Motor	1	$24.90	$24.90
90 deg Quad Hub Mount	2	$5.99	$11.98
6-32 Socket Head Machine Screw	3	$1.69	$5.07
Motor Mount D	1	$4.99	$4.99
Set Screw Shaft Coupler 6mm -0.25in	1	$4.99	$4.99
0.25in Clamping Hub	1	$7.99	$7.99
32P 32T Pinion	1	$12.99	$12.99
0.25in x2in D Shaft	2	$1.49	$2.98
Beam Gear Rack	1	$5.99	$5.99
0.25in Flat Bore Bearing	4	$5.99	$23.96
Multipurpose 6061 Aluminum	1	$56.67	$56.67
Servo	1	$24.99	$24.99
32P Gear	2	$5.99	$11.98
Servo Arm	1	$10.99	$10.99
		Overall Cost	**$243.99**

Educational Engagement Budget			
Description	**Quantity**	**Per Unit Cost**	**Total Cost**
Orbit 1" 24V Electronic Valve	3	$12.97	$38.91
7/8" Tire Valve (pkg of 2)	2	$2.09	$4.18
1 NPT Pipe Size Threading Bushing (Brass)	3	$7.97	$23.91
2-1/2" Male x 1 NPT Female Bushing (PVC)	3	$2.80	$8.40
1/2" Tube ID x 1/2 Male Pipe Size Barbed Fitting (Brass)	3	$4.66	$13.98
1/2" ID x 10' Red Tubing (Flexible PVC)	1	$11.50	$11.50
7/32" to 5/8" Hose Clamp (pkg of 10)	1	$5.87	$5.87
1/4" Wide x 14 Yards Teflon Tape	1	$5.19	$5.19
2 Pipe Size x 4' Length (PVC)	1	$36.94	$36.94
2 Pipe Size Cap (PVC)	3	$0.94	$2.82
Plastic Pipe Cement	1	$4.55	$4.55
3/4 Male Adapter to Female Slip (PVC)	6	$0.30	$1.80
3/4 Pipe Size x 5' Length (PVC)	1	$3.25	$3.25
3/4 Pipe End Male x 1/2 Female Bushing (PVC)	3	$0.36	$1.08
1/2 Pipe Size x 4' Length (PVC)	1	$9.08	$9.08
2 Pipe End Male x 3/4 Female Slip Bushing (PVC)	3	$1.57	$4.71
6mm, SPDT-NO Push Button Sw itch	3	$6.18	$18.54
15" Length Red Nylon Cable Tie (pkg of 25)	1	$6.12	$6.12
9V Battery (pkg of 12)	1	$14.36	$14.36
9V Battery Snap, I-Style	6	$0.68	$4.08
24 GA 25' Stranded Wire (Black)	1	$3.18	$3.18
24 GA 25' Stranded Wire (Red)	1	$3.18	$3.18
Gnome Rocket Bulk Pack (pkg of 24)	2	$123.99	$247.98
1/2A3-4T Engine Bulk Pack (pkg of 24)	2	$57.79	$115.58
Scotch tape (pack of 3)	40	$4.74	$189.60
		Overall Cost	**$778.79**

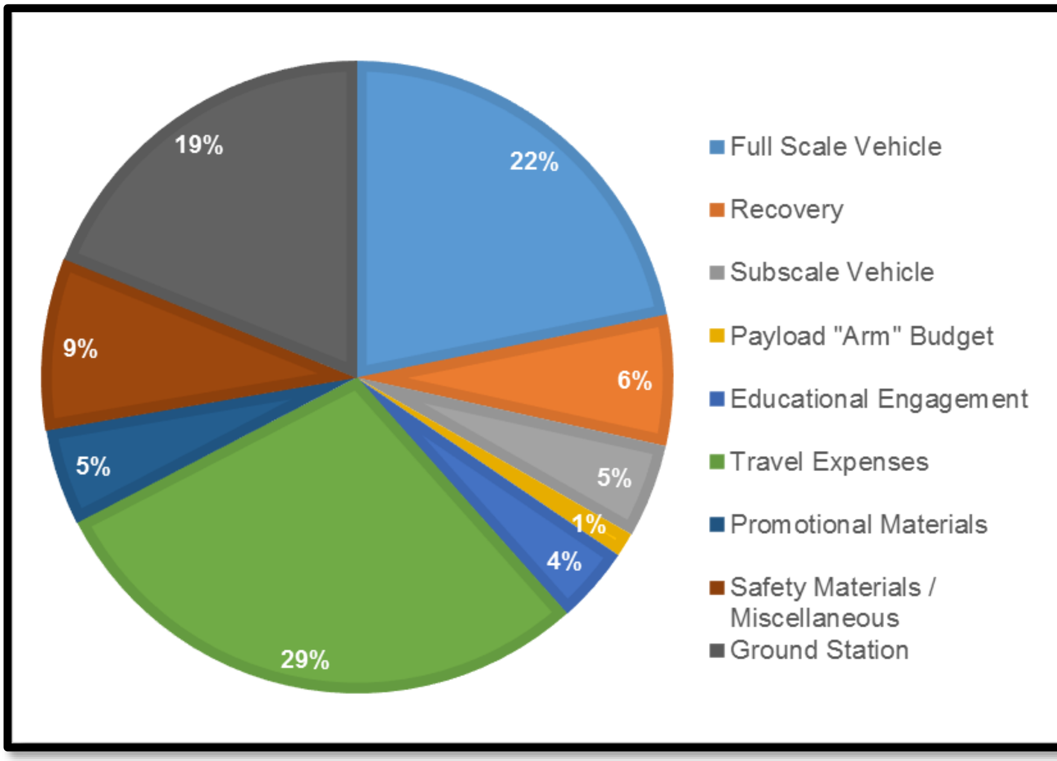
Travel Expenses Budget			
Description	**Quantity**	**Per Unit Cost**	**Total Cost**
Hotel (Competition in Huntsville, AL)	N/A	N/A	$4,000.00
Hotel (Testing at Thunderstruck in Ash Grove, IN)	N/A	N/A	$500.00
Gas (Competition in Huntsville, AL)	N/A	N/A	$1,000.00
Gas (For all out of tow n testing)	N/A	N/A	$250.00
		Overall Cost	**$5,750.00**

Promotional Materials Budget			
Description	Quantity	Per Unit Cost	Total Cost
Shirts	50	$8.00	$400.00
Stickers	500	$0.15	$75.00
Miscellaneous Kickstarter Rewards	N/A	N/A	$500.00
		Overall Cost	$975.00

Safety and Misc Budget			
Description	Quantity	Per Unit Cost	Total Cost
3M 20-Pack Sanding Respirators	3	$19.97	$59.91
Latex Disposable Gloves (100 count)	1	$9.34	$9.34
Loctite Instant Mix 5 min epoxy	20	$4.70	$94.00
Rocket Poxy	2	$38.25	$76.50
Misc Hardware	1	$500.00	$500.00
Additional Parts Bank	1	$1,000.00	$1,000.00
		Overall Cost	$1,739.75

Ground Station Budget			
Description	**Quantity**	**Per Unit Cost**	**Total Cost**
1515 Extrusion	360	$0.32	$115.20
1515 Extrusion	72	$0.32	$23.04
1515 Extrusion	36	$0.32	$11.52
Modified 10" Threaded rod	6	$3.88	$23.28
Stock Aluminum (0.25 inch)	1	$45.56	$45.56
Stock Aluminum Bar (0.375 thick)	1	$36.92	$36.92
5/16-18 Deep Hole Tap	1	$52.84	$52.84
Stock Aluminum Sheet (1/8 inch)	1	$147.34	$147.34
5/16-18 Button Head Screw (4inch length)	1	$11.63	$11.63
Anti-seize	1	$26.57	$26.57
5/16-18 Button Head Screw (0.375 inch)	3	$5.65	$16.95
5/16-18 Button Head Screw (1 inch)	3	$8.11	$24.33
Roll in T-nut with set screw	50	$1.58	$79.00
Double Slide in Economy T-nut	50	$0.53	$26.50
Inside Corner Gusset	24	$2.84	$68.16
2 Hole Flat Brace	12	$2.28	$27.36
End Piece 8020 Fastener	12	$1.12	$13.44
Aluminum Plate (0.25 thick)	1	$27.23	$27.23
Aluminum Plate (0.125 inch thick)	2	$24.17	$48.34
M3X0.5 screws	1	$10.72	$10.72
1/8 inch Dowel Pins 0.5 inch long	1	$8.03	$8.03
#8-32 Button head screws (0.75 inch long)	1	$5.91	$5.91
MSD Infused Nylon Rod (1 inch diameter)	2	$4.32	$8.64
Arduino	6	$30.00	$180.00
Motor Shield	2	$30.00	$60.00
Stepper Motor	4	$14.00	$56.00
Titanium Powder	0.18221292	$300.00	$54.66
1515 Extrusion	581	$0.32	$185.92
1530 Extrusion	206	$0.59	$121.54
Fasteners	1	$181.86	$181.86
Computer	1	$240.00	$240.00
12 V Lead Acid Batteries	3	$70.00	$210.00
Motor	2	$200.00	$400.00
1/2 Inch Lead Screw (6ft length)	2	$95.39	$190.78
Stock Aluminum (0.5 inch thick)	1	$21.27	$21.27
Stock Aluminum (0.3125 thick)	1	$14.28	$14.28
Stock Aluminum (0.3125 thick)	1	$11.00	$11.00
Nylon pads	1	$21.95	$21.95
Nylon pads	1	$14.05	$14.05
Shoulder Bolt	1	$26.22	$26.22
PCB Fabrication	5	$130.00	$650.00
		Overall Cost	**$3,498.04**

Overall Tentative Budget	
Budget	**Total Cost**
Full Scale Vehicle	$4,321.66
Recovery	$1,322.21
Subscale Vehicle	$946.08
Payload "Arm" Budget	$243.99
Educational Engagement	$778.79
Travel Expenses	$5,750.00
Promotional Materials	$975.00
Safety Materials / Miscellaneous	$1,739.75
Ground Station	$3,742.03
Overall Cost	**$19,819.51**



3) Funding

Kickstarter: For the past three competition years, River City Rocketry launched a Kickstarter site to connect with the community and gain support. Kickstarter is a fundraising platform that allows creative projects to find support from people near and far. River City Rocketry offered various rewards to its supporters such as custom science boards, team t-shirts, and even advertisement or logo space on the rocket so that sponsors have a personal connection to the team and project. The site was a huge success for the team over the years. By having a presence on Kickstarter, River City Rocketry has been able to share with the community their passion for science and rocketry.

Louisville Cardinal: The Louisville Cardinal is the independent student newspaper at the University of Louisville. The newspaper is widely read and respected by the students at the university. In years past, River City Rocketry took the opportunity to sit down for interviews with the Louisville Cardinal. This has allowed students from all over the university to see what the team is doing and the progress they have made.

Registered Student Organization: In the Spring of 2012, River City Rocketry became a Registered Student Organization (RSO) at the University of Louisville. Since receiving RSO status, the team has been able to reach out to the Student Senate as well as several of the university's Student Councils to gain support and increase the knowledge of rocketry at UofL. The team has received very positive feedback and was elected "Best New RSO" in its first year as an RSO.

4) Challenges and Solutions

Challenges	Solutions
Maintaining effective communication among team members.	The team began using a private blog on the team's website to post all information regarding design, educational engagement opportunities, and meetings.
Obtaining substantial funding.	Through several direct efforts with the University and private donors, the team aims to obtain ample funding to support all project facets.
Quality of Educational Engagement events.	The team will continue to focus on both large and small group outreach sessions. This year, the team will be teaching a custom six week curriculum to a select science heavy school.

Meeting report deadlines.	Immediately following report submission, the next report assignments will be posted. Documentation of each step along the way will make reporting and meeting deadlines easier.
Finding available launch opportunities.	The team continue its positive relationships with several NAR and TRA chapters within a 300 mile radius.
Gaining proper shop and manufacturing resources.	With the addition of the LVL1 and local shop facilities, the team should have access to a wide variety of manufacturing capabilities.
Making sure all members are doing a "fair" share of the workload.	The team will continue its "zero tolerance" policy for members who are not taking an active part in the project. We refuse to be a "résumé boosting" group for those who do not share the workload.

Table 20: Challenges and solutions to budgetary and outreach concerns.

5) Project Sustainability

We plan to ensure the continuation of River City Rocketry in three ways:

Local Exposure

The team will continue increasing awareness of the rocket project in the local area. This will be done through both community outreaches through local news media and making personal engagements with local schools. Currently, River City Rocketry has been published in multiple media outlets including the Louisville Cardinal independent student newspaper, CBS News Channel 18 in West Lafayette, Indiana, and NASA TV.

Figure 58: Interview with WDRB news station.

To further gain additional media exposure locally, the team will initiate follow-up stories from currently interested media as well as attempt intrigue the interest of unexplored media outlets. Thus far, the team initiated visits to multiple local schools, such as Olmsted North Academy and Lowe Elementary. We find one of the most rewarding methods of increasing exposure is through working with youth. Because of the success of last year, the team plans to host outreach events at the Louisville Science Center in the future so both student and adult visitors alike have the opportunity to gain hands-on experience in rocketry. Media coverage and publicity regarding previous years' achievements will likely gain the attention of newly interested participants; in turn, we hope to see an increase in attendance at these events in the future.

Figure 59: Educational outreach at the Kentucky Science Center

University Exposure

A secondary form of exposure is to highlight the importance of the rocket project. While local exposure increases future team membership and initial awareness, university exposure explains the importance of the rocket team as well as the excitement that ensues. To date, this was executed with a series of interest meetings which allowed previously uninvolved university students the opportunity to partake in a serious rocket project. Although many of these meetings are limited to initial design stages of the project, the meetings have been very successful, if not crucial, to the present and recent history of the rocket team. Interest meetings strongly encourage skeptical students to join and peak interest because the meetings are held during the exciting stage of design process. The team will also have the opportunity of presenting the project to incoming engineering students at an intro to engineering class and to all students at an RSO fair and an engineering fair.

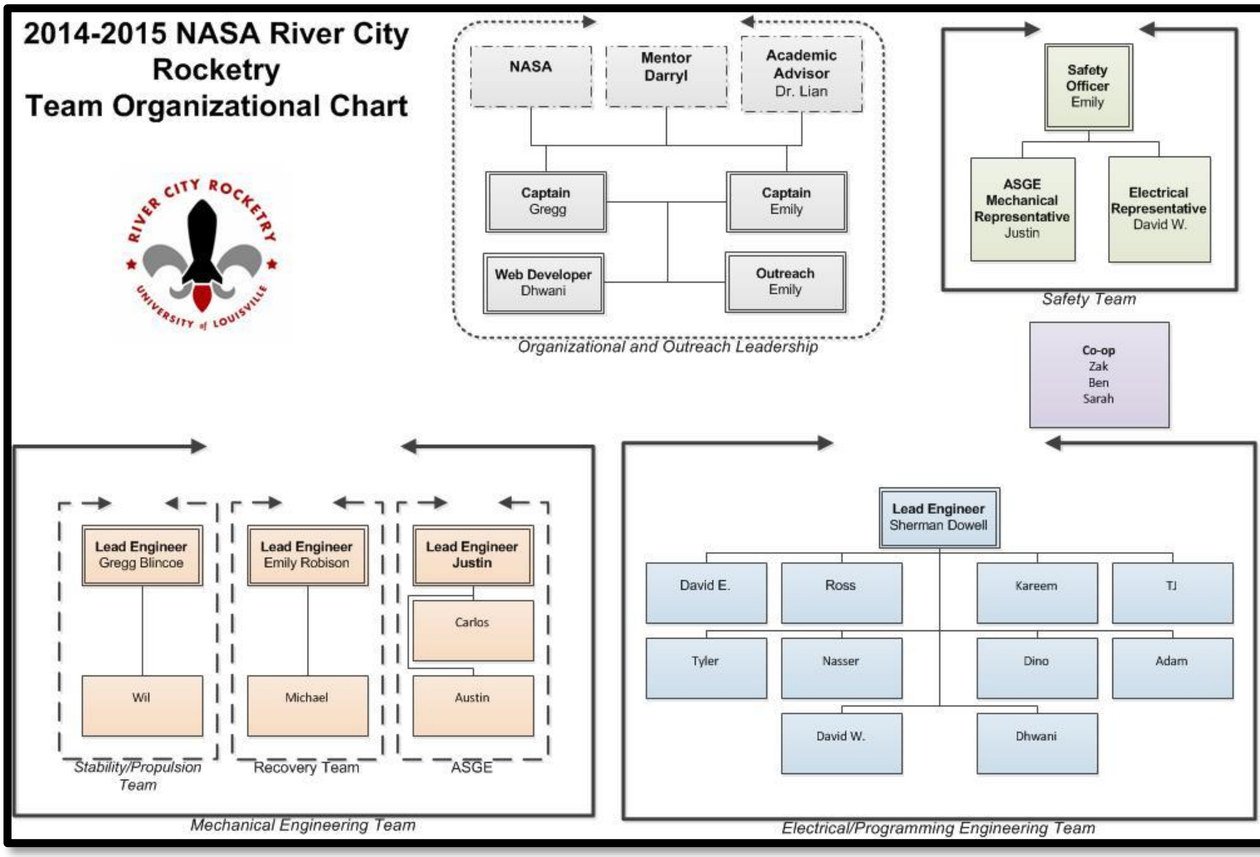
Securing Continuing Funding

Securing funds is fundamental to the core functions of the rocket project and team. Just as fuel launches the rocket, funding moves the project. The team plans to secure funds through two primary methods: community and individual contribution. Through public outreach, the team will continue gaining local community support for the project in terms of morale and monetary support. Through efforts of individual manufacturers for products used in construction of the rocket, continuation of assembling the physical rocket as well as providing learning experiences for team members and interested public can be sustained. Individual companies were used as means of funding again this year as local businesses and industries expressed excitement in aiding our program previously. Outside of approaching companies for support, the team successfully gained support from individuals, through private donations and through Amazon's Kickstarter program.

Section 9. Conclusion

After last year's success, River City Rocketry plans to attack the 2014-2015 NSL competition by utilizing the key skills and knowledge the team gained throughout the previous year's competition. The team understands continuous improvement in the quality of the design and manufacturing of the rocket. Therefore, the team will continue to strive for excellence in design efficiency, documentation, educational engagement programs, and safety awareness. River City Rocketry's goal this year is to create the most efficiently integrated launch vehicle and ground station by showcasing the team's engineering knowledge and cleverness. Our educational outreach has been designed to help spread our passion for rocketry throughout the community while teaching students the importance of math and science in the aerospace industry.

Appendix I – Supplemental Documentation



UNIVERSITY OF LOUISVILLE.
J.B. SPEED SCHOOL OF ENGINEERING

Austin

OBJECTIVE — **Fourth Mechanical Engineering Internship Position** — **May – August 2015**

EDUCATION

M. Eng in Mechanical Engineering — **Expected May 2016**
B.S. Mechanical Engineering — **Expected May 2015**
J.B. Speed School of Engineering, UofL, Louisville, KY
Dates Attended 8/2011 – present — Hours Completed: 98

High School Diploma
Bullitt East High School, Mt. Washington, KY — **May 2011**

SKILLS/ COURSEWORK

- SolidWorks
- AutoCAD
- Microsoft Access & VBA
- Microsoft SQL Server
- Web Systems Development
- MS Office Experience
- Robotics
- Mechanics of Materials
- Engineering Measurements

APPLIED EXPERIENCE

NASA Student Launch – River City Rocketry: Work with a team of fellow students to design, fabricate, test, and launch a high powered rocket. Serve as a member of the grounds team who designs our launch system and payload handling devices.

Robotics Regional Planning Coordinator: For the past 4 years have been a vital part of the local robotics regional tournament's planning and organization team. Managing and organizing prior to and during the event.

***FIRST* Robotics Team (Mentor):** For three seasons have organized and taught CAD training courses for students to use during the building process. Also worked alongside the students to help facilitate the design process.

***FIRST* Robotics Team (Student):** Worked to design, build, and program a robot for Competition in a six weeks with mentorship from industry professionals. Team Captain 2010-2011: managed schedules, the design process, and 10+ students.

EMPLOYMENT HISTORY

Altec Industries, Elizabethtown, KY — **Spring 2013, Fall 2013, Summer 2014**
Co-op
- Create and implement database systems to increase engineering efficiency
- Conduct training courses for new web based system concept
- Create and implement devices to aid production using Solidworks.
- Create detailed models to convey customer specifications using Solidworks.

Kentucky Golf Coaches Association, Mt. Washington, KY — **January 2011 - Present**
Website Engineering/Management
- Create and maintain entire website and custom content management system
- Design and maintain several web applications to serve the organization

University of Louisville Speed School, Louisville, KY — **January – July 2012**
Engineering Graphics Work Study
- Graded students work
- Instructed homework help sessions for struggling students

ACTIVITIES & HONORS

- UofL Dean's List
- 2010 Governor Scholar (Bellarmine Campus)
- Speed School Student Council (3rd Year Rep. – Spring '14, 4th Year Rep. – Fall '14)

REFERENCES — Furnished upon request

UNIVERSITY OF LOUISVILLE
J.B. SPEED SCHOOL OF ENGINEERING

Carlos

xxxx xxxxxxx xxxxxx
Louisville, KY, 402xx
(xxx) xxx-xxxx
xxxxxxxx@louisville.edu

EDUCATION

M. Eng. in Mechanical Engineering — Expected December 2016
B.S. in Mechanical Engineering — Expected December 2015
B.S. in Electrical Engineering — Expected December 2015
J.B. Speed School of Engineering, UofL, Louisville, KY — GPA: x.x/4.0

Honors High School Diploma — June 2010
Jeffersonville Sr. High School, Jeffersonville, IN

SKILLS/ COURSEWORK

- Thermodynamics I & II
- Mechanics of Materials with Lab
- Probability and Statistics
- Network Analysis I & II with Lab
- C, C++, C# Programming
- Matlab
- Orcad
- EagleCad PCB Design Software
- Machine Design I & II
- Fluid Dynamics I & II
- Logic Design with Lab
- Electronics I with Lab
- ANSYS
- SolidWorks
- Creo Parametric
- Fluent in Spanish & English

APPLIED EXPERIENCE

University Student Launch Initiative: Worked with a team in a NASA competition to design, build, and launch a reusable rocket with a scientific payload.
- **2011-2012:** Designed and built mass compensation system to stabilize rocket.
- **2012-2013:** Designed CO_2 deployment system to eject recovery parachutes. Designed and built the integration system for mounting payload electronics onto the rocket.
- **2013-2014:** Electronics Lead Engineer in charge of designing and building autonomous rover with hazard detection payload. Designed and built mechanical subsystem. Supervised and assisted with custom software package and electrical subsystems.

IRobiQ Robot Communication Project: Programmed an IRobiQ robot for a professor to perform primitive human-robot interactions, exchange commands, and execute actions based on data provided by humans or other robots.

Mickey R. Wilhelm Solar Flight Competition: Helped design and build an exclusively solar powered RC aircraft to fly a minimum distance of 100 yards. Won first place.

IEEE 2014 Student Hardware Competition: Designed and built mechanical system of a robot whose goal was to autonomously navigate an obstacle course and accurately shoot projectiles at targets. Helped design and assemble electrical system and write code for robot.

EMPLOYMENT HISTORY

GE Appliances, Louisville KY — September 2014 – Current
Technology Engineering Part-Time Co-op, Air and Water Products
- Aided in the Evaluation process for insourcing GE Zoneline air conditioners.

GE Appliances, Louisville KY — May 2014 – August 2014
Technology Engineering Co-op, Stainless Steel Dishwashers
- Analyzed finances and technical feasibility of projects for inclusion into the 2016 program.
- Interacted with suppliers, factory management, and other engineers on a daily basis.
- Designed parts using SolidWorks and prototyped them using 3D printers, also designed the tooling to prototype the parts in an injection molding machine.

GE Appliances, Louisville KY — August 2013 – December 2013
Technology Engineering Co-op, Gas Cooking Products
- Aided in the Design, Prototyping, and Evaluation for 2015 & 2016 Gas Range Programs.
- Obtained high-comfort level with power-tools to prototype sheet metal components.
- Created CAD models using Creo Parametric.

ACTIVITES & HONORS

- Dean's Scholar: 5 Semesters
- Member: Level 1 Hacker Space (LVL1)
- Member: University of Louisville Marching Band, 2010 – 2012

UNIVERSITY OF LOUISVILLE.
J.B. SPEED SCHOOL OF ENGINEERING

David

OBJECTIVE
Electrical Engineering Co-op Position

EDUCATION

M. Eng. in Electrical Engineering Expected May 2017
B. S. in Electrical Engineering Expected May 2016
B. S. in Computer Engineering & Computer Science Expected May 2016
J. B. Speed School of Engineering, UofL, Louisville, KY
Dates attended 8/2012 - Present Hours Completed: 96

High School Diploma
Louisville Male High School, Louisville, KY May 2010

SKILLS/ COURSEWORK

- Statistics
- Network Analysis I & Lab
- Logic Design & Lab
- Solid Edge
- Java/C/C++ Programming
- Microsoft Office
- AutoCAD
- Matlab/Simulink

APPLIED EXPERIENCE

Logic Design Lab: Design-oriented experiments on combinational and sequential logic circuits, using integrated circuit components.

EMPLOYMENT HISTORY

United Technologies Aerospace Systems, Rockford, IL January 2014 – May 2014
Co-op, Systems Department

- Analyze test data and isolate root cause problems with generator and power distribution performance on multiple programs
- Develop Matlab scripts to processes test data, generate reports, and automate generator software creation.
- Create comprehensive reports illustrating generator performance
- Support data acquisition in multiple test lab environments

Engineering Fundamentals Work-Study, Louisville, KY August 2013 – December 2013
Teacher Assistant

- Assist students with questions during lecture
- Proctor exams
- Responsible for sorting and grading material

Z-Xpress Car Wash, Louisville, KY July 2011 - August 2012
Car Detail

- Assumed responsibility of managerial duties as needed (handling customer complaints, resolving technical problems, motivating workers)
- Managed sales/Assisted customers
- Responsible for counting money and creating the day's report
- Assisted manager with fixing components (air compressor, pressure washers, chain, etc.)

ACTIVITIES & HONORS

- Gwong Sun Scholarship CECS Departmental Award
- Member of River City Rocketry (UofL Student Rocket Team)
- UofL J.B. Speed School Student Ambassador
- Active Member of the Sigma Chi Fraternity
- Speed School of Engineering Dean's Scholar
- Habitat for Humanity, volunteer
- Honors student
- Alumni of Freshman Lead (Bi-weekly leadership workshops)
- Speed School Student Council Volunteer

UNIVERSITY OF LOUISVILLE.
J.B. SPEED SCHOOL OF ENGINEERING

Emily

EDUCATION

M. Eng in Mechanical Engineering **Expected May 2016**
B.S. Mechanical Engineering **Expected May 2015**
J.B. Speed School of Engineering, UofL, Louisville, KY
Dates Attended 8/2011 – present

SKILLS/ COURSEWORK

- Statics
- Thermodynamics I/II
- Probability and Statistics
- Dynamics
- Measurements & Lab
- SolidWorks
- Mechanics of Materials
- Machine Design I
- Material Science
- Fluids I
- GD&T
- Energetics

APPLIED EXPERIENCE

River City Rocketry (University Student Launch Initiative):
2012-2013 Season:
Worked with a team in designing and building a reusable rocket with a scientific payload to launch exactly one mile above ground level. Technical reports detailing all systems were submitted, reviewed, and approved by a panel of NASA engineers at each milestone. The team placed second overall in the competition, while earning the awards of Best Overall Vehicle Design and Best Educational Outreach.

2013-2014 Season:
Worked with a team to design, build, and launch a dual stage rocket to 10,000 ft with a deployable rover. A member of the mechanical design team as well as the designated safety officer. As educational outreach coordinator, teach three classes a week to middle school students about space history, mechanics of flight, creating rocket simulations and building rockets. The team place third in overall competition and won the safety award.

EMPLOYMENT HISTORY

Raytheon Missile Systems, Tucson AZ **January 2013-May 2013**
Mechanical Engineering Junior Co-op, Mechanical Subsystems Directorate
- Redesigned components when problems arose in production.
- Developed test plan to verify redesigned components were acceptable.
- Worked directly with suppliers to ensure complete understanding of GD&T and improve drawings.

Raytheon Missile Systems, Tucson, AZ **August 2013-December 2013**
Mechanical Engineering Senior Co-op, Mechanical Subsystems Directorate
- Troubleshot designs while working on assembling first delivery product.
- Completed quality reports for assembly procedures.
- Modified models and drawings in Pro-E to present proposed changes to Engineering Review Board and Change Control Board.

Raytheon Missile Systems, Tucson, AZ **June 2014-May 2014**
Mechanical Engineering Senior Co-op, Mechanical Subsystems Directorate
- Managed company priority project on torque tolerances.
- Supported tolerance and structural analyses.
- Gathered and organized information to update warhead specifications and technical data package.

LEADERSHIP EXPERIENCE

Catholic Campus Ministry Leadership Team
Leadership Team
- Selected to stimulate Catholic Campus ministry at the University.
- Implementing and leading unique programs for growth in faith and community.
- Volunteer on service trip through spring break to assist a community in need.

ACTIVITIES & HONORS

- Raytheon: Team Achievement Award-First Delivery Team
- Dean's Scholar
- ASME, Member: *Mechanical Engineering ASME Student Section Award*

Gregg

EDUCATION	**M. Eng in Mechanical Engineering** **B.S. Mechanical Engineering** *J.B. Speed School of Engineering, UofL, Louisville, KY* Dates Attended 8/25/2008 – present	**Expected December 2016** **Expected July 2015** Hours Completed: 115
	High School Diploma *Trinity High School, Louisville, KY*	**May 2008**

SKILLS/ COURSEWORK

- Material Science
- Thermodynamics
- Fluid Dynamics
- Dynamics
- SolidWorks
- AutoCAD
- Machine Design
- C# Programming
- MATLAB Programming
- Basic Electrical Engineering
- Solid Edge
- Inventor Studios

Additional Skills

- Small Engine Repair
- Small Engine Teardown and Diagnostics
- Website Development and Management using HTML and .PHP programming
- High Powered Rocketry

APPLIED EXPERIENCE

UofL NASA Student Launch: In 2014, worked with the University of Louisville's Team, as co-captain, in the NASA Student Launch Competition and place 3rd overall. Working as captain for the 2014-2015 competition year, where the team is working to design the most efficient and technically challenging launch vehicle and ground station to take 1st place overall. Certified with a 'Level 1' and 'Level 2' high powered rocketry license through Tripoli Rocketry Association, Inc.

Personal Project: 3.0L Duratec Engine Diagnostics – Worked with a team to tear down and diagnose the exact cause of engine failure. Used specific equipment and tools, while following specified torque specs, to fully disassemble the engine. Examined all internal components of the engine and found the cause of failure to be a spun main rod bearing.

Website Projects: BlincoeandShutt.com – Design, developed and currently maintain websites for both 'Blincoe and Shutt: Aesthetic Family Dentistry'.

EMPLOYMENT HISTORY

FirstBuild, Louisville, KY **August 2014 – Present**
Mechanical Engineering Intern
- Educated new members of the goals and use of FirstBuild and its various equipment
- Trusted with designing various systems for the site as new projects come through the pipelines
- Authorized and entrusted to lock up shop

Topworx, Louisville, KY **August 2012 – May 2014**
Mechanical Engineering Co-Op
- Coordinated with multiple departments to ensure drawing revisions were made to the correct specifications and tolerances
- Entrusted in the research and design of various components
- Organized controlled documents for multiple presentations

ACTIVITIES & HONORS

- Habitat for Humanity, Volunteer
- High School: Member of National Beta Club
- High School: Member of National Honor Society
- Hobbies include troubleshooting, modifying and repairing automobiles, high powered rocketry, golfing, and skiing

REFERENCES Furnished upon request

UNIVERSITY OF LOUISVILLE.
J.B. SPEED SCHOOL OF ENGINEERING

Jonathon ___________

Permanent: ________________________

phone: ____________, **email: ________@louisville.edu**

OBJECTIVE

First Computer Engineering/ Science Co-op Position **January 5 – May 8, 2015**

EDUCATION

Bachelor of Science in Computer Engineering/Computer Science Expected May 2017
Master of Engineering in Computer Engineering Expected January 2018
J.B. Speed School of Engineering, UofL, Louisville, KY **GPA _____**
Dates attended 8/2012 - present Hours Completed: 66
Responsible for 100% of tuition costs

High School Diploma May 2012
Nelson County High School, Bardstown, KY **GPA _____**

SKILLS/ COURSEWORK

Technical Skills/Relevant Coursework

- C, C++ and Java
- Electrical Engineering*
- Webpage Design
- Microsoft Office
- Logic Design*
- Python
- Differential Calculus
- Discrete Structures
- Data Structures*
- Intro to Computer Science
- HTML

*Fall 2014

Additional Skills

- Event and activity organizing
- Ballroom and swing dancing

APPLIED

Course Project: Worked with a partner to research and design a program to run multiple array-based games and keep track of scores. Used **C programming**.
Independent Project: Website Design. Used **HTML** to design personal website.
Python: Created Pig Latin translator and file input/output programs.
Leadership: Organizes meetings and dances for Dancing with the Cards as well as for community service events.

WORK EXPERIENCE

Wendy's Louisville, KY
Sandwich Maker, Chef, Cashier, Coordinator July 2011 – Jan 2014

- Served high levels of customers with order times < 120 seconds
- **Trained** new employees
- Stocked freezers, stations, closets
- **Helped store receive three 100s in a row on cleanliness rating and a Best-In-the-District Award**

VOLUNTEER EXPERIENCE

University of Louisville, Dancing with the Cards Louisville, KY
President September 2014 – present
Advertises to students and potential new members, holds and engages in meetings. In charge of setting up and organizing dance events and selections of dances for the semester.

University of Louisville, Triangle Fraternity Louisville, KY
Community Service Chair April 2014 – present
-Security Team, Oldham County Project Grad; ensured safety by directing students and traffic.
-Dare to Care, distributed food to low-income housing complexes.
-Volunteer at Masonic Homes of Kentucky; walking residents to Bingo, teaching computer class, engaging in communications with Outreach Director.

ACTIVITIES & HONORS

- River City Rocketry, Electronics Team Programmer*
- **President**, Dancing with the Cards
- **Proxy Vice President** of Administration, Speed School Student Council
- Community Service Chair, Triangle Fraternity
- **Dean's List**, Fall 2012 and Spring 2013
- Helper, Leadership Advantage

Justin

EDUCATION

B.S. in Mechanical Engineering — Expected May 2015
J.B. Speed School of Engineering, UofL, Louisville, KY
Dates attended August 2012 - Present — Hours Completed 151; Transfer Hours 94

Associates of Science — May 2008
Elizabethtown Community and Technical College, Elizabethtown, KY

SKILLS/COURSEWORK

- Advanced Design Methods
- Dynamics
- System Dynamics and Controls
- Machine Design I
- Matlab Programming
- SolidWorks
- Fluid Mechanics and Dynamics
- Machine Design II

APPLIED EXPERIENCE

UofL USLI: Trainee with the UofL U.S.L.I. team. Designed custom assembly stands for final vehicle assembly. Determined if it would be possible to airfoil the vehicle fins for competition
Solar Flight Team: Fabricated the solar flight aircraft for the mechanical engineering team at UofL. The team placed first.
UofL USLI: Team captain of the UofL U.S.L.I. team. Lead team throughout competition. Designed and fabricated custom recovery scheme. Team finished third in the NASA Student Launch competition.

EMPLOYMENT HISTORY

Samtec, New Albany, Indiana — June 2013-Present
Intern with Process Controls Department
- Reviewed data to determine if processes were creating acceptable product.

Intern with Customer Quality Department
- Determined failure modes of returned failed product.
- Created tests to replicate unique environments or to accelerate part failure
- Designed solutions to avoid repeated failures in the future.
- Design and ran tests to verify solutions were adequate

Intern with Mainstream Tooling Department
- Designed and optimized components for automatic machinery
- Ran systems analysis to verify existing components would function for upgraded machines

J.B. Speed School of Engineering, UofL, Louisville, KY — January – May 2013
Student worker, Engineering Fundamentals Department
- Graded assignments
- Lead after class study session for engineering graphics

REFERENCES

Furnished upon request

UNIVERSITY OF LOUISVILLE
J.B. SPEED SCHOOL OF ENGINEERING

Kareem

EDUCATION

M. Eng. in Electrical and Computer Engineering Expected December 2014
J.B. Speed School of Engineering, UofL, Louisville, KY

B.S. in Electrical and Computer Engineering, minor in Mathematics Earned May 2014
J.B. Speed School of Engineering, UofL, Louisville, KY

- Degree with Highest Honors
- UofL Trustee's Scholarship, James D. Barnhouse Scholarship
- Dean's Scholar: 5 semesters, Dean's List: 3 semesters

SKILLS/ COURSEWORK

- Embedded Systems Programming
- Logic Design & Lab
- Control System Principles & Lab
- Network Analysis I, II & Lab
- Linear Systems and Signals
- Autonomous Robotics & Lab

APPLIED EXPERIENCE

Embedded Programming: Design and implementation of embedded systems concepts and hardware interfacing using Motorola and Renesas microcontrollers.
Analog IC Lab: Design, layout, and test analog temperature sensor IC using SPICE and L-Edit.
Autonomous Robotics Lab: Implement controls theory in creating autonomous robots to complete objective based exercises.
VLSI Lab: Analyze and model CMOS logic circuits using SPICE and Tanner Tools.
Control Systems Lab: Design, simulate, and verify feedback compensators to controls systems using Matlab and Simulink.

EMPLOYMENT HISTORY

University of Louisville, Louisville, KY
Student Assistant, Electrical and Computer Engineering Department February 2014 – May 2014

- Develop and test Android application to collect and organize GPS, time, and GSR data
- Design and execute stress measurement experiments

GE Appliances, Louisville, KY; Assignment Leader: Richard Whalen
Technical Engineering Co-op, Software Engineer May 2013 – August 2013

- Rewrite Oven Light module for Barracuda firmware team, applying GE coding standards in embedded C to increase legibility and reliability
- Develop CPU utilization test code for QF analysis to ensure acceptable usage statistics
- Aid engineers to investigate and root cause calibration failures in Roper flashing process

GE Appliances, Louisville, KY; Assignment Leader: Leo Hodapp
Technical Engineering Co-op, Design Engineer August 2012 - December 2012

- Design a flashing fixture for control boards to decrease overall flashing time by 900% to increase throughput
- Write embedded firmware to increase the security of dishwashers
- Work alongside engineers to develop new product with exposure to source code, design, and requirement specifications

GE Appliances, Louisville, KY; Assignment Leader: Mark Brian
Technical Engineering Co-op, Design Engineer January 2012 - May 2012

- Interpret circuit schematics and utilize them to create load boxes
- Aid engineers to develop Javascript code for simplification of Nucleus bulk update process, reducing required applications from three to one and improving cycle time by over twofold
- Conduct testing of Nucleus firmware

ACTIVITIES & HONORS

Vice Chair, UofL IEEE Student Branch Spring 2013 – Spring 2014
Winner, James D. Barnhouse Scholarship Award, Spring 2014
Winner, UofL Autonomous Robotics Competition Fall 2013
Member, River City Rocketry Summer 2013 – Spring 2014 (Awarded 3rd place at NASA SLI 2014)
Captain, IEEE Robotics Team Fall 2013 – Spring 2014
Researcher, Human-Machine Interactions Spring 2012, Summer 2013
Outstanding Achievement Award ECE 220 Fall 2011
Volunteer, Open Hands Committee Fall 2012, Summer 2013

UNIVERSITY OF
LOUISVILLE.
J.B. SPEED SCHOOL OF ENGINEERING

Ross

OBJECTIVE	First Electrical Engineering co-op position	**January 5 – May 8, 2015**

EDUCATION

M. Eng. in Electrical Engineering — Expected May 2018
B. S. in Electrical Engineering — Expected May 2017
J. B. Speed School of Engineering, UofL, Louisville, KY
Dates attended 8/2013 - Present — Hours Completed:

High School Diploma
St. Henry District High School, Erlanger, KY — May 2013

SKILLS/ COURSEWORK

- Statistics
- Network Analysis I & Lab
- Logic Design & Lab
- Physics I & II & Labs
- C++ Programming
- C Programing
- AutoCAD
- Microsoft Office

Additional Skills
- Computer, PCB, PLC and minor construction skills

APPLIED EXPERIENCE

Logic Design Lab: Design-oriented experiments on combinational and sequential logic circuits, using integrated circuit components
Eagle Scout Project: Used AutoCAD to design, organize, fundraise, and lead construction of an Eagle Scout Project
River City Rocketry: Member of University of Louisville Rocket Team. Electrical Engineer working with payload, platform and electronic hardware

EMPLOYMENT HISTORY

Silverlake Family Center, Eralnger, KY
Lifeguard — Summer 2010 - Spring 2013
- Lifeguard for indoor and outdoor pools
- Enforced rules and provided rescue and medical assistance
- Maintained facility discipline to help staff achieve a State-of-the-Art Facility Award from the National Aquatic Safety Company

FedEx Ground, Independence, KY
Package Handler/Unloader — Summer 2013
- Worked with others to achieve high marks and exceptional unload rates.
- Sorted and organized incompatible packages for proper processing
- Maintained a clean and organized working environment

University of Louisville Library, Louisville, KY
Desk Assistant for Media Resources Center — Summer 2014 - Present
- Assisted patrons with electronic rentals/library needs
- Maintained and repaired broken and disabled electronics
- Worked with team to maintain the library's highest standards

ACTIVITIES & HONORS

- Work 15 hours per week
- Boy Scouts of America, Eagle Scout, Troop 726 Quartermaster
- University of Louisville Rocket Team Member, Electrical Team
- Volunteer for Habitat for Humanity and the Kentucky Humane Society
- Hobbies include Frisbee Golf, troubleshooting and repairing electronics

REFERENCES Furnished upon request

Sherman

Objective

A position within the field of electrical engineering creating solutions to current challenges.

Education

University of Louisville — Louisville, Kentucky
Master of Science in Electrical Engineering — **Expected Spring *2017***
85 credit hours completed

Jefferson Community and Technical College — Louisville, Kentucky
General Education Coursework — *Sep 2011- May 2013*

Technical Knowledge and Coursework

MultiSim/ Pspice Simulations	Circuit Design	**KiCAD PCB Layout**
C++/Python Programming	Arduino/Atmel	AC/DC Circuit Analysis
Digital Communication	**Embedded Systems**	Independent Research
Isolated Sub-Circuit Analysis	Logic Design	Component Sourcing
Accelerated Life Product Testing	Surface Mount Soldering	**Wire Harness Design**

Applied Projects

Microcontroller based Acoustic Device for Making and Analyzing Noise — *May 2014- Present*

- Develop educational coursework
- Assist faculty research with independent coursework
- Create future "Embedded Systems" coursework
- Verify hardware changes in educational development hardware
- Report incremental progress to instructor/fellow researchers

NASA University Student Launch Initiative — *Sep 2013- May 2014*

- Designed electrical PCB to meet needs of robotic challenge
- Implemented circuitry designed to:
  - **Regulate microcontroller power supply**
  - **Integrate sensors**
  - **PWM control of brushless motors**
- Tested and qualified discrete sub-circuits for final use
- Drove final design from schematic to finished product
- Final printed circuit boards manufactured by Advanced Circuits

1

Honors and Community

- Engaged middle school students with Science, Technology, Math, and Science outreach
- Continuing Dean's List student *(Fall 2011 – Present)*
- Competed nationally in NASA University Student Launch Initiative

Previous Work Experience

General Electric (Control Panels LLC) — Louisville, KY

Electronics Technician — *Feb 2011-Sep 2011*

- Assisted engineers with development of Mission One dishwasher program.
- Designed, construct and utilize test fixtures and harnesses for HW/SWapplication.
- Supported/Maintained accelerated testing of dish systems (Root cause, fault tracking).
- Drove wide scope of investigations and improvements to closure.
- Integrated hardware and software updates to all machines in the plant and in the field.
- Cooperated with sub-system teams to attain common goals for the Piranha Dish team.

Geek Squad City

Computer Technician — *Aug 2008- Feb 2011*

- Diagnosed hardware and software issues on customer's laptops.
- Ordered minimum but correct parts that return laptops to complete functioning order.

Flextronics

Cell Phone Repair Technician — *May 2008- Aug 2008*

- Repaired Sanyo cell phones and diagnosed hardware faults to a component level.
- Worked in teams to meet and exceed productivity goals.

Ambush Sound Company

Head Lighting Technician — *Dec 2004- May 2008*

- Implemented mobile lighting setup for concert stage presentations.
- Setup procedures for dimmer modules, lighting cans, and control boards.
- Operated lighting show during concert presentations.

Interests

- Downtime with family
- Self-taught guitarist
- Youth education
- Maintaining Fitness

REFERENCES FURNISHED UPON REQUEST

UNIVERSITY OF LOUISVILLE.
J.B. SPEED SCHOOL OF ENGINEERING

Wil

EDUCATION

M. Eng. in Mechanical Engineering Expected May 2018
B.S. in Mechanical Engineering Expected May 2017
J.B. Speed School of Engineering, UofL, Louisville, KY
Dates attended August 2013 - Present Hours Completed: 67

High School Diploma
Martha Layne Collins High School, Shelbyville, KY May 2013
Graduated with a 4.19 GPA and received Suma Cum Laude honors

SKILLS/ COURSEWORK

- Statics
- Material Science w/ lab
- Thermodynamics I
- Calculus and Differential Equations
- C Programming
- Microsoft Suite
- AutoCAD
- SolidWorks
- Physics I & II

Additional Skills

- Thrive in team based environments
- Substantial leadership experience
- Exceptional work ethic
- Experience with wide variety of power tools
- Experience locating problems and applying my conceptualized solutions
- Knowledge of basic structural design and the steps it takes for a project to be approved by the local government and by other safety standards.

APPLIED EXPERIENCE

Eagle Scout Project- I designed and constructed a Pavilion for the Dorman Center for kids. The pavilion covered an area of 80 square feet and was 12 feet tall. Assisted by other members of the troop, the project required 120 hours to complete.

ME 180 Projects-

- designed a plate for a transmission that allowed fluid flow through it using solid works.
- designed a bicycle transmission that would benefit a targeted rider using solid works and excel.
- designed a tool that would allow a "home mechanic" to separate components of an exhaust pipe using solid works.

River City Rocketry-

- Member of University of Louisville's student led rocket team
- Currently working on the propulsion systems of the rocket along with helping to design the air frame of the rocket.

FRA (Facilities Resident Assistant)- As an FRA my main responsibilities are to maintain UofL's residence halls from a technical side. Since my job is concerned with facilities, a team of six other workers and I are called whenever there is a problem concerning physical aspects of a residence hall. Problems that occur within residence halls are spontaneous and completely unplanned and my job as an FRA is to solve these problems hastily and efficiently. From day to day activities I am expected to work within my team and with my supervisor to not only solve problems dealing with physical aspects of residence halls but also in conveying other technical information to my supervisor, physical plant workers, residents, and other housing employees on a daily basis.

EMPLOYMENT HISTORY	**University of Louisville Housing Department**, Louisville, KY	
	Facilities Residential Assistant	August 2014 -Present
	• Maintain residence halls • Work with a team of Facilities Assistants and physical plant workers in order to upkeep the quality of on campus living. • Carry out various task asked of me for the housing department. • Input work orders into a campus-wide electronic database. • Interact and assist various contracted services that maintain the residence halls. • Assist supervisor in various administrative tasks in the central housing office. • Inform and educate students and undergraduate staff on policies and procedures in the facilities department.	
	Cattleman's Roadhouse, Shelbyville, KY	
	Busboy	November 2012- August 2013
	• Clean tables • Assisted waiters with their responsibilities • Worked with managers to maintain store	
ACTIVITIES & HONORS	• Work 15 hours per week as an FRA	
	• Dean's List	August 2013 - Present
	• High school freshman math tutor	
	• Eagle Scout of America	May 2011
	• National Society of Collegiate Scholars member • National Honors Society member • TSA Music Production State champion • University of Louisville Tennis Club member	
REFERENCES	Furnished upon request	

Appendix II – Safety Risk Assessments

See following pages for competed safety risk assessments.

Lab and Machine Shop Risk Assessment						
Hazard	**Cause/ Mechanism**	**Outcome**	**Severity Value**	**Probability Value**	**Risk Level**	**Mitigation**
Using power tools and hand tools such as blades, saws, drills, etc.	1. Improper training on power tools and other lab equipment.	1a. Mild to severe cuts or burns to personnel. 1b. Damage to rocket or components of the rocket. 1c. Damage to equipment	2	4	Low	1. Individuals must be trained on the tool being used. Those not trained should not attempt to learn on their own and should find a trained individual to instruct them. 1. Safety glasses must be worn at all times. 1. Sweep or vacuum up shavings to avoid cuts from debris.
Sanding or grinding materials.	1. Improper use of PPE. 2. Improper training on the use of a Dremel tool.	1a. Mild to severe rash. 1b. Irritated eyes, nose or throat with the potential to aggravate asthma. 2. Mild to severe cuts or burns from a Dremel tool and sanding wheel.	3	3	Low	1a. Long sleeves should be worn at all times when sanding or grinding materials. 1b. Proper PPE should be utilized such as safety glasses and dust masks with the appropriate filtration required. 2. Individuals must be trained on the tool being used. Those not trained should not attempt to learn on their own and should find a trained individual to instruct them.
Working with chemical components resulting in mild to severe chemical burns on skin or eyes, lung damage due to inhalation of toxic fumes, or chemical spills	1. Chemical splash. 2. Chemical fumes.	1. Mild to severe burns on skin or eyes. 2. Lung damage or asthma aggravation due to inhalation of fumes,	2	4	Low	MSDS documents will be readily available at all times and should be thoroughly reviewed prior to working with any chemical. 1. Nitrile gloves shall be used when handling hazardous materials. 1. Personnel are familiar with locations of safety features such as an eye wash station.

						1. Safety goggle are to be worn at all times when handling chemicals. 2. When working with chemicals producing fumes, appropriate precautions should be taken such as working in a well-ventilated area, vapor masks, fume hood.
Damage to equipment while soldering	1. Soldering iron is too hot 2. Prolonged contact with heated iron	The equipment could become unusable. If parts of the payload circuit get damaged, they could become inoperable.	3	3	Low	1. The temperature on the soldering iron will be controlled and the team is experienced in soldering. The soldering iron will be set the correct temperature 2. For temperature sensitive components we can use the sockets to solder our ICs to.
Dangerous fumes while soldering	1. Use of leaded solder can produce toxic fumes 2. Leaving soldering iron too long on plastic could cause plastic to melt producing toxic fumes.	Team members could become sick due to inhalation of toxic fumes. Irritation could also occur.	3	3	Low	1. The team will use well ventilated areas while soldering. Fans will be used. 2. The soldering iron will only be on parts for the recommended amount of time.
Potential burns to team members while soldering	Team members do not pay attention while soldering	The team member could suffer minor to severe burns.	4	3	Low	Team members will be encouraged to follow all safety protocols related to soldering.

Overcurrent from power source while testing	Failure to correctly regulate power to circuits during testing	Team members could suffer electrical shocks which could cause burns to heart arrhythmia	2	4	Low	The circuits will be analyzed before they are powered to insure they don't pull too much power. Power supplies will also be set to the correct levels.

Table 21: Lab and machine shop risk assessment.

AGSE -Launch Pad Functionality Risk Assessment						
Hazard	**Cause/ Mechanism**	**Outcome**	**Severity Value**	**Probability Value**	**Risk Level**	**Mitigation**
Unstable launch platform	Un-level ground or improperly staked launch tower.	If the launch pad is unstable while the rocket is leaving the pad, the rocket's path will be unpredictable.	1	3	Moderate	Confirm that all personnel are at a distance allowed by the Minimum Distance Table as established by NAR. Ensure that the launch pad is stable and secure prior to launch. Outriggers will be added to increase the footprint of the launch platform providing increased stability.
Unleveled launch platform	Un-level ground or improperly leveled launch tower.	The launch tower could tip over during launch, making the flight of the rocket unpredictable.	1	4	Moderate	The launch pad should always be placed on a level surface. Confirm that all personnel are at a distance allowed by the Minimum Distance Table as established by NAR. Outriggers will be implemented to allow for fine adjustments on un-level terrain.
Rocket gets caught in launch tower or experiences high friction forces	Misalignment of launch tower joints	Rocket may not exit the launch tower with a high	2	5	Low	During setup, the launch tower will be inspected for a good fit to the rocket. A spare piece of airframe is taken out and run through the launch pad. If any resistance is noted, the joints of the tower can be moved to improve the

						alignment of the tower, allowing the rocket to freely move through the tower. Also, graphite is applied to each beam in order to reduce any frictional forces on the rocket.
Sharp edges on the launch pad	Manufacturing processes.	Minor cuts or scrapes to personnel working with, around, and transporting the launch tower.	4	3	Low	Sharp edges of the launch pad should be filed down and de-burred.
Brush fire caused by rocket during launch	Dry launching conditions.	Small brush fire.	4	3	Low	Wait until the range safety officer has cleared personnel to approach the launch pad and extinguish any fires that have been started. The launch tower also has a blast deflector to prevent brush fires.
Loss of power during vehicle erection	Faulty circuit	Vehicle crashes back to horizontal position.	1	4	Moderate	The power screw geometry combined with the gearboxes resistance to back drive will prevent the tower from moving. To lower the vehicle the motors that drive the system must be run in reverse.
Lead screw shears during actuation	1. Undersized screw selection. 2. Material failure.	Platform crashes back to horizontal position.	1	4	Moderate	All actuation devices will be analyzed and have a factor of safety of at least 2.

Table 22: AGSE - Launch pad functionality risk assessment.

Stability and Propulsion Risk Assessment						
Hazard	**Cause/ Mechanism**	**Outcome**	**Severity Value**	**Probability Value**	**Risk Level**	**Mitigation**

Motor fails to ignite.	1. Faulty motor. 2. Delayed ignition. 3. Faulty e-match. 4. Disconnected e-match.	1,3,4. Rocket will not launch. 2. Rocket fires at an unexpected time.	3	4	Low	Follow NAR safety code and wait a minimum of 60 before approaching the rocket to ensure that the motor is not simply delayed in launching. If there is no activity after 60 seconds, have the safety officer check the ignition system for a lost connection or a bad igniter. If this does not fix the failure mode, be prepared to remove the ignition system from the rocket motor, retrieve the motor from the launch pad and replace the motor with a spare. Igniters have been securely installed throughout the season, having a 100% success rate.
Motor explodes on the launch pad.	Faulty motor	Rocket and interior components significantly damaged.	1	5	Low	Confirm that all personnel are at a distance allowed by the Minimum Distance Table as established by NAR in order to ensure that no one is hurt by flying debris. Extinguish any fires that may have been started when it is safe to approach. Collect all debris to eliminate any hazards created due to explosion. The motors the team have selected are from a reliable supplier. The team has had a 100% success rate.
Rocket doesn't reach high enough velocity before	1. Rocket is too heavy. 2. Motor impulse is too low.	1,2. Unstable launch.	1	5	Low	Too low of a velocity will result in an unstable launch. Simulations are run to verify the motor selection provides the necessary

leaving the launch pad.	3. High friction coefficient between rocket and launch tower.					exit velocity. The launch pad will be coated in graphite prior to each launch in order to minimize friction. Should the failure mode still occur, the issue should be further examined to determine if the cause was due to a faulty motor or in the booster needs to be redesigned.
Fins shear during flight	Insufficient adhesion during installation resulting in a failure in the epoxy.	Unstable rocket, causing the flight path to become unpredictable.	1	5	Low	Confirm all personnel are alert and at a distance allowed by the Minimum Distance Table as established by NAR. Examine external epoxy beads for cracks prior to launch.
Airframe buckles during flight	Airframe encounters stresses higher than the material can support.	Rocket will become unstable and unsafe during flight.	1	5	Low	Through prediction models, appropriate material selection, and a secure factor of safety, this failure mode can be nearly eliminated.
Internal bulkheads fail during flight	Forces encountered are greater than the bulkheads can support.	1. Internal components supported by the bulkheads will no longer be secure. 2. Parachutes attached to bulkheads will be left ineffective.	1	5	Low	The bulkheads will be designed to withstand the force from the motor firing with an acceptable factor of safety. 1. Electrical components could be damaged and will not operate as intended during flight. 2. A catastrophic failure is likely. A portion of the rocket or the fairing would become ballistic.

Table 23: Stability and propulsion risk assessment.

Recovery Risk Assessment

Hazard	Cause/ Mechanism	Outcome	Severity Value	Probability Value	Risk Level	Mitigation
Rocket does not split to allow for recovery system deployment.	1. Not enough pressurization to break shear pins. 2. Coupling has too tight of fit.	1,2. Rocket follows ballistic path, becoming unsafe.	1	5	Low	1. The separation section of the rocket will be designed to ensure that the black powder charge provides sufficient pressurization, allowing the rocket to separate and deploy its recovery system. 2. The coupling between the sections will be sanded down to have a loose fit, preventing the two sections from getting stuck together during flight. If separation does not occur, the rocket will follow a ballistic path, becoming unsafe. All personnel at the launch field will be notified immediately.
Altimeter or e-match failure	Parachutes will not deploy.	Rocket follows ballistic path, becoming unsafe.	1	5	Low	Multiple altimeters and e-matches are included into systems for redundancy to eliminate this failure mode. Should all altimeters or e-matches fail, the recovery system will not deploy and the rocket will become ballistic, becoming unsafe. All personnel at the launch field will be notified immediately.
Parachute does not open	1. Parachute gets stuck in the deployment bag. 2. Parachute lines become tangled.	1,2. Rocket follows ballistic path, becoming unsafe.	1	4	Moderate	Deployment bags will be specially made for the parachutes. This will allow for an organized packing that can reduce the chance of the parachute becoming stuck or the lines becoming tangled. Should the rocket become ballistic, all

						personnel at the launch field will be notified immediately.
Rocket descends too quickly	Parachute is improperly sized.	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2	5	Low	The parachutes have each been carefully selected and designed to safely recover its particular section of the rocket. Simulations have been performed to validate the design.
Rocket descends too slowly	Parachute is improperly sized.	The rocket will drift farther than intended, potentially facing damaging environmental obstacles.	3	3	Low	The parachutes have each been carefully selected and designed to safely recover its particular section of the rocket. Should this be too large, the parachute will have to be resized.
Parachute has a tear or ripped seam	Parachute is less effective or completely ineffective depending on the severity of the damage.	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2	5	Low	Through careful inspection prior to packing each parachute, this failure mode should be eliminated.
Parachute or chords become burnt	Parachute is less effective or completely ineffective depending on the severity of the damage.	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2	5	Low	Through careful packing and the appropriate use of Nomax material, this failure mode is unlikely.

Recovery system separates from the rocket	1. Bulkhead becomes dislodged. 2. Parachute disconnects from the U-bolt.	1,2. Parachute completely separates from the component, causing the rocket to become ballistic.	1	5	Low	The cables and bulkhead connecting the recovery system to each segment of the rocket are designed to withstand expected loads with an acceptable factor of safety. Should the rocket become ballistic, all personnel at the launch field will be notified immediately.

Table 24: Recovery risk assessment.

Cache Capsule Risk Assessment						
Hazard	**Cause/ Mechanism**	**Outcome**	**Severity Value**	**Probability Value**	**Risk Level**	**Mitigation**
Lower airframe does not eject from the rocket	1. Nylon shear pins do not fully shear. 2. Friction coefficient between upper and lower airframe is too high.	Cache capsule will be unable to be jettisoned from the rocket. Rocket will still completely recover.	1	4	Moderate	1. Black powder charges will be designed to overcome the shear strength of the shear pins, allowing the rocket to separate easily. 2. The coupling between the two sections will be sanded down to have a loose fit, preventing the two sections from getting stuck together during flight.
Battery in altimeter housing dies.	1. Use past the normal life of the battery. 2. Extremely cold weather	1,2. Ejection charges will not fire, preventing the rocket from splitting and the rover being deployed.	2	5	Low	Batteries will be checked for sufficient charge during launch day preparations. If the launch is delayed and the batteries have been left on, batteries should be rechecked for a sufficient charge to power the systems.
E-match fails	1. E-match become dislodged. 2. Faulty e-match.	1,2. Ejection charges will not fire, preventing the rocket from	1	5	Low	Redundant charges will be used. If one e-match fails, there will be a back-up that will still ignite the charge.

		splitting and the rover being deployed.				
Cache does not eject from the rocket	Non-explosive separation device does not operate properly.	Cache remains in the rocket and one mission criteria is not met.	2	3	Moderate	Ground testing will be performed in order to ensure that the system works prior to any flight tests.

Table 25: Cache capsule risk assessment.

Vehicle Assembly Assessment						
Hazard	**Cause/ Mechanism**	**Outcome**	**Severity Value**	**Probability Value**	**Risk Level**	**Mitigation**
Rocket drop (INERT)	Mishandling of the rocket during transportation.	Minimal damage and scratches to components of the rocket.	4	5	Low	The rocket has been designed to be durable in order to survive loads encountered during flight and upon landing. Careful handling should be practiced while transporting the rocket.
Rocket drop (LIVE)	Mishandling of the rocket during transportation.	1. Minimal damage and scratches to components of the rocket if no charges go off. 2. Charges prematurely go off, resulting in a serious safety threat to personnel in the area and significant damage to the rocket.	1	5	Low	The rocket has been designed to be durable in order to survive loads encountered during flight and upon landing. Careful handling should be practiced while transporting the rocket.

Black powder charges go off prematurely	1. Altimeters send a false reading. 2. Open flame sets off charge.	1,2. Charges prematurely go off, resulting in a serious safety threat to personnel in the area and significant damage to the rocket.	1	5	Low	All electronics will be kept in their OFF state for as long as possible during preparation. Open flames and other heat sources will be prohibited in the area.
Seized nut or bolt due to galling or cross threading	Repetitive uninstalling and reinstalling of parts made of materials prone to galling.	Component becomes unusable, potentially ruining expensive, custom machined parts. Amount of rework depends on the location and component that seized.	2	4	Low	Through proper choice in materials, appropriate pre-load, and proper installation, the risk of galling can be eliminated.

Table 26: Vehicle assembly risk assessment.

Environmental Hazards to Rocket Risk Assessment						
Hazard	**Cause/ Mechanism**	**Outcome**	**Severity Value**	**Probability Value**	**Risk Level**	**Mitigation**
Low cloud cover.	N/A	Unable to test entire system.	1	4	Moderate	When planning test launches, the forecast should be monitored in order to launch on a day where weather does not prohibit launching or testing the entire system.

Rain	N/A	1. Unable to launch. 2. Damage electrical components and systems in the rocket.	1	4	Moderate	1. When planning test launches, the forecast should be monitored in order to launch on a day where weather does not prohibit launching or testing the entire system. 2. Have a plan to place electrical components in water tight bags. Have a location prepared to store the entire rocket to prevent water damage.
High winds	N/A	1. Have to launch at high angle, reducing altitude achieved. 2. Increased drifting. 3. Unable to launch.	1	4	Moderate	1,2,3. When planning test launches, the forecast should be monitored in order to launch on a day where weather does not prohibit launching or testing the entire system. If high winds are present but allowable for launch, the time of launch should be planned for the time of day with the lowest winds.
Trees	N/A	1. Damage to rocket or parachutes. 2. Irretrievable rocket components.	1	4	Moderate	Launching with high winds should be avoided in order to avoid drifting long distances. Drift calculations have been computed, so we can estimate how far each component of the rocket will drift with a particular wind velocity. The rocket should not be launched if trees are within the estimated drift radius.
Swampy ground	N/A	Irretrievable rocket components.	1	4	Moderate	With the potential of the salt flats being extremely soft, as well as local launch sites, the rocket should not be launched if there is

						swampy ground within the predicted drift radius that would prevent the team from retrieving a component of the rocket.
Ponds, creeks, and other bodies of water.	N/A	1. Loss of rocket components. 2. Damaged electronics.	1	4	Moderate	Launching with high winds should be avoided in order to avoid drifting long distances. The rocket should not be launched if a body of water is within the estimated drift radius. Should the rocket be submerged in water, it should be retrieved immediately and any electrical components salvaged. Electrical components are to be tested for complete functionality prior to reuse.
Extremely cold temperatures.	1. Batteries discharge quicker than normal. 2. Shrinking of fiberglass.	1. Completely discharged batteries will cause electrical failures and fail to set off black powder charges, inducing critical events. 2. Rocket will not separate as easily.	1	5	Low	1. Batteries will be checked for charge prior to launch to ensure there is enough charge to power the flight. Should the flight be delayed, batteries will should be rechecked and replaced as necessary. 2. If the temperatures are below normal launch temperature, black powder charges should be tested to ensure that the pressurization is enough to separate the rocket. If this test is successful, the rocket should be safe to launch.
Humidity	N/A	Motors or black powder charges become moist and don't ignite.	1	5	Low	Motors and black powder should be stored in a location free from moisture to remove

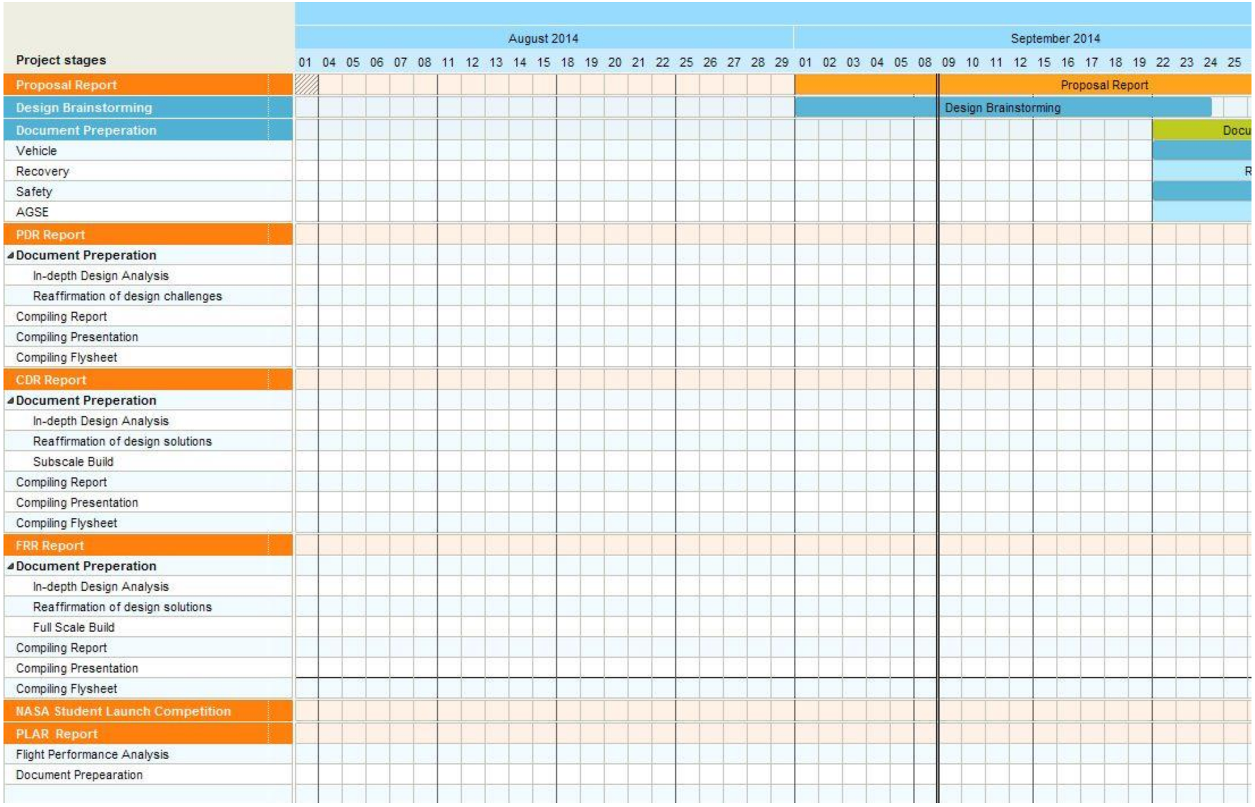
UV exposure	Rocket left exposed to sun for long periods of time.	Possibly weakening materials or adhesives.	4	4	Low	Rocket should not be exposed to sun for long periods of time. If the rocket must be worked on for long periods of time, shelter should be sought.

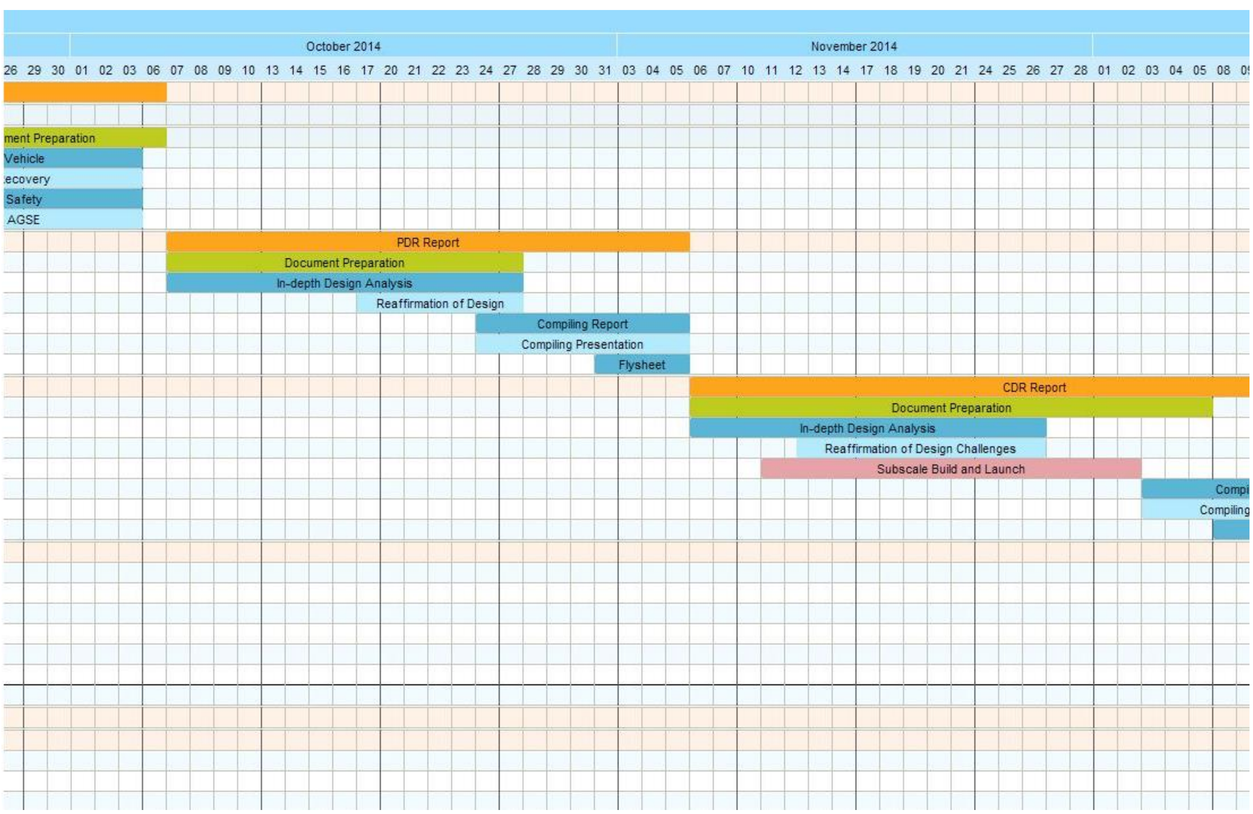
Table 27: Environmental hazards to rocket risk assessment.

Hazards to Environment Risk Assessment						
Hazard	**Cause/ Mechanism**	**Outcome**	**Severity Value**	**Probability Value**	**Risk Level**	**Mitigation**
Harmful substances permeating into the ground or water.	Improper disposal of batteries or chemicals.	Impure soil and water can have negative effects on the environment that in turn, work their way into humans, causing illness.	4	3	Low	Batteries and other chemicals should be disposed of properly in accordance with the MSDS sheets. Should a spill occur, proper measure are to be followed in accordance with the MSDS sheets and any OSHA standards.

Table 28: Hazards to environment risk assessment.

Appendix III – Timeline






2015
December 2014
January 2015
February 2015
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Presentation
Flysheet
FRR Report
Document Preparation
In-depth Design Analysis
Justification of Design Solutions
Full Scale Build and Launch
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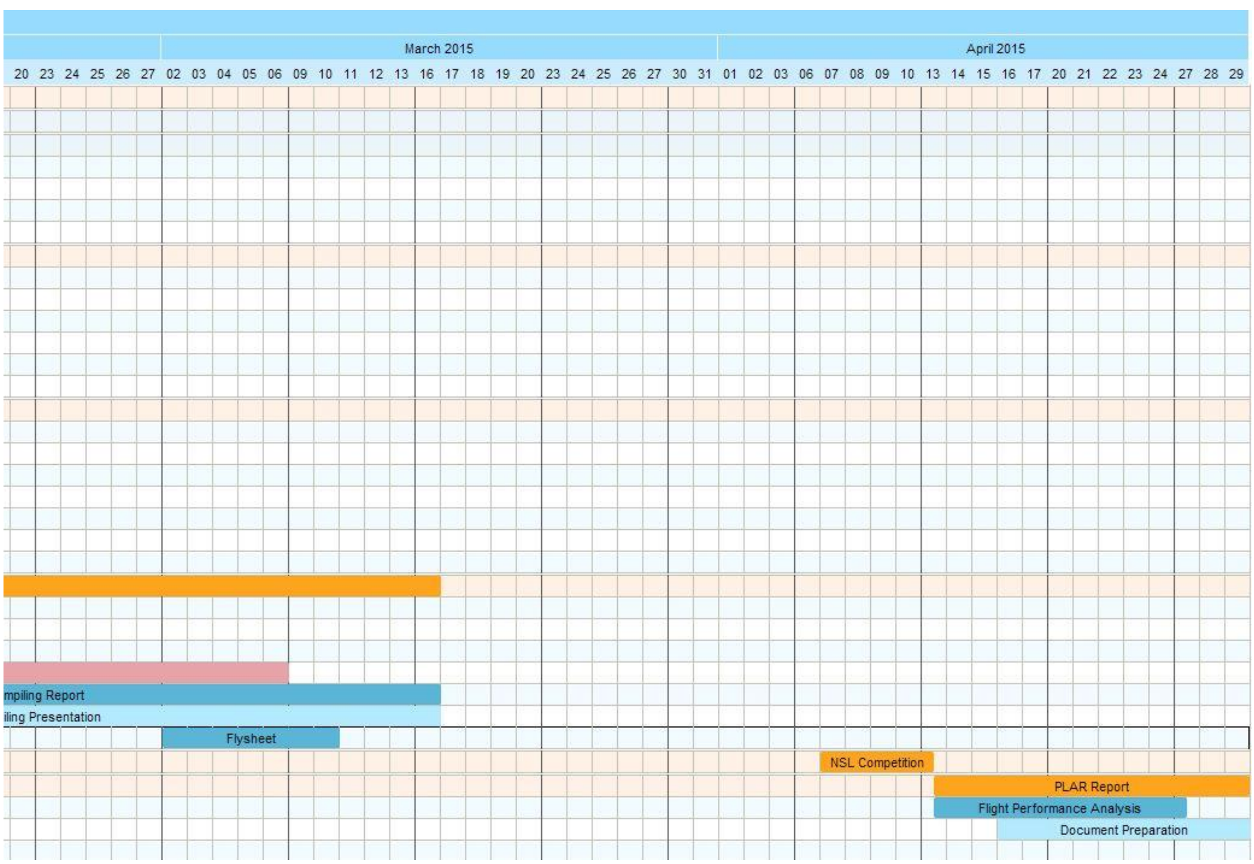
March 2015
April 2015
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Flysheet
NSL Competition
PLAR Report
Flight Performance Analysis
Document Preparation