NASA Student Launch

2014 – 2015

Maxi-MAV Proposal

Mobile Autonomous Launch Platform for a Martian Ascent Vehicle Analogue Mission

Icarus Rocketry

Arizona State University

ASU School of Earth and Space Exploration
PO Box 871404
Tempe, AZ 85282-1404

Contents

1 General Information

1.1 School/Team Information

Team Name
Icarus Rocketry

School
Arizona State University

Contact Information

Mailing Address:
ASU School of Earth and Space Exploration
PO Box 871404
Tempe, AZ 85282-1404

Shipping Address:
ASU School of Earth and Space Exploration
550 East Tyler Mall
PSF Rm #686
Tempe, AZ 85287

Project Title
Mobile Autonomous Launch Platform for a Martian Ascent Vehicle Analogue Mission

1.2 Executive Project Summary

The Icarus Rocketry team proudly presents their proposed entry to the NASA SLP 2015 competition. Our rocket will nominally be 105 inches tall, with a diameter of 4 inches, and featuring a novel robotic system with an arm that will be used to load a Martian regolith sample tube into the rocket payload containment bay. Once the payload will be loaded, the system will mount the igniter and swing the rocket upwards to an 85 degree slope. The rocket will reach an apogee of 3,270 ft in 14.0 seconds, with a max velocity of 550 ft/s and max acceleration of 8.21 G. The rocket will use an Aerotech J401FJ motor with Fast Blackjack propellant. The combination with the rocket will yield a thrust to weight ratio of 7.6. The rocket will have an overall length of 105 inches and weigh 12.3 lbs. The report is organized as follows: Section 1 outlines team organization and members. Section 2 presents facilities and equipment available as resources to the team. Section 3 presents safety procedures and consideration, followed by section 4 containing the technical design. Section 5 outlines education outreach activities and section 6 the project plan and budget.

1.3 Adult Educator

Dr. Jekan Thanga
Assistant Professor, School of Earth and Space Exploration
Arizona State University
(480) 727-2218
jekan@asu.edu

1.4 Safety Officer

Jonathon Hill
Phone: (602) 622-1303
Email: jonathon.hill@asu.edu

1.5 Team Leader

Project Director: Peter Nguyen
Phone: (850) 496-1308
Email: nguyenp@asu.edu

1.6 Team Members and Organization

Icarus Rocketry will consist of at least 15 members actively participating in Project MALP, from several majors and levels; including undergraduate and graduate students from astrophysics, aerospace engineering, and mechanical engineering. We only formed as a team at the start of the semester, and up until two weeks ago, we have been running a series of high power rocketry workshops, so our numbers have been in flux. But now that we're starting on a concrete project, with our numbers should stabilize, and have a more accurate estimate by the PDR.

The basic team hierarchy has been established as follows:

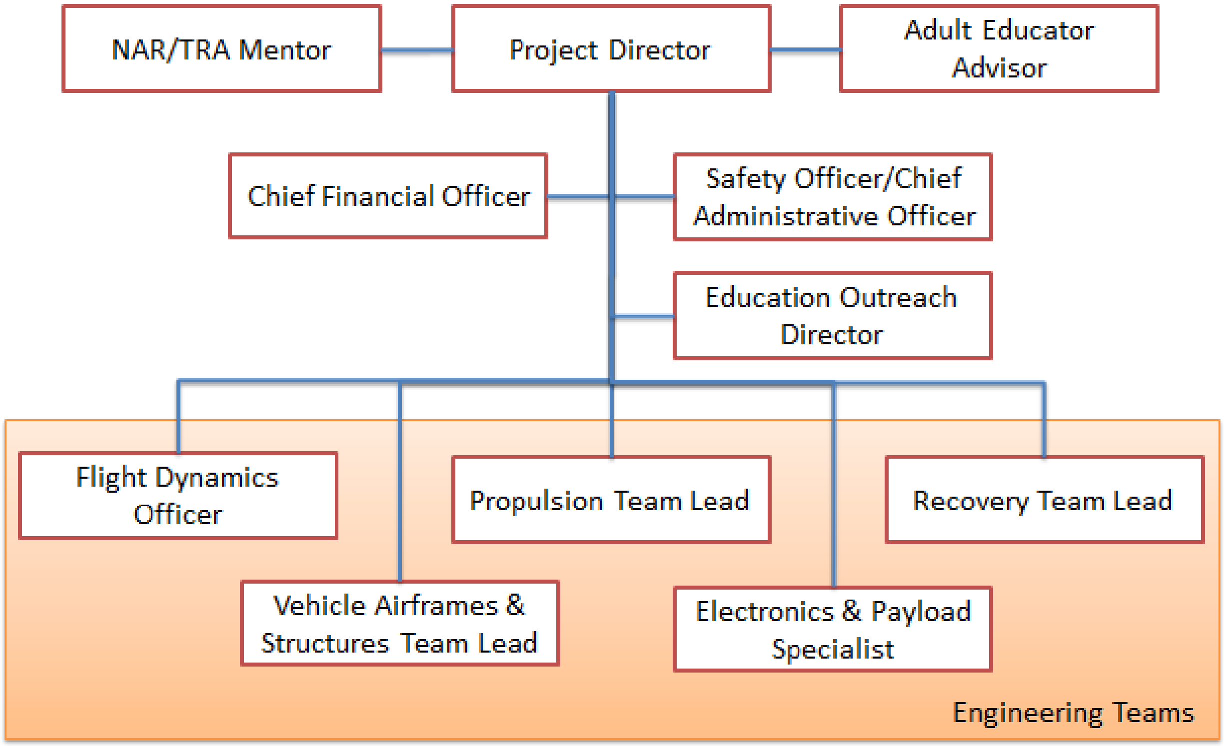

Figure 1: Team Hierarchy Diagram

The officers and leaders the teams are as follows:

1.6.1 Project Director

Peter
3rd Year Astrophysics, Ph.D.
Experience: Level 1 and (soon-to-be) Level 2 certified. 7 years of rocketry experience, including 3 years of high power rocketry
Responsibilities: The Project Director shall oversee general operations of the team to ensure that the overall long-term mission goals of Icarus Rocketry are achieved. Duties and responsibilities shall also include but are not limited to: ensuring the engineering teams are functioning and acting in a cohesive and timely manner to design and construct the rocket; overseeing rocket design and construction, and intervening in the process as necessary to resolve issues between engineering teams; serving as a high power rocketry subject matter expert for projects.

1.6.2 Vehicle Airframe and Structures Team Lead

Kurt
2nd Year Mechanical Engineering, Undergraduate
Experience: (soon-to-be) Level 1 certified.
Responsibilities: The Vehicle Airframe and Structures Team Lead is responsible for overseeing the manufacturing of the rocket. The group must properly devise methods to secure the fins, motor, recovery system, avionics, and other payloads. The group is responsible for the overall structural integrity of the rocket.

1.6.3 Flight Dynamics Team Lead

Kat
3nd Year Aerospace Engineering, Undergraduate
Experience: (soon-to-be) Level 1 certified.
Responsibilities: The Flight Dynamics Officer is responsible for overseeing the design of the rocket in such a fashion that it is both statically and dynamically stable. The flight dynamics team calculates a theoretical prediction of the rocket's flight profile. When designing the rocket, they must ensure that (1) the weight distribution of the rocket does not cause instability, and (2) drag is minimized, without sacrificing stability, structural integrity, the function of the recovery system, or the function of the payload.

1.6.4 Propulsion Team Lead

Eric
2nd Year Chemical Engineering, B.S.
Experience: (soon-to-be) Level 1 certified. Experience in hydrogen peroxide propellants.
Responsibilities: The Propulsion Team Lead is responsible for choosing and assembling the most efficient rocket motor to launch the rocket given specific altitude goals. The propulsion team is responsible for launch operations of the motor, and conducting motor tests throughout the design process for research purposes and to verify the motor's certified thrust curve data.

1.6.5 Electronics and Payload Specialist

Jose
4rd Year Exploration Systems Design, Undergraduate
Experience: Hardware microcontroller and programming experience.
Responsibilities: The Electronics and Payload Specialist is responsible for overseeing the equipment of the rocket and payload with flight electronics as necessary for the project requirements including but not limited to altimeters, GPS transponders, and/or flight computers. The Electronics and Payload Team is responsible for integration of both science/research payloads and flight-critical electronics in the rocket.

1.6.6 Recovery Team Lead

Milan
2nd Year Physics, B.S.
Experience: (soon-to-be) Level 1 certified.
Responsibilities: The Recovery Team Lead is responsible for overseeing the implementation of an appropriate recovery system to ensure the rocket is returned to earth at a safe velocity. Using the dimensions and weight specifications of the rocket, the Recovery Team will determine the appropriate parachute size to ensure a safe descent rate as well as the amount of black powder necessary to provide successful parachute deployment. This team will manufacture the ejection charges and will conduct ground tests verifying the amount of black powder used is sufficient to break shear pins holding components together. On launch day, this team is also responsible for packing the drogue and main parachutes as well as working with the electronics team to hook up the charges to the avionics bay. Finally, the tam is also responsible for leading the ground-team efforts to locate and recover the rocket post-landing.

1.6.7 Chief Administrative Officer

Jonathon
3rd Year Planetary Geology, Ph.D.
Experience: (soon-to-be) Level 1 certified.
Responsibilities: The Chief Administrative Officer is responsible for duties pertaining to project and team operations. Duties and responsibilities include: serving as liaison with the University, University departments, student organizations, and local NAR and TRA chapters; filing FAA waivers and liaising with other federal agencies as required for launch operations; and ensuring safety compliance for all aspects of the team.

1.6.8 Chief Financial Officer

Miekkal
3rd Year Exploration Systems Design, Undergraduate
Experience: (soon-to-be) Level 1 certified.
Responsibilities: The Chief Financial Officer is responsible for: securing sources of funding for the team; handling all financial transactions; working in conjunction with the Project Director and Engineering Team leads to prepare the budget; and keeping accurate and current financial records.

1.6.9 Education and Outreach Director

Janeen
3rd Year Secondary Education specializing in Earth and Space Sciences, Undergraduate
Experience: Intern Teacher at the Western School of Science and Technology
Responsibilities: The Education and Outreach Director is responsible for: generating content and outreach activities, and organizing outreach events at local schools and events.

1.7 NAR/TRA Partners

Based in the Tempe/Phoenix Metropolitan area, our team benefits from regular contact with high power rocketeers from a number of local NAR and TRA sections in the surrounding area.

1.7.1 NAR/TRA Sections

Southern Arizona Rocketry Association
NAR Section #545
TRA Prefecture #93

Superstition Spacemodeling Society
NAR Section #506

Tripoli Phoenix
TRA Prefecture #47

Arizona High Power Rocketry Association
TRA Prefecture #50

Mohave Area Rocket Society
TRA Prefecture #122

1.7.2 NAR/TRA Mentor

Roy Polmanteer
NAR #83979
TRA #11283

TRA Technical Advisory Panel Member
Level 3 Certified

2 Facilities and Equipment

As a team, we have access to a number of on- and off-campus facilities for fabrication of components, and rocket assembly.

2.1 On Campus Facilities

2.1.1 ASU Student Machine Shop

Equipment:

- Bridgeport series 2 manual milling machines w/ DRO's
- Colchester 11" manual lathe
- Colchester 13" manual lathe
- Cincinnati 12-1/2" manual lathe
- Sheldon 11" manual lathe
- Powermatic drill press
- Doall vertical bandsaw
- Jet horizontal saw
- ICM sandblaster
- Rotex turret punch

Figure 2: One of the many machines available to the team in the ASU Student Machine Shop.

Availability and Access: Six team members from our team are already certified to use these equipment. We also get assistance from operators in case of any problems and complex machining operations.

Hours of Operation: Open from 7am-4pm, we can gain access with extended hours with special permission.

2.1.2 ASU Digital Design Lab

This facility provides ASU students cheap access to equipment with capabilities such as laser cutting, 3D printing, 3D scanning, and large format printing.

Equipment:

- Two laser cutters,
- medium-format color printers for 8.5 x 11 inch and 13 x 19 inch prints,
- Two large-format color printers which print on 24 and 36-inch wide roll-feed paper and a large-format scanner.
- Three 3-D printers: the Dimension SST printer produces white ABS plastic models up to 8 x 8 x 12 inches;
- **Two ZCorp ZPrinters** produce plaster-based models up to 8 x 10 x 8 inches in color.

Figure 3: Example of 3D printed rocket components from the ASU Digital Design lab.

2.1.3 Foundry

This ASU facility has different furnaces, and tools to allow complete start to finish production of any molded parts needed such as engravers, and cut-off tools. This will be useful to design and make the custom exhaust cut-outs on the tower of the proposed LAS.

Equipment:

- #40 Melt Furnace
- #70 Melt Furnace
- Two burnout kilns
- 12" Cupola with iron casting capacity
- State-of-the-art ceramic shell facility with primary and secondary fluidized beds and slurry tanks
- Green sand, Petrobond, sodium silicate and linocure sand systems
- Investment casting capability
- Two sand mullers
- Banding machine
- Complete pneumatic metal chasing equipment including die grinders, turbo grinders, angle grinders, needle scalers, engravers, cut-off tools, hand tools

Figure 4: Example of a rocket fabricated in the Foundry.

2.1.4 Graduate Studio

Equipment:

- Cold saw
- Table saw
- Chop saws
- Band saws
- High capacity MIG TIG welders
- Oxyacetylene welders
- Hydraulic sheet metal shear (6' capacity)
- Hydraulic work table

2.1.5 Metal Shop

ASU shop with some special equipment with traditional machining facilities that includes **a** PlasmaCam CNC Plasma Cutter.

Equipment:

- Beverly Shear
- Grizzly horizontal band saw
- A-frame crane
- Gantry crane
- Do-All 36" throat band saw
- Scotchman hydraulic punch/bender
- Six-foot sheet metal break
- Pneumatic power shear
- Rollin metal band saw
- Manual punch
- Forge dies
- Two Lincoln MIG welders
- Three oxyacetaline kits
- Hypertherm plasma cutter
- Miller dialarc arc welder
- Cobramatic MIG 260
- Lincoln square wave TIG welder
- Dayton spot welder
- Rockwell vertical band saw
- MSC 3 Axis milling machine
- Logan metal lathe
- Miscellaneous bench grinders and drill presses
- Large and small sheet/rod rollers
- Extensive hand power tools such as right angle grinders, die grinders, nibbler, saber saw and Sawzall
- PlasmaCam CNC Plasma Cutter

2.1.6 Woodshop

This shop will be useful in the custom fabrication of bulkheads and centering rings.

Equipment:

- Rockwell 24" throat band saw
- Grizzly spindle sander
- Rockwell drill press
- Delta 12" disc/bench grinder
- Saw stop 12" table saw
- Dewalt Miter saw
- 18" radial arm saw
- Two jig saws
- Electrostatic flocker
- High frequency probe
- Extensive hand power tools including routers, saber saws, pneumatic nail guns and screw guns

2.2 Off-Campus Facilities

In addition to these on-campus facilities, ASU has collaborations with outside facilities, providing discounted rates to students.

2.2.1 TechShop at ASU Chandler Innovation Center

A do-it-yourself workshop and studio that allows students and members access to a wide range of machinery, tools, and software. The team will have access 24 hours, 7 days a week.

Equipment:

- Lathe, large metal, with digital readout and tooling
- Milling machine, large, with digital readout and tooling
- Milling machine, 4-axis, CNC (Tormach)
- 3D FDM printer, ABS
- Laser cutter, 60 Watt
- 3D scanner (NextEngine)
- Plasma cutter, CNC, 4' x 8' (Torchmate)
- Welder, TIG
- Welder, MIG
- Welder, spot
- Plasma cutter, hand held

2.3 Computer Equipment and Access

Our team is backed by host department, the School of Earth and Space Exploration (SESE), which has state of the art facilities for communication via WebEx video teleconferencing. SESE's Interdisciplinary Science and Technology Building IV (ISTB4) has multiple conference rooms capable of WebEx video teleconferencing, including a small lecture hall style classroom with whole room video camera and microphone coverage, which is available all the time to students.

As a facility, ISTB4 already complies with the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194) Subpart B-Technical Standards:

- 1194.21 Software applications and operating systems. (a-l)
- 1194.22 Web-based intranet and internet information and applications. (a-p)
- 1194.26 Desktop and portable computers. (a-d)

The team is in the process of developing a website, which will adhere to all of the applicable regulations above, and will in general apply with all of the above regulations when developing technological applications.

3 Safety

The safety of our team members and those observing our launches is of paramount importance to Icarus Rockety. To that end, we have developed the following project safety plan to guide our efforts during construction, transportation and launch operations.

Jonathon Hill, Icarus Rocketry's Chief Administrative Officer, will be serving as the Safety Officer for this project. He will be responsible for briefing all team members on standard safety procedures, ensuring all applicable FAA and NFPA laws are observed, confirming compliance with NAR Safety Code, conducting safety reviews of all construction activities and coordinating with our team's mentor to establish safe launch operation procedures for all flights. Roy "No Chute" Polmanteer will be serving as our group's NAR Level 3 qualified mentor. He will be responsible for purchasing, storing and transporting the rocket motors, as well as providing oversight during construction and launch operations to ensure compliance with NAR quality and safety standards.

3.1 Safety Plan Briefings

Prior to participating in any activities related to the construction, transportation or launching of the vehicle, all team members will be required to participate in a safety briefing conducted by the Safety Officer. The briefing will cover the team's safety plan for participating in the Student Launch Projects competition, including: 1) the FAA and NFPA regulations for high-powered rocketry, 2) the NAR safety code and the team's associated compliance plan (see Table 1), 3) safety concerns related to the construction of the vehicle and 4) proper interpretation of material safety data sheets (MSDS).

At the conclusion of the safety briefing all team members will be required to sign a statement verifying that they attended the briefing, understand the material presented and agree to abide by the team's safety plan. The signed safety statement from our team's initial safety briefing has been included as Appendix X. Any team members not present at our initial safety briefing will be required to attend an identical safety briefing before beginning work on the vehicle.

The Safety Officer will also be responsible for conducting follow-up briefings if any additional safety concerns are raised during the construction and testing process. He will also conduct safety briefings on launch days to review basic safety procedures, expand on launch-specific safety procedures (especially those related to the main and launch abort motors) and review any additional safety concerns specific to the launch site.

3.2 FAA, NFPA, ATF and State Law Compliance

The operation of high-powered rockets in the United States is subject to both Federal Aviation Administration (FAA) and National Fire Protection Association (NFPA) regulations, which are summarized below. Our team has reviewed these regulations and our Safety Officer will be responsible for ensuring our compliance.

3.2.1 Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C

The primary purpose of these regulations is to prevent high-powered rockets from posing a threat to aircraft, particularly general aviation aircraft flying at low altitudes. The regulations require that high-powered rockets be constructed of breakable or compactable materials, that they be launched in areas that are verifiably-free of air traffic and can be safely recovered. By adhering to the NAR Safety Code we will ensure compliance with these regulations.

3.2.2 NFPA Code 1127

This set of regulations more clearly defines what qualifies a rocket as "high-powered', what propellants may be used in the motor and what materials may be used to construct the vehicle. They also define classes of motors based on impulse and set requirements for purchasing and operating motors from various classes. By adhering to the NAR Safety Code we will ensure compliance with these regulations.

3.2.3 Code of Federal Regulation 27 Part 55: Commerce in Explosives

These regulations control the sale, transportation and storage of explosive materials, which include high-powered rocket motors. They require that the motor manufacturer only sell and ship motors to those with the appropriate certification. In our case, the motor will have to be sold and shipped to our group's mentor since no one else in the group has either NAR or TRA Level 3 certification. These regulations also require that explosive materials only be stored by those with appropriate certifications, which means our mentor will also need to be responsible for storing our motors prior to launch. By adhering to the NAR Safety Code we will ensure compliance with these regulations.

3.2.4 State Laws

Both the states of Arizona and Utah have based their local laws regarding the operation of high-powered rockets on the FAA, NFPA and ATF regulations cited above. By maintaining compliance with those regulations and the NAR Safety Code we can ensure compliance with all applicable local laws.

3.3 NAR Safety Code Compliance

The National Association of Rocketry's (NAR's) Safety Code will serve as the basis for our team's safety plan. The Safety Code specifies best practices for the design, construction, launch and recovery of high-powered rockets. Table 1 lists the 13 points of the NAR Safety Code along with our team's plan for ensuring compliance with each point.

Table 1: NAR Safety Code Compliance

Section	Code	Compliance Plan
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.	All flight operations will be performed under the supervision of the team's mentor. Team members will only be allowed to handle motors above their qualification level under his DIRECT supervision.
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 design of our vehicle only includes approved materials. The Safety Officer will be responsible for ensuring no unapproved materials are used during construction.
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.	The team will be using an Aerotech N-1000 motor, which will be purchased, stored and transported by the team's mentor. Any team members without the proper NAR or TRA qualifications will only be allowed to handle the motor under his DIRECT supervision.
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 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. If my rocket has onboard ignition systems for motors or recovery devices, these will have safety interlocks that interrupt the current path until the rocket is at the launch pad.	Only an approved electrical launch system will be used for the primary motor. The launch abort motor, which will be ignited by the flight computer during flight, will include a safety interlock that will only be removed once the vehicle is on the pad and prepared for flight.
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 battery, and will wait 60 seconds after the last launch attempt before allowing	The Safety Officer will be responsible for enforcing the misfire protocols. In addition, if it is necessary to re-approach the vehicle after a misfire, the launch abort motor safety interlock will be

	anyone to approach the rocket.	replaced before any additional work is performed.
6. Launch Safety	I will use a 5-second countdown before launch. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table, and that a means is available to warn participants and spectators in the event of a problem. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable.	The team's mentor and Safety Officer will be responsible for ensuring proper countdown procedures. The Project Director and the Safety Officer will be responsible for jointly verifying the stability of the vehicle prior to all launches.
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, and will increase this distance by a factor of 1.5 if the rocket motor being launched uses titanium sponge in the propellant.	All launches will be performed at NAR and/or TRA certified events using proper launch pad equipment. The Safety Officer will be responsible for verifying the compliance of launch pad conditions. The team will NOT be using a motor containing titanium sponge material.
8. Size	My rocket will not contain any combination of motors that total more than 40,960 N-sec (9,208 pound-seconds) of total impulse. My 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.	The design of the main vehicle complies with the total impulse requirements. The Propulsion System Lead will be responsible for verifying the launch abort component of the vehicle complies with the average thrust requirement during design and prior to launch.
9. 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	The Safety Officer will be responsible for verifying compliance with all flight safety requirements prior to any launches.

	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.	
10. Launch Site	I will launch my rocket outdoors, in an open area where trees, power lines, 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.	All launches will be performed at NAR and/or TRA certified events using properly-size launch sites.
11. Launcher Location	My launcher will be at least one half the minimum launch site dimension, or 1,500 feet (whichever is greater) from any inhabited 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.	All launches will be performed at NAR and/or TRA certified events using launches properly-placed within the boundaries of the launch site.
12. 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-resistant or fireproof recovery system wadding in my rocket.	The primary vehicle and the launch abort component will both use parachutes and fire-proof materials in their recovery systems. The Recovery Systems Lead will be responsible for verifying compliance.
13. 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.	Only trained members of the Recovery Systems group will be allowed to recover the vehicle components.

3.4 Vehicle Construction and Operation Safety

The process of constructing, launching and recovering of our rocket will include a number of tools and materials that could potentially harm our team members or bystanders if they are used improperly. Summarized below are potential dangers associated with construction phase (Table 2), launch phase (Table 3) and recovery phase (Table 4). During these project phases, subsystem leads will be required to periodically review the phase-specific safety concerns with their team members and to monitor their work for compliance.

Table 2: Construction Safety Plan

Activity	Potential Risks	Mitigation Plan
Power Tool Use	- mild to severe cuts - mild to severe burns - eye injury - blunt force trauma - damage to tools/property	- tools are only to be operated by those with proper training - eye protection is required - close-toed shoes required - no food or drink allowed in the work areas
Adhesive/Paint Use	- mild to severe chemical burns - eye injury - inhalation of toxic fumes - damage to property	- MSDS information must be available whenever chemicals are in use - gloves and eye protection is required for all chemical use - chemicals must be used in well-ventilated areas - protective work surface coverings must be used
Welding	- mild to severe burns - eye injury - damage to tools/property	- welding masks and gloves are required - close-toed shoes required - long pants and long-sleeve shirts required - only those with aluminum-specific welding training and/or experience may be involved in the welding operations

Table 3: Launch Safety Plan

Activity	Potential Risks	Mitigation Plan
Transportation	- damage to components	- subsystem leads will be in charge of properly packing their components for transportation
Launch Pad Quality	- mis-angled guide rod	- before mounting the vehicle on the guide rod, the Safety Officer will verify it is at an acceptable angle
Pre-Launch	- misfire	- the igniter's safety interlock will be inserted and all personnel will wait 60 seconds before approaching the Rocket - after approaching the rocket, the launch abort rocket's interrupt will be inserted immediately
	- early launch abort	- all personnel working on the rocket must wear full eye protection, gloves, long-sleeved shirts and long pants after the launch abort motor has been installed
Post-Launch	- near-pad brush fire	- a minimum of two fire extinguishers will be available (compatible with motor materials)

Table 4: Vehicle Recovery Safety Plan

Activity	Potential Risks	Mitigation Plan
Parachute Descent	- components free-fall	- team members will use binoculars to monitor the parachute deployments; if the parachutes fail to deploy properly they will warn the launch site personnel
Launch Abort Test	- abort motor misfire	- if the launch abort motor misfires, only recovery team members wearing full eye protection, gloves, long-sleeved shirts and long pants will be allowed to approach the motor in order to safe it

3.4.1 Project Failure Mode Identification and Mitigation

As with any complex system, there are numerous potential failures that could result in the loss of the vehicle and/or failure to achieve the project's stated research objectives. Summarized below are potential Personnel/Logistics (Table 5) and Vehicle (Table 6) failure modes along with their associated mitigation strategies.

Table 5: Personnel and Logistics Failure Mitigation

Failure Mode	Probability	Effect	Mitigation
Loss of Mentor	Low	Unable to purchase motor or launch rocket due to insufficient certifications	- Our mentor search identified other possible mentors whom we could recruit if necessary
Loss of Students	High	Unable to complete critical work due to student unavailability	- Team leaders will stay familiar with all aspects of the design so they can fill-in for other students if necessary - Subsystem leaders will ensure all their team members are familiar with all aspects of the subsystem
Budget Exceeded	Intermediate	Unable to purchase components, materials or services	- Approach additional local aerospace companies for sponsorship - Apply for additional funds from the department and student government
Material/Equipment Unavailability	Low	Unable to complete critical tasks	- All subsystem leads will front-load purchases and major equipment use so time is available to deal with any unavailabilities

Table 6: Vehicle Failure Mitigation

Failure Mode	Probability	Effect	Mitigation
Nose Assembly Structural Failure	Low	The primary research objective is not completed and the vehicle is potentially lost.	- The nose assembly structure will undergo careful, but rigorous, testing prior to launch.
Parachute Failure	Intermediate	Vehicle components are not safely recovered intact	- The custom parachutes will undergo ground and small-height testing, as well as flight testing on smaller rocket, schedule permitting
Structural Failure During Trans-sonic Flight	Low	Loss of vehicle	- The vehicle structure will undergo very careful construction and ground testing. - The structure will be closely examined for potential damage (ie: buckling, etc) after the initial test flight.

3.5 Updating the Project Safety Plan

Throughout the project, the Safety Officer will monitor the construction process in order to update the safety plan with newly identified potential dangers and plans to mitigate the associated risks. He will also monitor the quality of the work being performed and arrange for additional safety and/or equipment training as necessary.

3.6 Written Safety Compliance Statement

All team members shall be briefed on, and understand, Icarus Rocketry's Safety Plan for the NASA Student Launch Projects competition and agree to abide by the Safety Plan during all vehicle design, construction, transportation, and launch activities. This safety plan includes, but is not limited to the following safety regulations:

- Range safety inspections of each rocket before it is flown. Icarus Rocketry shall comply with the determination of the safety inspection.
- The RSO has the final say on all rocket safety issues. Therefore, the RSO has the right to deny the launch of any rocket for safety reasons.

4 Technical Design

4.1 Airframe Design and Construction

For the purposes of rocket design and modeling, flight dynamics simulations and predictions, Open Rocket[1] is used for its all-around strengths are simulation. A decision was made not to use the more widely used RockSim[2] based on reports that for high-altitude flights, its drag calculation algorithm overestimates drag, and hence underestimated altitude [1]. The same report by the AeroPac team noted that Open Rocket, "as one integrated tool for multistage design and simulation may be the best all around choice." The free, open-source nature of Open Rocket was also an advantage, eliminating the need and cost of procuring multiple RockSim software licenses.

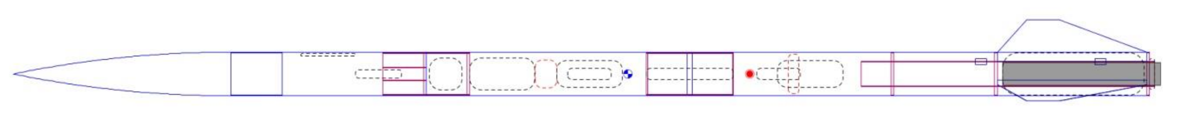

Figure 5: Simulated Model of our rocket in Open Rocket

Our design philosophy for this rocket is to follow basic tried-and-true designs, to allow us to focus on the more complex MALP AGSE. Another design consideration for our rocket is to incorporate materials and construction techniques that we intend to fly on our team's other project for the year – designing and flying a rocket to 100,000 ft AGL – thus allowing this rocket to serve as a testbed for our future mission.

4.1.1 Technical Specifications

To ensure strong, stable fin mounts, the rocket will utilize a through-the-wall fin mount. This in addition to the choice of a 54mm motor, necessitates that the rocket will be 4 inches in diameter.

The overall length of the rocket will be 105 inches long.

The rocket has a number of "bays" included, for the different payloads and recovery equipment. The bays and their corresponding lengths are as follows:

1)	Regolith Sample Containment Bay	10.0 inches
2)	Main Parachute Bay	16.5 inches
3)	Electronics Bay	8.0 inches
4)	Drogue Parachute Bay	11.75 inches

The bay lengths are an estimate and may be adjusted as the electronics mounting systems and sample containment bay get completed and a more realistic estimate of the length will be available.

[1] http://openrocket.sourceforge.net/
[2] http://www.apogeerockets.com/Rocksim/Rocksim_information

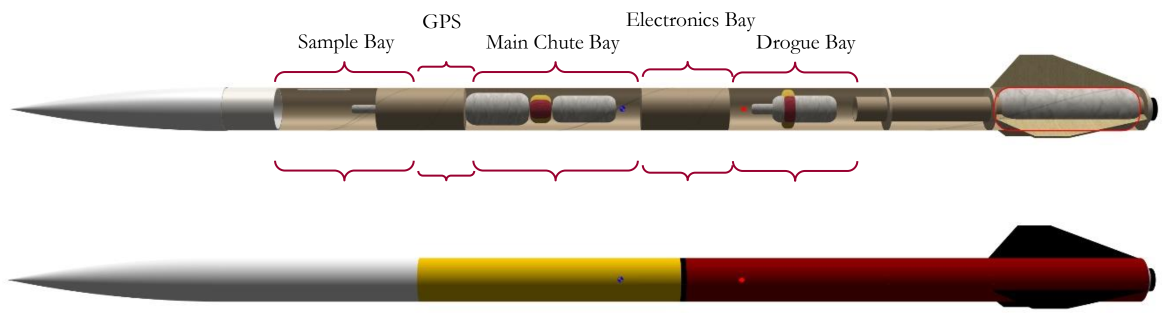

Figure 6: Finish View of Our Rocket

The weight of the rocket with motor will be 12.3 lbs, and 9.79 lbs without a motor.

4.1.2 Airframe Materials

The main body of the rocket will be constructed from Blue Tube 2.0, which provides a strong airframe “Mach-capable” without additional reinforcement.[3] G-10 fiberglass will be used for the fin material. Expanding two-part urethane foam will be used as filler material and additional reinforcement for the fins in the fin can region between the motor mount tube, and the body tube.

4.1.3 Construction Methods

The team will leverage knowledge from previous HPR competition projects to streamline construction methods. Standard techniques for construction of the payload bay, through-the-wall fin mounts, and motor tube mount will be used. The team will explore the use of different CNC milling, and 3D printing to construct the sample bay door mechanisms.

4.2 Projected Altitude

Based on Monte Carlo simulations of our initial model in Open Rocket, we nominally predict the rocket to achieve an apogee at 3,279 ft in 14.0 seconds, with a max velocity of 550 ft/s and max acceleration of 8.21 G.

Our simulation parameters assume a launch site location in the Huntsville, Alabama area of 34.7°N, 86.5°E, with a surface altitude of 4,000 ft. We also assume a temperature of 68°F, based on average weather for the area during mid/early-May. Additionally, an average windspeed of 3 mph is adopted with a standard deviation of 0.3 mph, and medium turbulence intensity of 10%. Finally, a 5° off vertical 8 ft launch rod is assumed for flight.

4.3 Recovery System

Safe recovery of all components of our rocket is always an important aspect of rocket design. With our sample containment bay separating from the launch vehicle, two recovery systems are required: one for the sample containment bay, and one for the launch vehicle.

[3] http://www.alwaysreadyrocketry.com/about-us/blue-tube-2-0/

4.3.1 Launch Vehicle Recovery System

The larger mass of the launch vehicle requires a much more complex and redundant dual-deploy recovery system. Contained within the electronics bay will be a PerfectFlite Stratologger, and MissileWorks RRC3 altimeter which will be wired independently from each other and tied to independent power supplies. The Stratologger altimeter is a very reliable altimeter which has been successfully flown in dual-deploy configurations in the past by other team members. The RRC3 altimeter is an altimeter which comes highly recommended by experienced high-power rocketeers at local club launches. The choice to use two different altimeters from different manufacturers is to ensure an additional level of redundancy against any defects or manufacturing flaws resulting from a single batch from one company.

Figure 7: TAC-1 parachute our drogue/LAS parachutes are based on.

Each altimeter will be connected to machined aluminum "Blastcap" ejection charge canisters located on either end of the payload bay for deployment of the drogue and main parachutes. There will be four canisters in total – two each for each altimeter, to deploy the drogue and main chutes.

FFFFg black powder will be used for ejection charges. The amount of black powder used will be computed to generate the optimal amount of pressure in the chambers to break the 2-56 x ¼" nylon screws used as shear pins. Ground tests of the ejection charges will be completed to ensure that the size of the charges are sufficient to break the shear pins without overpressurizing the chambers.

Figure 8: Example of the Fruity Chutes Classic Elliptical Parachute to be used as the main parachute.

The Stratologger will serve as the primary altimeter for deployment of parachutes. It will be programmed to deploy a 24" parachute at apogee, which will ensure that the rocket reaches a terminal velocity of 60.7 ft/s during the main portion of descent. The RRC3 altimeter will serve as backup and be programmed to fire its drogue ejection charge 1 second after apogee. This will avoid any chances of overpressurization should both altimeters fire at apogee, but still allow for a safe deployment of the drogue in case the Stratologger fails.

The main parachute will be a 36" parachute with a coefficient of drag, Cd = 1.55. Such a parachute will be required to ensure that the rocket lands with KE <58 ft-lbf. The Stratologger will be programmed to deploy the main parachute at an altitude of 1000 ft during descent. Again, the RRC3 will serve as the backup altimeter, and be programmed to deploy the main at an altitude of 950 ft. These altitudes were chosen to minimize drift under a large main parachute, but still allow enough time to reach a stable, slow terminal impact velocity to minimize kinetic energy at impact.

4.3.2 Sample Containment Bay

The main parachute bay will actually contain two Kevlar shockcords and main parachutes. One shockcord and parachute will be connected to the electronics bay and therefore the rest of the launch vehicle. The upper airframe which encompasses the sample containment bay and nosecone above it will be connected to their own shockcord/parachute.

When the altimeters fire the main parachute ejection charge, the rocket will separate into untethered sections. The nosecone and sample containment bay will be separated from the rocket and descend under their own 36" parachute.

4.4 Motor Selection

A number of factors were considered in selecting a motor for our rocket. With any rocket, the thrust to weight ratio should always be at least 3:1 to ensure a safe and stable flight, with larger ratios generally more advisable. An Aerotech J401FJ was chosen as it meets this criteria with a thrust to weight ratio of ~7.64 (see below).

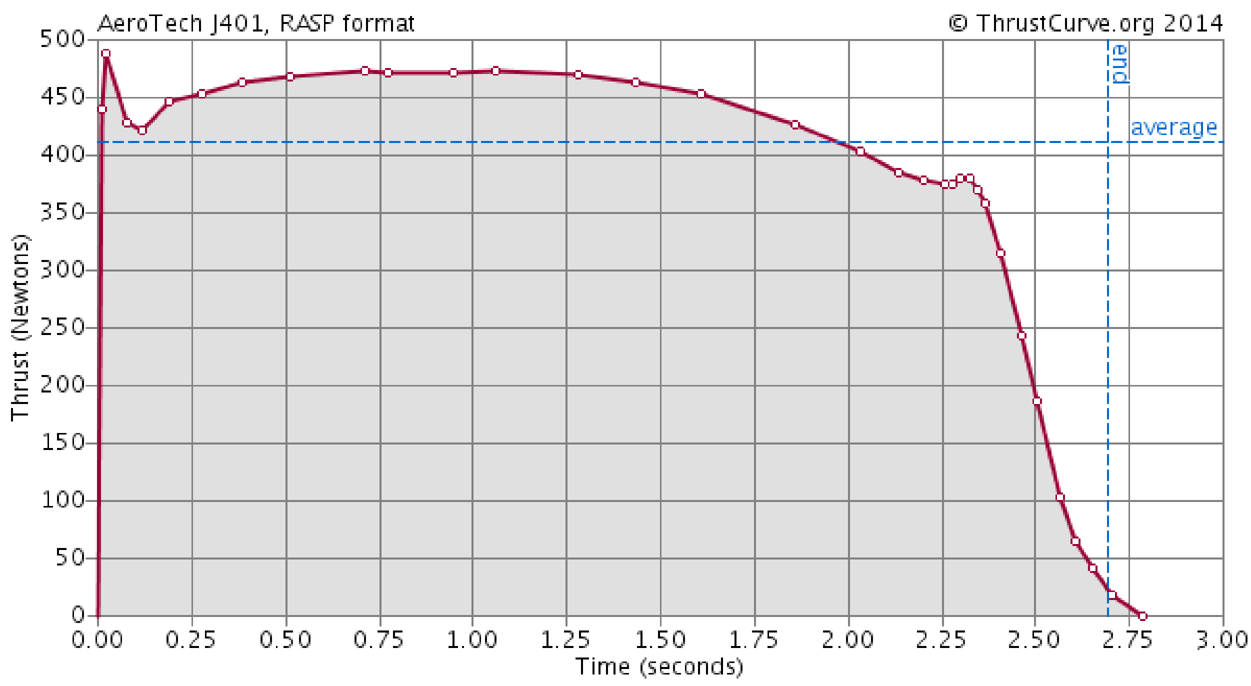

Figure 9: Experimentally determined thrust curve for the Aerotech J410FJ motor. Source: www.thrustcurve.org

4.5 Mobile Autonomous Launch Platform (MALP) Autonomous Ground Support Equipment

The Mobile Autonomous Launch Platform (MALP) will serve as our Autonomous Ground Support Equipment nominally planned to be operated as follows with the Figure 10 and

Figure 11 serving as reference.

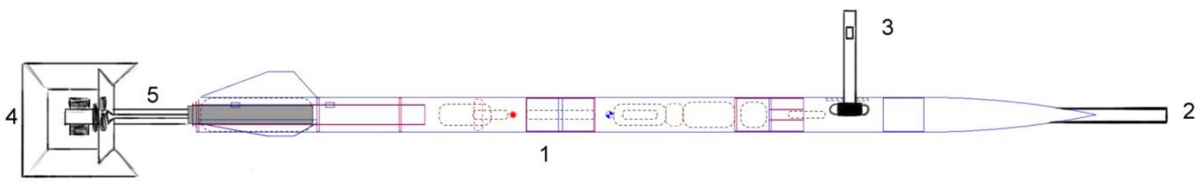

Figure 10: Top-down view of MALP

1. The rocket will be laid on the 80/20 1010 rail, with the payload opening facing upwards. The doors will rest on hinges with plates inside that will give way under the weight of the payload capsule, swinging them down and sealing them shut with neodymium magnets for stability.
2. The launching rail will be raised with a 7:1 gear ratio servo, enabling the rocket to be raised to the specified 85 degree launch angle. The servo will be encased in the base of the ASGE, and protected by the launch plate attached to the railing. The end of the rail also has a support arm the help maintain a horizontal position while the payload is deposited into the rocket, and it will swing freely until it reaches rest position at the side of the rail once it is vertical.
3. The payload arm will run along a rail beneath the main launch rail while it is horizontal, and the arm will swivel at the base to pick up the payload beside the rocket and then drop it into the payload bay. The end of the arm will have a clamp to grasp the payload, and the arm itself will raise and lower the clamp along the axis beside the rocket. Once it swivels to the side and the rocket is raised to the vertical, it will remain stationary on the ground.
4. The base of the ASGE will consist of aluminum tubing and joints, covered with aluminum sheet metal to help protect the inside components from the rocket's ignition once it launches. Inside is the servo to raise the launch rail, as well as all the electronics to facilitate the automated launch sequence, and the power source for all the electronic components.
5. The igniter will be inserted with a two-wheel feeder that is aligned with a guide tube that leads to the base of the rocket. The motor for the two wheels will be housed below the launch plate, which is attached to the launch rail. It will be started by contacts on the plate and inside the base that will not allow the feeder to begin the final loading procedure of the launch sequence.

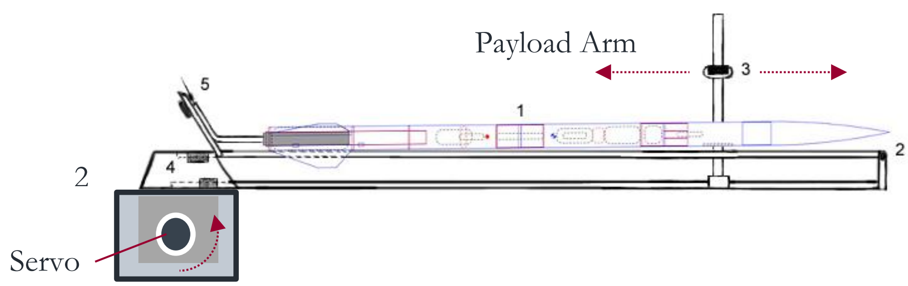

Figure 11: Side view of MALP

5 Educational Engagement

Icarus Rocketry is a new student organization at Arizona State University; our group closely works with the School of Earth and Space Exploration (SESE) in education and public outreach (EPO). EPO has been a main component and a focus of SESE since the beginning of the department, as a group mainly comprised of SESE students, Icarus Rocketry can utilize the EPO infrastructure created by SESE in the past years. Icarus' educational engagement plan relies on the connections and partnerships already in place within the department—primarily with middle schools in the metro Phoenix area.

5.1 Local School Outreach

Icarus Rocketry will be providing a full day of science and engineering outreach to approximately 100 7^{th} grade students at the Western School of Science and Technology where Education and Outreach Officer Janeen is an intern teacher.

5.1.1 Lesson Plan

Icarus Rocketry plans to provide a full day of instruction for the students of Mr. Chappell's three block periods. Instruction will be utilizing the scientific method to lead up to the actual rocket launches.

The first half of instruction will be indoor. This will include discussions about rocketry basics such as how rockets work, why they are useful, the modern applications of rockets, and what types of rockets the class will be working with that day. After discussion and formal instruction, the students will be asked to come up with independent variables that could affect how high a rocket will fly. After a large list of variables have provided by the students, the instructors will then narrow "available" variables down to payload, aerodynamics, fin shape, and strength of the motor. After discussing each of these variables, the instructors will "pick" motor strength (this is because the motors will already be installed in the rockets).

Instructions will then have the students write out a data table in their Interactive Student Notebooks with the following table:

	Control	Motor 1	Motor 2	Motor 3
Observed launch peak height				

The instructors will then lead the students outside where the launch site will be set up. The schematics of the rockets will be "rehashed" and the control rocket will be watched to qualitatively observe how high the rocket flies. The instructors will then discuss which rockets will be flown next, and the students will write their qualitative observations in their data tables.

After the rockets fly, the students' regular teacher will then have the students write up a conclusion of the day's events in their ISN's before the period is over.

5.2 Outreach Engagement with the Community at Large

Arizona State University (ASU) has fostered partnerships with many schools in the communities surrounding the university. ASU has four campuses which are located throughout the greater Phoenix area. The main campus in Tempe, AZ is located close to many schools throughout the area. Education and Outreach Officer Janeen has contacts at many schools in the area and we are planning to utilize teacher's needs for outreach in their schools to teach STEM areas to their students.

In addition to Icarus Rocketry, SESE conducts education and outreach within the department, which many members—particularly Michael, are involved with. Icarus Rocketry has access to ASU's STARLAB portable planetarium to also bring to schools in order to do planetarium shows for students who many not otherwise have the chance or opportunity to see a planetarium show. It is also true for many students in the greater Phoenix area that they have never seen the Milky Way, or many of the constellations. STARLAB education works to provide this opportunity to students and introduce them to the night sky they have not met before.

Icarus Rocketry plans to utilize SESE's EPO component and send out officers and members to outreach events planned by SESE in the community. One such example was Earth and Space Exploration Day (ESE Day), which occurred on 11/2/13 on the ASU Tempe campus, reached an audience close to 4,000 people of the general public where Icarus Rocketry occupied a booth. We also launched model rockets in a field next to the event, which garnered the attention of close to 200 people (Figure 13). Icarus Rocketry will in the future occupy booths at future monthly open houses held by SESE, where Icarus members show kids how to build paper rockets, and officers explain the basics of rocketry with our rockets on display.

Figure 12: (Left) ESE Day Rocket Launch Outreach Activity (Right) Camp SESE – Freshmen Activity Weekend that Culminated in a Rocket Launch Event.

6 Project Plan

6.1 Project Schedule and Timeline

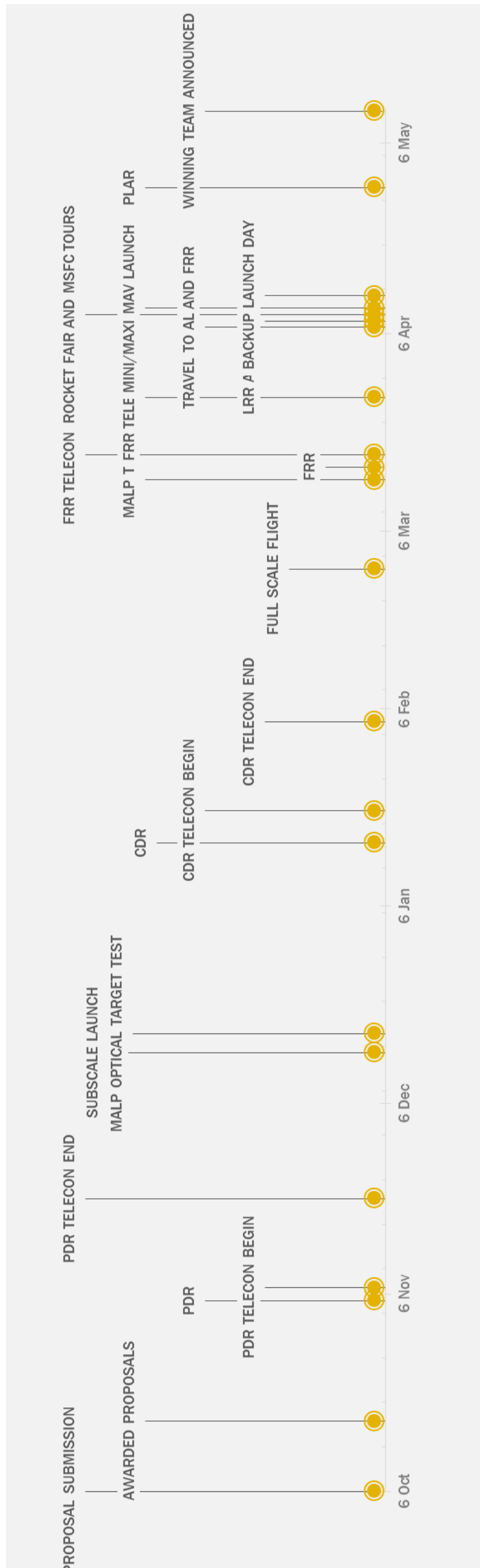

Figure 13: Projected Project Timeline

6.2 Project Budget

The following proposed project budget assumes the team will have contingency capabilities to build at least two identical complete rockets, with the exemption of the electronics.

Table 7: Rocket Airframe Budget

Item	Qty	Price	Subtotal
US Composites 150 Epoxy, 2 Gallon, Medium	1	$128	$128.00
Blue Tube 2.0 3.9"x0.062 wall x 48"	4	$38.95	$155.80
Blue Tube 2.0 54mm x 0.062 wall x 48" MMT	2	$23.95	$47.90
Blue Tube Electronics Bay 4.0" x 8"	2	$41.95	$83.90
3.9" Ogive Nose Cone	2	$21.95	$43.90
Hardpoint Anchor	2	$6.51	$13.02
Hardpoint Motortube Adapter	2	$10.49	$20.98
Acme Conformal Launch Rail	2	$3.66	$7.32
Removable Rivets (x10)	3	$2.58	$7.74
Brass Screws (x4)	6	$1.00	$6.00
2-56 1/4" Nylon Screw (x100)	1	$8.86	$8.86
2 Quart Kit Mega Foam	1	$22.50	$22.50
G10 Fins	6	$30	$180.00
		Subtotal	$725.92

Table 8: Propulsion Budget

Item	Qty	Price	Subtotal
Aerotech J401FJ-L 54mm fits 54/1280	3	$74.99	$224.97
		Subtotal	$299.96

Table 9: Electronics Budget

Item	Qty	Price	Subtotal
PerfectFlite Stratologger	2	67.96	$135.92
PerfectFlite USB Data Transfer Kit	1	$26.96	$26.96
MissileWorks RRC3 Altimeter System	2	$79.96	$159.92
HD Wing Camera 1280x720p 30fps 5MP CMOS	2	$37.18	$74.36
Push-Hold Switch Trigger	3	$20.00	$60.00
BigRedBee GPS Transmitter/Receiver	1	$378	$378.00
		Subtotal	$835.16

Table 10: Recovery Budget

Item	Qty	Price	Subtotal
Classic Elliptical 36" Parachute	2	$72.00	$144.00
GLR Tac-1 24" Parachute	2	$79.79	$159.58
1/2" Tubular Kevlar Shock Cord /yd	30	$3.75	$112.50
1500 lb test 2.25" 23g Swivel	16	$6	$96.00
1/4" 880 lb test Quick Link	24	$1.35	$32.40
Medium Blastcap (Pair)	6	$24.00	$144.00
FFFFg Black Powder (1lb)	1	$15	$15.00
Firewall 18"x18" Nomex Chute Protector	2	$10.95	$21.90
Firewall 6"x6" Nomex Chute Protector	1	$4.95	$4.95
		Subtotal	$730.33

Table 11: MALP Budget

Item	Qty	Price	Subtotal
Servo Gearbox 7:1 Ratio	2	$129.98	$259.96
80/20® 1010-145 1" X 1" T-Slotted Profile, 145" Stock Bar	1	$36.95	$36.95
.125" thick 6061 Aluminum Sheet	2	$60.32	$120.64
1 X 1 X 11GA 3' A513 Steel Structural Square Tube	4	$10.77	$43.08
1 X 1 X 11GA 1' A513 Steel Structural Square Tube	4	$5.59	$22.36
Misc Motors & Aluminum Frame	1	$250	$250.00
		Subtotal	$732.99

Table 12: Outreach Budget

Item	Qty	Price	Subtotal
Wix - Unlimited 1 Yr Website Hosting	1	$150	$150.00
Generic E2X Model Rockets Educator Pack (12)	5	$72.59	$376.05
Estes Blast Off Pack 24 asst motors	3	$47	$139.77
Additional Materials, Giveaways	1	$600	$600.00
		Subtotal	$1265.82

Table 13: Miscellaneous/Contingency Budget

Item	Qty	Price	Subtotal
Misc Tools	1	$300	$300.00
Shipping Costs	1	$750	$750.00
Contingencies	1	$750	$750.00
		Subtotal	$1800.00

Table 14: Projected Complete Budget

Airframe Budget	$752.92
Propulsion Budget	$299.96
Electronics Budget	$835.16
Recovery Budget	$730.33
MALP Budget	$732.99
Outreach Budget	$1,265.82
Misc. Budget	$1,800.00
Total	**$6,417.18**

6.3 Funding Plan

Our team intends to pursue a number of different funding sources for our participating in NASA SLP. Among the more traditional route, the team is pursuing possible sponsorship opportunities from Orbital Sciences, Raytheon, Microchip, Moog, and other aerospace and technology companies in the greater Phoenix Metropolitan area.

Additionally, the team expects to receive support from the Undergraduate Student Government appropriations for student organizations, and the School of Earth and Space Organization – our host department.

In addition to these more traditional sources of funding, our team will also be pursuing crowdfunding opportunities as well. This follows on a successful crowdfunding campaign team members ran on IndiGoGo over the summer for another HPR competition. We plan to include, among the perks for support, small Estes motor-capable 3D printed rockets (Figure 15). In addition to using them as perks, we also hope to offer the 3D printed rockets up for sale at our various public engagement events, given their huge popularity when exhibited at a previous outreach event the team participated in, Earth and Space Exploration Day.

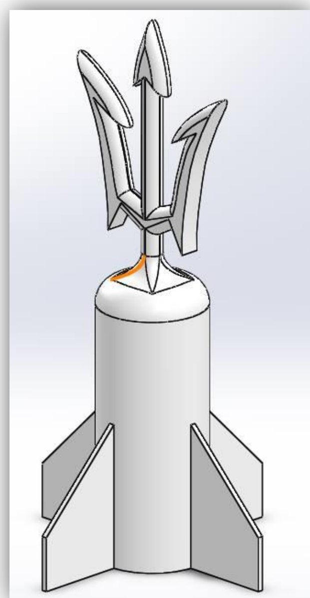

Figure 14: SolidWorks model of our Pitchfork 3D printed rocket in spirit of the ASU Sun Devils.

6.4 Additional Community Support

Community support of Icarus Rocketry has been quite abundant. Our team was recently featured in two articles, in the State Press[4], as well as ASU News[5]. With our forward thinking ideas and goal, we hope this method of publicity within the community will grow. Within the past month, we participated in a day-long outreach event in which we launched Estes rockets (throughout the day, on the hour) and had children make and decorate paper and straw rockets. At this event, we were approached by an enthusiastic elementary school teacher, who invited us to the grade school. We have now arranged a public outreach event with the school in December. We plan to run a crowd-funding campaign, receiving continued encouragement from the community. Donating via Kickstarter or a similar crowd-funding platform, would not only provide high visibility to the top sponsor, but additional incentives include including the logo/name on rocket, having their logo/name on our banner at our operations and prep tent at launches. Student Government will offer financial support for outreach supplies, transportation, and other team-building incentives like t-shirts and key chains, etc. We expect to maintain this due to our committed efforts in volunteering in outreach and we are actively pursuing sponsorships from corporations. Several of our members recently attended the Students for the Exploration and Development of Space (SEDS) Space Vision conference where our goals as a rocketry team were well received, and it helped build our network of industry contacts.

---

[4] http://www.statepress.com/2013/11/14/icarus-rocketry-reaches-for-the-sky/

[5] https://asunews.asu.edu/20131030-icarus

6.5 Major Programmatic Challenges

The aspects of the competition that may pose the biggest challenges are developing autonomous control systems; how recently the team was formed which would attribute to a lack of experience; as well as difficulties with time management; and lastly, securing funding. To address the issue dealing with autonomous control, we intend to recruit computer science undergraduate and graduate students will experience in robotics. As a new club, we will be quite resilient. The major challenge is maintaining the momentum every new organization begins with. Although we may encounter unforeseen difficulties, this may happen no matter how new the team. We will strongly encourage keeping communication open at all times, exploring many avenues, putting our heads together, and following the intelligent foresight of mentors.

6.6 Project Sustainability

We have a variety of outlets to encourage and inspire the inexperienced to experienced rocketeers. We intend to participate in monthly outreach events in with the School of Earth and Space Exploration at ASU, inspiring the next generation of scientists and engineers. We recognize the importance in creating a strong network of mentors and colleagues; thus we participate in conferences. We also participate in local rocket launches, monthly, quickly becoming familiar faces to see. Attending rocket launches is not only good to stay in touch with the community, but the closest launch site is a little over two hours away. Thus, a day-long (or sometimes longer) road trip builds great camaraderie among team members. To inspire non-majors, we have hosted events such as a movie night open to any student on campus. To keep members of the club in tune, we have held a series of high power rocketry workshops. This is encouraging for entry level students, while not overwhelming while developing a solid foundational knowledge in the field. The team is also organized into engineering sub-teams, allowing for closer, more personal interactions; and greater, more fundamental integration with the project throughout the design and build process for team members. We continue to interact with group members on Facebook and Twitter, less informally, as well as to keep the community updated via these social media outlets. We also intend to recruit members at the beginning of each semester. Lastly, it should be mentioned that a multitude of motivated 1st and 2nd year PhD graduate students will provide a firm backbone to the team.