NASA University Student Launch Initiative

Payload Fairing Design and Deployment of Atmospheric Measurement Probe

Prepared for:

NASA Marshall Space Flight Center Academic Affairs Office

By:

Astro Cats - University of Cincinnati Senior Design Team

2850 Campus Way Baldwin 745, Cincinnati OH 45221

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UNIVERSITY OF Cincinnati

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Acronym Dictionary

NAR = National Association of Rocketry

PPE = Personal Protective Equipment

STEM = Science, Technology, Engineering, and Mathematics

TRA = Tripoli Rocketry Association

AGL = Above Ground Level

ASL = Above Sea Level

CNC = Computer Numerical Control

FAA = Federal Aviation Administration

GPS = Global Positioning System

GSM = Global System Mobile Communication

IR = Infrared

LSO = Launch Safety Officer

MPH = Miles per Hour

OSGC = Ohio Space Grant Consortium

PCB = Printed Circuit Board

PIL = Planetary Investigation Lander

RSO = Range Safety Officer

SLI = Student Launch Initiative

SMS = Short Message Service

UC = University of Cincinnati

UFB = University Funding Board

UML = Unified Modeling Language

UV = Ultraviolet

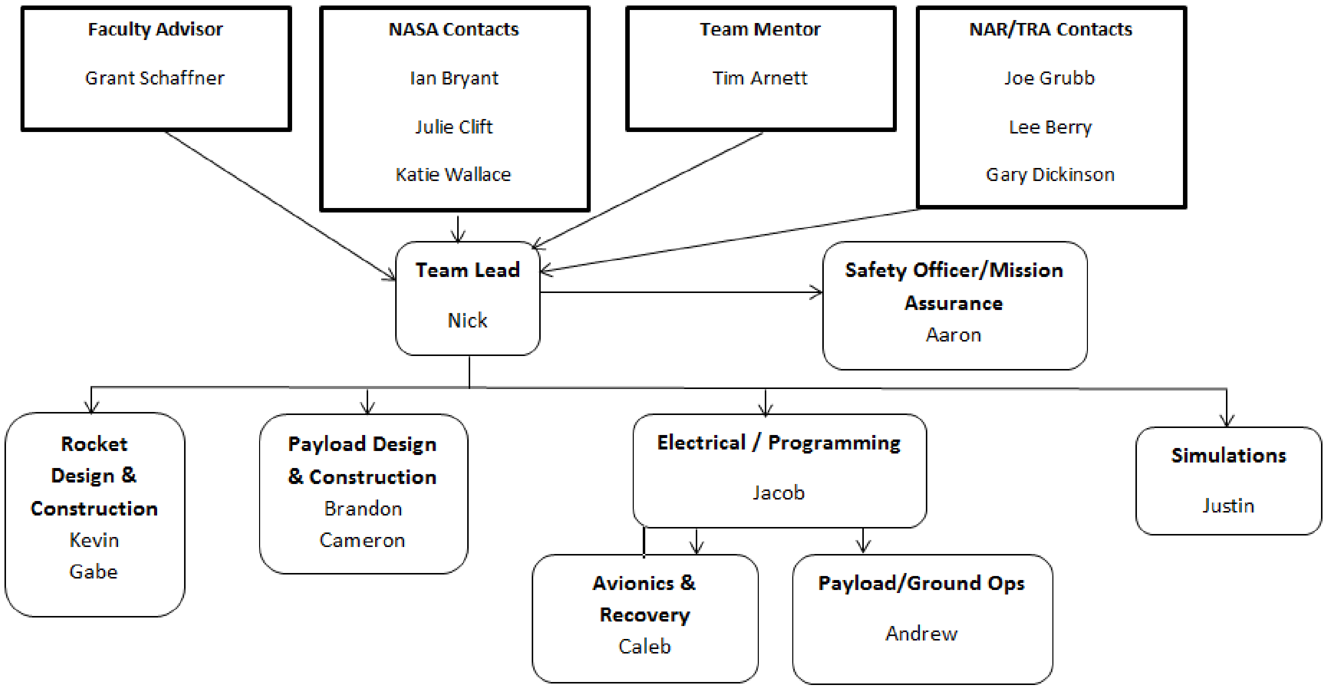
HPR = High Powered Rocket

1. GENERAL INFORMATION

1.1 TEAM CONTACT INFORMATION AND NAR/TRA INFORMATION

Organization Name:	UC Astro Cats Department of Aerospace Engineering and Engineering Mechanics College of Engineering & Applied Science University of Cincinnati
Faculty Advisor:	Grant Schaffner Assistant Professor of Aerospace Engineering & Engineering Mechanics Phone: (513) 556-3032 Email: grant.schaffner@uc.edu
Team Lead:	Nick Fagan Phone: (419) 348-2573 Email: faganna@mail.uc.edu
Safety Officer:	Aaron Deutsch Phone: (513) 348-8928 Email: deutscan@mail.uc.edu
Team Mentor:	Tim Arnett - NAR Level 2 Graduate Student, Aerospace Engineering University of Cincinnati Email: arnetttj@mail.uc.edu
NAR Contacts:	Joe Grubb - NAR 78797 L3 & TRA 1206 L3 TAP West Virginia and Southern Ohio Association of Rocketry NAR Section 564 Email: grubb1326@yahoo.com
	Lee Berry Team Ohio Rocketry, NAR Section 703 Phone: (937)667-5297 Email:klnjberry@hotmail.com
	Gary Dickinson Tripoli Mid Ohio Section 31 Email: gdickinson@woh.rr.com

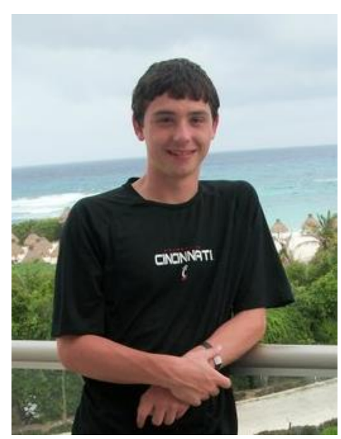
1.2 Project Organization



1.3 Team Roster

Nick Fagan: Currently a 5th year Aerospace Engineering Student at the University of Cincinnati and will graduate with his Bachelors in May 2016. He has worked with Schindler Elevator and Federal Equipment Company holding roles in Mechanical Design, Project Management, and Manufacturing. He is currently the President of the University of Cincinnati Rocketry Club and has been a member since 2011. He participated in Space Grant Midwest High-Power Rocketry Competition in 2013 and was Rover Team Lead for the first place 2015 Battle of the Rockets team. He has experience in Autodesk Inventor, AutoCAD, Matlab, Simulink, and LabView.

Aaron Deutsch: Currently he is a 5th year Aerospace Engineering Student at the University of Cincinnati. His expected graduation is in spring 2016. For his previous work experience, he has worked for 5 semesters at Duke Energy. The first being the Steam Turbine Subject Matter Expert, the second being the High Energy Piping Subject Matter Expert, and the third being part of the Metrics and Measures group and the fourth and fifth being part of the Outage Projects Support group. Some skills of his that



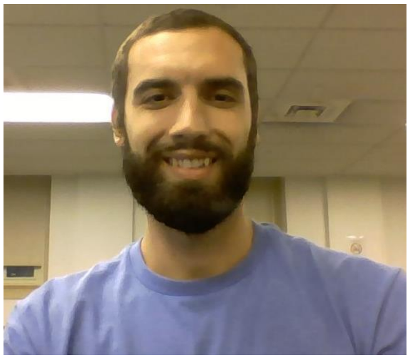
are applicable to the team are project management experience, experience building quadcopters, programming experience, safety experience from working at a power plant, and financial analysis experience.

Kevin Eliason: Currently a 5th year Aerospace Engineering student looking to get his Bachelor of Applied Science degree in the summer of 2016. He has been the Vice President of the UC Rocketry Club since 2014 and has been a member of the club since 2011. Since then, he has competed in the Space Grant Midwest High-Power Rocketry Competition in 2013 and was the Team Lead for the first place team at the Battle of the Rockets competition in 2015. His past experience includes: intern at NASA Glenn Research center, research assistant at the University of Cincinnati Combustion Lab, two semesters as a systems engineering co-op with Rockwell Collins Inc., and one semester with Sierra Nevada as a software engineering co-op. He has experience with Matlab and Simulink, SolidEdge, Autodesk Inventor, Satellite Toolkit and various programming languages. After college, he plans to pursue a career in Space Systems Engineering and hopes to develop the next generation of spacecraft.

Gabriel Puente-Lay: Currently a 5th year aerospace student at the University of Cincinnati. Gabriel will graduate May 2016 with a Bachelor in Aerospace Engineering. He has work experience with the companies Wright Brothers Global Gas and Allegion Steelcraft. Gabriel has worked with telemetry systems and lean manufacturing engineering. He has experience with AutoCAD, Matlab, Solidworks and 5s training.

Brandon Horne: Currently a 5th year Aerospace Engineering Student at the University of Cincinnati. Brandon will graduate in May 2016 with a Bachelor of Science degree in Aerospace Engineering. Brandon has 3 years (5 semesters) of experience working at ThyssenKrupp Bilstein, with experience ranging from machining to LEAN manufacturing and process flow. Brandon also has experience in Autodesk Inventor, AutoCAD Lt, Solid Edge, Java, MATLAB, Simulink, Lab View, Objective C, as well as training to operate a manual lathe, and Bridgeport style mill. Brandon has participated in the Battle of the Rockets planetary rover event 2015 in Culpepper Virginia. He performed mechanical design and fabrication on the teams' Autonomous rover that won the National event.

Cameron Crippa: Currently a 5th year aerospace student at the University of Cincinnati. He will graduate May 2016 with a Bachelor in Aerospace Engineering. Cameron has a year of work experience with the University of Cincinnati's Acoustics Linear Research Lab and six months of experience with GoHypersonic Inc. He worked with data acquisition in both positions. Cameron has experience with LabVIEW, SolidWorks, AutoCAD, MATLAB, and C++.

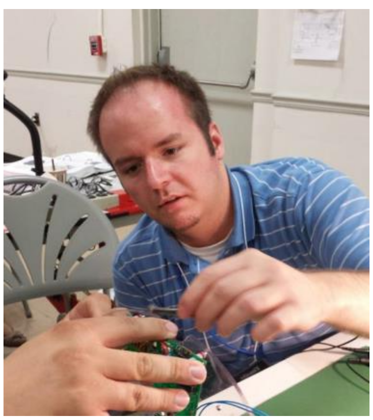


Jacob Chesley: Jacob is pursuing a Bachelor of Science in Computer Science at the University of Cincinnati, College of Engineering and Applied Science and expecting to graduate in spring of 2016. He has had five semesters of co-op experience as a software developer at International TechneGroup Incorporated in Milford Ohio. At ITI, Jacob developed third party software that integrated various PLM and ERP software. He has experience in many programming languages, including C, C++, C#, Java, Python, Ruby, PHP and JavaScript. He also has experience in front end web development using HTML and CSS. Jacob will be the electronics and software leader for this project, and the website developer. He has experience with Arduino and electronics that he developed for past UC Rocketry projects. These projects include designing an electronic control system for air brakes and the electronics and software for an autonomous ground rover.

Caleb Wasmund: Currently a 5th Aerospace student. Caleb plans to graduate May 2016 with a Bachelor in Aerospace Engineering. He has had five rotations of work experience in two large industries such as GE Aviation and ThyssenKrupp Bilstein. Caleb held roles in Product Engineering, Process Engineering, Engine Dynamics, and Support Equipment. He has experience in Matlab, Solidworks, AutoCAD, shop floors, and shop machinery.

Andrew Auffenberg: Andrew is a 5th year Aerospace Engineering student. In high school, he interned at NASA on the OASIS project. In college, Andrew was a co-op at Kowalski Heat Treating as a Lab Technician, as well as at Roush Industries as a NVH Engineer. Andrew has experience with LABVIEW, Solidworks, Photoshop, and VB6. After undergraduate, Andrew plans to get his MBA.

Justin Mulloney: Currently a 5th year Aerospace Engineering student at the University of Cincinnati who will graduate in May of 2016. He has done six semesters of co-op at Barnes Aerospace in Manufacturing and Quality Engineering roles. He has experience in Lean Manufacturing and process capability analysis and is currently getting his Six Sigma Green Belt. Applicable skills that he brings to the team are project management experience, process mapping and flow, and financial analysis experience. After graduation he will be working for the United States Navy as Civil Engineer Corps Officer.



(Team Mentor) Tim Arnett: Tim is a graduate student working on his M.S. Degree in Dynamics and Controls, with his thesis being on the Verification and Validation of Fuzzy Control Systems. He is the Co-founder and former Vice President of the UC Rocket Club and holds a class 2 HPR certification. Tim participated in the 2012 Space Grant Midwest High-Power Rocketry Competition and was in charge of simulations, systems engineering and post flight analysis. In 2013 he competed in the Battle of The Rockets competition. He was in charge of organizing club activities and launch events. Tim oversaw multiple competition teams as a technical mentor including the 2015 Battle of The Rockets Senior design team.

2 FACILITIES & EQUIPMENT

2.1 FACILITIES

2.1.1 University of Cincinnati Rocketry Lab

The rocketry lab for the University of Cincinnati located in room 300L Rhodes Hall across from the Gas Dynamics and Propulsion lab. The lab is open twenty-four hours a day seven days a week. All meetings will be conducted here as well as assembly of the rocket and payload.

The Rocketry Lab utilizes the following tools:
Common Household Tools (Screwdrivers, Wrenches, Plyers, etc.)
Hand Drill
Sawzall
Heat gun
Belt Sander
Dremel
Jigsaw
Soldering Irons
Multimeter

Members will be briefed on hand tool safety by team safety officer before use and the member who unlocks the lab is responsible for ensuring proper and safe hand tool use.

2.1.2 University of Cincinnati Machine Shop

The machine shop of the University of Cincinnati is located in 407 Rhodes. The machine shop coordinator is Ronald Hudepohl. His e-mail is Ronald.hudepohl@uc.edu and his phone number is 513-556-5218. The hours of the machine shop are between 9:00 A.M and 5:00P.M with a break from 12:00 P.M to 1:00 P.M.

The CEAS Rhodes Hall Machine Shop utilizes the following tools:
3 Manual Mills
4 Manual Lathes
2 Band Saws
2 Vertical Band Saws
1 Kick Shear
1 Press Brake
2 Drill Presses
1 Belt Sander
1 Wet Blast Machine

The team will use the machine shop when making parts for the rocket or payload that require heavy machinery. All safety is monitored by the machine shop staff and will be within accordance of the teams safety regulations found in section 3.

2.1.3 University of Cincinnati Computer Labs & Internet Access

Students of the University of Cincinnati have access to several computer labs all around campus. The labs contain several computers with multiple programs for student use. The team will be utilizing these labs to compile reports and work on various aspects of the project. A list of the software that is loaded on the computers is shown below.

Matlab
Labview
Microsoft Office
Autodesk
C++
Python
Solid Edge

All computers are connected through the University of Cincinnati network UCNet and all wireless devices can be connected to either the UC guest or Securewireless Wi-Fi systems of the university.

2.1.4 Software and Programs

RockSim 9: A computer program that allows the user to design a rocket to their specifications and simulate the flight. The program contains an extensive database of parts and motors. For launch simulation it allows the user to enter atmospheric conditions and calculates a predicted value for flight details such as downrange drift, altitude, acceleration, and velocity.

Inventor 16: A professional-grade 3D CAD software for mechanical design. The software allows the user to enter loads, friction characteristics, and dynamic components. The user can then run dynamic tests to see how the design will work under real conditions. The program also utilizes finite-element analysis to see how the design will perform under loads and use this information to optimize all aspects of the design.

Cisco WebEx: A web-based conferencing system implemented this year by the University of Cincinnati. This software just needs Internet access and can be used to share all types of files as well as having audio and video conference call. The team will primarily be using this to communicate with NASA.

yEd Graph Editor: A free computer program allowing users to create high quality diagrams with vector graphics. This can be used to create block diagrams, flow charts, UML Class diagrams and many other diagrams. Graphs can be exported in bitmap or vector format.

KiCad: An open source computer program used to create electrical schematics and PCB layouts. With an electrical schematic created, KiCad can generate an efficient PCB layout within specifications that are entered. Trace widths can be modified and spacing between traces can be specified. This also allows for multiple layer PCB's, up to 32 layers.

Arduino IDE: An open source IDE that can be used with any Arduino board. This IDE makes code development and deployment for Arduino easy by integrating with the Arduino board and offering a serial monitor.

Brackets: An open source text editor created by Adobe. It has many features including code hints and live preview. Live preview starts a local server and allows the user to change html and css code in the editor and see the results in a browser in real time, without having to save the document and reload the page in the browser.

Visual Studio Community: A free IDE created by Microsoft that can create applications for multiple operating systems.

2.1.5 Current Supplies

The following lists of supplies are left over supplies from previous years senior design team projects. They are stored in the Rocketry Lab and are available for use.

Table 1: List of current supplies available for use

Supplies Currently In Stock
Various Body Parts for 4”, 5.5”, and 7.5” Rockets
Airframe Tubing
38mm & 54 mm Motor Mount Tubes
Payload Bay
Bulkheads
Retaining Rings
Nose Cones
Rail Buttons
Swivels
15 min Set Epoxy
38mm & 54mm quick change Motor Retainers
Cesaroni Pro38 & Pro54 Motor Casings
1/4" Chain Eye Connector (Quicklink)
Various Size Drogue Parachutes
Various Size Main Parachutes
Shock Cords
Carbon Fiber w/ Epoxy
Perfectflite Stratologger Altimeter
G-Wiz HCX Flight Controller
Arduino Mega 2560
Various Hardware (Screws, Bolts, Washers, Eye Hooks)
Aluminum (Sheet, Rod, Angle, Tubing, Mesh, random other scraps)

3 Safety Overview

3.1 Overview

Safety is of the utmost importance to the University of Cincinnati Astro Cats. The purpose of this section is to go over all Federal Aviation Administration (FAA) regulations, the National Association of Rocketry (NAR) regulations, National Fire Protection Association Code 1127 (NFPA 1127), the Code of Federal Regulations (CFR) and any regulations and procedures for building, transporting and launching high-powered rockets. Any hazardous materials to be used during this project will be listed along with the measures to handle them safely. The team's safety plan as well as team members responsible for maintaining the highest level of safety will be discussed.

This document is to serve as a guideline into how the Astro Cats will ensure that the team meets all safety regulations and state and federal laws.

Safety Officer: Aaron J. Deutsch

3.2 Federal Aviation Administration Model Rocketry Law

A full copy of the FAA Model Rocketry Law Title 14, Chapter 1, Subchapter F, Part 101, Subpart C can be found in Appendix A.

3.3 NAR Procedure and Safety Regulations

1. **Certification:** The team will only fly high power rockets or possess high power rocket motors that are within the scope of user certification and required licensing.
2. **Materials:** The rocket will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal.
3. **Motors:** Only certified, commercially made rocket motors are to be used, and will not be tampered with or used for any other purposes except those recommended by the manufacturer. Smoking, open flames, nor heat sources within 25 feet of these motors will not be tolerated.
4. **Ignition System:** Rockets are to be launched 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. The launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when the rocket is in the launching position.
5. **Misfires:** If the rocket does not launch when the button of the electrical launch system is pressed, the launcher's safety interlock will be removed or disconnect its battery, and 60 seconds must have passed after the last launch attempt before allowing anyone to approach the rocket.

6. **Launch Safety:** A 5-second countdown will be used before launch. The safety officer will ensure that a means is available to warn participants and spectators in the event of a problem. The safety officer 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, the safety officer will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. He or She shall 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 the team will observe the additional requirements of NFPA 1127.
7. **Launcher:** The rocket will be launched 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 a launcher length that permits the rocket to attain a safe velocity before separation from the launcher will be used. A blast deflector is to be used to prevent the motor's exhaust from hitting the ground. The safety officer will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
8. **Size:** The rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. The rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
9. **Flight Safety:** The rocket will not launched 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 contain any flammable or explosive payload. The team will not launch any rockets if wind speeds exceed 20 miles per hour. Each team member will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that the rocket will not exceed any applicable altitude limit in effect at that launch site.
10. **Launch Site:** The rocket is to be launched outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. **Launcher Location:** The launch pad 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 in from any boundary of the launch site. The Minimum Distance table can be found in Appendix A
12. **Recovery System:** The rocket will use a recovery system such as a parachute so that all parts return safely and undamaged and can be flown again, and only flame-resistant or fireproof recovery system wadding is to be used in the rocket. No attempt will be made to recover the 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.

3.4 Safety Plan

The objective of this safety plan is to ensure all team members practice safe habits when building, transporting, and launching rockets. The Safety Officer is in charge of understanding all rules and regulations, conveying all safety information to the other team members, and overseeing all activities to ensure safe practices are being utilized. The Safety Officer will follow the Trained Safety Officer handbook provided on NAR's website. The Safety Officer will also comply with all orders from the Range Safety Officers (RSO) and Launch Safety Officers (LSO). Any additional rules or procedures created by the Safety Officer will be enforced. If weather conditions do not permit a safe launch or the rocket is deemed unsafe to fly, then the team will not be permitted to launch the rocket. All team members will be trained in various topics that are applicable by a competent person. For all trainings to count, the individuals will need to have written permission from the Safety Officer, and have the trainer sign off that the person has been properly trained and understands all risks and hazards associated with what they just learned. Every team member will take a safety quiz that they must pass in order to be involved in the construction and launching of any component of the rocket or payload. Any blatant disregard for our safety plan or the regulations put in place by the FAA, NFPA, CFR, NAR, TRA, OSHA, NASA, NTSB or any other governing agency, will result in probation or immediate removal of that member or members from the team.

Training Topics (more will be introduced if deemed necessary by the Safety Officer)

- FAA Regulations (See Appendix A.1)
- National Fire Protection Association Code 1127
- Hazard Recognition and Mitigation Training
- Pre-Job Briefing Training
- Personal Protective Equipment Training
- High Powered Rocketry Standards Training
- Hand and Power Tool Training
- Fire Extinguisher and Fire Mitigation Training
- National Fire Protection Association Code 1127
- Accident Avoidance and the S.T.A.R (Stop, Think, Act, Review) Training
- Hazardous Material Training

After all training has been completed; the training material and signed training sheets will be posted to the team's website within 48 hours of completion. All training material will be posted to the team's website, and can be reviewed or re-trained at any time. Any actions deemed to be unsafe by the Safety Officer will be stopped and the team members involved will be required to take all steps necessary to ensure that they complete their work in a safe manner.

3.4.1 Pre-Job Brief, Hazard Recognition, and Accident Avoidance:

While it is not a rule that can be enforced by OSHA (Occupational Safety and Health Administration), the Safety Officer has deemed that OSHA standard 1926.952 is a best practice and will be enforced by the Safety Officer throughout the duration of this project. OSHA standard 1926.952 discusses how a Pre-Job Brief (PJB) should be performed, and why a PJB is important. The purpose of a PJB is to discuss all work that is being performed that day, what hazards exists with the job associated to it, what Personal Protective Equipment (PPE) must be used, how to mitigate any and all hazards, routes of evacuation in the event of an emergency, and what to do in the event of an emergency. The PJB will be performed at the start of all team meetings and events. If any conditions change while at the job site, another PJB must be performed to discuss the changed conditions with all applicable team members. The PJB will also be used in conjunction with the Pre-Launch Safety Procedure. All PJBs will be posted on the team's website (as soon as the team's website goes live) along with the team's meeting minutes to allow anyone to view the progression that the Astro Cats are making. When the Astro Cats have an effective PJB, the entire team will be able to identify and mitigate all hazards that exist and could potentially exist. Along with the PJB, the entire team will be trained on NFPA Code 1127, which discusses the design and construction of high powered rockets. Again, safety is of the utmost importance and one of the most effective tools to ensure that everyone is safe is to discuss and document the PJB so that everyone is aware of what could go wrong.

3.4.2 Pre-Launch Safety Procedure (PLS):

Prior to the launch of any rocket, multiple safety activities must occur before written permission from the Safety Officer is given to launch the rocket. On the day of a launch an effective PJB must occur, in which all team members at the launch must sign off on in order to proceed. After the PJB the Safety Officer will perform a PLS. The PLS is designed to ensure that all steps have been taken so that the launch of the rocket can be done safely and legally. This will include a thorough checklist that includes but is not limited to minimum clear space for rocket launch, minimal personnel distance from the rocket, all parts of the rocket have been assembled properly, all igniters are set properly, all hazardous material is handled properly, and all federal and state regulations have been met. After a PLS has been completed and signed by the Safety Officer, the team will be given permission to launch the rocket. All team members and mentors will abide by any stipulations that the Range Safety Officer (RSO) or Launch Safety Officer (LSO) give. Since the launch of a rocket is one of the most dangerous parts of the competition, the Astro Cats have taken on the responsibility to ensure that all measures have been taken to avoid any potential injuries to ourselves or others.

3.4.3 Personal Protective Equipment and Power/Hand Tool Safety:

All team members will undergo training on proper use of tools and required Personal Protective Equipment (PPE) for those tools. When the team members undergo tooling safety, the instructor must inform the students how to properly use the tools, what to look for when using the tools, what they must wear to prevent any injuries, and what to do in the event of an emergency. In order for any team member to use any power tools, they must go through additional training on how to use them, proper PPE, and what do in the event of an emergency for that specific power tool. In order to use the power tools, the team member must have a signed form by the Safety Officer and Ron Hudepohl (the person responsible for the University of Cincinnati machine shop) that states that they have been trained in the proper use of power tools and understand all risks associated with those tools. These training documents will be uploaded to the team's website and are valid for a period of 1 year.

3.4.4 Hazardous Materials:

All possible actions will be taken to prevent injuries from hazardous materials. Every team member will be trained on the use of hazardous materials and what PPE must be worn, they will also be required to read the Material Safety Data Sheets (MSDS). The Safety Officer will keep a binder with all MSDS that are applicable to the project and can be presented at any time deemed necessary. Any and all hazardous materials that are brought onto the University of Cincinnati property (that are applicable to this project), or any hazardous material that the Astro Cats use, must have an attached MSDS sheet that must be given to the Safety Officer. These sheets will be posted to the team's website, and a hard copy will be put in a binder on the door of the rocketry lab so they will be available at all times for anyone's use.

3.4.5 Rocket Motor Purchase:

The University of Cincinnati Astro Cats will comply with all federal and state laws regarding the purchasing of rocket motors. All rocket motors will be purchased by a federally licensed mentor for the Astro Cats in accordance with Federal Regulation 27 part 55.

3.4.6 Rocket Motor Storage:

The University of Cincinnati Astro Cats will comply with all federal and state laws regarding the storage of rocket motors. Rocket motors will be stored by the University of Cincinnati in an Armag Type 2 ABC, ATF spec indoor magazine. The magazine is located in a concrete storage room. The storage room is equipped with a security system, smoke detector and sprinkler system. The security system is monitored 24/7 by University of Cincinnati police department and the storage room is checked once a week by University of Cincinnati staff. The doors of the magazine and the storage room have locks and safety signage is posted on both doors.

3.4.7 Rocket Motor Transportation:

The University of Cincinnati Astro Cats will comply with all federal and state laws regarding the transportation of rocket motors. A Federal Low Explosives User Permit (LEUP) from the Bureau of Alcohol, Tobacco, and Firearms (BATF) will be obtained for the transport of hazardous materials across state lines. Permits will be obtained to transport hazardous materials in all applicable states. The rocket motors will be stored in a portable magazine (type 3). The igniters will be packed in a separate container and the containers will be stored in different compartments. A fire extinguisher will be present on the vehicle. The driver will be trained on the use of the fire extinguisher, state and federal laws pertaining to the transport of hazardous materials, and what to do in case of an emergency or accident. The route will be planned such that the vehicle will always comply with NRHM routing designations.

3.5 Hazard Assessment

Overview:

This is to serve as the University of Cincinnati Astro Cats hazards assessment. The purpose behind this hazard assessment is to identify all hazards and give steps on how to mitigate or eliminate all risks and hazards.

3.5.1 General Safety

a. Ensure that everyone has the proper training for the proper job.
b. Have a meaningful PJB to discuss all hazards.
c. Always wear the right PPE and if the PPE is faulty, stop all work and replace it.
d. If at any time anyone is unaware of what work or what hazards exist stop all work, think about the situation, act upon those decisions, and then review the work being performed.
e. When using any chemicals, MSDS sheets must be present and reviewed prior to working with the chemical.
f. Lastly, take the time to find hazards that could exist for other people and eliminate them when possible.

3.5.2 Chemical Safety

a. Have a meaningful PJB to talk about all hazards that exist with the task being completed.
b. Anyone using any chemicals will need to be properly trained by a competent person.
c. Have the MSDS sheet available when using that chemical.
d. Review the MSDS sheet before using it.
e. Ensure that the PPE specified in the MSDS for that chemical is worn.
f. Follow the proper procedure on the MSDS if a spill occurs.
g. When working with dangerous chemicals, ensure that you a second person is nearby to who can follow all necessary procedure in the event of an emergency.

3.5.3 Power Tool and Hand Tool Safety

a. Have a meaningful PJB to talk about all hazards that exist with the task being completed.
b. All personnel will be trained on how to use general hand tools.
c. Any personnel that need to use power tool must attend additional training, and have the proper signatures to ensure that they have been properly trained.
d. Wear proper PPE when using tools.
e. If there are any questions on how to use the equipment or what to do, follow the STAR procedure.

3.5.4 Pre-launch and Rocket Safety

a. Have a meaningful PJB to talk about all hazards that exist with the task being completed.
b. All team members will be properly trained and must have the proper certifications to purchase, transport, store, and launch the rocket.
c. Have a meaningful PLS and ensure that the rocket is safe, and that it has been filled out by the proper authorities.

3.6 CONCLUSION

The University of Cincinnati Astro Cats are dedicated to ensuring that the entire project has no safety incidents. The Safety Officer will ensure that all team members have the proper training, and ensure that the team follows all rules and regulations that are imparted onto the Astro Cats in order to compete at the NASA Student Launch Competition.

Team Safety Compliance

By agreeing to this document, you have read and fully comply with the all rules and regulations that this document sets forth.

1. **NASA Specific Safety Regulations**

1.1. There must be range safety inspections of each rocket before it is flown.

1.2. I will comply with the determination of the safety inspection, or I may be removed from the program.

1.3. 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 any safety reasons.

1.4. Any and all individuals that do not comply with the safety requirements will not be allowed to launch their rocket.

Signature Section: Please sign and date onto the lines below

Nicholas Jagan 9/7/15	[illegible] 9/7/15
Justin Mullaney 9/7/15	[illegible] 9/8/15
[illegible] 9/7/15	[illegible] 9/8/15
[illegible] 9/8/15	Caleb [illegible] 9/8/15
[illegible] 9/8/15	
[illegible] 9/8/18	

4 TECHNICAL DESIGN

4.1 MISSION STATEMENT

The Astro Cats will develop vehicle capable of deploying a planetary probe via a fairing design, to capture valuable data on UV radiation, solar irradiance, temperature, humidity, and pressure. Then plot and describe collected date to show the relationship of these values with respect to altitude and velocity.

In summary the team aims to:

- Develop a high-powered rocket capable of delivering our probe to an altitude of 5,280 ft.
- Develop a deployable probe that contains a suite of sensors to measure basic atmospheric data.
- Develop custom fairing design to contain the payload.
- Measure solar irradiance to determine the effectiveness of solar panels.
- Record UV radiation data at various points of the atmosphere.
- Use image processing to identify objects in the camera's field of view.

4.1.1 Mission Motivation

Atmospheric data is essential in the study of planetary bodies. Whether it be for our own planet or other planets within our solar system. Our sensors will provide insight into atmospheric conditions, solar panel effectiveness, and radiation exposure. In addition to this data, we will use image processing to identify objects in the camera's field of view. Much like NASA's *Huygens* atmospheric probe that landed on Saturn's moon, Titan, our probe intends to gather and transmit scientific data from the time of deployment, through descent and several minutes after landing.

4.1.2 System Requirements

Astro Cats will be constrained to the rules of the NASA SLI 2015-2016 competition guide book, including but not limited to:

4.1.2.1 Vehicle Requirements

- Rocket apogee shall be as close to 5,280 feet as possible.
- Rocket altitude shall not exceed 5,600 feet.
- Rocket shall be recoverable and reusable without making any modifications.
- Rocket shall not have more than four independent sections.
- The vehicle shall carry one commercially available, barometric altimeter for recording the official altitude used in the competition scoring.
- Vehicle shall be single stage. No motor clusters are permitted.
- Launch vehicle shall be capable of being launched by a standard 12 volt DC firing system.
- Subscale model shall have a successful flight prior to full scale test flight.
- Full-scale flight model shall be successfully flown prior to FRR.
- Vehicle must be capable of remaining in launch-ready configuration for a minimum of 1 hour without losing the functionality of any critical components.
- 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.

4.1.2.2 Motor Requirements

- Launch vehicle shall use a solid motor propulsion system using ammonium perchlorate composite propellant (APCP).
- Only commercially available, NAR/TRA certified motors may be used.
- Motor impulse shall not exceed 5,120 Newton-seconds (L-class).

4.1.2.3 Recovery Requirements

- Dual-staged deployment shall be used.
- The team must perform a successful ground ejection test for both main and drogue chute.
- Each section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf upon landing.
- Redundant altimeters must be used for all electronic flight systems.
- Each altimeter must have its own battery and externally located arming switch.
- Motor ejection is not permissible.
- Recovery and payload electronics must be independent from each other.
- At all times the system must remain subsonic.
- Shear pins must be used in the deployment of both the drogue and main parachute.
- Electronic tracking devices must be used to transmit the location of all components after landing.
- The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).

4.1.2.4 Payload Requirements

- Payload shall be designed to be recoverable and reusable.
- Payload shall consist of at least 2 of the competition payload options listed below.

Task 1 (select any 2)	Task 2
3.1.1 Atmospheric Measurements 3.1.2 Landing Hazards Detection 3.1.3 Liquid Sloshing in Micro-G 3.1.4 Propulsion System Analysis 3.1.5 Payload Fairing Design and Deployment 3.1.6 Aerodynamic Analysis 3.1.7 Design your own (limit of one)	3.1.8 Centennial Challenge – MAV

4.1.2.5 Safety Requirements

- Team must provide written safety plan addressing the safety of the materials used, facilities involved, and team member responsible for ensuring the plan is followed.
- Team must designate a Safety Officer.
- Must provide plan for complying with federal state and local laws regarding unmanned rocket launches and motor handling.
- Provide a plan for NAR/TRA mentor purchase, storage, transport, and use of rocket motors and energetic devices.
- Provide a written statement that all team members understand and will abide by all rules and regulations
- The team must identify a mentor to support in the competition.
- The team must abide by the rules and guidance of the local rocketry club's RSO during test flights.
- The team shall abide by all rules and regulations set forth by the FAA

4.1.2.6 General Requirements

- The team shall provide and maintain a project plan.
- Students must do 100% of all work for SLI competition related projects.
- The team shall engage a minimum of 200 participants in educational outreach.
- The team shall identify all team members attending launch week.
- The team shall develop and host a website for project documentation.
- The team shall make available for download, the required deliverables to the team website.
- The team shall provide any computer equipment necessary to perform a video teleconference with the review board.
- $7500 maximum value of rocket and science payload.
- Scientific method must be used in the collection, analysis and reporting of all data.

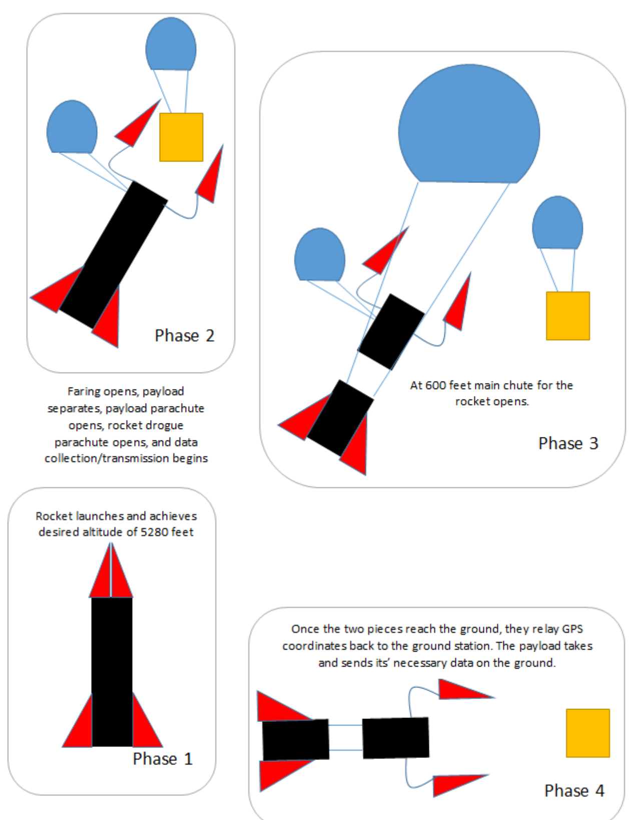


Figure 1: Diagram of mission phases

4.2 Mission Operations

The mission we chose to complete consists of four separate phases. The first phase or Launch phase begins after the rocket is armed on the launch pad and continues until the rocket reaches apogee. During this time all electronics will be in low power mode and only transmission will include status of electronics and battery if we choose from the ground station. Once at apogee the first set of altimeters will trigger a black powder charge to deploy the fairing sections, payload with its parachute and the rockets drogue parachute. The electronics of the payload will be become active and will begin collecting data from the sensor package and storing it onboard. The radio will become active and begin transmitting only the location of the payload at a specified time interval. The next phase occurs when the rocket reaches 600 feet and the second set of altimeters trigger the black powder charge to separate the upper and lower body sections and deploy the main parachute. The tracking electronics in the rocket remain in low power mode and the payload continues the same operation as in phase 2. Phase 4 or the recovery phase occurs as the payload and rocket reach the ground. The rocket tracking electronics turn on and begin to transmit the location of the rocket via a text message, which is received by team members so the rocket can be found and recovered. Upon landing the payload will continue to collect data from its sensors at a rate of 1 sample per minute and begin. After 10 minutes the radio will begin to transmit all the data back to the ground station so it can be analyzed.

4.3 Rocket Design

The proposed rocket design is shown below in Figure 2. It is comprised of three independent sections: lower body tube, upper body tube, and a nose cone fairing which will house the Planetary Investigation Lander (PIL). The outside diameter of the vehicle is 5.54” and it is 81” in length. The lower and upper body tube sections house two electronic bays and two parachute compartments. The top 8” electronic bay being for all recovery related electronics and the other 6” bay next to the motor mount houses the tracking equipment. The drogue chute compartment is located between the fairing and recovery electronic bay and the main chute compartment is located between the two electronic bays. The motor mount is made for a 54mm diameter motor and features a removable fin design.

4.3.1 Lower Body Tube

The lower body tube is to be constructed out of a LOC Precision 5.38 ID fiber airframe tubing. It is 42.5” in length and features three equally spaced fin slots for the removable fins. The tracking electronics bay will be constructed out of a LOC Precision 5.38” electronics bay and will be permanently attached to the lower body tube with the use of epoxy. The bay’s electronics will be accessible through a removable bulkhead on the in the main chute compartment. The 54mm motor mount is to be constructed from LOC Precision 2.14 strong fiber tubing and will be cut to the desired length to house up to Cesaroni 6G length motors. The motor mount is housed inside the lower body tube and is to be secured in place through the use of epoxy and LOC Precision 5.38-2.14 centering rings.

4.3.2 Removable Fins

Past experience has shown that the most vulnerable part of a rocket is its fins that are either hit during a landing or during shipment. Over time this impact causes the fins to begin to loosen from the lower body tube and motor mount or have even become warped affecting flight performance. Since we plan to test launch the rocket and payload twice before launch we want to mitigate any possible risk or this by implementing a removable fin design that is capable of removing each fin separately and replacing it with an undamaged fin before locking the fins back into place in the lower body tube.

4.3.3 Upper Body Tube

The upper body tube is also to be constructed out of LOC Precision 5.38 ID fiber airframe tubing secured to a LOC Precision 5.38” electronics bay with epoxy. Inside this section we will house the drogue parachute and lower attachment section of the fairing that remains attached to the rocket. The upper body section will be connected to the lower body section via the recovery E-bay with the use of shear pins to prevent drag separation.

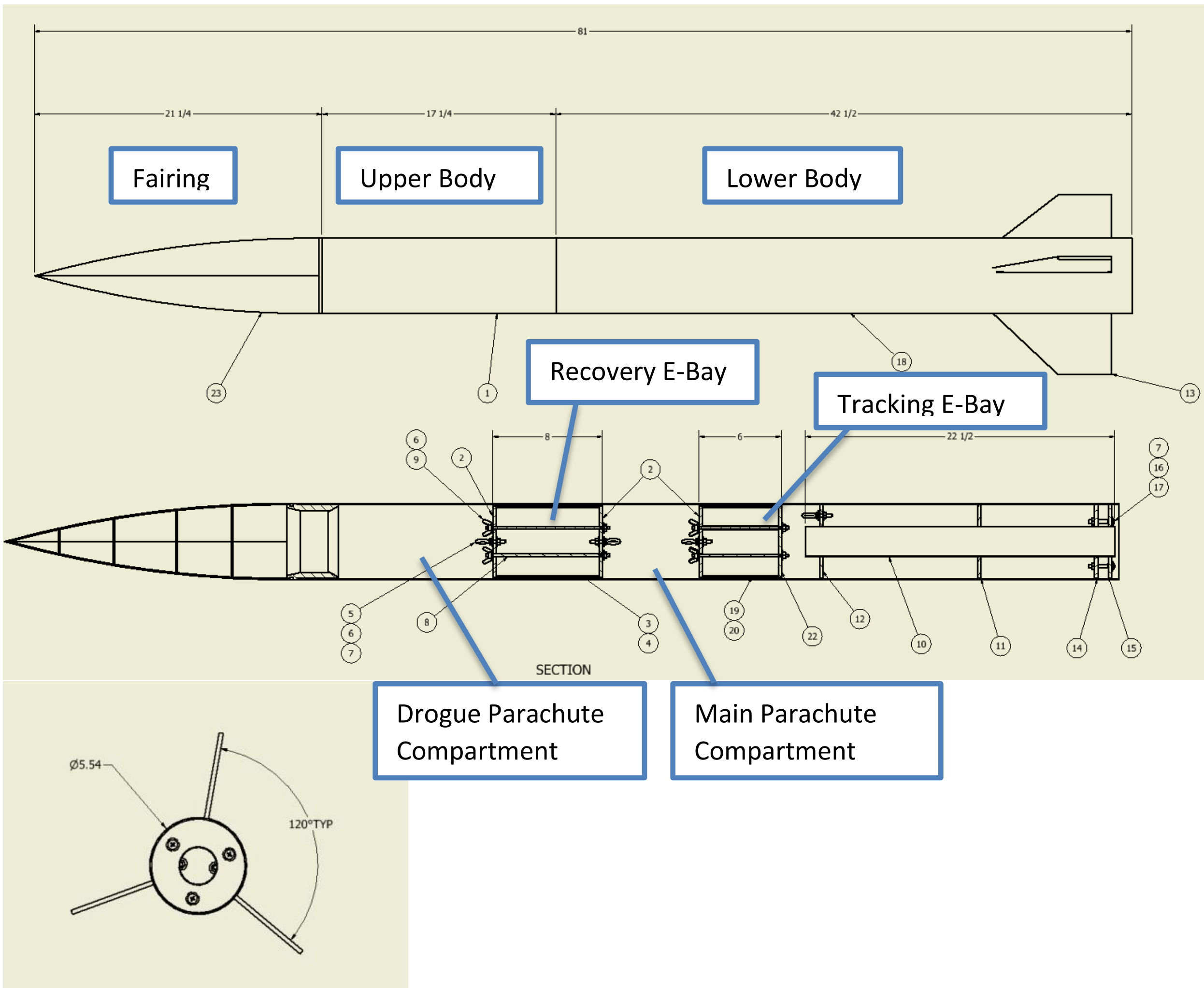


Figure 2: General Details of Launch Vehicle

4.3.4 Fairing Design

The fairing will be a clamshell model, designed to blow apart with a similar powder charge separating that will separate the main body from the lower body. The fairing is designed with Autodesk Inventor, and will be either machined with a CNC, or 3d printed, pending cost analysis. The chosen material for the fairing will be a low density Polystyrene plastic, similar to factory stock nose cones, or a similar low-density polymer more readily available for 3d printing or machining. Both fairing shells are designed to be identical, with an overlapping “tab” on one side of the edge. This tab will interlock with the other side of the fairing, and will be bolted together via 4 or more shear pins, making sure the separation of the fairing will cause the pins to be in shear stress. The fairings will be loaded with a single powder charge, located in a pressure cylinder, fabricated from aluminum, in the tip of the nose cone. This pressure should cause the fairing to break free of the shear pins and release the payload. The nose cone will separate at apogee, and will be tethered to the same shock cord as the drogue parachute. The fairings will also need a base adapter, to attach our fairing design to the factory stock 5.5” rocket body.

This base will be made of a similar polymer to the fairing, but should be easily turned on a CNC lathe. The base will be permanently fixed to the rocket body.

4.3.5 Recovery and Electronics

The recovery system deployed by the rocket will include a two stage deployment, with a drogue chute deploying at apogee and a main chute at 600ft to slow our descent to 15 ft/s < 75 ft-lbf. The deployment system shall consist of four StratoLogger altimeters, two for each chute, and four separate power supplies, and shear pins will be used for each section. The chutes will deploy using a minor gunpowder charge for each stage of deployment. Individual arming switches will be attached to each altimeter and will be capable of being locked into the ON position. Prior to first subscale launch a test deployment of chutes shall be performed. In order to locate and retrieve the rocket section a GPS will be installed. All components within the chute compartments will include appropriate shielding for electronics.

Parachute	Description	Decent Rate
Drogue	36" Diameter Round	50 ft/sec
Main	84" Diameter Round	15 ft/sec
Payload	50" Diameter Round	16 ft/sec

*These numbers were found using the following online parachute descent rate calculator.
http://www.onlinetesting.net/cgi-bin/descent3.3.cgi

Table 3: Parachute sizes and Descent Rates

4.3.5.1 Recovery Electronic Diagram

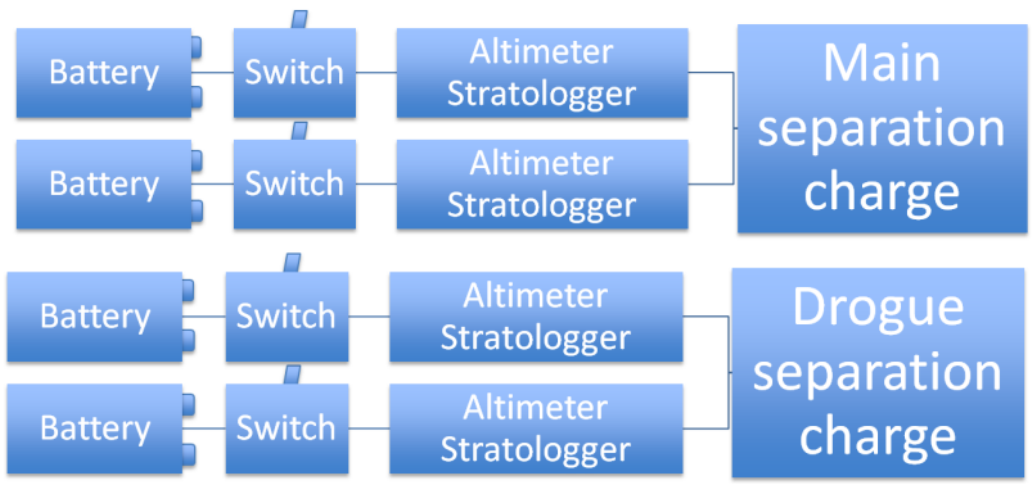


Figure 3: Diagram of Recovery Electronics

4.3.5.2 StratoLogger SL 100 Details

The StratoLogger is "A miniature, high accuracy, extreme range altimeter with two event deployment and flight data logging" device. Each altimeter will require an individual power source which will be a 9-volt battery. The logger is capable of both post-flight data retrieval and real time data output. It is capable of calculating an instantaneous and smoothed velocity of the rocket which it uses to determine when apogee is reached within +-.02 seconds.

4.3.5.3 Rocket Tracking Electronics

The rocket body electronics will consist of an Arduino microcontroller as well as a GPS receiver and the SainSmart GSM Module. This will allow the rocket body to transmit its location data to the ground control via SMS messaging.

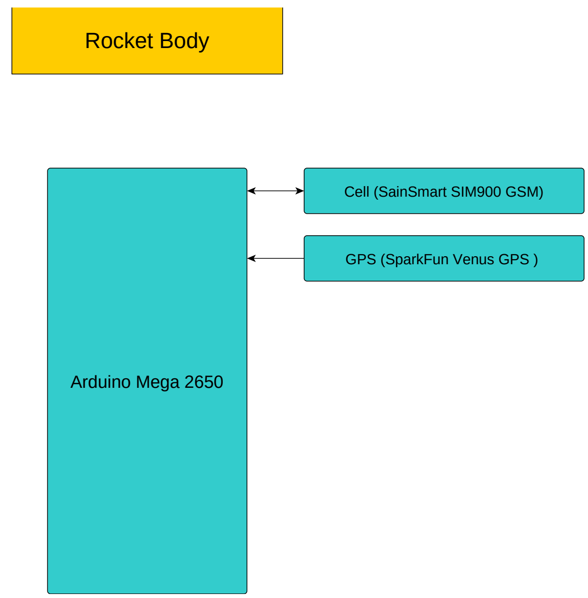
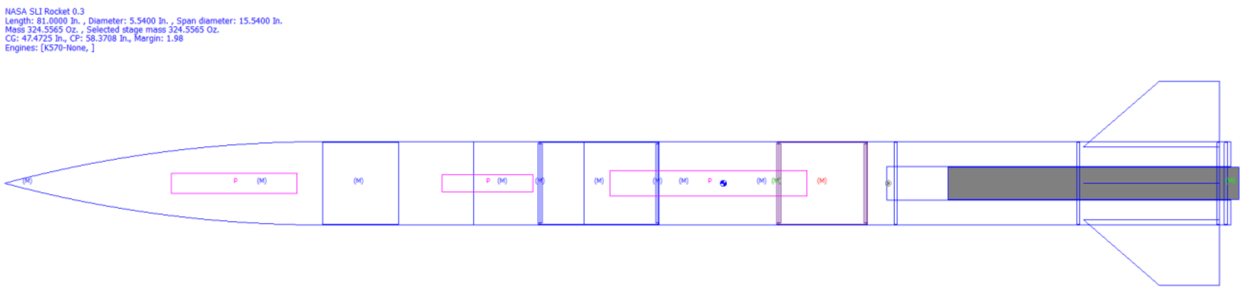


Figure 4: Motor Tracking Electronics Diagram

4.3.6 Motor Selection & Simulations

Using RockSim 9's simulation tool we were able to make a select the Cesaroni K570 motor. With a total impulse of 2070.258 N-Sec and a 3.90 sec burn time, the average thrust is relatively low so that the rocket is not subject to unnecessary high forces during launch that come with short burn motors. Figure 5 shows that the K570 is able to send our proposed rocket in light winds (0-2 MPH) to a max altitude of 5503 feet AGL which is shown in simulation 0. Simulation 1 is the same rocket with medium winds (3-7 MPH) and in Simulation 2 the rocket is subject to high winds (8-14 MPH). Simulation 3 is the result of using a 0.75 lb. ballast placed near the center of gravity, as not to affect the rockets stability, to reach the desired altitude of 5280 feet above ground level. The flight profile for simulation 3 can be seen in Figure 6. The team plans to use this tactic along with two test launches to accurately predict the needed ballast weight to reach the desired altitude at differing wind conditions.



	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deployment Feet / Sec	Altitude at deployment Feet
1	0		[K570-None]	5502.79	636.83	301.85	18.49	10.56	5502.80
2	1		[K570-None]	5498.16	636.82	301.85	18.48	16.97	5498.15
3	2		[K570-None]	5447.67	636.63	301.85	18.39	46.96	5447.67
4	3		[K570-None]	5272.34	612.00	289.49	18.25	0.10	5272.34

Figure 5: Rocket Diagrams & RockSim 9 Simulation Results

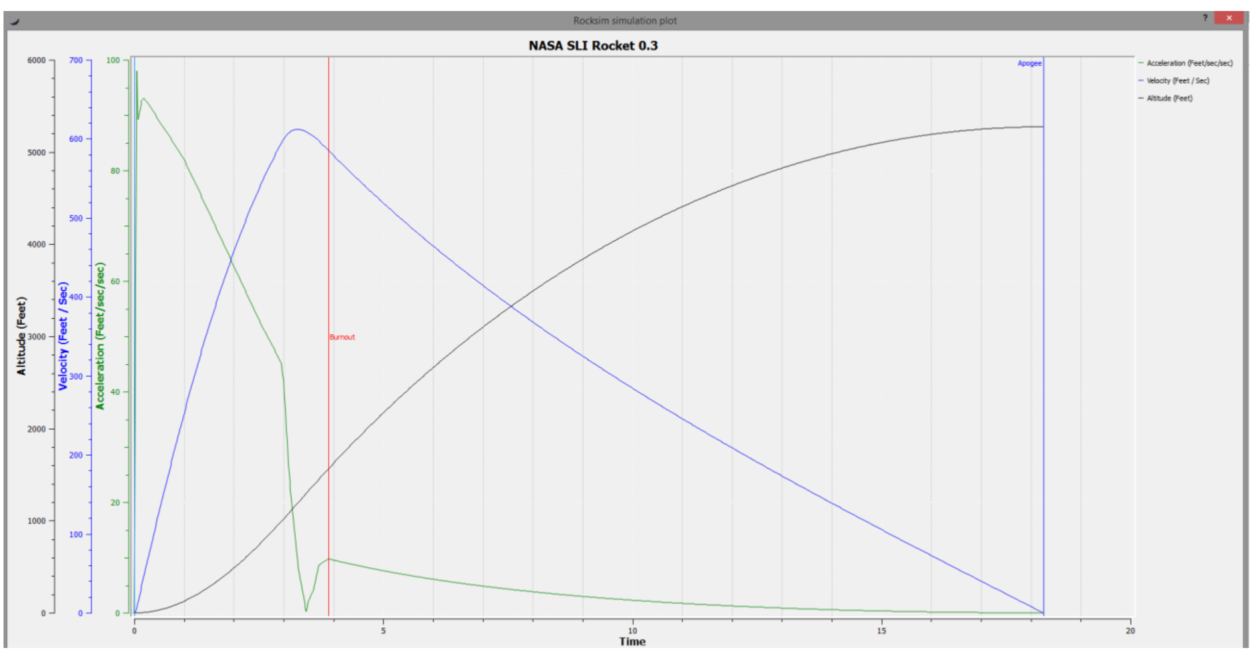


Figure 6: RockSim 9 rocket flight profile with Cesaroni K570

4.4 PAYLOAD DESIGN

4.4.1 Planetary Investigation Lander (PIL) – Payload Design

The PIL will house all of the sensors for detecting Atmospheric temperature, pressure, relative humidity, solar irradiance, UV radiation, as well as the camera for pictures during descent & landing, and a radio for data transmission. The payload also contains a GPS for finding landing location, as well as an accelerometer for acceleration and vibration data. Below is a table of the measurement parameter and the corresponding sensor.

Table 4: List of sensors being used to measure atmosphere

Parameter	Sensor
Temperature	SHT15 Temp. & Humidity sensor
Relative Humidity	SHT15 Temp. & Humidity sensor
Pressure	BMP180 Barometer
Solar Irradiance	SP Lite 2 Pyranometer
UV Radiation	ML8511 UV sensor
Images	LinkSprite JPEG Color Camera
Accelerometer	ADXL345
Data Transmission	XTend 900 1W RPSMA radio SainSmart Small GSM GPRS SIM900 cellular
GPS	Spark Fun Venus GPS
Micro Controller	Arduino Mega 2650
Ground Antenna	L-COM 900 MHz 8 dBi Flat Patch Antenna

The preliminary design for the payload housing is 'pill' shaped, with the 1 hemisphere section for our pyranometer, and the other for the camera. The general dimensions are 4.5"Ø by 10" long. The payload will be loaded into the fairing adapter from the top, which has an internal retaining ring to hold the payload in place when the rocket is launched. Once the PIL has been loaded the fairing will shroud the payload, to make the rocket more aerodynamic on ascent. The parachute will be attached to the middle of the cylindrical body of the PIL, and the parachute will be carefully folded and stored above the PIL inside the fairing.

4.4.2 Planetary Investigation Lander (PIL) – Payload Electrical Components

Component Name	**SHT15 Breakout Board**
Description	Humidity and temperature sensor
Specifications	Temperature range: -20°C to 60°C Humidity range: 0% - 90%
Power Consumption	1.8 mW
Dimensions (Length x Width x Height)	18 mm x 18 mm x [Estimated 2 mm]
Weight	Estimated 5 g
Cost	$41.95

Component Name	BMP180 Breakout Board
Description	Barometric pressure sensor
Specifications	Absolute Accuracy Pressure: 300 hPa to 1100 hPa
Power Consumption	3.3 mW
Dimensions (Length x Width x Height)	16 mm x 16 mm x [Estimated 2 mm]
Weight	Estimated 5 g
Cost	$9.95

Component Name	Kipp and Zonen SP Lite 2 Silicon Pyranometer
Description	Solar Irradiance Sensor
Specifications	Field of View: 180 degrees Spectral Range: 400 to 1100 nm Detector Type: Photo-diode
Power Consumption	0 mW
Dimensions (Diameter x Height)	52 mm x 34 mm
Weight	150 g
Cost	$378.25

Component Name	ML8511 Breakout Board
Description	UV sensor
Specifications	Wavelength Detection Range: 280 nm to 390nm Max Sensitivity Wavelength: 365 nm
Power Consumption	30 mW
Dimensions (Length x Width x Height)	16 mm x 16 mm x [Estimated 2 mm]
Weight	Estimated 5 g
Cost	$12.95

Component Name	LinkSprite JPEG Color Camera
Description	Color camera that outputs jpeg data over serial
Specifications	1600 x 1200 pixels
Power Consumption	600 mW
Dimensions (Length x Width x Height)	32 mm x 32 mm x [Estimated 20 mm]
Weight	91 g
Cost	$54.95

Component Name	ADXL345 Breakout Board
Description	Triple axis accelerometer
Specifications	Acceleration Range: ± 16g
Power Consumption	1 mW
Dimensions (Length x Width x Height)	20 mm x 16 mm x [Estimated 2 mm]
Weight	Estimated 5 g
Cost	$17.95

Component Name	XTend 900 1W RPSMA
Description	Radio transceiver
Specifications	Maximum Range: 40 mile (with high gain antenna and line of sight) Throughput data rate: 115,200 bps Frequency: 900 MHz
Power Consumption	4750 mW
Dimensions (Length x Width x Height)	37 mm x 60 mm x 5 mm
Weight	18 g
Cost	$194.95

Component Name	SIM900 GPRS/GSM Board
Description	GSM Board for SMS messaging
Specifications	Radio Frequencies: 850/900/1800/1900 MHz Control: AT commands – Standard Commands – GSM 07.07 & 07.05
Power Consumption	96 mW transmitting
Dimensions (Length x Width x Height)	85 mm x 57 mm x 20 mm
Weight	3.4 g
Cost	$25.73

Component Name	SparkFun Venus GPS
Description	GPS receiver
Specifications	Accuracy: 2.5 m Update Frequency: 20 Hz Memory: Internal flash for up to 75K point logging
Power Consumption	67 mW
Dimensions (Length x Width x Height)	30 mm x 18 mm x [Estimated 10 mm]
Weight	Estimated 10 g
Cost	$49.95

Component Name	Arduino Mega 2650
Description	Microcontroller
Specifications	Number of Digital IO pins: 54 Number of Analog IO pins: 16 Number of UARTs: 4 Clock frequency: 16 MHz Flash Memory: 256 KB
Power Consumption	1 mW
Dimensions (Length x Width x Height)	102 mm x 54 mm x 15 mm
Weight	37 g
Cost	$45.95

Component Name	L-COM 900 MHz 8 dBi Flat Patch Antenna
Description	Ground antenna
Specifications	Gain: 8dBi Frequency: 902 MHz to 928 MHz Horizontal Beam Width: 75 Degrees Vertical Beam Width: 65 Degrees
Power Consumption	0 mW
Dimensions (Length x Width x Height)	216 mm x 216 mm x 30 mm
Weight	450 G
Cost	$54.95

Table 5: Specifications of sensors being used in atmospheric probe

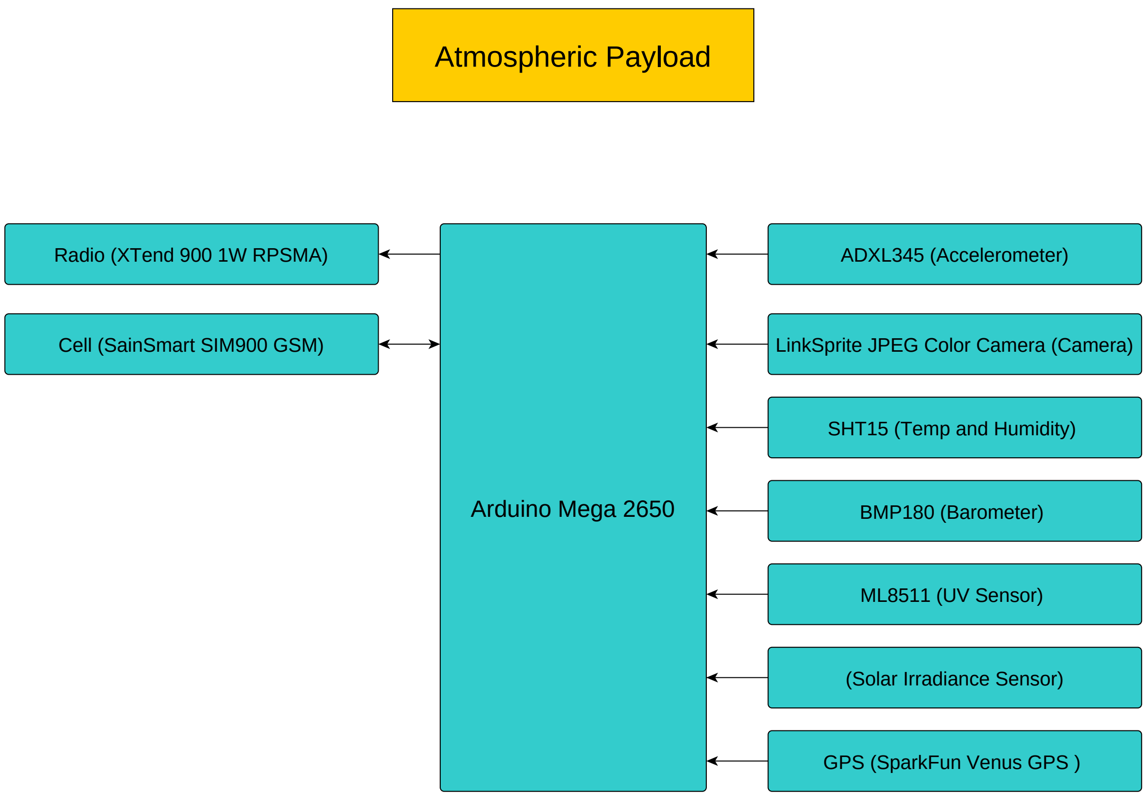
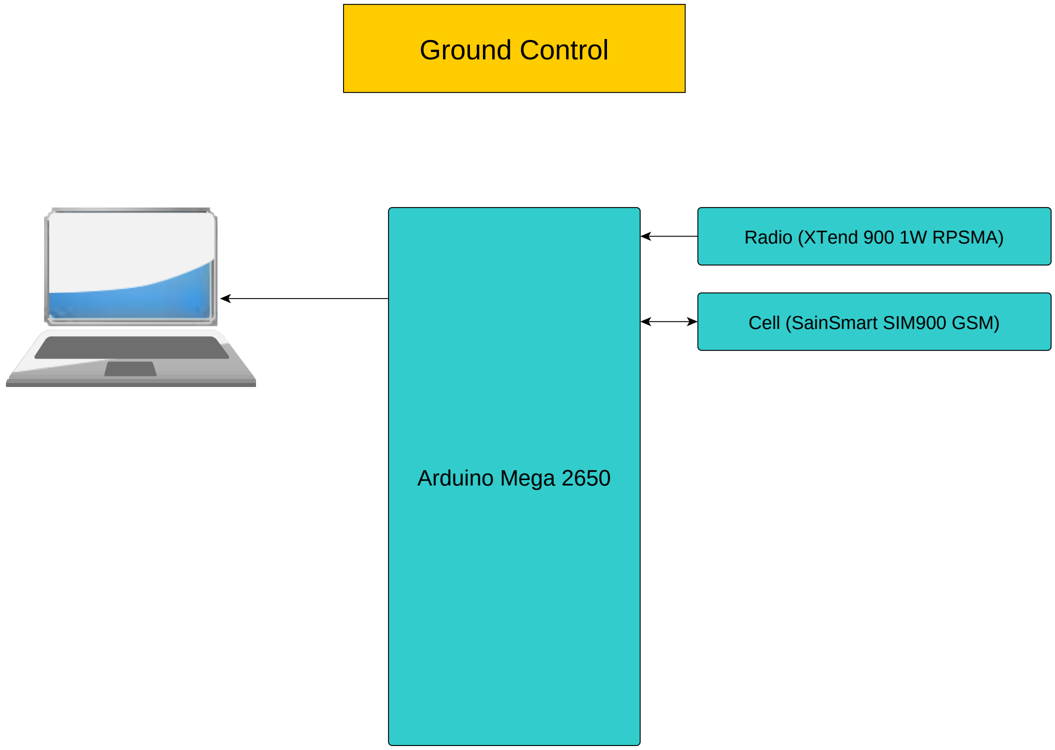


Figure 5: Diagram of atmospheric payload electronics

The atmospheric payload will consist of an Arduino microcontroller with a series of atmospheric sensors and communication devices attached. The atmospheric sensors will consist of a camera, temperature and humidity sensor, a barometer, UV Sensor, solar irradiance sensor and accelerometer. A GPS receiver will be included as well for location tracking. Communication devices include an XTend 900 1 watt radio and a SainSmart GSM Module. The scientific and location data will be transmitted in real time to the ground control via the XTend 900 1 watt radio. A backup of location data will be transmitted to the ground control via SMS messaging as well.

4.4.3 Ground Support Electronics & Description



The ground control will consist of a laptop used for processing and displaying the data that is received from the atmospheric payload and the rocket body. The information is passed to the computer using an Arduino board connected to one of the XTend 900 1 watt radios and a SainSmart GSM Module. The radio will receive scientific and location data from the atmospheric payload. The GSM Module will receive location data from the rocket body and the atmospheric payload as a backup to the radio.

When the data is transmitted to the ground from the atmospheric payload, the radio receiver will send the data over serial to the Arduino board. SMS messages will be transmitted from the GSM Module on a second serial port on the Arduino. The Arduino will send this data to the computer via USB, where the computer will decode the encoded data, process the data and display it in a graphical user interface.

Messages can and will be sent from the ground to both the rocket body via SMS messaging and to the atmospheric payload via radio and SMS messaging as a backup. The messages will contain instructions on power settings to apply to the components based on the battery status. The higher power components such as the radio and GPS can be put into a power saving sleep mode, and the radios transmit power can be adjusted via software as well.

4.5 Design Challenges

4.5.1 Rocket Challenges

- Reaching an altitude of 5280 feet without going over
  - This will take some simulation in RockSim, as well as a few iterations of launches, and gathering the weather (temperature, pressure, wind, etc) data to take into effect the drag induced on the rocket. From there we can better estimate real world flights to ballast our rocket for the exact height of apogee.
  - We will test the rocket in OpenRocket as well to verify RockSim simulation results.
  - We also plan to use test to find the most accurate drag coefficient value to get the most accurate data out of our simulations.
  - The two planned test launches will help us better understand how the rocket preforms and verify our simulation results or determine what ballast changes need to be made before the competition.
- Preventing recovery systems from tangling
  - This challenge will require careful packing and planning of our recovery systems.
- Structural stability of removable fin design
  - In order for this removable fin design to work, we must be sure our tolerances of fabrication are tight, to prevent any slack in the connection point from the rocket to the fins. This will also require testing to determine the design is structurally sound.
- Accuracy of tracking equipment on rocket
  - This task will require the team to do some testing of our GPS system, to insure that it can update its position accurately and quickly.

4.5.2 Fairing Challenges

- Clean separation with no binding or shearing of clamshell component
  - Clean separation will require scale testing, and proof of concept rapid 3d prototyping, to ensure all part fit together as intended.
- Powder Charge balancing, enough charge to shear the pins but not the shell.
  - We plan on feasibility testing a mockup of our fairing design, to experiment to find our upper and lower limits of powder charge. Initial ideas for fairing separation testing include using an air pressure pump to find necessary gas pressure to shear the shear pins. In accordance with the safety regulations, all pressure containers will have a minimum factor of safety of 4.

4.5.3 Payload Challenges

- Maintain orientation of camera to horizon
  - This task may require image processing to stabilize photos, but we are investigation a physical camera balancing mechanism
- Make sure pyranometer is with-in 180 degrees of the sun
  - We need to investigate how the payload will swing around on its descent, to optimize the readings from the pyranometer.
- Maintaining radio communication and correct encoding & decoding data transmission
  - We have to test our radio communication systems from at minimum 1 mile; to be sure they can transmit any data over the desired distance.

4.6 Testing

The first test our team will undertake is a feasibility study of the fairing design. During this test, we will try different types of fairings in order to meet design criteria. These criteria include payload clearance, structural rigidity, and separation ability.

Our second test is a pop test, which checks that all of our charges will separate the rocket and payload. This test will also check that the charges will properly break the shear pins holding the rocket together.

Next, we will test a scale model of our rocket. This will test the stability of our rocket design. This will verify that the fins, nose cone, and rocket body are of the proper shape.

Our second to last test is electronics verification. As part of this test, we will test individual components and finally a completed setup. We will take the completed setup a distance away from the ground station and verify the radios can transmit the distance required on landing.

Our final tests are 2 full scale tests. The tests will verify all components of the payload and faring work properly and compare our altitude results to our simulator. These tests will satisfy the FRR requirements to launch a complete setup and determine our ballast weight for the competition.

5 Educational Engagement

5.1 Overview

In order to fulfill our requirement, we plan to have direct interactions with over 200 high school students at a local area high school. This will consist of teaching these students rocket physics using water bottle rockets, culminating in the students launching their own rockets. The information taught will come from NASA documentation on water bottle rockets. We will work with the teachers at the high school to make sure our lesson will relate to what the students have learned in the classroom.

5.2 Lesson Plans

It is anticipated that each class of around 30 students will have around 1 hour of lesson time. The lesson will be broken into three parts.

5.2.1 Presentation - 15 minutes

A short PowerPoint explaining Newton's laws, center of gravity, center of pressure, g forces, fins, etc. This will be based on the information at http://exploration.grc.nasa.gov/education/rocket/BottleRocket/about.htm. We will work with the teachers at the high school to make sure that the material taught relates to the curriculum and is at the level of understanding for the students.

5.2.2 Build - 30 minutes

This part of the lesson will involve groups of students building a water rocket. The students will be given one bottle and an array of materials to build fins for their rocket. At the end of this part of the lesson, each rocket will be checked for safety by a Student Launch member before the last step.

Supplies for each team-

- 2L bottle
- Array of materials to choose from for fins
  - Craft foam
  - Cardboard
  - HDPE plastic
- Electrical tape to attach fins
- #16 Rubber O-Ring for launcher seal

5.2.3 Launch - 15 minutes

Each team will launch their rocket. An emphasis on safety will be used in this step. If weather conditions do not allow launches, alternate plans may occur.

The launcher and air pump will be provided by the Student Launch team. The bottles will be pressurized to ~70 psi, well below the failure limit of ~150 psi. Below are pictures of the launcher. The string attached to the launcher allows students to stand at least 20 feet away during launch.

Figure 6: Photos of water bottle rocket stand and launching mechanism

5.3 CONTACT INFORMATION

The team has already reached out to a local school and found a faculty member willing to host our educational engagement. Their information is listed below.

Brad Ciminowasielewski
Cimino.brad@wintonwoods.org
Winton Woods High School
1231 West Kemper Rd, Cincinnati, OH 45240

5.4 Evaluation, Documentation

Within one week of the rocket launch, we will send a survey to the faculty of the school asking for feedback on our lesson. Within two weeks, we will complete an education engagement form and send it to the appropriate NASA contacts.

6. Project Plan

6.1 Project Schedule

The timeline for our project was based on the competition schedule. Some additional dates were added to reflect due dates for our Spacecraft design class. Below is the top level overview of the entire project, including due dates for each step and a Gantt chart. An additional six views were included to show the next level of requirements. Each subgroup will have a list of tasks that have to be completed. Teams have been assigned to each subgroup to determine exactly what those tasks are.

	ℹ	Task Mode	Task Name	Duration	Start	Finish
1	✓		Develop Team	7 days	Fri 8/28/15	Mon 9/7/15
2	✓		Project Definition-Class	4 days	Thu 9/3/15	Tue 9/8/15
11			Project Proposal	10 days	Mon 8/31/15	Fri 9/11/15
27			Project Plan-Class	11 days	Wed 9/9/15	Wed 9/23/15
35			Systems Requirements Review-Class	16 days	Thu 9/24/15	Thu 10/15/15
36			PDR-Class	23 days	Fri 10/16/15	Tue 11/17/15
50			PDR-NASA	26 days	Fri 10/2/15	Fri 11/6/15
122			CDR-Class	21 days	Wed 11/18/15	Wed 12/16/15
136			CDR-NASA	51 days	Fri 11/6/15	Fri 1/15/16
249			FRR-NASA	41 days	Mon 1/18/16	Mon 3/14/16
362			LRR-NASA	22 days	Tue 3/15/16	Wed 4/13/16
369			PLAR-NASA	13 days	Wed 4/13/16	Fri 4/29/16

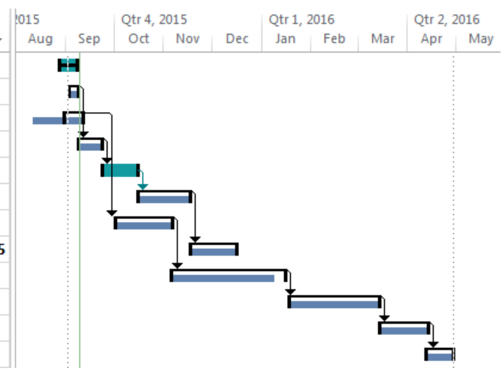


Figure 7: Top Level View of Project Schedule

	Task Mode	Task Name	Duration	Start	Finish
11		**Project Proposal**	**10 days**	**Mon 8/31/15**	**Fri 9/11/15**
12		Safety Plan	5 days	Mon 8/31/15	Fri 9/4/15
13		Determining Facilities and Resources	4 days	Mon 8/31/15	Thu 9/3/15
14		**Technical Design**	**23 days**	**Tue 8/11/15**	**Thu 9/10/15**
15		Rocket Design	21 days	Tue 8/11/15	Tue 9/8/15
16		Avionics and Recovery	5 days	Mon 8/31/15	Fri 9/4/15
17		Motor Selection and Simulation	5 days	Mon 8/31/15	Fri 9/4/15
18		**Payload**	**9 days**	**Mon 8/31/15**	**Thu 9/10/15**
19		Fairing Design	6 days	Mon 8/31/15	Mon 9/7/15
20		Atmospheric Probe	8 days	Mon 8/31/15	Wed 9/9/15
21		Education Engagement Plan	9 days	Mon 8/31/15	Thu 9/10/15
22		**Project Plan**	**4 days**	**Wed 9/2/15**	**Sun 9/6/15**
23		Budget	4 days	Wed 9/2/15	Sun 9/6/15
24		Schedule	4 days	Wed 9/2/15	Sun 9/6/15
25		Funding Plan	3 days	Thu 9/3/15	Sun 9/6/15
26		Community Support	3 days	Thu 9/3/15	Sun 9/6/15

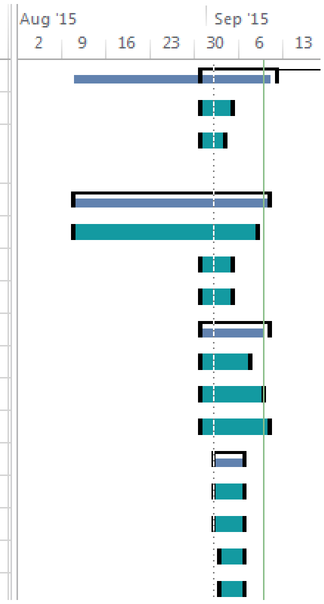


Figure 8: Subgroup view of the Project Proposal

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	Task Mode	Task Name	Duration	Start	Finish
50		**PDR-NASA**	**26 days**	**Fri 10/2/15**	**Fri 11/6/15**
51		Summary of PDR	21 days	Fri 10/2/15	Fri 10/30/15
52		Changes to Proposal	21 days	Fri 10/2/15	Fri 10/30/15
53		**Vehicle Criteria**	**21 days**	**Fri 10/2/15**	**Fri 10/30/15**
54		**Selection, Design, Verification**	**16 days**	**Fri 10/2/15**	**Fri 10/23/15**
67		**Interfaces and Integration**	**16 days**	**Fri 10/2/15**	**Fri 10/23/15**
71		**Recovery Subsystem**	**21 days**	**Fri 10/2/15**	**Fri 10/30/15**
74		**Mission Performance Predictions**	**18 days**	**Fri 10/2/15**	**Tue 10/27/15**
80		**Safety**	**17 days**	**Fri 10/2/15**	**Mon 10/26/15**
85		**Payload Criteria**	**18 days**	**Fri 10/2/15**	Tue 10/27/15
86		**Selection, Design, Verification**	**16 days**	**Fri 10/2/15**	**Fri 10/23/15**
95		**Concept Features and Definition**	**11 days**	**Fri 10/2/15**	**Fri 10/16/15**
99		**Science Value**	**16 days**	**Fri 10/2/15**	**Fri 10/23/15**
106		**Project Plan**	**16 days**	**Fri 10/2/15**	**Fri 10/23/15**
107		Budget Plan	16 days	Fri 10/2/15	Fri 10/23/15
108		Funding plan	16 days	Fri 10/2/15	Fri 10/23/15
109		Timeline (Gantt Chart)	16 days	Fri 10/2/15	Fri 10/23/15
110		Educational engagement plan	16 days	Fri 10/2/15	Fri 10/23/15
111		Conclusion	21 days	Fri 10/2/15	Fri 10/30/15
112		**Presentation**	**26 days**	**Fri 10/2/15**	**Fri 11/6/15**
113		Vehicle Dimensions, Materials, and Ju	21 days	Fri 10/2/15	Fri 10/30/15
114		static stability margin	21 days	Fri 10/2/15	Fri 10/30/15
115		plan for vehicle safety verification an	21 days	Fri 10/2/15	Fri 10/30/15
116		baseline motor selection and justific	21 days	Fri 10/2/15	Fri 10/30/15
117		thrust-to-weight ratio and rail exit ve	21 days	Fri 10/2/15	Fri 10/30/15
118		launch vehicle verification and test p	21 days	Fri 10/2/15	Fri 10/30/15
119		drawing/discussion of each major cor	21 days	Fri 10/2/15	Fri 10/30/15
120		baseline payload design	21 days	Fri 10/2/15	Fri 10/30/15
121		payload verifiication and test plan ov	21 days	Fri 10/2/15	Fri 10/30/15

Figure 9: Subgroup view of the PDR

	Task Mode	Task Name	Duration	Start	Finish
136		CDR-NASA	51 days	Fri 11/6/15	Fri 1/15/16
137		Summary of CDR	46 days	Fri 11/6/15	Fri 1/8/16
138		Changes since PDR	46 days	Fri 11/6/15	Fri 1/8/16
139		Vehicle Criteria	46 days	Fri 11/6/15	Fri 1/8/16
140		Design and Verification of Launch Vehicle	46 days	Fri 11/6/15	Fri 1/8/16
161		Subscale Flight Results	18 days	Fri 11/6/15	Tue 12/1/15
165		Recovery Subsystem	40 days	Fri 11/6/15	Thu 12/31/15
172		Mission Performance Predictions	39 days	Fri 11/6/15	Wed 12/30/15
178		Payload Integration	17 days	Fri 11/6/15	Mon 11/30/15
183		Luanch Concerns and Operation Procedures	40 days	Fri 11/6/15	Thu 12/31/15
191		Safety and Enviroment	40 days	Fri 11/6/15	Thu 12/31/15
195		Payload Criteria	46 days	Fri 11/6/15	Fri 1/8/16
196		Testing and Design of Payload Equipment	41 days	Fri 11/6/15	Fri 1/1/16
215		Concept Features and Definition	13 days	Fri 11/6/15	Tue 11/24/15
219		Science Value	17 days	Fri 11/6/15	Mon 11/30/15
226		Project Plan	46 days	Fri 11/6/15	Fri 1/8/16
227		Budget Plan	46 days	Fri 11/6/15	Fri 1/8/16
228		Funding plan	46 days	Fri 11/6/15	Fri 1/8/16
229		Timeline (Gantt Chart)	46 days	Fri 11/6/15	Fri 1/8/16
230		Educational engagement plan	46 days	Fri 11/6/15	Fri 1/8/16
231		Conclusion	7 days	Thu 12/31/15	Fri 1/8/16
232		Presentation	15 days	Mon 12/21/15	Fri 1/8/16

Figure 10: Subgroup view of the CDR

	Task Mode	Task Name	Duration	Start	Finish
249		FRR-NASA	41 days	Mon 1/18/16	Mon 3/14/16
250		Summary of CDR	35 days	Mon 1/18/16	Fri 3/4/16
251		Changes since CDR	35 days	Mon 1/18/16	Fri 3/4/16
252		Vehicle Criteria	31 days	Mon 1/18/16	Mon 2/29/16
253		Design and Construction of Vehicle	31 days	Mon 1/18/16	Mon 2/29/16
264		Recovery Subsystem	25 days	Mon 1/18/16	Fri 2/19/16
275		Mission Performance predictions	25 days	Mon 1/18/16	Fri 2/19/16
282		Verification (vehicle)	25 days	Mon 1/18/16	Fri 2/19/16
285		Safety and Environment	25 days	Mon 1/18/16	Fri 2/19/16
289		Payload Integration	25 days	Mon 1/18/16	Fri 2/19/16
294		Payload Criteria	31 days	Mon 1/18/16	Mon 2/29/16
295		Experiment Concept	25 days	Mon 1/18/16	Fri 2/19/16
298		Science Value	25 days	Mon 1/18/16	Fri 2/19/16
305		Payload Design	25 days	Mon 1/18/16	Fri 2/19/16
315		Verification	25 days	Mon 1/18/16	Fri 2/19/16
318		Safety and Environment	25 days	Mon 1/18/16	Fri 2/19/16
322		Luanch Operations Procedure	31 days	Mon 1/18/16	Mon 2/29/16
323		Checklist	25 days	Mon 1/18/16	Fri 2/19/16
331		Safety and Quality Assurance	31 days	Mon 1/18/16	Mon 2/29/16
336		Project Plan	31 days	Mon 1/18/16	Mon 2/29/16
337		Budget Plan	25 days	Mon 1/18/16	Fri 2/19/16
338		Funding plan	25 days	Mon 1/18/16	Fri 2/19/16
339		Timeline (Gantt Chart)	25 days	Mon 1/18/16	Fri 2/19/16
340		Educational engagement plan	25 days	Mon 1/18/16	Fri 2/19/16
341		Conclusion	41 days	Mon 1/18/16	Mon 3/14/16
342		Presentation	41 days	Mon 1/18/16	Mon 3/14/16

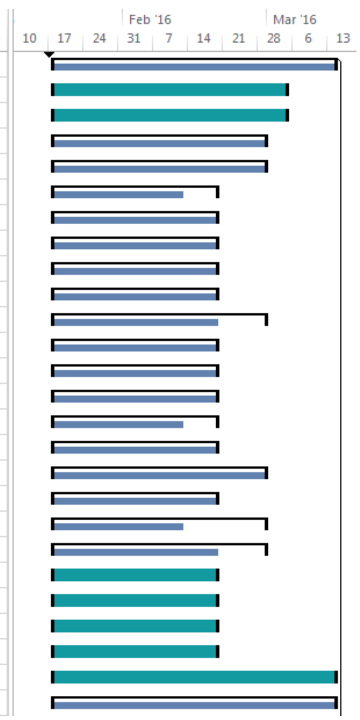

Figure 11: Subgroup view of the FRR

	Task Mode	Task Name	Duration	Start	Finish
362		LRR-NASA	22 days	Tue 3/15/16	Wed 4/13/16
363		An airframe prepared for flight with exception of energetic materials	22 days	Tue 3/15/16	Wed 4/13/16
364		Data from the previous flight	22 days	Tue 3/15/16	Wed 4/13/16
365		A list of flight anonmalies that occurred	22 days	Tue 3/15/16	Wed 4/13/16
366		Any changes to the Airframe	22 days	Tue 3/15/16	Wed 4/13/16
367		Flight Simulations	22 days	Tue 3/15/16	Wed 4/13/16
368		Pre-flight checklist and Fly Sheet	22 days	Tue 3/15/16	Wed 4/13/16

Figure 12: Subgroup view of the LRR

	Task Mode	Task Name	Duration	Start	Finish
369		PLAR-NASA	13 days	Wed 4/13/16	Fri 4/29/16
370		Team name	13 days	Wed 4/13/16	Fri 4/29/16
371		Motor Used	13 days	Wed 4/13/16	Fri 4/29/16
372		Brief Payload description	13 days	Wed 4/13/16	Fri 4/29/16
373		Vehicle Dimensions	13 days	Wed 4/13/16	Fri 4/29/16
374		Altitude Reached	13 days	Wed 4/13/16	Fri 4/29/16
375		Vehicle Summary	13 days	Wed 4/13/16	Fri 4/29/16
376		Data analysis and Results	13 days	Wed 4/13/16	Fri 4/29/16
377		Payload Summary	13 days	Wed 4/13/16	Fri 4/29/16
378		Data analysis and Results of payload	13 days	Wed 4/13/16	Fri 4/29/16
379		Scientific Value	13 days	Wed 4/13/16	Fri 4/29/16
380		Visual Data observed	13 days	Wed 4/13/16	Fri 4/29/16
381		Lessons Learned	13 days	Wed 4/13/16	Fri 4/29/16
382		Summary of overall Experience	13 days	Wed 4/13/16	Fri 4/29/16
383		Educational Engagement Summary	13 days	Wed 4/13/16	Fri 4/29/16
384		Budget Summary	13 days	Wed 4/13/16	Fri 4/29/16

Figure 13: Subgroup view of the PLAR

6.2 Project Budget

The tables below outline our projected budget for the NASA SLI. This projection was based off of actual part costs from previous rocket builds. The payload projection budget comes from actual part cost of our initial payload design. The travel budget was based on current gas prices as well as online booking for a hotel for the week of the competition.

Projected Total Expenses

ITEM	Subtotal
Travel Expenses	$ 3,442.00
Rocket Expenses	$ 1,344.38
Payload Expenses	$ 2,564.21
Outreach Expenses	$ 55.00
TOTAL	**$ 7,464.39**

Projected Rocket Expenses

Part	Quantity	Price	Part Number	Subtotal
54 mm Motor Mount Tube	1	$8.09	MMT-2.14	$8.09
5.38" Plastic Nose Cone Long	1	$65.95	PNC-5.38L	$65.95
5.38" Airframe Tubing 42"	2	$38.50	BT-5.38	$77.00
Centering Ring 5.38", 54mm	4	$7.21	CR-5.38-2.14	$28.84
Tube Coupler 5.38"	1	$9.08	TC-5.28	$9.08
Tube Stiffener 5.38	1	$10.85	STC-5.38	$10.85
Bulkhead 5.38"	1	$7.98	BA-5.38	$7.98
Rail Buttons 1500 Series	1	$5.78	RB-1500	$5.78
Swivels 400# Test	2	$3.50	4/0 Swivel	$7.00
15 min Epoxy 9 oz.	2	$15.95	EPY-15	$31.90
54mm quick change Motor Retainer	1	$34.00	RA-54L	$34.00
Electronic Bay	2	$42.95	EB-5.38	$85.90
1/4" Chain Eye Connector (Quick link)	2	$4.13	CEC-2	$8.26
Drogue Parachute	1	$18.95		$18.95
Main Chute	1	$79.95		$79.95
ABC Fire Extinguishers	2	$39.99		$79.98
Arming Switches	4	$9.46		$37.84
Goex Black Powder	1	$17.75		$17.75
Shock Cords	2	$13.70		$27.40
Scale Model Kit	1	$76.95	PK-56	$76.95
Cessaroni Rocket Engine	3	$106.95		$320.85
Website Hosting Cost	1	$11.99	www.ucrocketry.com	$11.99
Misc. Overheads	-	-		$260.08
Shipping & Handling	-	-		$72.82
UC School Discount From LOC Precision				-$40.80
			TOTAL	**$1,344.38**

Projected Payload Expenses

Part	Quantity	Price	Part Number	Subtotal
Arduino Mega 2560	3	$ 45.00		$ 90.00
4S 5200 mAh LiPo Battery Pack	2	$ 39.88	912700002-0	$ 79.76
StratoLogger Altimeter	4	$ 58.80		$ 235.20
Energizer Max 9V Batteries, 5pk	2	$ 16.49	552538432	$ 32.98
Aluminum 6061 Material for Payload	1	$ 40.00		$ 40.00
MG Chemical's Ferric Chloride Etchant	1	$ 36.95	70125797	$ 36.95
Misc. Wiring and Electrical Components	1	$ 20.00		$ 20.00
MG Chemical's Solder	1	$ 16.99	4895-227G	$ 16.99
SP Lite2 Pyranometer	1	$ 378.25	13493	$ 378.25
LinkSprite JPEG Color	2	$ 54.95		$ 109.90
Temperature/Humidity SHT15	1	$ 41.95		$ 41.95
Barometer BMP180	1	$ 9.95		$ 9.95
UV Sensor ML8511	1	$ 12.95		$ 12.95
SparkFun Venus GPS	2	$ 49.95		$ 99.90
Accelerometer ADXL345	1	$ 17.95		$ 17.95
Xtend 900 1W RPSMA	3	$ 194.95		$ 584.85
Blank Circuit Board	1	$ 15.00		$ 15.00
Soller Composites Carbon Fiber	1	$ 70.00		$ 70.00
Acrylic Frame	1	$ 50.00		$ 50.00
Misc. Overhead Costs	-	-		$ 536.64
Shipping & Handling	-	-		$ 150.26
			TOTAL	**$2,833.46**

Projected Outreach Expenses

ITEM	Quantity	Price	Subtotal
Gas(UC to Winton Woods 40@ 23MPG & $2.745/Gal)	1	$ 5.00	$ 5.00
Misc. Building Materials	1	$ 50.00	$ 50.00
		TOTAL	**$ 55.00**

Projected Travel Expenses

Description	Estimated Price
Rental Car (3 SUV/ Mini Van for 5 days)	$ 1,350.00
Gas (Round Trip Cincinnati to Huntsville +100 miles @ 23MPG & $2.745/Gal)	$ 312.00
Hotel (Holiday Inn Express Huntsville 4 rooms 4 nights @107.50/Night)	$ 1,720.00
Gas (2 Round Trip Cincinnati to Test Launch Site) 500@ 23MPG & $2.745/Gal)	$ 60.00
Food (Team members will be responsible for their own food expenditures)	$ -
TOTAL	**$ 3,442.00**

6.3 FUNDING PLAN

Our senior design team will be getting $2333.34 from the University of Cincinnati. This money comes from the University Funding Board (UFB). Also we will be getting $333.34 from the leftover money from last year's design team. We also plan to request funds from the OSGC (Ohio Space Grant Consortium). We plan to acquire the rest of the money from private donors and businesses through fundraising. We plan to approach businesses with our project and ask for donations with a tier approach. For $100 or more we will do a thank you on our website, for $250 or more we will do an advertisement on our website. For $500 or more we will do the first two as well as put their company logo on our rocket. Companies could also help us in terms of donations of time on machines or parts and expertise.

6.4 COMMUNITY SUPPORT

As a senior design team we plan to approach companies, professors, and professionals with our project and ask for support. We may need support in expertise needed, equipment and supplies, sponsorship, or partnering with other schools.

1. For expertise needed we plan to work closely with our Professor, Dr. Schaffner, as well as several graduate students who ran the University of Cincinnati Rocket Club. These individuals have made themselves available for questions and support.
2. The University of Cincinnati has an incredible selection of tools and machines at our disposal. If we need additional machines and equipment we can approach several companies where teammates have worked, and solicit use of their more intensive machining centers. For supplies we can solicit help/materials from the University of Cincinnati's Rocket Club which have extra materials for rocket building at their disposal.
3. For sponsorship we plan to follow our outline in the Funding Plan Overview.
4. We do not plan to partner with other schools.

6.5 PROJECT SUSTAINABILITY

Throughout the life of the project the team plans to take the following steps to ensure that successive teams are able to continue to pursue opportunities such as the NASA Student Launch Initiative.

1. The team will talk with the UC Rocketry Club and other underclassman throughout the project lifespan to inspire them to pursue opportunities in rocketry available to them through the university. We will document all of our deliverables and establish a network for future team members to use as reference if they need help on future projects. Toward the end of the project life we will be presenting our work at the Senior Design Symposium which is a public event hosted by the University of Cincinnati every Spring to show underclassman, professors and the public what projects current graduating seniors completed during the school year.
2. The team worked with the school's senior design advisors to gain approval of the NASA Student Launch Initiative as a university recognized senior design project and to establish a method for allowing students from different majors to work on the same senior design project that fulfills all majors' educational requirements.
3. As we establish industry partners we will strive to make sure they have a good experience so that we can maintain those partnerships for use by future rocketry teams.
4. Any remaining project funds will be placed in an account dedicated to future rocketry related senior design projects.

APPENDIX A

1. FAA Regulations

FAR Title 14 → Chapter I → Subchapter F → Part 101 → Subpart C

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§101.21 Applicability.

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

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

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

§101.22 Definitions.

The following definitions apply to this subpart:

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

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

(2) Uses a slow-burning propellant;

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

(4) Contains no substantial metal parts; and

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

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

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

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

§101.23 General operating limitations.

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

(1) Is launched on a suborbital trajectory;

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

(3) Is unmanned; and

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

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

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

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

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

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

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

(c) Into any cloud;

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

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

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

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

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

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

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

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

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

§101.27 ATC notification for all launches.

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

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

(b) Date and time the activity will begin;

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

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

(e) Highest affected altitude;

(f) Duration of the activity;

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

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

§101.29 Information requirements.

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

(1) Estimated number of rockets,

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

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

(4) Description of recovery system,

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

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

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

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

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

(2) Maximum possible range,

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

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

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

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

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

(8) Launch commit criteria,

(9) Countdown procedures, and

(10) Mishap procedures.

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

Minimum Distance Table

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 – 320.00	H or smaller	50	100	200
320.01 – 640.00	I	50	100	200
640.01 – 1,280.00	J	50	100	200
1,280.01 – 2,560.00	K	75	200	300
2,560.01 – 5,120.00	L	100	300	500
5,120.01 – 10,240.00	M	125	500	1,000
10,240.01 – 20,480.00	N	125	1,000	1,500
20,480.01 – 40,960.00	O	125	1,500	2,000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Revision of July 2008

Provided by the National Association of Rocketry (www.nar.org)

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