1 Executive Summary

As part of a two-semester senior design class, the Charger Rocket Works (CRW) team will launch a rocket carrying an Unmanned Aerial Vehicle (UAV) payload to 5,400 ft. After landing, the team will deploy the UAV, which will then be remotely piloted to a competition-provided Future Excursion Area (FEA) and deposit a beacon. Design efforts are ongoing, but the launch vehicle is currently planned to be 6 inches in diameter and 95 inches long, and will fly on an AeroTech L1390G motor. The team will make two full-scale flights during the months of February and March, including the payload. The team expects to operate on a budget of approximately $6,200, which will cover several planned community outreach activities, in addition to fabrication and testing of the vehicle and payload. The team is organized into Management, Payload, Vehicle, and Public Relations sub-teams, with a Safety Committee to ensure safe procedures are created and followed in every part of the project.
Table of Contents

1 Executive Summary ........................................................................................................... 1
2 General Information ........................................................................................................... 4
  2.1 School Information ....................................................................................................... 5
  2.2 Team Overview ........................................................................................................... 5
  2.3 Organizational Structure ............................................................................................. 5
    2.3.1 Management Team ............................................................................................... 6
    2.3.2 Payload Team ....................................................................................................... 6
    2.3.3 Vehicle Team ....................................................................................................... 6
    2.3.4 Public Relations Team ......................................................................................... 6
3 Facilities and Equipment ................................................................................................... 7
  3.1 Charger Rocket Works Laboratory .............................................................................. 7
  3.2 Propulsion Research Center ....................................................................................... 7
  3.3 MAE Machine Shop ..................................................................................................... 8
    3.3.1 Turning and Milling ............................................................................................. 8
    3.3.2 Additive Manufacturing ...................................................................................... 8
    3.3.3 Composite Material Production ......................................................................... 8
    3.3.4 Metal and Composite Cutting ............................................................................. 9
  3.4 Computer Capabilities ................................................................................................ 9
  3.5 VBRH Failure Analysis Lab Use and Equipment ......................................................... 10
  3.6 UAH Wind Tunnel ..................................................................................................... 10
  3.7 Launch Field Locations and Dates ............................................................................. 10
4 Safety ............................................................................................................................... 10
  4.1 Management, Leadership, and Employee Participation Policy .................................. 11
  4.2 Safety Goals and Responsibilities as a Team ........................................................... 11
  4.3 Safety Officer ............................................................................................................. 12
  4.4 Responsibilities of the Safety Committee .................................................................. 12
  4.5 Hazard Prevention and Control .................................................................................. 12
  4.6 Material Hazard Communication Program ............................................................... 13
  4.7 Workplace Analysis and Inspection .......................................................................... 13
  4.8 PRC Safety Procedures .............................................................................................. 13
    4.8.1 Supervision and Buddy System ......................................................................... 14
    4.8.2 Personal Protective Equipment .......................................................................... 14
    4.8.3 Emergency Response ......................................................................................... 14
    4.8.4 Mishap Recording ............................................................................................... 14
4.9 Safety Regarding Motor and Charges ................................................................. 14
4.10 State and Federal Regulations ........................................................................ 14
4.11 Range Safety Officer Compliance .................................................................. 15
5 Technical Design ................................................................................................ 15
  5.1 Vehicle Description & Goals ........................................................................... 15
    5.1.1 Listed Requirements................................................................................ 15
    5.1.2 Structural Design ...................................................................................... 16
    5.1.3 Propulsion ................................................................................................ 16
    5.1.4 Flight Projection ....................................................................................... 17
  5.2 Payload Description & Goals ........................................................................... 18
    5.2.1 Listed Requirements................................................................................ 18
    5.2.2 Structural Design ...................................................................................... 19
    5.2.3 System Overview ..................................................................................... 19
  5.3 Recovery Description & Goals .......................................................................... 20
    5.3.1 Listed Requirements................................................................................ 20
    5.3.2 Parachutes ................................................................................................. 21
    5.3.3 Tracking System ...................................................................................... 21
6 Education and Outreach ....................................................................................... 22
7 Project Plan ........................................................................................................... 24
  7.1 Schedule .......................................................................................................... 24
  7.2 Budget .............................................................................................................. 24
  7.3 Funding ............................................................................................................ 26
  7.4 Sustainability ................................................................................................... 26
8 Primary Challenges and Solutions ........................................................................ 27
  8.1 Vehicle ............................................................................................................. 27
  8.2 Payload ............................................................................................................ 28
  8.3 Recovery .......................................................................................................... 28
  8.4 Project Management ......................................................................................... 28
9 Conclusion ............................................................................................................. 29
10 Appendix A: Risk and Hazard Assessment .......................................................... 30
11 Appendix B: JRC Evacuation Plan ....................................................................... 37
12 Appendix C: Applicable Laws and Regulations .................................................. 38
13 Appendix D: MSDS ............................................................................................. 47
14 Appendix E: Team Member Resumes ................................................................. 57


2 General Information

Faculty Advisor
Dr. David Lineberry
Research Engineer, Propulsion Research Center, UAH
David.Lineberry@uah.edu
256.824.2888

NAR Mentor
Mr. Jason Winningham
Comp. Sys. Engineer,
Electrical and Computer Engineering Department
(Level 3 NAR: 89526/TRA: 13669)
Jason.Winningham@uah.edu
256.824.6132

Graduate Student Mentor
Ms. Vivian Braswell
Vrb0004@uah.edu
256.824.2863

Program Manager
Mr. Zachary Ruta
Senior, UAH Mechanical and Aerospace Engineering Department
Zachary.Ruta@uah.edu
256.429.8632

Safety Officer
Ms. Hope Cash
Senior, UAH Mechanical and Aerospace Engineering Department
hac0008@uah.edu
2.1 School Information

The University of Alabama in Huntsville (UAH) is a public university located in North Alabama on the edge of Cummings Research Park, the 2nd largest research park in the United States. UAH enrolls over 9,500 students annually, of which nearly half are science and engineering majors. The university has a history of providing outstanding support for student-led teams in design-build competitions and events. These include the following: NASA University Student Launch (USLI), NASA Moonbuggy Competition, NASA Microgravity University, ASCE Concrete Canoe, and AIAA/AAS Cansat.

2.2 Team Overview

The 20 students on the Charger Rocket Works (CRW) team are participating in the NASA Student Launch program through a two semester senior design course, offered by UAH to all Mechanical & Aerospace (MAE) engineering students. Dr. David Lineberry will be the course instructor of the senior design course (MAE 490) and also the team’s Faculty Advisor. Jason Winningham will serve as the team’s National Association of Rocketry (NAR) Mentor due to his NAR Level 3 certification. Vivian Braswell will serve as the Graduate Mentor for the course. Lastly, the team’s Program Manager (team lead) is Zachary Ruta and the Safety Officer is Hope Cash.

2.3 Organizational Structure

The students of the CRW team have many difficult engineering challenges to address during the competition. To make sure all these challenges are distributed evenly the team has been divided into four sub-teams. The sub-teams consist of a Management, Payload, Vehicle, and Public Relations team. An organization chart has been provided in Figure 1.

![Figure 1: Organization Chart](image-url)
2.3.1 Management Team

The Management team will be responsible for overall program management and program level tasks. The team consists of the Program Manager, Safety Officer, Technical Lead, and Communication Lead. The Project Manager will be responsible for leading the team through major decisions by managing the budget, the schedule, and will act as the documentation lead. The Safety Officer will work to ensure the rocket is safe for flight and team safety is maintained through fabrication and flight operations. This individual will manage all working safety documents such as Material Safety Data Sheets (MSDS), evacuation routes, safety reviews, incident reports, and test operation procedures to ensure that all test procedures are followed correctly. The Safety Officer will also conduct pre-launch safety reviews and lead the Safety Committee consisting of a Deputy Safety Officer and two sub-team Safety Leads. The Technical Lead will be responsible for technical oversight, integration of vehicle subsystems, and payload deployment. This individual will work directly with the two team leads for payload and vehicle.

2.3.2 Payload Team

The Charger Rocket Works payload team is comprised of eight members tasked with designing and deploying a payload from the rocket. The team has one team leader in charge of task organization, budget, requirement checking, scheduling, and payload integration with the overall project. The team also has a Payload Safety Lead in charge of ensuring the payload meets all safety regulations and works directly with the Safety Officer. The remainder of the team is tentatively subdivided into groups of three, with one group responsible for payload design and manufacturing and the other responsible for payload deployment and integration with the rocket system.

2.3.3 Vehicle Team

The Vehicle team consists of seven members that will be responsible for developing the full structure of the rocket. This includes design and fabrication of the airframe, nosecone, fins, coupler, and propulsion system. The team will also be in charge of the recovery system which includes design and fabrication of both main and drogue parachute systems. The team will ensure that both rocket and payload ascend and descend safely and are recovered in an operational and reusable condition. The tasks of determining vehicle materials, motor type, and any needed supplies are performed by the vehicle team. The team will also perform all analysis of the vehicle including stress analysis, stability analysis, drift analysis, tracking, and trajectory analysis. Any sensors placed on or in the airframe of the rocket, as well as the development of the avionics bay will be governed by the vehicle team. Perhaps most importantly, the vehicle team will work closely with the payload team to ensure a successful interface between the two systems. It is the job of the vehicle team to make sure the payload will fit inside the rocket, reach the goal apogee, and have a successful deployment.

2.3.4 Public Relations Team

The Public Relations team will consist of 18 members including the Public Relations Lead. This year the UAH communication department has planned to provide aid in the areas of STEM outreach, social media, and display events. They have divide 17 team members into three sub-
teams specializing in outreach, social media, and event displays. The Public Relations Lead will be the point of contact between the Charger Rocket Works team and the UAH communication department. This will be the first time the communication department joins the Charger Rocket Works team. The partnership will prove greatly beneficial for both parties involved. This will provide both teams with valuable collaboration experience and insight into each respective field of interest.

3 Facilities and Equipment

The Charger Rocket Works team has access to several on-campus facilities for the purpose of manufacturing and testing rockets. These facilities include the Charger Rocket Works Laboratory, the Propulsion Research Center, UAH MAE Machine Shop, UAH Computer Labs, UAH Wind Tunnel, and the Reliability and Failure Analysis Lab. These allow for fabrication, assembly, and testing to be performed in-house on the UAH campus. The capabilities and uses of the facilities are detailed in the following sections.

3.1 Charger Rocket Works Laboratory

The Charger Rocket Works Laboratory is the primary workspace that will be used by the team. This workspace is a 1600 ft² bay located in the Propulsion Research Center laboratories in the Johnson Research Center building on campus. The CRW laboratory has two 10 ft. by 3.5 ft. assembly tables, an electronics work station, a filament winding station, two 6 ft. by 3 ft. work benches, a mobile tool chest for general hand tools, project storage cabinets, and some power tools: drill presses, a jig saw, a chop saw, and a belt sander. The electronics workbench includes a soldering station, electrical testing equipment, and basic electronic components and supplies. The filament winding station consists of an X-winder 4-axis filament winder. This is capable of creating nose cones, body tubes, and other parts up to 8” in diameter, and will be used for composite part manufacturing by the team. A self-closing flame cabinet is also located in the laboratory for safe storage of epoxies and chemicals. The CRW Laboratory will serve as the team’s primary manufacturing and assembly location, and as storage for all rocket components and supplies. This lab is available 24/7 to all members of the CRW team.

3.2 Propulsion Research Center

The Propulsion Research Center (PRC) at UAH is a research center on campus focused on propulsion and energy technology research and development. The PRC has several laboratories around campus with equipment and research area that is available for students that are working on this project. The main PRC laboratories are located in the Johnson Research Center. Within this facility, the PRC has a Robo3D R2 3D printer that is available for Charger Rocket Works (CRW) usage. This printer supports additive manufacturing of parts up to 8”x8”x10” out of ABS, PLA, nylon, and other commonly-used plastics. The CRW team plans to use this for rapid prototyping of parts before final machining, and for final manufacture of plastic parts with complex geometries.
The PRC contains a 6’ dia. x 13’ long vacuum chamber capable of reaching pressures as low as $10^{-6}$ Torr. With an appropriate SOP, the team could use it for testing altimeters and other avionics.

Behind the Johnson Research Center, the PRC operates a hot-fire test cell which can be used for static motor testing and for black powder deployment charge testing on the project. The PRC also has three propellant magazines on campus for storage of up to 250 lb of 1.3 energetics. CRW will be allowed to store high powered rocket motors as well as deployment energetics in these magazines.

### 3.3 MAE Machine Shop

The UAH machine shop is located in the Olin B. King Technology Hall and is available 24/7 to support UAH College of Engineering students for the fabrication of components for academic and extracurricular projects. The machine shop is also used as a teaching aid for students by giving them hands-on experience with various machines and fabrication processes. Only students who have successfully completed a semester-long course may operate machines while in the shop; three of the 2018-2019 CRW students have taken this training. Other team members can use hand tools and participate in composite fabrication in the shop, under appropriate supervision. A rigorous dress code is enforced, including long pants, closed toed shoes, short sleeves, and safety glasses at all times while on the shop floor. The CRW team plans to use the machine shop’s resources for machining metallic components, 3d printing, producing composites, and cutting body tubes and fins.

#### 3.3.1 Turning and Milling

The machine shop has several lathes and mills available for use. These include manual machines with digital position readouts and a CNC lathe (Haas TL-1) and CNC mills (Haas VF-1 and TM-1). In past years, these have been used for parts such as aluminum fin brackets, polycarbonate and aluminum centering rings and bulkheads, and payload components.

#### 3.3.2 Additive Manufacturing

The shop includes two 3D printers, which are available for the creation of plastic parts. These are primarily used with ABS plastic, but also support other materials, such as polycarbonate. They are also capable of printing a dissolvable support material, allowing for the creation of even more complex geometries than are possible with a standard 3D printing. The CRW team will use these to complement the 3D printer in the Johnson Research Center; parts too complex for the Robo 3D printer will be manufactured in the machine shop.

#### 3.3.3 Composite Material Production

The machine shop is equipped to produce fiberglass and carbon fiber layups, and stocks rolls of pre-impregnated carbon fiber appropriate for many components. An oven is available for elevated-temperature curing of parts up to 48” x 48” x 72”, and larger components can be produced using a wet layup with epoxy that cures at room temperature.
3.3.4 Metal and Composite Cutting

The machine shop has table saws, vertical band saws, and a horizontal band saw, in addition to a wet tile saw appropriate for cutting composite materials. The table saw comes equipped with an automatic braking system to stop rotation of the saw blade in less than five milliseconds in order to prevent operator injury. Saws will be used for cutting metal stock prior to final machining, as well as for cutting composite body tubes and fins to their final geometry.

3.4 Computer Capabilities

The team has access to a multitude of computers and software. The Olin B. King Technology Hall labs offer students various computer labs with all of the necessary engineering software. Table 1 lists the software available to the team:

<table>
<thead>
<tr>
<th>Software</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Edge</td>
<td>CAD Modeling</td>
</tr>
<tr>
<td>MathCAD</td>
<td>Mathematical Programming</td>
</tr>
<tr>
<td>MATLAB</td>
<td>Mathematical Programming</td>
</tr>
<tr>
<td>RockSim 9.0</td>
<td>Flight Simulation</td>
</tr>
<tr>
<td>Open Rocket</td>
<td>Flight Simulation</td>
</tr>
<tr>
<td>Microsoft Office 2013</td>
<td>Document Writing</td>
</tr>
<tr>
<td>Adobe Professional Package</td>
<td>PDF Editing</td>
</tr>
<tr>
<td>System Tool Kit (STK)</td>
<td>Mission System Simulation</td>
</tr>
<tr>
<td>Nastran</td>
<td>Finite Element Analysis</td>
</tr>
<tr>
<td>Patran</td>
<td>Finite Element Analysis</td>
</tr>
</tbody>
</table>

As indicated in Table 1, the team has access to a large variety of software. Software such as MATLAB, MathCAD and Nastran / Pastran will allow team members to solve complex problems throughout the finite element analysis process. Solid Edge gives the team the ability to create accurate models of rocket components. RockSim and Open Rocket will let the students simulate various flights to ensure the rocket design meets requirements. Microsoft Office and Adobe Professional Package will allow the CRW team to create and edit all required documents for USLI. Nastran and ESI ACE give the team an effective way to solve complex fluid dynamics problems. The System Tool Kit allows the team to simulate mission systems and integration of those systems. It allows the team to generate, report, graph, and vary thousands of qualitative and quantitative metrics. All software mentioned is available to all team members at all times of the day.
3.5 VBRH Failure Analysis Lab Use and Equipment

The Reliability and Failure Analysis Lab (RFAL) located in the Von Braun Research Hall on the UAH campus allows the students to investigate possible failure mechanisms of a rocket component through mathematical modeling and physical testing. The RFAL allows the team to perform structural load testing prior to flight to prevent structural failure. The facility is equipped with an autoclave, thermal shock and vibration chamber, cyclic corrosion chamber, servo-hydraulic tension compression fatigue test machine, accelerometer calibration station, and a modal exciter. The facility also works in tandem with the MAE machine shop to provide a composites manufacturing facility to cure large composite structures. This facility is available during business hours.

3.6 UAH Wind Tunnel

The team has access to a subsonic wind tunnel that will be used for testing the aerodynamics of subscale models of the rocket. The UAH MAE subsonic wind tunnel has an operable test section of one foot tall, one foot wide, and two feet long. The wind speeds in the tunnel can reach a velocity of up to 160 ft./sec (110 mph), allowing the team to test the models in relatively high wind velocities. To ensure the wind tunnel is minimally invasive to the surrounding area, a diverging section follows the test section to reduce wind speeds to an acceptable speed before it exits the tunnel.

3.7 Launch Field Locations and Dates

The team has access to three launch facilities that are within a reasonable distance. Huntsville Area Rocketry Association, located in Northeast Alabama, SouthEast Alabama Rocketry Society, located in Southeast Alabama, and Bluegrass Rocketry Society, located in southern Kentucky all offer monthly launch dates. Each location allows the launch of high powered rockets. By having access to the three fields, the team will have the opportunity for at least two launches a month starting in October. This will provide a great opportunity for the team to reach the required amount of subscale and full scale flights.

4 Safety

The safety of the Charger Rocket Works personnel and advisors as well as the safety of other teams, equipment, and outreach participants are of the highest importance to the Charger Rocket Works team. Care and caution will be exercised throughout all design, fabrication, transportation, and launch of rocket and payload materials to ensure all members and bystanders are protected from potential hazards. This will be done by following thorough checklists and procedures written by the Safety Officer, Deputy Safety Officer, and Sub-Team Safety Leads for all necessary operations.
4.1 Management, Leadership, and Employee Participation Policy

The CRW team’s value and emphasis on safety shall be made evident by the care taken to compose safety documentation and implement procedures to reduce risk to team members, mentors, and bystanders. The safety procedures will be in effect for all participants as a condition for participation in the NASA USLI competition. In addition to individual accountability, the team will appoint a Safety Committee to reinforce exhaustive safety in all areas. The Safety Committee will consist of the Safety Officer, a Deputy Safety Officer, and a sub-team Safety Lead for both the Payload and Vehicle Teams.

4.2 Safety Goals and Responsibilities as a Team

The team has decided on the following objectives for the Safety Plan based on the requirements stated by NASA as well as the goals of the team. The requirements listed in Table 2 are the points necessary to meet the objectives.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify Risks Through Analysis</td>
<td>Leadership and the Safety Committee will consider the potential risks and hazards throughout the project. Team members will be responsible for understanding the nature of the risks.</td>
</tr>
<tr>
<td>Prevent Risks Through Mitigations</td>
<td>Leadership and the Safety Committee will design mitigations to potential risks and hazards. Team members will be responsible for understanding the proper mitigations.</td>
</tr>
<tr>
<td>Inform Personnel Through Written Documents and Briefings</td>
<td>The Safety Committee will compose Standard Operating Procedure and safety checklists. The Safety Officer will conduct safety briefings to formally inform the team about safety procedures. Team members will be responsible for understanding safety procedures.</td>
</tr>
<tr>
<td>Ensure Safety Success Through Implementation</td>
<td>Leadership and the Safety Committee will supervise and assist team members in carrying out the safety procedures in being present for high risk operations including tests and launches. Team members will be responsible for following all safety procedures for all operations.</td>
</tr>
</tbody>
</table>
4.3 Safety Officer

The Safety Officer will work with additional team members comprising an informal safety team as well as mentors, the faculty advisor, launch field personnel, and necessary PRC personnel to ensure all Safety Plan components are exhaustive and implemented. Duties of the Safety Officer include ensuring all students have had proper safety briefings for necessary tasks, ensuring all students understand and have access to Standard Operating Procedures (SOPs) and the Safety Plan, and is responsible for the implementation of designated risk mitigations. The Safety Officer is also responsible for approving the risk and hazard analysis and mitigations done by the sub-team Safety Leads under the Safety Officer’s direction. The Safety Officer will hold meetings regarding new or revisions to previous safety protocol. Approval of the Safety Officer is required for major decisions including launch and testing.

4.4 Responsibilities of the Safety Committee

In addition to the Safety Officer position, the Charger Rocket Works team has assigned duties to a Deputy Safety Officer and one sub-team Safety Lead for the Payload Team and the Vehicle Teams. The students in these positions will assist the Safety Officer in drafting the checklists and procedures and performing hazard analyses pertaining to his or her respective team. This is to ensure all material in the Safety Plan is comprehensive and accurate. The Deputy Safety Officer will assist in hazard analyses and mitigations as well as in ensuring implementation of the Safety Plan. All team members are responsible for following the Safety Plan and pertinent SOP for all tasks.

4.5 Hazard Prevention and Control

Appropriate control measures will be set in the SOPs, checklists, and additional safety guidelines within the Safety Plan. Instructions for use of PPE will come from PRC requirements as well as Material Safety Data Sheets (MSDS) recommendations and team leadership with the Safety Officer. SOPs will be developed in accordance to existing PRC SOPs and with consideration of the Risk and Hazard Analysis. The Risk and Hazard Analysis will be maintained and updated throughout the duration of the project, an initial analysis can be found in Appendix A. Mitigations will come from MSDS recommendations, the Occupational Safety and Health Administration (OSHA), the UAH Office of Environmental and Health Safety (OEHS), general safe workplace practices, and any additional necessary research to provide the maximum protection for all team members and affiliated parties.

Due to the inherent risk of rocket construction, testing, and launches, not all risk can be completely eliminated but all measures and mitigations will be in place to lower all risk to an acceptable level. The acceptable level is determined by the team leadership, Mentors, and Faculty Advisors based on the nature of the task and whether or not all mitigation options have been exhausted. All team members will be made aware of all acceptable and unavoidable risk.
4.6 Material Hazard Communication Program

The Material Hazard Communication Program will be in effect to best ensure the safety of team members when working with hazardous materials. All chemical and hazardous materials will be correctly and neatly labeled. All team members are responsible for ensuring labels are displayed properly in the storage areas. The Safety Officer is responsible for ensuring all chemical and hazardous materials have correct and up to date MSDS included with SOPs in which the hazardous chemicals are to be used should team members need them for reference or in case of an emergency. The Safety Officer is also in charge of ensuring all team members are properly trained on handling all hazardous materials as well as being able to locate the MSDS database on the OEHS website.

To ensure all hazardous materials are accounted for, the Safety Officer will perform an inventory of all chemicals initially owned or to be used by the team. Correct and up to date MSDS will be verified. Throughout the duration of the project, the Safety Officer will maintain and update the records of chemicals and hazardous materials brought into the team’s possession. Team members are responsible for notifying the Safety Officer of any change in inventory.

4.7 Workplace Analysis and Inspection

Prior to beginning testing or fabrication, the work area will be inspected for any debris, material, and nonessential equipment for operation; any items found will be removed prior to beginning the operation. The SOP and safety checklists will be reviewed and the listed hazards will be noted. If any additional hazards are found, they will be reported to the Safety Officer for analysis and mitigation before continuing the operation.

4.8 PRC Safety Procedures

The PRC has additional safety requirements that must be adhered to for use of space and equipment for designated testing and fabrication purposes. The following list is directly from the UAH PRC Facility Usage Policy which is signed by the director of the PRC and must be followed by all team members.

PRC Facility Protocol:

1) All PRC Test operations are under the authority of the PRC Director and UAH campus safety practices.
2) All personnel involved in testing are UAH employee, UAH students under PRC supervision, or customers with an active contract with UAH.
3) All tests involving pressures over 100 psi, high voltage, combustion, or other sources or possibly injury require a Standard Operation Procedure (SOP), reviewed and signed by the test team, and approved by the PRC Director.
4) The tests are conducted by a designated Red Team who has at least one UAH staff member and has at least two members who are Red Cross Safety and CPR/AED Certified.
5) After any major test anomaly, all PRC test operations are automatically suspended until a determination of the basic cause of the incident is determined and all active SOPs are reviewed in light of the findings of the incident before resuming testing.
The PRC 2017 Safety Plan (revised 21 February 2018) is available to all team members for reference. As stated in 4.1 of the PRC Safety Plan, any team member participating in work in the PRC has the right and responsibility to stop operations if he or she deems it to be unsafe.

4.8.1 Supervision and Buddy System

Team members will perform all actions using the Buddy System. No test or fabrication work will be done alone; all procedures will have, at minimum, two personnel involved. Testing will be supervised by the Faculty Advisor, Team Mentor, or other UAH College of Engineering or PRC faculty and staff. The Team Mentor will also be present at all rocket launches to ensure the safety of the team members and rocket hardware.

4.8.2 Personal Protective Equipment

Proper Personal Protective Equipment (PPE) is expected to be worn for every operation. PPE lists and guidelines will be developed by the Safety Officer as a part of the SOP or checklist.

4.8.3 Emergency Response

The PRC has specified locations for evacuations in the event of a fire or tornado. These are found in Appendix B. All team members are aware of the location of the AED machine within the Johnson Research Center in the event a certified administrator needs assistance. First aid certified team members may administer basic first aid. If medical care more than basic first aid is required, emergency services will be summoned.

4.8.4 Mishap Recording

Any significant accidents, i.e. any accident resulting in damage to materials, equipment, or requiring first aid or other medical treatment, will be reported to the Safety Officer, Program Manager, Faculty Advisor, and any necessary PRC personnel. The Safety Officer will perform an analysis of the incident and review and revise as necessary the SOP or checklist pertaining to the operation. The Safety Officer will hold a Safety Briefing for the team after the cause of the incident has been determined and new mitigations have been declared.

4.9 Safety Regarding Motor and Charges

Any ejection charges to be used will be handled by the Team Member. All motors will be purchased from licensed vendors by team members or the Team Mentor who hold a High Power Rocketry certification from the National Association of Rocketry (NAR) or Tripoli Rocketry Association, Inc. (TRA). Purchased motors and charges will be stored properly in propellant magazines rated for solid rocket motors. The magazines will be contained in a locked bunker operated by the PRC.

4.10 State and Federal Regulations

The team will abide by all state and federal regulations pertaining to all aspects of the rocket and payload. Governing bodies include, but are not limited to, the Federal Aviation Administration (FAA), National Fire Protection Association (NFPA), NAR, TRA, and the Department of Transportation (DOT).
4.11 Range Safety Officer Compliance

The team understands and agrees that the Range Safety Officer (RSO) at any launch field has the final say on if the rocket will fly after his or her inspection. If the rocket is determined to be unsafe by the RSO, the team understands the potential of removal from that launch.

5 Technical Design

The Charger Rocket Works team will design and fabricate a launch vehicle capable of deploying an unmanned aerial vehicle. The vehicle will consist of an upper airframe which houses the payload and payload deployment system and a lower airframe containing the propulsion system. A dual-deployment recovery system will be employed to recover the vehicle. The CRW team hopes to build off the success of previous USLI teams as well as employ new, cutting edge manufacturing and fabrication techniques.

5.1 Vehicle Description & Goals

The success of the structural vehicle is required to safely deliver and deploy the project payload. The vehicle must launch, reach a specific apogee, release a main and drogue parachute, and land successfully. The vehicle system is necessary for a successful launch and will be designed according to payload needs.

5.1.1 Listed Requirements

Vehicle design baseline that is required to fulfill the requirements of a successful mission are as follows:

1) The vehicle will deliver a payload to an altitude between 4000 and 5500 feet.
2) The vehicle will carry one altimeter for recording the official altitude.
3) The vehicle will have an exterior altimeter arming switch.
4) The vehicle will be designed to be recoverable and reusable.
5) The launch vehicle will not be more than four sections.
6) Coupler/airframe shoulders will be at least 1 body diameter in length.
7) Nose cone shoulders will be at least \( \frac{1}{2} \) body diameter in length.
8) The launch vehicle will be a single stage.
9) The vehicle will be capable of being prepared for flight in 2 hours.
10) The vehicle will be capable of remaining in launch-ready configuration for 2 hours.
11) The vehicle will be launched by a 12-volt direct current firing system.
12) The vehicle will require no external circuitry for launch.
13) The vehicle will use a commercially available solid APCP motor.
14) Each pressure vessel will include a pressure relief valve.
15) The total impulse will not exceed 5120 Newton-seconds.
16) The vehicle will have a minimum static stability margin of 2.0 at rail exit.
17) The launch vehicle will accelerate to at least 52 fps at rail exit.
18) The payload will be fully retained throughout the flight.
19) Any structural protrusion on the rocket will be located aft of the burnout Cg.
20) The team’s name and contact information will be in or on the rocket airframe.
21) The launch vehicle will not exceed Mach 1.
22) Vehicle ballast will not exceed 10% of the total unballasted weight.
23) Transmissions will not exceed 250 mW of power.
24) Each section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.

### 5.1.2 Structural Design

The design of the vehicle is driven primarily by the predicted size and mass of the payload. The vehicle is designed to deliver a combined payload and deployment system weight of up to ten pounds to an altitude close to 5,400 ft. The vehicle has a 6-inch body diameter and an overall length of 95 inches. There are three tethered sections to the rocket. The upper airframe holds the main parachute and shock cord as well as the payload and payload deployment system. The avionics are held in a coupler connecting the lower and upper airframes. The lower airframe contains the motor, fins, shock cord, and drogue parachute. Table 3 can be referenced for the dimensions of the vehicle.

<table>
<thead>
<tr>
<th>General Vehicle Specification</th>
<th>Fin Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>6 in</td>
</tr>
<tr>
<td>Length</td>
<td>95 in</td>
</tr>
<tr>
<td>Wet Mass</td>
<td>35.7 lb</td>
</tr>
<tr>
<td>Center of Gravity</td>
<td>57 in</td>
</tr>
<tr>
<td>Center of Pressure</td>
<td>70 in</td>
</tr>
<tr>
<td>Fin Shape</td>
<td>Trapezoidal</td>
</tr>
<tr>
<td>Root Chord</td>
<td>12 in</td>
</tr>
<tr>
<td>Tip Chord</td>
<td>8 in</td>
</tr>
<tr>
<td>Height</td>
<td>5 in</td>
</tr>
<tr>
<td>Fin Thickness</td>
<td>0.125 in</td>
</tr>
</tbody>
</table>

Four trapezoidal fins will be mounted to the lower airframe of the rocket to aid in flight stability. The dimensions were refined using OpenRocket, a free open source rocket simulation tool, to ensure a stability greater than the required 2.0 calibers. The calculated location of the center of gravity is 57 inches from the tip of the rocket. The center of pressure is located at 70 inches from the tip.

Both the lower and upper airframes as well as the coupler and fins are currently designed to be constructed out of fiberglass and manufactured in house to reduce costs. Carbon fiber is also being considered as an alternative material for some of the structural components. A fiberglass Von Karman nosecone was chosen due to its performance and efficiency at subsonic speed. The nose cone will be purchased from a commercial supplier due to the complexity of manufacturing the required shape. The projected total mass of the rocket with a payload is 35.7 pounds.

### 5.1.3 Propulsion

Using OpenRocket, motors which would provide the stability margin required while also achieving the required altitude could be compared could be compared; the OpenRocket model showed that an Aerotech L1390G motor (Table 4) would be capable of meeting the mission requirements. The AeroTech L1390G contains solid ammonium perchlorate composite propellant.
(APCP) in the “L” impulse range (2,560.01-5,120.00 N s) and will allow for a successful mission with 2.08 caliber stability.

<table>
<thead>
<tr>
<th></th>
<th>Table 4: Motor Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor Selection</strong></td>
<td></td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Aerotech</td>
</tr>
<tr>
<td>Motor Designation</td>
<td>L1390G</td>
</tr>
<tr>
<td>Hardware</td>
<td>Aerotech 75-2460</td>
</tr>
<tr>
<td>Diameter</td>
<td>2.95 in</td>
</tr>
<tr>
<td>Length</td>
<td>20.4 in</td>
</tr>
<tr>
<td>Propellant Weight</td>
<td>4.4 lb</td>
</tr>
<tr>
<td>Average Thrust</td>
<td>1374 lb</td>
</tr>
<tr>
<td>Total Impulse</td>
<td>3946 N-s</td>
</tr>
<tr>
<td>Launch Mass</td>
<td>8.6 lb</td>
</tr>
<tr>
<td>Empty Mass</td>
<td>4.2 lb</td>
</tr>
</tbody>
</table>

5.1.4 Flight Projection

A draft trajectory analysis was obtained with the vehicle's general dimensions to solidify motor selection using OpenRocket. The proposed model is shown in Figure 2 with flight projected results shown in Table 5. Throughout the project, it is expected that the mass of the rocket and payload will grow beyond their initial estimates and reduce the apogee safely beneath the flight ceiling of 5500 ft.

<table>
<thead>
<tr>
<th>Flight Projections</th>
<th>Table 5: Flight Projections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apogee</td>
<td>5439 ft</td>
</tr>
<tr>
<td>Max Velocity</td>
<td>682 ft/s</td>
</tr>
<tr>
<td>Max Acceleration</td>
<td>301 ft/s²</td>
</tr>
<tr>
<td>Stability</td>
<td>2.08 cal</td>
</tr>
</tbody>
</table>
5.2 Payload Description & Goals

The Charger Rocket Works team has selected the UAV payload option for the 2018-19 NASA USLI competition. The UAV payload concept is a remote controlled (RC) quadcopter. Each propeller will be powered by its own motor, which will receive power from two batteries. Each propeller arm will be designed and fabricated to fold to allow for UAV packaging and securement within the rocket. The UAV will be equipped with an accelerometer, a gyroscope, and a camera with which to provide a visual image of the flight path to the ground operating station, the UAV pilot. A radio receiver and transmitter will be attached to the UAV to enable communication with the ground operating station. The UAV concept proposes a grab-and-release mechanism powered by a servo motor to enable the transportation and release of a beacon, as required by NASA. A flight computer located within the UAV will host the aforementioned sensors, camera, and grab-and-release system. An extensive testing campaign will be conducted to ensure safety, flight-readiness, and mission completion during the competition. A payload requirements checklist plan has been created to ensure that the UAV payload meets the NASA competition requirements as well as the FAA drone regulation laws.

5.2.1 Listed Requirements

UAV payload mission is required to complete deployment and travel for a certain distance and drop a beacon at the determined area. Payload design baseline should be determined based on vehicle needs and under conditions to fulfill the requirements of NASA Student Launch handbook. The mission requirements for Unmanned Aerial Vehicle (UAV) / Beacon Delivery option are as followed:

1) The UAV will be deployed from the launch vehicle.
2) The UAV will be powered off until the rocket has safely landed on the ground.
3) The UAV will be powered on remotely after landing.
4) The UAV will need a retention system within the vehicle.
5) The retention system will be robust enough to retain the UAV.
6) The UAV deployment will be remotely activated at the landing.
7) After deployment, the UAV will take off and fly to a NASA specified location, called Future Excursion Area (FEA).
8) FEA specification is as followed;
9) Approximately 10 ft. x 10 ft. and visibly outstanding on the ground.
10) One or more FEA’s will be located in the recovery area of the launch field.
11) Both autonomous and pilot flight are permissible during the flight.
12) The reorientation or unpacking maneuvers must be autonomous.
13) The UAV will place or drop a simulated navigational beacon on the target area.
14) The simulated beacon specification is as followed;
15) The beacon will be designed and built by each team.
16) Minimum design is 1 in W x 1 in H x 1 in D.
17) The school name must be located on the external surface of the beacon
18) The UAV’s batteries have to be protected from ground impact.
19) The UAV's batteries should be brightly colored, clearly marked as a fire hazard.
20) The team will abide by all applicable FAA regulations, including the FAA’s Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs)

21) Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle

5.2.2 Structural Design

The Charger Rocket Works team has selected the UAV payload option for the 2018-19 NASA USLI competition. The UAV payload concept is a remote controlled (RC) quadcopter. Each propeller will be powered by its own motor, which will receive power from two batteries. Each propeller arm will be designed and fabricated to fold to allow for UAV packaging and securement within the rocket. The UAV will be equipped with an accelerometer, a gyroscope, and a camera with which to provide a visual image of the flight path to the ground operating station, and the UAV pilot. A radio receiver and transmitter will be attached to the UAV to enable communication with the ground operating station. The UAV concept proposes a grab-and-release mechanism powered by a servo motor to enable the transportation and release of a beacon, as required by NASA. A flight computer located within the UAV will host the aforementioned sensors, camera, and grab-and-release system. An extensive testing campaign will be conducted to ensure safety, flight-readiness, and mission completion during the competition. A payload requirements checklist plan has been created to ensure that the UAV payload meets the NASA competition requirements as well as the FAA drone regulation laws.

5.2.3 System Overview

The UAV will be assembled by the payload team from Commercially Off The Shelf (COTS) and in-house components. Currently, the payload team plans to acquire a COTS flight computer and interface it with a custom-designed power distribution and a COTS communication system. The propulsion system will be designed to use commercially available motors, Electrical Speed Controllers (ESC), propellers, and motor controllers, but assembled in-house. A model of the payload can be seen in Figure 3.

The output voltage and capacity of the power management system will be designed to provide the propulsion system for the required flight time. In addition, it will also provide regulated power output to the flight controllers, communications components, peripheral sensors and camera. The communications system will facilitate data and image transmission to ground and receive commands from the remote control. The release mechanism will be designed to be triggered by the flight computer, upon command from the operator’s remote control.
5.3 Recovery Description & Goals

The recovery system is required to achieve the mission of the payload to deploy and fly to a pre-determined location. The recovery system must launch a main and drogue parachute in flight to ensure a safe landing of both the vehicle and payload. The recovery system is necessary for a successful launch and will be designed such that the vehicle lands within a pre-determined radius regardless of winds or weather.

5.3.1 Listed Requirements

Recovery design baseline that is required to fulfill the requirements of a successful mission are as follows:

1) A drogue parachute will be deployed at apogee.
2) The main parachute shall be deployed no lower than 500 feet.
3) The apogee event delay will be less than 2 seconds.
4) Recovery system electrical circuits will be independent of payload.
5) Recovery electronics will be powered by batteries.
6) The recovery system will contain redundant altimeters.
7) Removable shear pins will be used for both parachute compartments.
8) Recovery area is limited to a 2500 ft. radius.
9) Descent time will be limited to 90 seconds.
10) The recovery system electronics will be shielded from any other devices.
5.3.2 Parachutes

The recovery system will consist of both a drogue and main parachute. The drogue parachute will deploy at apogee and reduce the vehicle’s descent velocity. The main parachute will deploy once the vehicle reaches an altitude of approximately 600 ft. AGL. The main parachute will slow the vehicle to the necessary speeds that USLI requires for landing. This will also ensure that no damage is dealt to the payload upon landing.

Based upon the current OpenRocket model, the drogue parachute will need to be approximately 3.37 ft. in diameter while the main will need to be approximately 11.73 ft. The main parachute is modeled after the most extreme conditions for deployment which would be 20 mph crosswinds at the minimum allowable deployment. However, these serve as rough estimates and are subject to change as designs advance. The suspension lines for the drogue and main parachute will be approximately 60 in. and 210 in. in length, respectively; the lines will be designed such that individual portions of the rocket to not contact one another after separation. This will ensure no damage is dealt to the vehicle, the avionics, or the payload during recovery. Both parachutes will be COTS; recovery team members have prior experience with crafting recovery systems in-house, but due to time constraints this would not be a viable option.

The parachutes will most likely be purchased from popular rocketry recovery system vendors such as FruityChutes, Apogee Rockets, or The Rocketman Parachutes. A trade study will need to be conducted to select the best options for the vehicle. The preferred material is ripstop nylon which should be brightly colored to aid in visual tracking once the rocket begins to descend. The suspension lines for both parachutes will be made from tubular nylon as it provides good tension for low cost; however, the base of the suspension lines may be crafted out of Kevlar since nylon may be cut on the edges of the rocket’s body tubes.

The parachutes will be deployed from the rocket via black powder charger which will be ignited by an e-match once the rocket’s altimeter determines apogee and the predetermined height for the main parachute. Two altimeters will be used in the event that one device should fail. As a result, a secondary black powder charge will be ignited slightly after the primary charge. Nomex blankets and fire-resistant material will be used to ensure that the chords do not ignite during ignition of the black powder.

The total load exerted on a parachute system during deployment and recovery is not equal to the mass of the payload suspended below it. The total load is much higher than the total payload mass. Calculators can be used to determine opening shock force when given certain system parameters; filling time and canopy porosity and permeability are the most important parameters involved in this consideration. Two programs that can be used are Oscalc and Pifcalc which are both available for free from the Parks College Parachute Research Group website. These programs can be used to better calculate the expected opening force and shock forces once fill time is known; averages can be assumed for permeability and porosity of the canopy material.

5.3.3 Tracking System

In accordance with USLI requirements, the vehicle must contain a tracking device for all parts of the vehicle which are separable. Previous CRW teams have used a prototyped GPS device
shown below in Figure 4 which, via an XBee radio transmitter, will transmit the rocket’s position to an XBee radio receiver operated by team personnel. The device will be powered by an independent power source and will be secured in the nose cone of the rocket. Here, it will be securely housed and will not interfere with avionic systems. Given that the device has had success in previous projects, its integration will be simpler for design and will save the team from having to purchase one from a third party. Tests will need to be conducted to assess device calibration.

![Image: CRW Prototype GPS Tracker](image)

**Figure 4: CRW Prototype GPS Tracker**

## 6 Education and Outreach

The 2018-2019 Charger Rocket Works team aims to engage and educate the local community as well as communities in multiple states with the help of the UAH Communications Department – the planned outreach activities are outlined in Table 6. The goal of engaging and educating the local community will be accomplished through information sessions given at local schools - specifically at Davis Hills Elementary School, Challenger Middle School, and Jemison High School. Examples of other events that will engage the community include Girl’s Science and Engineering Day and the Society of Women Engineers First Lego League Qualifier. This year, the CRW team aims to educate and engage students at high schools in the native states of the CRW team members. The Charger Rocket Works team is projected to reach 1,610 students through the established outreach programs which exceeds the minimum requirement of 200 set by NASA. The presentation for Davis Hill Elementary School will consist of two hands-on activities in which the students will learn about propulsion and vehicle design using diet coke, Mentos, and paper airplanes. The Challenger Middle School presentation includes hands-on activities focusing on projectile motion, the effect of forces on motion, and accuracy and precision. Outreach at Jemison High School incorporates hands-on activities concentrating on chemical reactions and designing to protect a payload. Lastly, Charger Rocket Works team members will be visiting their respective high schools to give a demonstration of a small-scale rocket – information about the university and the STEM majors offered will also be given.
CRW plans to participate in the 2018 Girl’s Science and Engineering Day by hosting a rocketry event. This event is offered annually by UAH and reaches approximately 400 girls between the ages of 6 and 12. This event allows the girls to work in teams to build and launch small rockets at the Shelby Center for Science & Technology. The launches will be conducted by members of CRW and the Propulsion Research Center. Additionally, the Charger Works Rocketry Team will be assisting the UAH Society of Women Engineers First Lego League Qualifier on November 10 – the CRW team will volunteer in a variety of roles including judges, referees and score keeper. Approximately, 200 students from ages 8-14 will be in attendance competing against other students using small autonomous robots capable of completing simple timed tasks.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Purpose</th>
<th>Anticipate Number of Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girl’s Science &amp; Engineering Day</td>
<td>Nov-3</td>
<td>Present rocketry basics</td>
<td>400</td>
</tr>
<tr>
<td>Society of Women Engineers: First Lego League Qualifier</td>
<td>Nov-10</td>
<td>To assist UAH SWE in robotics event, while presenting rocketry seminar to attendees</td>
<td>200</td>
</tr>
<tr>
<td>Science Olympiad</td>
<td>TBA</td>
<td>Present rocketry basics</td>
<td>50</td>
</tr>
<tr>
<td>Davis Hill Elementary</td>
<td>Varies</td>
<td>Propulsion and Vehicle Design activities</td>
<td>100</td>
</tr>
<tr>
<td>Challenger Middle School</td>
<td>Varies</td>
<td>Projectile motion, Forces’ effect on motion &amp; precision and accuracy</td>
<td>100</td>
</tr>
<tr>
<td>Jemison High School</td>
<td>Varies</td>
<td>Heat Shields &amp; Payload Protection Design</td>
<td>100</td>
</tr>
<tr>
<td>Additional High School Outreach</td>
<td>Varies</td>
<td>Present rocketry basics</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Impacted</td>
<td>1,610</td>
</tr>
</tbody>
</table>
# Project Plan

The CRW team has developed a preliminary schedule and budget for this year’s rocketry project. The schedule will meet and display all major milestones outlined in the NASA USLI SOW. Actual project cost from previous CRW USLI teams were used to estimate a budget for this year’s team. Both the preliminary schedule and budget will be discussed further in the following sections.

## Schedule

Figure 5 contains an outline for the project’s timeline starting in August and coming to an end in April. The project’s lifecycle consists of seven main phases: Proposal, Preliminary Design Review (PDR), Critical Design Review (CDR), Fabrication, Testing, Flight Readiness Review (FRR), and Post Launch Assessment Review (PLAR). The schedule includes launch days for sub-scale and full-scale flights. The dates were provided by the Huntsville Area Rocketry Association (HARA). Their launch field is located in Woodville, Alabama. The schedule includes two sub-scale flight tests and one full-scale flight test. These dates are subject to change due to weather conditions. Lastly, the schedule includes all major milestones provided by NASA.

![Figure 5: Project Timeline](image)

## Budget

The project budget is summarized in Table 7. Given the use of the X-Winder filament Winder filament to manufacture body tube sections, there is a high variability in the type of
filament tow selected, as well as the required volume and accompanying epoxy. The Rocket Fabrication detailed budget can be found in Table 8. Additionally, because the Charger Rocket Works team has no experience in manufacturing UAV’s, there is a high variability in payload budget, found in Table 9. Table 10 show the detailed breakdown of the Subscale Rocket Budget.

Table 7: Overall Budget

<table>
<thead>
<tr>
<th>Budget Summary</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle fabrication and flight budget</td>
<td>$4,677.50</td>
</tr>
<tr>
<td>Payload budget</td>
<td>$580.47</td>
</tr>
<tr>
<td>Subscale rocket budget</td>
<td>$720.00</td>
</tr>
<tr>
<td>10% Margin</td>
<td>$560.64</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>$6,167.88</strong></td>
</tr>
</tbody>
</table>

Table 8: Rocket Fabrication Budget

<table>
<thead>
<tr>
<th>Line Item</th>
<th>Vendor</th>
<th>Cost</th>
<th>Amount</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Tubes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPOOL - 40 LBS FIBERGLASS ROVING</td>
<td>Rock West Composites</td>
<td>$128.00</td>
<td>3</td>
<td>$384.00</td>
</tr>
<tr>
<td>105-C WS Epoxy Resin (4.35 gal)</td>
<td>West Systems</td>
<td>$356.33</td>
<td>3</td>
<td>$1,068.99</td>
</tr>
<tr>
<td>209-SC WS Extra Slow Hardener (1.5 gal)</td>
<td>West Systems</td>
<td>$254.64</td>
<td>3</td>
<td>$763.92</td>
</tr>
<tr>
<td><strong>Propulsion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerotech 75mm Motor Hardware</td>
<td>Chris's Rocket Supplies</td>
<td>$450.00</td>
<td>1</td>
<td>$450.00</td>
</tr>
<tr>
<td>Aerotech 75-2560 L1390 Reloads</td>
<td>Chris's Rocket Supplies</td>
<td>$200.00</td>
<td>3</td>
<td>$600.00</td>
</tr>
<tr>
<td><strong>Recovery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&quot; Tubular Nylon 25'</td>
<td>Chris's Rocket Supplies</td>
<td>$25.00</td>
<td>3</td>
<td>$75.00</td>
</tr>
<tr>
<td>Fruity Chutes Drouge</td>
<td>Fruity Chutes</td>
<td>$64.00</td>
<td>1</td>
<td>$64.00</td>
</tr>
<tr>
<td>Cert 3 Sky Angle Main Parachute</td>
<td>Chris's Rocket Supplies</td>
<td>$140.00</td>
<td>1</td>
<td>$140.00</td>
</tr>
<tr>
<td><strong>Other Hardware</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machining Stock</td>
<td>McMaster Carr</td>
<td>$400.00</td>
<td>1</td>
<td>$400.00</td>
</tr>
<tr>
<td>Fasteners</td>
<td>Various Vendors</td>
<td>$250.00</td>
<td>1</td>
<td>$250.00</td>
</tr>
<tr>
<td><strong>Flight Controller</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratologger CF</td>
<td>Chris's Rocket Supplies</td>
<td>$55.00</td>
<td>2</td>
<td>$110.00</td>
</tr>
<tr>
<td><strong>15% Margin</strong></td>
<td></td>
<td></td>
<td></td>
<td>$371.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total Cost</strong></td>
<td></td>
<td><strong>$4,677.50</strong></td>
</tr>
</tbody>
</table>
### Table 9: Payload Budget

<table>
<thead>
<tr>
<th>Line Item</th>
<th>Vendor</th>
<th>Cost</th>
<th>Amount</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium Polymer Battery</td>
<td>Lectron</td>
<td>$40.00</td>
<td>2</td>
<td>$79.99</td>
</tr>
<tr>
<td>RS2306 2400KV Brushless Motor 4 pack</td>
<td>EMAX</td>
<td>$40.00</td>
<td>2</td>
<td>$79.99</td>
</tr>
<tr>
<td>DAL 5045BN Bullnose 4 pack</td>
<td>Dalprops</td>
<td>$0.50</td>
<td>3</td>
<td>$1.49</td>
</tr>
<tr>
<td>Brushless Electric Speed Control</td>
<td>NIDICI</td>
<td>$19.28</td>
<td>2</td>
<td>$38.55</td>
</tr>
<tr>
<td>Pixhawk 4 Flight Controller</td>
<td>Pixhawk</td>
<td>$43.90</td>
<td>2</td>
<td>$87.79</td>
</tr>
<tr>
<td>Transmitter/Receiver Remote Control</td>
<td>FlySky</td>
<td>$52.99</td>
<td>1</td>
<td>$52.99</td>
</tr>
<tr>
<td>Holybro Pixhawk 4 Neo-M8N GPS</td>
<td>Pixhawk</td>
<td>$21.50</td>
<td>2</td>
<td>$42.99</td>
</tr>
<tr>
<td>FPV Camera and Transmitter</td>
<td>AKK</td>
<td>$18.00</td>
<td>2</td>
<td>$35.99</td>
</tr>
<tr>
<td>Servoless Payload Release</td>
<td>E-flite</td>
<td>$12.50</td>
<td>2</td>
<td>$24.99</td>
</tr>
<tr>
<td>Motor Mounts 4 pack</td>
<td>Blade</td>
<td>$3.33</td>
<td>3</td>
<td>$9.99</td>
</tr>
<tr>
<td>Miscellaneous items (nuts, bolts, screws, paint, etc.)</td>
<td>N/A</td>
<td></td>
<td></td>
<td>$50.00</td>
</tr>
<tr>
<td>15% Margin</td>
<td></td>
<td></td>
<td></td>
<td>$75.71</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$580.47</strong></td>
</tr>
</tbody>
</table>

### Table 10: Subscale Rocket Budget

<table>
<thead>
<tr>
<th>Line Item</th>
<th>Vendor</th>
<th>Cost</th>
<th>Amount</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocket Kit</td>
<td>Chris’s Rocket</td>
<td>$200.00</td>
<td>2</td>
<td>$400.00</td>
</tr>
<tr>
<td>Motors</td>
<td>Chris’s Rocket</td>
<td>$50.00</td>
<td>4</td>
<td>$200.00</td>
</tr>
<tr>
<td>Recovery Kits</td>
<td>Madcow</td>
<td>$30.00</td>
<td>4</td>
<td>$120.00</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$720.00</strong></td>
</tr>
</tbody>
</table>

### 7.3 Funding

CRW will solicit funding for the program from various sources. Historically, The Alabama Space Grant Consortium (ASGC), has supported the project with $5,000 outreach grants. Additionally funds have been provided from the UAH VPR office, the Mechanical and Aerospace Engineering Department, and from the Propulsion Research Center. The team will reach out to previous sponsors for funding or in-kind project support. In addition, the PRC will cost match with ASGC. UAH will also provide cost share support with facilities access and supervision in the PRC laboratory space.

### 7.4 Sustainability

As a popular senior design option at UAH, Charger Rocket Works has traditionally had no shortage of new team members. In order to ensure that this trend continues, the current team will promote USLI and CRW within the UAH student community. Sustainability efforts will include a team presence at events such as the UAH Open House for prospective students. Many of this year’s
CRW team members conversed with past members and referred to their experience as a positive factor in their decision to study aerospace or mechanical engineering at UAH. The team will also share its progress with UAH’s student news site and the Office of Marketing and Communications. These updates will go up on the UAH website for the public to view, thereby attracting the attention of potential future CRW students. As opportunities arise throughout the school year, the team will actively encourage fellow students to consider CRW for their senior design project.

The team will conduct test flights at launches hosted by the Huntsville Area Rocketry Association and Phoenix Missile Works. Partnership with these local rocketry clubs has been and will continue to be an important aspect of Charger Rocket Works efforts, from a perspective of both test flight opportunities and critique from experienced rocketeers.

The Alabama Space Grant Consortium (ASGC) and PRC are expected to be sustainable funding sources for future teams. They have been crucial supporters for several years in the past and their mission scope continues to include CRW. CRW continues to seek industry and government partnerships in order to promote the organization and UAH.

8 Primary Challenges and Solutions

It is difficult to foresee the various possible challenges that a large-scale project may bring during its conception; however, it is critical that any design team recognize any challenges they may face and develop possible solutions to overcome them. CRW is dedicated to designing and developing a system which will perform exceedingly well at competition by overcoming all adversities that this year’s project brings to its members. Listed below are some of the unique challenges this year’s team are faced with and are determined to overcome.

8.1 Vehicle

Open source software such as OpenRocket and Rocksim will provide good estimates for how the rocket will perform in ideal conditions; however, these programs do not account for a variety of first order errors which will cause the rocket to perform differently on launch day. To develop the most accurate results, personally developed programs and calculations will have to be made. This becomes problematic as it adds time to the development phase and pushes back possible launch-ready dates.

Construction of the sub-scale and full-scale vehicles will potentially become problematic since the entire team only holds one Blue Card member capable of using advanced instrumentation required to create vehicle components for both sub-scale and full-scale. A majority of the members are also unfamiliar with most of the instrumentation and will have to devote time to familiarizing themselves with tools to avoid damage and injury as well as wasting resources due to improper handling.
8.2 Payload

This year’s payload will be particularly difficult as it is the first time CRW has attempted to develop a UAV in nearly seven years. Since there will be limited resources to design the payload around, the payload team will have to conduct extensive research on UAVs and possibly collaborate with outside sources for aid on a working design. Furthermore, to allow for ample time in troubleshooting any possible errors, the payload team will have to work immediately and extensively on its construction once a design is finalized.

Integration of the payload has frequently been a hurdle that teams in the past have failed to overcome. The payload is the driving force of the rocket and it is vital that it is properly delivered as designed. It is important to maintain constant communication between the payload and vehicle teams to ensure a feasible solution for housing and deployment is developed. Given that the rocket will have landed horizontally, this makes deployment of a vertically launching UAV rather difficult. Designs which use the payload’s arms to position itself vertically after being deployed out of the rocket are being considered, but do not ensure successful positioning.

8.3 Recovery

The recovery team faces a challenge of balancing descent time and the kinetic energy at landing. Furthermore, the team must account for wind speeds as high as 20 miles per hour affecting the descent path of the rocket. Wind speeds this high could elongate the descent time of the rocket and possibly increase the kinetic energy at landing. Additionally, the rocket could potentially drift out of regulation or into an area where payload deployment would not be possible. Therefore, the selection of parachutes and the time of deployment is critical to ensuring all recovery requirements are met, that the rocket safely lands without any irreparable damages, and that the payload is kept intact and is able to successfully deploy itself.

8.4 Project Management

To keep up with the overall costs, the individual sub-teams will also need to report any expenses to the project manager to maintain a record of the overall project budget. To keep the budget relatively small, sub-teams will need to select materials which best accomplish the task without draining the team of finances. The project will need to be funded by outside donations; any grants which the team receives will not fully cover the costs of the project and the CRW team will be required to find other means of revenue. This could possibly be accomplished by seeking donations from local rocket teams, from local aerospace businesses, or from university funding.

Scheduling is critical to ensuring continuous progress is made on the project; a master schedule will need to be drafted which details specific tasks, who is responsible for that task, and approximately when the task will need to be completed. The schedule will also need to account for conflicting dates such as holidays and breaks as well as other conflicting dates in other courses.

To ensure complete vehicle success at competition, CRW plans on conducting several field tests of both sub-scale and full-scale models to analyze any problems and develop solutions to fix the problem. It becomes difficult to perform multiple tests as there are limited launch sites which
are open scarcely throughout the year. It will be important that CRW not only works timely to complete the vehicles by the planned launch dates but to also anticipate inclement weather to postpone any scheduled launches. It is important that the team prepare to travel out of state to possible launch sites and to allocate proper funding to travel expenses in this event.

9 Conclusion

This year, Charger Rocket Works returns to NASA’s Student Launch as determined as ever to deliver the best design and to outperform other teams in winning awards for this year’s competition. With the help of the UAH Communications Department, CRW will meet their high standards by setting the following goals:

1) To successfully build and fly a high-powered rocket that meets the competition requirements.
2) To create CRW’s first operating UAV in nearly a decade and to successfully fulfill competition requirements for payload.
3) To create the most comprehensive safety standards and to set the bar for safety standards for future competitions.
4) To create an intriguing display at the Rocket Fair to interest the community in CRW’s vision.
5) To create a social media presence which informs and engages the general public with CRW’s progress and success throughout the product’s life-cycle.
6) To engage 1000+ students in STEM related Outreach events and to sustain the success of rocketry and other science related fields by inspiring the next generation.
7) To compose professional-grade technical documents detailing the progress of the project as required by NASA

With this year’s team, CRW will undoubtedly be able to overcome all adversity and will be determined to take home the gold at this year’s competition.
Appendix A is an initial and preliminary examination of risks and hazards that may occur throughout the duration of this project. In the tables below shows the Risk Assessment Criteria (RAC) matrix. The accompanying tables define each parameter of the matrix. The initial risk and hazards assessment includes the RAC value prior to mitigation assessment (Pre-MA) as well as the RAC value following the mitigation assessment (Post-MA).

### RAC

<table>
<thead>
<tr>
<th>Probability Level</th>
<th>Severity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Catastrophic</td>
</tr>
<tr>
<td>2</td>
<td>Critical</td>
</tr>
<tr>
<td>3</td>
<td>Marginal</td>
</tr>
<tr>
<td>4</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A – Highly Probable</th>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
</tr>
</thead>
<tbody>
<tr>
<td>B – Likely</td>
<td>1B</td>
<td>2B</td>
<td>3B</td>
<td>4B</td>
</tr>
<tr>
<td>C – Moderate</td>
<td>1C</td>
<td>2C</td>
<td>3C</td>
<td>4C</td>
</tr>
<tr>
<td>D – Unlikely</td>
<td>1D</td>
<td>2D</td>
<td>3D</td>
<td>4D</td>
</tr>
<tr>
<td>E – Improbable</td>
<td>1E</td>
<td>2E</td>
<td>3E</td>
<td>4E</td>
</tr>
</tbody>
</table>

### Severity Level

<table>
<thead>
<tr>
<th>Description</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Catastrophic</td>
<td>Loss of life or permanent injury, irreparable major damage to facilities or hardware, complete project failure.</td>
</tr>
<tr>
<td>2 – Critical</td>
<td>Severe personal injury, significant damage to hardware or facilities, significant impact on overall schedule.</td>
</tr>
<tr>
<td>3 – Marginal</td>
<td>Minor personal injury, reparable damage to facilities or hardware, significant impact on immediate schedule.</td>
</tr>
<tr>
<td>4 – Negligible</td>
<td>Minor personal injury, little to no damage to hardware, little impact on immediate schedule.</td>
</tr>
</tbody>
</table>
### Probability Level

<table>
<thead>
<tr>
<th>Description</th>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>A – Highly Probable</td>
<td>Highly expected to occur or to occur frequently during project duration.</td>
<td>85% &lt; Probability</td>
</tr>
<tr>
<td>B – Likely</td>
<td>Expected to occur or to occur several times during project duration.</td>
<td>50% &lt; Probability &lt; 85%</td>
</tr>
<tr>
<td>C – Moderate</td>
<td>Potential to occur multiple times during project duration.</td>
<td>25% &lt; Probability &lt; 50%</td>
</tr>
<tr>
<td>D – Unlikely</td>
<td>Remote potential to occur with exception of rare occasion during project duration.</td>
<td>1% &lt; Probability &lt; 25%</td>
</tr>
<tr>
<td>E – Improbable</td>
<td>Highly unexpected to occur during project duration.</td>
<td>Probability &lt; 1%</td>
</tr>
</tbody>
</table>

### Risk Level and Approval Chart

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Risk</td>
<td>Unacceptable, must be mitigated. Risk level too extreme for operation.</td>
</tr>
<tr>
<td>Moderate Risk</td>
<td>Undesirable; requires signature of Team Leadership, Team Mentor, Faculty Advisor, and Safety Committee for approval.</td>
</tr>
<tr>
<td>Low Risk</td>
<td>Acceptable; requires signature of Team Leadership and Safety Committee for approval.</td>
</tr>
<tr>
<td>Minimal Risk</td>
<td>Acceptable; does not require signature for approval.</td>
</tr>
</tbody>
</table>
### Risk Assessment and Mitigation

**Topic: Overall Project**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Cause</th>
<th>Effect</th>
<th>Pre-MA</th>
<th>Mitigation</th>
<th>Verification</th>
<th>Post-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient Funds</td>
<td>Funds were not properly obtained from academic and outside sources.</td>
<td>Necessary parts may have to be selected by cheapest value alone. There may be no remaining funds for replacement parts.</td>
<td>2C</td>
<td>A detailed list including fund sourcing will be written. Funds will be obtained prior to part ordering.</td>
<td>Project Manager will ensure all funds are accounted for and will order parts as necessary.</td>
<td>2E</td>
</tr>
<tr>
<td>Disagreement Between Team Members</td>
<td>Communication failures and unreceptive to ideas.</td>
<td>Tensions lead to project failure due to lack of teamwork.</td>
<td>3C</td>
<td>Concerns within sub-teams will be brought to sub-team leads who will diffuse situations or escalate issues as necessary.</td>
<td>Periodic Leadership meetings will discuss any issues resolved or otherwise within sub-teams.</td>
<td>3D</td>
</tr>
<tr>
<td>Schedule Setbacks</td>
<td>Missed deadlines.</td>
<td>Delayed fabrication or testing may result in missed flight opportunities or NASA deadlines.</td>
<td>2B</td>
<td>Gnatt charts will be made and reminders will be sent out prior to deadlines.</td>
<td>Schedule check-ins will occur during every team meeting.</td>
<td>2D</td>
</tr>
<tr>
<td>Unavailable Parts</td>
<td>Back orders, vendors going under, out of stock parts.</td>
<td>Construction is delayed.</td>
<td>3C</td>
<td>Parts will be ordered with sufficient time to obtain alternate parts before integration. Additionally, parts will be sourced from various vendors.</td>
<td>Sub-team leads and the Technical Leads will make sure parts are ordered in time and are available from multiple vendors.</td>
<td>3E</td>
</tr>
</tbody>
</table>
### Risk Assessment and Mitigation

**Topic: Vehicle**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Cause</th>
<th>Effect</th>
<th>Pre-MA</th>
<th>Mitigation</th>
<th>Verification</th>
<th>Post-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery Failure</td>
<td>Recovery system is packed poorly and remains in rocket.</td>
<td>Rocket descent is uncontrolled and dangerous.</td>
<td>2B</td>
<td>Successfully test recovery system before first launch. The recovery system will be packed carefully into rocket.</td>
<td>Ground and flight tests.</td>
<td>2E</td>
</tr>
<tr>
<td>Structural Failure</td>
<td>Insufficient or damaged airframe structure.</td>
<td>Rocket body collapse resulting in uncontrolled or unstable flight.</td>
<td>1D</td>
<td>Carefully calculate stress on the body and points of integration. Perform successful structural tests.</td>
<td>Ground and sub-scale flight tests.</td>
<td>1E</td>
</tr>
</tbody>
</table>

### Risk Assessment and Mitigation

**Topic: Payload**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Cause</th>
<th>Effect</th>
<th>Pre-MA</th>
<th>Mitigation</th>
<th>Verification</th>
<th>Post-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Loss to one or more systems</td>
<td>Battery Failure</td>
<td>Loss of data, failure of mission</td>
<td>2D</td>
<td>Design robust battery retention, ensure batteries are fully charged.</td>
<td>Flight testing, installation of new batteries before every launch.</td>
<td>2E</td>
</tr>
<tr>
<td>Data collection failure</td>
<td>Software or hardware failure due to flight loads</td>
<td>Loss of data</td>
<td>2C</td>
<td>Successfully test payload prior to launch.</td>
<td>Ground and flight testing.</td>
<td>2E</td>
</tr>
<tr>
<td>Payload fails to deploy</td>
<td>Deployment system failure due to flight loads</td>
<td>Payload cannot complete mission</td>
<td>2C</td>
<td>Successfully test deployment system prior to launch.</td>
<td>Ground and flight testing.</td>
<td>2E</td>
</tr>
<tr>
<td>Payload fails to fly</td>
<td>Propulsion or electrical system failure due to flight loads</td>
<td>Payload cannot complete mission</td>
<td>2D</td>
<td>Successfully test payload flight prior to launch.</td>
<td>Ground and flight testing.</td>
<td>2E</td>
</tr>
<tr>
<td>Payload drops beacon outside of designated zone</td>
<td>Beacon retention system fails due to flight loads</td>
<td>Payload fails to complete mission</td>
<td>3C</td>
<td>Successfully test system prior to launch.</td>
<td>Ground and flight testing.</td>
<td>3E</td>
</tr>
<tr>
<td>Risk</td>
<td>Cause</td>
<td>Effect</td>
<td>Pre-MA</td>
<td>Mitigation</td>
<td>Verification</td>
<td>Post-MA</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------</td>
<td>-------------------------------</td>
<td>--------</td>
<td>--------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Unloaded Motor Fire</td>
<td>Improper handling of motor.</td>
<td>Fire or explosion.</td>
<td>1D</td>
<td>Motors only be handled by HPR level specific members or mentors. Motors will be stored in locked protective case.</td>
<td>Leadership will plan who will transport and handle motors. Faculty Advisor has access to locked protective case.</td>
<td>1E</td>
</tr>
<tr>
<td>Motor Dislodges from Proper Position</td>
<td>Structural Failure.</td>
<td>Motor may eject from the rocket body.</td>
<td>2C</td>
<td>Proper motor retention and compression testing.</td>
<td>Flight testing and inspection of motor tube following test.</td>
<td>2E</td>
</tr>
<tr>
<td>Risk</td>
<td>Cause</td>
<td>Effect</td>
<td>Pre-MA</td>
<td>Mitigation</td>
<td>Verification</td>
<td>Post-MA</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------------------------</td>
<td>-------------------------------------------------------</td>
<td>--------</td>
<td>----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Weather Cocking</td>
<td>Incorrect exit velocity or static margin.</td>
<td>Rocket flies off track, beyond launch field perimeter. Forces on the rocket may result in insufficient altitude.</td>
<td>1C</td>
<td>Simulate flight with flight software, design rocket to have CG/CP in stable locations and proper exit velocity.</td>
<td>Measure the stability margin and calculate the thrust to weight ratio based on measured weight of the rocket and accepted thrust data of motor.</td>
<td></td>
</tr>
<tr>
<td>Unstable Flight</td>
<td>Weather cocking, excessive fin flutter, or structural failure.</td>
<td>Unpredictable flight path or landing area. Potential to destroy the rocket.</td>
<td>1C</td>
<td>Simulate flight with flight software, test rocket design with subscale flight.</td>
<td>Analyze simulation results, analyze subscale test results; alter the flight characteristics to ensure safe flight.</td>
<td>1E</td>
</tr>
<tr>
<td>Insufficient Altitude</td>
<td>Insufficient thrust to weight ratio.</td>
<td>Rocket does not meet minimum altitude requirement.</td>
<td>3C</td>
<td>Simulate flight with flight software use sub-scale and full-scale flight tests to ensure use of proper motor. Maintain rocket in proper weight margin.</td>
<td>Analyze software results and altimeter data from test flights.</td>
<td>3E</td>
</tr>
<tr>
<td>Excessive Altitude</td>
<td>Excessive thrust to weight ratio.</td>
<td>Rocket exceeds maximum altitude requirement.</td>
<td>3C</td>
<td>Simulate flight with flight software use sub-scale and full-scale flight tests to ensure use of proper motor. Maintain rocket in proper weight margin.</td>
<td>Analyze software results and altimeter data from test flights.</td>
<td>3E</td>
</tr>
</tbody>
</table>
### Hazard Assessment and Mitigation

#### Chemical Handling: Black Powder, Loose

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Cause</th>
<th>Effect</th>
<th>Pre-MA</th>
<th>Mitigation</th>
<th>Verification</th>
<th>Post-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unintentional Detonation</td>
<td>Friction, heat, outside sources of energy, improperly handled.</td>
<td>Fire or explosion. Immediate physical danger potentially resulting in severe injury or death. Minor damage to facilities.</td>
<td>1B</td>
<td>Safe handing by trained personnel. Correct PPE including impervious rubber gloves and non-static producing clothing.</td>
<td>SOP and MSDS.</td>
<td>1D</td>
</tr>
</tbody>
</table>

#### Chemical Handling: Alcohol, Isopropyl

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Cause</th>
<th>Effect</th>
<th>Pre-MA</th>
<th>Mitigation</th>
<th>Verification</th>
<th>Post-MA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye Irritant</td>
<td>Contact (direct or vapor) with eyes.</td>
<td>Mild irritation.</td>
<td>3D</td>
<td>Proper PPE including safety glasses. Chemical must be used in close proximity to an eyewash station.</td>
<td>MSDS.</td>
<td>3E</td>
</tr>
<tr>
<td>Skin Irritant, Sensitizer, Permeator</td>
<td>Direct contact with skin.</td>
<td>Mild irritation.</td>
<td>3C</td>
<td>Proper PPE including gloves and protective clothing.</td>
<td>MSDS.</td>
<td>3E</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Inhalation of large quantities.</td>
<td>Irritation.</td>
<td>3C</td>
<td>Use in well ventilated area.</td>
<td>SOP and MSDS.</td>
<td>3E</td>
</tr>
<tr>
<td>Highly Flammable</td>
<td>Presence of open flames, sparks, heat, or oxidizing materials.</td>
<td>Fire. Damage to personnel, hardware, and facilities.</td>
<td>1B</td>
<td>Safe workplace practices and avoiding flame.</td>
<td>SOP and MSDS.</td>
<td>1E</td>
</tr>
</tbody>
</table>
11 Appendix B: JRC Evacuation Plan
12 Appendix C: Applicable Laws and Regulations

FAA Regulations, CFR, Title 14, Part 101, Subpart C, Amateur Rockets

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.

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.

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.

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 or Class 3 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.

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.

**FAA – Small Unmanned Aircraft Regulations (Part 107)**

**107.1 Applicability.**

(a) Except as provided in paragraph (b) of this section, this part applies to the registration, airman certification, and operation of civil small unmanned aircraft systems within the United States

(b) This part does not apply to the following:

(1) Air carrier operations

(2) Any aircraft subject to the provisions of part 101 of this chapter; or

(3) Any operation that a remote pilot in command elects to conduct pursuant to an exemption issued under section 333 of Public Law 112-95, unless otherwise specified in the exemption.

**107.3 Definitions.**

The following definitions apply to this part. If there is a conflict between the definitions of this part and definitions specified in §1.1 of this chapter, the definitions in this part control for purposes of this part:

(a) **Control Station** means an interface used by the remote pilot to control the flight path of the small unmanned aircraft.

(b) **Corrective Lenses** means spectacles or contact lenses.

(c) **Small Unmanned Aircraft** means an unmanned aircraft weighing less than 55 pounds on takeoff, including everything that is on board or otherwise attached to the aircraft.

(d) **Small Unmanned Aircraft System (small UAS)** means a small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and the efficient operation of the small unmanned aircraft in the national airspace system.

(e) **Unmanned Aircraft** means an aircraft operated without the possibility of direct human intervention from within or on the aircraft.
(f) Visual Observer means a person who is designated by the remote pilot in command to assist the remote pilot in command and the person manipulating the flight controls of the small UAS to see and avoid other air traffic or objects aloft or on the ground.

107.13 Registration.

A person operating a civil small unmanned aircraft system for the purposes of flight must comply with the provisions of §91.203(a)(2) of this chapter.

107.15 Condition for safe operation.

(a) No person may operate a civil small unmanned aircraft system unless it is in a condition for safe operation. Prior to each flight, the remote pilot in command must check the small unmanned aircraft system to determine whether it is in a condition for safe operation.

(b) No person may continue flight of the small unmanned aircraft when he or she knows or has reason to know that the small unmanned aircraft system is no longer in a condition for safe operation.

107.19 Remote pilot in command.

(a) A remote pilot in command must be designated before or during the flight of the small unmanned aircraft.

(b) The remote pilot in command is directly responsible for and is the final authority as to the operation of the small unmanned aircraft system.

(c) The remote pilot in command must ensure that the small unmanned aircraft will pose no undue hazard to other people, other aircraft, or other property in the event of a loss of control of the aircraft for any reason.

(d) The remote pilot in command must ensure that the small UAS operation complies with all applicable regulations of this chapter.

(e) The remote pilot in command must have the ability to direct the small unmanned aircraft to ensure compliance with the applicable provisions of this chapter.

107.51 Operating limitations for small unmanned aircraft.

A remote pilot in command and the person manipulating the flight controls of the small unmanned aircraft system must comply with all of the following operating limitations when operating a small unmanned aircraft system:

(a) The groundspeed of the small unmanned aircraft may not exceed 87 knots (100 miles per hour).

(b) The altitude of the small unmanned aircraft cannot be higher than 400 feet above ground level, unless the small unmanned aircraft:

(1) Is flown within a 400-foot radius of a structure; and
(2) Does not fly higher than 400 feet above the structure's immediate uppermost limit.

c) The minimum flight visibility, as observed from the location of the control station must be no less than 3 statute miles. For purposes of this section, flight visibility means the average slant distance from the control station at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night.

d) The minimum distance of the small unmanned aircraft from clouds must be no less than:

(1) 500 feet below the cloud; and

(2) 2,000 feet horizontally from the cloud.

NAR High Power Rocket Safety Code

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.

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.

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.

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. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.

5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.

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 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.

8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 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.

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 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, 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.** My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

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.

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.

**National Fire Protection Association Regulations**

**NFPA 1122: Code for Model Rocketry**

'Model rockets' are rockets that conform to the guidelines and restrictions defined in the NFPA 1122 document. These rockets weigh less than 1500 grams, contain less than 125 grams of total fuel, have no motor with more than 62.5 grams of fuel or more than 160 NS of total impulse, use only pre-manufactured, solid propellant motors, and do not use metal body tubes, nose cones or fins. One inconsistency with this is the CPSC definition of a model rocket motor, which by their definition must contain no more than 80NS total impulse. NFPA 1122 contains the most complete definition of a model rocket and the model rocket safety code. This is the same safety code as adopted by NAR. 'Large Model Rockets' is a term used in the FAA FAR 101 regulations. It refers to NAR/NFPA model rockets that are between 454 and 1500 grams (1 to 3.3 pounds) total liftoff weight and contain more than 113 grams but less than 125 grams of total fuel.

**NFPA 1127: Code for High Powered Rocketry**
'High power rockets' are rockets that exceed the total weight, total propellant or single motor total impulse restrictions of model rockets, but otherwise conform to the same guidelines for construction materials and pre-manufactured, commercially made rocket motors. High power rockets also allow the use of metal structural components where such a material is necessary to insure structural integrity of the rocket. High power rockets have no total weight limits, but do have a single motor limit of no more than O power (40,960NS maximum total impulse) and have a total power limitation of 81,920NS total impulse. NFPA document 1127-1985 contains the most complete definition of a high-power rocket and also the high-power rocketry safety code. This safety code has been adopted by both the NAR and TRA. Metal bodied rockets are allowed by NFPA 1127 where metal is required to insure structural integrity of the rocket over all of its anticipated flight.

**State of Alabama Regulations**

**13A-11-224. Keeping black powder or explosives in city or town**

Any person who keeps on hand, at any one time, within the limits of any incorporated city or town, for sale or for use, more than 50 pounds of gunpowder or other explosives shall, on conviction, be fined not less than $100.00. The explosive material on such terms as the corporate authorities may prescribe.

**Tripoli Rocketry Association Requirements for High Powered Rocket Operation**

1. **Operating Clearances,** A person shall fly a high-power rocket only in compliance with:
   - This code and NFPA 1127;
   - *Federal Aviation Administration Regulations,* Part 101 (Section 307,72 Statute 749, Title 49 United States Code, Section 1348, “Airspace Control and Facilities,” Federal Aviation Act of 1958);
   - Other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.
   - Landowner permission.

2. **Participation,** Participation and Access at Tripoli Launches shall be limited to the following:

   2-1 HPR Fliers may access and conduct flights from the High-Power Launch Area and/or Model Rocket Launch Area

   2-2 Non-Tripoli Members age 18 and over that are students of an accredited educational institution may participate in join projects with Tripoli members. These individuals are allowed in the High-Power Launch Area and/or Model Rocket Launch Area if escorted by a Tripoli member. The maximum number of non-member participants shall not exceed five (5) per Tripoli Member.

   2-3 Non-Tripoli Members that are members of a Named Insured Group may participate in join projects with Tripoli Members. These individuals are allowed in the High-Power Launch Area and/or Model Rocket Launch Area if escorted by a Tripoli member. The maximum number of non-member participants shall not exceed five (5) per Tripoli Member.

   2-4 Tripoli Junior Members that have successfully completed the Tripoli Mentoring Program Training may access and conduct flights from the High-Power Launch Area while under the direct supervision of a Tripoli Senior member in accordance with the rules of the Tripoli Mentored Flying program. The Tripoli Senior member may provide supervision for up to five (5) individuals that have successfully completed the Tripoli Mentoring Program Training at a time in the High-Power Launch Area.
2-5 An invited guest may be permitted in the Model Rocket Launch Area and preparation areas upon approval of the RSO.

2-6 An Invited Guest may be allowed in the High-Power Launch Area if escorted by an HPR Flier. An HPR Flier may escort and be accompanied by not more than five (5) non-HPR fliers in the High-Power Launch Area. The HPR flier escort is required to monitor the actions of the escorted non-HPR fliers, and the escort is fully responsible for those actions and for the safety of those escorted.

2-7 Spectators, who are not invited guests, shall confine themselves to the spectator areas as designated by the RSO and shall not be present in the High-Power Launch Area or Model Rocket Launch Area.

3. Referenced Publications

The following documents, or portions thereof, are referenced within this code. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

3-1 NFPA Publications. National Fire Protection Association, I Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

- NFPA 1122, Code for Model Rocketry
- NFPA 1125, Code for Manufacture of Model Rocket Motors
- NFPA 1127, Code for High Powered Rocketry


- Hazardous Substances Act, from the United States Code (re. Airspace Control)

3-3 TRA Publications. Tripoli Rocketry Association, Inc., P.O. Box 87, Bellavue NE 68005.

- Articles of Incorporation and Bylaws
- High Powered Rocketry Safety Code
- Tripoli Motor Testing Committee (TMT), Testing Policies

4. Additional Tripoli Rulings

A-1 NFPA 1127 was adopted by the Tripoli Board of Directors as the Tripoli Safety Code. (Tripoli Report, April 1994, Tripoli Board Minutes, New Orleans, 21, January 1994, Motion 13.)

A-2 All Tripoli members who participate in Association activities shall follow the Tripoli Certification Standards.

A-3 Any Board action(s), with regard to safety, made previous to or after publication of this document shall be a part of the Tripoli Safety Code.

A-4 A rocket motor shall not be ignited using:
a. A switch that uses mercury

b. “Pressure roller” switches
13 Appendix D: MSDS

Goex Powder, Inc.

Material Safety Data Sheet
MSDS-BP (Potassium Nitrate)
Revised 3/17/09

PRODUCT INFORMATION

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Black Powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade Names and Synonyms</td>
<td>N/A</td>
</tr>
<tr>
<td>Manufacturer/Distributor</td>
<td>GOEX Powder, Inc. (DOYLINE, LA) &amp; various international sources</td>
</tr>
<tr>
<td>Transportation Emergency</td>
<td>800-255-3524 (24 hrs – CHEM TEL)</td>
</tr>
</tbody>
</table>

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES

The prevention of accidents in the use of explosives is a result of careful planning and observance of the best known practices. The explosives user must remember that he is dealing with a powerful force and that various devices and methods have been developed to assist him in directing this force. He should realize that this force, if misdirected, may either kill or injure both him and his fellow workers.

WARNING

All explosives are dangerous and must be carefully transported, handled, stored, and used following proper safety procedures either by or under the direction of competent, experienced persons in accordance with all applicable federal, state and local laws, regulations, or ordinances. ALWAYS lock up explosive materials and keep away from children and unauthorized persons. If you have any questions or doubts as to how to use any explosive product, DO NOT USE IT before consulting with your supervisor, or the manufacturer, if you do not have a supervisor. If your supervisor has any questions or doubts, he should consult the manufacturer before use.

HAZARDOUS COMPONENTS

<table>
<thead>
<tr>
<th>Material or Components</th>
<th>%</th>
<th>CAS NO.</th>
<th>TLV</th>
<th>PEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium nitrate</td>
<td>70-76</td>
<td>007757-79-1</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Charcoal</td>
<td>8-16</td>
<td>N/A</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Sulfur</td>
<td>9-20</td>
<td>007704-34-9</td>
<td>NE</td>
<td>NE</td>
</tr>
<tr>
<td>Graphite</td>
<td>Trace</td>
<td>007782-42-5</td>
<td>15 mppct (TWA)</td>
<td>2.5 mg/m³</td>
</tr>
</tbody>
</table>

N/A = Not assigned
NE = Not established

1 Not contained in all grades of black powder.

P.O. Box 659, Doyline, LA 71023-0659, (318) 352-0300
www.goexpowder.com
### PHYSICAL DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling Point</td>
<td>N/A</td>
</tr>
<tr>
<td>Vapor Pressure</td>
<td>N/A</td>
</tr>
<tr>
<td>Vapor Density</td>
<td>N/A</td>
</tr>
<tr>
<td>Solubility in Water</td>
<td>Good</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.70 – 1.82 (mercury method) 1.92 – 2.08 (pycnometer)</td>
</tr>
<tr>
<td>PH</td>
<td>8.0 – 8.0</td>
</tr>
<tr>
<td>Evaporation Rate</td>
<td>N/A</td>
</tr>
<tr>
<td>Appearance and Odor</td>
<td>Black granular powder. No odor detectable.</td>
</tr>
</tbody>
</table>

### HAZARDOUS REACTIVITY

**Instability**
Keep away from heat, sparks, and open flames. Avoid impact, friction and static electricity.

**Incompatibility**
When dry, black powder is compatible with most metals; however, it is hygroscopic and when wet, attacks all common metals except stainless steel.

Black powder must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials, and other similar materials, situations, and equipment.

**Hazardous decomposition**
Detonation produces hazardous overpressures and fragments (if confined). Gasses produced may be toxic if exposed in areas with inadequate ventilation.

**Polymerization**
Polymerization will not occur.

### FIRE AND EXPLOSION DATA

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flashpoint</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Auto Ignition Temperature</td>
<td>Approx. Range: 392°F-967°F / 200°C-464°C</td>
</tr>
<tr>
<td>Explosive temperature (5 sec)</td>
<td>Ignites @ approx. 427°C (801°F)</td>
</tr>
<tr>
<td>Extinguishing media</td>
<td>Water</td>
</tr>
</tbody>
</table>

Special fire fighting procedures:

- **ALL EXPLOSIVES: DO NOT FIGHT EXPLOSIVES FIRES.** Try to keep fire from reaching explosives. Isolate area. Guard against intruders.

  Division 1.1 Explosives (heavily encased): Evacuate the area for 5,000 feet (approximately 1 mile) if explosives are heavily encased.

  Division 1.1 Explosives (not heavily encased): Evacuate the area for 2,500 feet (approximately ½ mile) if explosives are not heavily encased.

Division 1.1 Explosives (all): Consult U.S. DOT Emergency Response Guide 112 for further details.
| Unusual fire and explosion hazards | Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement. |

| HEALTH HAZARDS |  |
| General | Black powder is a Division 1.1 Explosive, and detonation may cause severe physical injury, including death. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced persons in accordance with all applicable federal, state and local laws, regulation and ordinances. |
| Carcinogenicity | None of the components of Black Powder are listed as a carcinogen by NTP, IARC, or OSHA. |

| FIRST AID |  |
| Inhalation | Not a likely route of exposure. If inhaled, remove to fresh air. If not breathing give artificial respiration, preferably by mouth-to-mouth. If breathing is difficult, give oxygen. Seek prompt medical attention. Avoid when possible. |
| Eye and skin contact | Not a likely route of exposure. Flush eyes with water. Wash skin with soap and water. |
| Ingestion | Not a likely route of exposure. If ingested, dilute by giving two glasses of water and induce vomiting. Avoid when possible. |
| Injury from detonation | Seek prompt medical attention. |

| SPILL OR LEAK PROCEDURES |  |
| Spill/leak response | Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in clean up procedures. Carefully pick up spills with non-sparking and non-static producing tools. |
| Waste disposal | Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with Federal Regulations under the authority of the Resource Conservation and Recovery Act (40 CFR Parts 260-271). |

| SPECIAL PROTECTION INFORMATION |  |
| Ventilation | Use only with adequate ventilation. (If required) |
| Respiratory | None |
| Eye | None |
| Gloves | Impervious rubber gloves. (If required) |
| Other | Metal-free and/non-static producing clothes |
SPECIAL PRECAUTIONS

- Keep away from friction, impact, and heat and open flame. Do not consume food, drink, or tobacco in areas where they may become contaminated with these materials.
- Contaminated equipment must be thoroughly water cleaned before attempting repairs.
- Use only non-spark producing tools.
- No smoking.

STORAGE CONDITIONS

Store in a cool, dry place in accordance with the requirements of Subpart K, ATF: Explosives Law and Regulations (27 CFR 55.201-55.219).

SHIPPING INFORMATION

<table>
<thead>
<tr>
<th>Proper shipping name</th>
<th>Black Powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard class</td>
<td>1.1D</td>
</tr>
<tr>
<td>UN Number</td>
<td>UN0027</td>
</tr>
<tr>
<td>DOT Label &amp; Placard</td>
<td>DOT Label EXPLOSIVES 1.1D</td>
</tr>
<tr>
<td>Alternate shipping</td>
<td>Limited quantities of GOEX black powder (1# cans only) may be transported as “Black powder for small arms – flammable solid” pursuant to U.S. Department of Transportation 49 CFR.</td>
</tr>
</tbody>
</table>

The information contained in this Material Safety Data Sheet is based upon available data and believed to be correct; however, as such has been obtained from various sources, including the manufacturer, military and independent laboratories, it is given without warranty or representation that it is complete, accurate, and can be relied upon. GOEX, Incorporated, has not attempted to conceal in any manner the deleterious aspects of the product listed herein, but makes no warranty as to such. Further, GOEX, Incorporated, cannot anticipate nor control the many situations in which the product or this information may be used; there is no guarantee that the health and safety precautions suggested will be proper under all conditions. It is the sole responsibility of each user of the product to determine and comply with the requirements of all applicable laws and regulations regarding its use. This information is given solely for the purposes of safety to persons and property. Any other use of this information is expressly prohibited.

For further information contact: GOEX Powder, Incorporated
P. O. Box 659
Doyline, LA 71023-0659
Telephone Number: (318) 382-9300
Fax Number: (318) 382-9303
BLACK POWDER

FRICION TEST
PA
Steel – Snaps
Fiber – Unaffected

IMPACT TEST
PA
16 Inches (10% Point)

ELECTROSTATIC DISCHARGE TEST

Bureau of Mines
  0.8 Joules (Confined)
  12.5 Joules Unconfined

STABILITY
  75° C International Heat Test – 0.31% Loss
  Vacuum Stability – 0. 5cc @ 100° C

BRISANCE – Sand Test 8 gm.

VELOCITY
In the open, trains of black powder burn very slowly, measurable in seconds per foot. Confined, as in steel pipe, speeds of explosions have been timed at values from 560 feet per second for very coarse granulations to 2,070 feet per second for the finer granulations. Confinement and granulation will affect the values.

CHEMICAL DECOMPOSITION
Use water to dissolve the potassium nitrate. By leaching out the potassium nitrate, the residue of sulfur and charcoal is non-explosive but combustible when dry – dispose separately.

SPECIAL REQUIREMENTS.
Black Powder is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

When dry, it is compatible with most metals. However, it is hygroscopic and when wet, attacks all common metals except stainless steel.

CAUTION: Explosives must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials and other similar materials, situations and equipment. Explosives include propellants and pyrotechnics.
Material Safety Data Sheet
Isopropyl alcohol MSDS

Section 1: Chemical Product and Company Identification

<table>
<thead>
<tr>
<th>Product Name: Isopropyl alcohol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalog Codes: SLI1153, SLI1576, SLI1606, SLI1246, SLI1432</td>
</tr>
<tr>
<td>CAS#: 67-63-0</td>
</tr>
<tr>
<td>RTECS: NT8000000</td>
</tr>
<tr>
<td>TSCA: TSCA (b) inventory: Isopropyl alcohol</td>
</tr>
<tr>
<td>CW: Not available.</td>
</tr>
<tr>
<td>Synonym: 2-Propanol</td>
</tr>
<tr>
<td>Chemical Name: isopropanol</td>
</tr>
<tr>
<td>Chemical Formula: C3H8O</td>
</tr>
</tbody>
</table>

Contact Information:
ScienceLab.com, Inc.
14025 Smith Rd.
Houston, Texas 77390
US Sales: 1-800-901-7247
International Sales: 1-281-441-4400
Order Online: ScienceLab.com
CHEMTREC (24HR Emergency Telephone), call: 1-800-424-9300
International CHEMTREC, call: 1-703-527-3887
For non-emergency assistance, call: 1-281-441-4400

Section 2: Composition and Information on Ingredients

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS #</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isopropyl alcohol</td>
<td>67-63-0</td>
<td>100</td>
</tr>
</tbody>
</table>

Toxicological Data on Ingredients: Isopropyl alcohol: ORAL (LD50): Acute: 5045 mg/kg [Rat], 3600 mg/kg [Mouse], 6410 mg/kg [Rabbit]. DERMAL (LD50): Acute: 12800 mg/kg [Rabbit].

Section 3: Hazards Identification

Potential Acute Health Effects:
Hazardous in case of eye contact (irritant), of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer, permeator).

Potential Chronic Health Effects:
Slightly hazardous in case of skin contact (sensitizer). CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal) by ACGIH, 3 (Not classifiable for human) by IARC. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Classified Reproductive system/toxin/female, Development toxin [POSSIBLE]. The substance may be toxic to kidneys, liver, skin, central nervous system (CNS). Repeated or prolonged exposure to the substance can produce target organs damage.

Section 4: First Aid Measures
Eye Contact:
Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention.

Skin Contact:
Wash with soap and water. Cover the irritated skin with an emollient. Get medical attention if irritation develops. Cold water may be used.

Serious Skin Contact: Not available.

Inhalation:
If inhaled, remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention if symptoms appear.

Serious Inhalation:
Evacuate the victim to a safe area as soon as possible. Loosen tight clothing such as a collar, tie, belt or waistband. If breathing is difficult, administer oxygen. If the victim is not breathing, perform mouth-to-mouth resuscitation. Seek medical attention.

Ingestion:
Do NOT induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Loosen tight clothing such as a collar, tie, belt or waistband. Get medical attention if symptoms appear.

Serious Ingestion: Not available.

Section 5: Fire and Explosion Data

Flammability of the Product: Flammable.

Auto-Ignition Temperature: 399°C (750.2°F)

Flash Points: CLOSED CUP: 11.067°C (53° F) - 12.778 deg. C (55 deg. F) (TAG)

Flammable Limits: LOWER: 2%, UPPER: 12.7%

Products of Combustion: These products are carbon oxides (CO, CO2).

Fire Hazards in Presence of Various Substances:

Explosion Hazards in Presence of Various Substances:

Fire Fighting Media and Instructions:
Flammable liquid, soluble or dispersed in water. SMALL FIRE: Use DRY chemical powder. LARGE FIRE: Use alcohol foam, water spray or fog.

Special Remarks on Fire Hazards:
Vapor may travel considerable distance to source of ignition and flash back. CAUTION: MAY BURN WITH NEAR INVISIBLE FLAME. Hydrogen peroxide sharply reduces the autoignition temperature of isopropyl alcohol. After a delay, isopropyl alcohol ignites on contact with dihydrogen tetrafluoroborate, chromium trioxide, and potassium tert-butoxide. When heated to decomposition it emits acrid smoke and fumes.

Special Remarks on Explosion Hazards:
Secondary alcohols are readily autooxidized in contact with oxygen or air, forming ketones and hydrogen peroxide. It can become potentially explosive. It reacts with oxygen to form dangerously unstable peroxides which can concentrate and explode during distillation or evaporation. The presence of 2-butane increases the reaction rate for peroxide formation. Explosive in the form of vapor when exposed to heat or flame. May form explosive mixtures with air. Isopropyl alcohol + phosgene forms isopropyl chlorofomate and hydrogen chloride. In the presence of iron salts, thermal decomposition can occur, which in some cases can become explosive. A homogeneous mixture of concentrated peroxides + isopropyl alcohol are capable of detonation by shock or heat. Barium perchlorate + isopropyl alcohol gives the highly explosive alkyl perchlorates.
It forms explosive mixtures with trinitromethane and hydrogen peroxide. It produces a violent explosive reaction when heated with aluminum isopropoxide + crotonaldehyde. Mixtures of isopropyl alcohol + nitroform are explosive.

**Section 6: Accidental Release Measures**

**Small Spill:**
Dilute with water and mop up, or absorb with an inert dry material and place in an appropriate waste disposal container.

**Large Spill:**
Flammable liquid. Keep away from heat. Keep away from sources of ignition. Stop leak if without risk. Absorb with DRY earth, sand or other non-combustible material. Do not touch spilled material. Prevent entry into sewers, basements or confined areas; dilute if needed. Be careful that the product is not present at a concentration level above TLV. Check TLV on the MSDS and with local authorities.

**Section 7: Handling and Storage**

**Precautions:**
Keep away from heat. Keep away from sources of ignition. Ground all equipment containing material. Do not ingest. Do not breathe gas/fumes/vapor/spray. Avoid contact with eyes. Wear suitable protective clothing. In case of insufficient ventilation, wear suitable respiratory equipment. If ingested, seek medical advice immediately and show the container or the label. Keep away from incompatibles such as oxidizing agents, acids.

**Storage:**
Store in a segregated and approved area. Keep container in a cool, well-ventilated area. Keep container tightly closed and sealed until ready for use. Avoid all possible sources of ignition (spark or flame).

**Section 8: Exposure Controls/Personal Protection**

**Engineering Controls:**
Provide exhaust ventilation or other engineering controls to keep the airborne concentrations of vapors below their respective threshold limit value. Ensure that eyewash stations and safety showers are proximal to the work-station location.

**Personal Protection:**
Splash goggles. Lab coat. Vapor respirator. Be sure to use an approved/certified respirator or equivalent. Gloves.

**Personal Protection in Case of a Large Spill:**
Splash goggles. Full suit. Vapor respirator. Boots. Gloves. A self-contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might not be sufficient; consult a specialist BEFORE handling this product.

**Exposure Limits:**
TWA: 983 STEL: 1230 [mg/m³] [Australia] TWA: 200 STEL: 400 [ppm] from ACGIH (TLV) [United States] [1999] TWA: 980 STEL: 1225 [mg/m³] from NIOSH TWA: 400 STEL: 500 [ppm] from NIOSH TWA: 400 STEL: 500 [ppm] [United Kingdom (UK)] TWA: 999 STEL: 1259 [mg/m³] [United Kingdom (UK)] TWA: 400 STEL: 500 [ppm] from OSHA (PEL) [United States] TWA: 988 STEL: 1225 [mg/m³] from OSHA (PEL) [United States] Consult local authorities for acceptable exposure limits.

**Section 9: Physical and Chemical Properties**

**Physical state and appearance:** Liquid.

**Odor:**
Pleasant. Odor resembling that of a mixture of ethanol and acetone.

**Taste:** Bitter. (Slight.)

**Molecular Weight:** 0.1 g/mole
Color: Colorless.
pH (1% soln/water): Not available.
Boiling Point: 82.5°C (180.5°F)
Melting Point: -88.5°C (-127.3°F)
Critical Temperature: 235°C (455°F)
Specific Gravity: 0.78505 (Water = 1)
Vapor Pressure: 4.4 kPa (@ 20°C)
Vapor Density: 2.07 (Air = 1)
Volatile: Not available.
Odor Threshold:
22 ppm (Sittig, 1994) 700 ppm for unadapted panelists (Verschuren, 1983).
Water/Oil Dist. Coeff.: The product is equally soluble in oil and water; log(oil/water) = 0.1
Ionicity (in Water): Not available.
Dispersion Properties: See solubility in water, methanol, diethyl ether, n-octanol, acetone.
Solubility:
Easily soluble in cold water, hot water, methanol, diethyl ether, n-octanol, acetone. Insoluble in salt solution. Soluble in benzene. Miscible with most organic solvents including alcohol, ethyl alcohol, chloroform.

Section 10: Stability and Reactivity Data

Stability: The product is stable.
Instability Temperature: Not available.
Conditions of Instability: Heat, Ignition sources, incompatible materials
Incompatibility with various substances: Reactive with oxidizing agents, acids, alkalis.
Corrosivity: Non-corrosive in presence of glass.

Special Remarks on Reactivity:
Reacts violently with hydrogen + palladium combination, nitroform, oleum, COCl2, aluminum triisopropoxide, oxidants
Incompatible with acetaldehyde, chlorine, ethylen oxide, isocyanates, acids, alkaline earth, alkali metals, caustics, amines, crotonaldehyde, phosgene, ammonia, isopropyl alcohol reacts with metallic aluminum at high temperatures. Isopropyl alcohol attacks some plastics, rubber, and coatings. Vigorous reaction with sodium dichromate + sulfonic acid.

Special Remarks on Corrosivity: May attack some forms of plastic, rubber and coating
Polymerization: Will not occur.

Section 11: Toxicological Information

Routes of Entry: Absorbed through skin. Dermal contact. Eye contact. Inhalation.
Toxicity to Animals:
WARNING: THE LC50 VALUES HEREUNDER ARE ESTIMATED ON THE BASIS OF A 4-HOUR EXPOSURE. Acute oral toxicity (LD50): 3800 mg/kg [Mouse]. Acute dermal toxicity (LD50): 12800 mg/kg [Rabbit]. Acute toxicity of the vapor (LC50): 10000 8 hours [Rat].
Chronic Effects on Humans:
CARCINOGENIC EFFECTS: A4 (Not classifiable for human or animal.) by ACGIH, 3 (Not classifiable for human.) by IARC.
DEVELOPMENTAL TOXICITY: Classified Reproductive system/toxin/female, Development toxin [POSSIBLE]. May cause damage to the following organs: kidneys, liver, skin, central nervous system (CNS).
Other Toxic Effects on Humans:
Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant, sensitizer, permeator).

Special Remarks on Toxicity to Animals: Not available.

Special Remarks on Chronic Effects on Humans:
May cause adverse reproductive/teratogenic effects (fertility, fetotoxicity, developmental toxicity) based on animal studies. Detected in maternal milk in human.

Special Remarks on other Toxic Effects on Humans:
Acute Potential Health Effects: Skin: May cause mild skin irritation, and sensitization. Eyes: Can cause eye irritation. Inhalation: Breathing in small amounts of this material during normal handling is not likely to cause harmful effects. However, breathing large amounts may be harmful and may affect the respiratory system and mucous membranes (irritation), behavior and brain (Central nervous system depression - headache, dizziness, drowsiness, stupor, incoordination, unconsciousness, coma and possible death), peripheral nerve and sensation, blood, urinary system, and liver. Ingestion: Swallowing small amounts during normal handling is not likely to cause harmful effects. Swallowing large amounts may be harmful. Swallowing large amounts may cause gastrointestinal tract irritation with nausea, vomiting and diarrhea, abdominal pain. It also may affect the urinary system, cardiovascular system, sense organs, behavior or central nervous system (somnolence, generally depressed activity, irritability, headache, dizziness, drowsiness), liver, and respiratory system (breathing difficulty). Chronic Potential Health Effects: May cause dermatitis and allergic reaction. May cause adverse reproductive effects based on animal data (studies).

Section 12: Ecological Information

Ecotoxicity: Ecotoxicity in water (LC50): 100000 mg/l 96 hours [Fathead Minnow]. 64000 mg/l 96 hours [Fathead Minnow].
BOD5 and COD: Not available.

Products of Biodegradation:
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.

Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:
Waste must be disposed of in accordance with federal, state and local environmental control regulations.

Section 14: Transport Information

DOT Classification: CLASS 3: Flammable liquid.
Identification: : Isopropyl Alcohol UNNA: 1219 PG: II
Special Provisions for Transport: Not available.

Section 15: Other Regulatory Information

Federal and State Regulations:
14 Appendix E: Team Member Resumes

The following pages contain resumes of the CRW team members.
Zachary B. Ruta  
Huntsville, AL  
US Citizen

**Education**

Bachelor of Science in Mechanical Engineering  
University of Alabama in Huntsville  
In Progress

**Experience**

Contractor for Dynetics  
(May 2018 – Present)

Aviation Missile Research Development and Engineering Center  
Joint Technology Center Systems Integration Laboratory

- Configured approximately 40 Mobile Data Archive and Retrieval – Tactical (MDAR-T) Systems and were shipped to Unmanned Aerial Systems (UAS) units all across the United States and Korea. Assisted in the development of automation scripts to increase configuration completion time. Performed validation testing on scripts and MDAR-T systems. Performed 60% of all test cases on the Mission Server System.

Contractor for UAH  
(Feb 2017 – Jan 2018)

Aviation Missile Research Development and Engineering Center  
Technical Data Management Division

- Designed a training manual to expedite the new employee training process for uploading and analyzing delivered data to Windchill. Uploaded CAD, drawing, part, and document files into PTC’s Windchill, a product lifecycle management (PLM) software. Analyzed delivered content for missing data then created reports documenting errors.

Research Aide for UAH  
(Mar 2016 – Feb 2017)

System Management and Production Center

- Lead a team of four co-workers on a weather balloon project. Performed system design and analysis to determine required updates to the weather balloon. Integrated and tested the updated weather balloon payload while decreasing overall cost by $610 (approximately 50% cost reduction) and weight by 1.1 pounds, while increasing its overall capabilities (communication and imagery). Presenter for UAH STEM Outreach Program while visiting schools and community colleges across the Southeast demonstrating the importance of higher education and technology to students between the ages of nine to twenty.

Intern  
(Jan 2014 – May 2014)

Marshall Space Flight Center

- Tested and evaluated five inertial measurement unit (IMU) systems varying in cost from $20 to $2,000, located in a Marshal Space Flight Center laboratory. Analyzed performance by programming and operating a 3-axis rate table, which simulates space travel.

**Skills**

- Proficient in Microsoft Office, Solid Edge, Patran, and Nastran
- Basic programming in Excel VBA, MATLAB, and PowerShell ISE
Hope C.  
Alton, IL  
US Citizen

Education
Bachelors of Science, Aerospace Engineering  
The University of Alabama in Huntsville

Experience
Space Camp, The US Space and Rocket Center  
May 2018 – August 2018,  
May 2017 – August 2017  
Huntsville, AL  
Crew Trainer
- Led Space Camp, Space Academy, and Advanced Space Academy teams during weeklong programs.
- Taught spaceflight history, low powered rocketry, various other STEM camp activities, and fostered teamwork and individual growth.
- Served in supporting roles for camp operations.
- Was entrusted with the care and safety of children ages 9 – 17, gave safety briefings prior to simulator use and low powered rocket launch.

Skills
- Skilled in Matlab, Microsoft Office applications, Solid Edge, Autodesk Inventor
- Experience with Simulink, XFOIL
- Soldering

Academic Projects
MAE 311  
January 2018 – May 2018
The objective of the project was to build, test, and analyze an instrument for purposes of measurement. The type of measurement was left to the group and was agreed on to be direct pressure values used for calculating velocity by means of a pitot tube. The original plan was to integrate the constructed Pitot tube into the nose cone of a medium powered rocket and retrieve values from the flight. Due to postponement of launch dates, the pitot tube was tested within the nose cone but outside of a moving car. The instrumentation unit included accelerometers and pressure transducers. All electrical wiring of components was done by the group.
Benjamin C.
Huntsville, AL
US Citizen

Education
Bachelor of Science, Aerospace Engineering  The University of Alabama in Huntsville
Bachelor of Arts, German  Lipscomb University

Experience
Dynamic Concepts, Inc.  May 2018 - Current
Huntsville, AL  Dynamic Loads Analyst
• Assist in the analysis of expected loads for Space Launch System
National Toxicology Specialists  January 2014 – July 2016
Nashville, TN  Drug Test Collector
• DOT certified in urine, hair, and nail drug test collections
• DOT certified breath alcohol technician
Gemeinde Christi Hildesheim  August 2011 – August 2012
Hildesheim, Germany  Community Service Worker
• Prepared and taught classes for children and youth ages 7-18
• Planned and worked youth camps
Nashville, TN  Electrician’s Assistant
• Assisted in installation of low and high voltage electrical systems

Skills
• Proficient in MATLAB, Solid Edge, Patran, Femap, and Nastran
• Fluent in German
• Experience in teaching and management

Academic Projects
Principles of Measurements Semester Project  January 2018 – April 2018
Designed, built, and calibrated an accelerometer controlled using an Arduino
Principles of Aeronautics and Astronautics Semester Project  January 2017 – April 2017
Designed, built, and flew rubber band powered airplane using only recycled materials
Colton C.
Tullahoma, TN
US Citizen

Education
Bachelors of Science, Aerospace Engineering
The University of Alabama in Huntsville

Experience
Jacobs
Tullahoma, TN
Engineer Associate IV
5/09/17 – 8/11/18

- Worked closely with subsonic, closed-circuit, 3/4 open jet wind tunnel
- Conducted wind tunnel tests to determine axial static pressure gradient along the test section length and designed methods to maintain the desired local constant pressure
- Conducted wind tunnel tests to determine frequencies of problematic CPrms pressure pulsations within the wind tunnel circuit
- Built, tuned, and positioned Helmholtz resonators at strategic locations along the wind tunnel circuit to alleviate unwanted pressure pulsations
- Training in StarCCM+ CFD software (defining regions, boundary conditions, and meshing)
- Aided in CFD post-processing work

Skills
- Proficient at MATLAB, Inventor, AutoCAD, MathCAD, Microsoft Excel, Word, and PowerPoint
- Developing basic skills in StarCCM+ CFD software
- Leadership skills development from HS Men’s Soccer team captain, MAE 200 Project Leader, and Jacobs Lab Technician

Academic Projects
MAE 200 RB Aircraft Project
02/07/16 – 04/29/16
- Squadron leader for Principles of Aeronautics and Aerospace design, build, fly model airplane competition; project required the designing, building, and flight of a homemade rubber band powered propeller aircraft.

MAE 311 Arduino Project
03/15/18 – 04/30/18
- Built a LIDAR sewage depth Arduino sensor for Huntsville Utilities
Daniel C.
Reston, VA
US Citizen

Education
Bachelors of Science, Mechanical Engineering The University of Alabama in Huntsville

Experience
Blue Origin
January 2018 – July 2018
Van Horn, TX
Test Facilities Intern
- Tuning and data processing/analysis of high-flow fluid systems
- Auditing and improvements to gas and flame detection systems
- Rewriting software to cut down engine test data processing time
- Participated in engine test operations, procedure reviews, and HAZOPs on the BE3 test stand

NASA MSFC
May 2017 – August 2017
Huntsville, AL
Intern
- Assessed in-space performance of a GPS receiver for use on the SLS Exploration Upper Stage
- Wrote software tools for using a GPS RF simulator with output of existing SLS simulations

UAH Propulsion Research Center
January 2016 – Present (while in school)
Huntsville, AL
Undergraduate Research Assistant
- Designed, analyzed, and fabricated components for rocket engine test stand and test articles
- Designed and fabricated instrumentation and control systems for a supersonic wind tunnel
- Wrote MATLAB and LabVIEW software for data collection and analysis on wind tunnel

Skills
- Circuit design and fabrication: KiCAD and DesignSpark PCB, through-hole and SMD soldering
- Mechanical design: SolidEdge CAD, PATRAN/NASTRAN FEA, Surfcam
- Mechanical fabrication: CNC and manual mill, lathe, additive manufacturing
- Software: LabVIEW, MATLAB, Simulink, C/C++, Python, and Java

Academic Projects
UAH Spaceport America Cup Liquid Rocket Competition Team
August 2017 – December 2017
I collaborated with two other students to model the performance and behavior of a liquid-fueled rocket in MATLAB and Simulink. I developed models for fluid pressures and mass flow rates, and used that to determine engine performance and the rocket’s trajectory.

International CanSat Competition Team
October 2015 – June 2016
Created a glider to be deployed from a rocket and send competition-mandated telemetry throughout its descent, as part of an 8-member team. Worked on printed circuit board design, embedded programming, and mechanical prototyping, as well as writing content for and editing design reviews.
Darnisha C.  
Center Point, AL  
US Citizen

Education  
Bachelor of Science, Aerospace Engineering  
The University of Alabama in Huntsville

Experience  
University of Alabama Aerospace and Mechanics Department  
Tuscaloosa, AL  
May 2018 – June 2018  
Student Researcher  
- Designed and fabricated test stand used for a tilt-rotor arrangement  
- Quantified rotor-wing interaction for a dual-rotor configuration in hover above a simple wing  
- Measured pressures, thrust and torque using an in-house LabVIEW code

University of Alabama in Huntsville Mechanical and Aerospace Department  
Huntsville, AL  
May 2017 – May 2018  
Student Researcher  
- Designed and fabricated flapping wing MAV test stand to mount live and mechanical specimens for force measurement testing  
- Assisted Ph.D. student with recording flight pattern of Monarch Butterflies using a Vicon Motion Capture System.  
- Data collected was presented to UAH faculty, staff and students at a poster session.

University of Alabama in Huntsville Honors College  
Huntsville, AL  
September 2016 – Present  
Peer Advisor  
- Advise Honors College engineering students about courses and requirements that satisfy Honors College diploma and engineering degree.  
- Design marketing campaigns to improve Honors advising brand  
- Interact with prospective students and parents at UAH recruitment events.

Skills  
- Basic Proficiency in MATLAB and LabVIEW  
- Working knowledge in SolidEdge, SolidWorks, Microsoft Office and Patran/Nastran

Academic Projects  
Principles of Measurements & Instrumentation Project  
August 2017 – November 2017  
Designed and fabricated a simplified robotic arm to test the accuracy of a flex sensor for robotic applications.

Principles Aeronautics & Astronautics  
August 2016 – November 2016  
Designed, fabricated, and flew rubber band powered airplane made with recycled materials.
Elena P.  
Kathmandu, Bagmati  
Nepalese Citizen  

**Education**

Bachelors of Science, Aerospace Engineering  
The University of Alabama in Huntsville  
Minor in Mathematics

**Experience**

National Space Science and Technology Centre  
Huntsville, Alabama  
May 2017 – August 2017  
Research Assistant

- Wrote a machine learning algorithm to cluster radio events of lightning  
- Used the clusters to investigate temporal and spatial correlation between terrestrial gamma ray flashes and lightning  
- Presented in American Geophysical Union and university poster symposium

Student Success Centre  
Huntsville, Alabama  
August 2016 – Present  
PASS Leader

- Lead PASS(Peer Assisted Study Sessions) for Calculus A and Calculus B and Thermodynamics  
- Developed ability to convey concepts within a group environment

College of Engineering  
Huntsville, Alabama  
May 2016 – Present  
Teaching Assistant

- Helped students in class with MATLAB, Excel and Python in class and at office hours  
- Graded their assignments and exams

**Skills**

- Electrical simulation, design and fabrication: LTspice, Eagle, Design Spark PCB, soldering and testing  
- Mechanical Design: Solid Edge  
- Software: MATLAB, C#, Python

**Academic Projects**

**ALFRED**  
May 2016 – August 2018  
I led a team of 3 other student to simulate, design, solder, test and assemble electrical system for a high altitude science experiment ALFRED(Active Luminescence For x-Ray Emission Detection). I presented technical design reviews for NASA at Wallops. The payload flew August 2018 at New Mexico on a 60 MCF balloon.

**HELEN**  
May 2017 – Present  
This is an ongoing project where the HELEN team is designing, building, testing and flying a network of four radiation detectors and electric field meters during a thunderstorm to detect Terrestrial Gamma Ray flashes and analyze potential correlations with the local electric field.
William H.
Lexington, AL
US Citizen

Education
Bachelors of Science, Aerospace Engineering
The University of Alabama in Huntsville

Experience
Software Integration and Testing Team
Lockheed Martin Corporation
Intern
- Tested UNIX models of Terminal High Altitude Area Defense (THAAD) System
- Verified and Validated models to qualify requirements and generate new requirements
- Created and updated extensive software test documents in Microsoft Word

Products Definition Team
The Boeing Company
Member
- Supported the design of the Space Launch System Exploration Upper Stage
- Generated product drawings and populated models with product manufacturing information using CREO Parametric 3.0

Structural Hazard Mitigation & Intelligent Materials Group
The University of Alabama in Huntsville
Undergraduate Research Assistant
- Designed and modelled metamaterial lattices with Solid Edge ST8 and ST9
- Operate fused deposition modelling 3D printer for production of metamaterial lattices
- Performed compression and moment testing of lattices with compression test machine

Skills
- Solid Edge ST8, ST9, ST10, and CREO Parametric 3.0
- C, C++, Java, Python, Linux/UNIX, MATLAB/Simulink, Excel, Excel VBA
- Microsoft Office Suite 2010 – 365
- Active Department of Defense Secret Clearance

Academic Projects
Space Hardware Club Suborbital Atmospheric Balloon Elevated Rocket
January, 2017 – Present
- Work to design suborbital launch vehicle that is cheaper than commercial alternatives
- Currently serve as avionics and guidance, navigation, and control team lead
- Designing custom solid rocket motor for reduced cost and increased performance
- Won 1st place at AIAA Region II 2016 Student Conference with paper entitled Concept Study of a Reusable Suborbital Launch Vehicle

Space Hardware Club CubeSat Polaris
July, 2016 – January, 2018
- Worked to place CubeSat in orbit to measure polarity of X-rays
- Developed the mechanical and avionics hardware that will be used for the satellite
Hunter H.
Haleyville, AL
US Citizen

Education
Bachelors of Science, Mechanical Engineering  The University of Alabama in Huntsville

Experience

<table>
<thead>
<tr>
<th>Employer</th>
<th>Starting – Ending Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Concepts, Inc</td>
<td>May 2018 - August 2018</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Position Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huntsville, AL</td>
<td>Summer Intern</td>
</tr>
</tbody>
</table>

- List of duties/description
  - Analyze and process MATLAB codes to produce charts for documentation
  - Conduct modal analysis on dynamic systems

Skills
- 3D Modeling: Solidworks, SolidEdge
- Microsoft Office: Excel, Word, PowerPoint
- MATLAB, C++
- Finite Element Analysis: FEMAP, Patran, Nastran

Academic Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Starting – Ending Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous Vehicle</td>
<td>February 2017 – April 2017</td>
</tr>
</tbody>
</table>

An autonomous vehicle was designed to maneuver through a track consisting of various obstacles. The vehicle was constructed using various brackets, bolts, wheels, servo motors, and a Parallax programming board. The team was responsible for producing the design and code. The coding language was written using the PBASIC computer program. The vehicle consisted of QTI and IR sensors in order to maneuver through the course.
Joshua C.
St. Paul, IN
US Citizen

Education
Bachelors of Science, Mechanical Engineering (2019)  The University of Alabama in Huntsville

Experience
Never officially employed.

Skills
- MSSC Production Technician Certifications
  - Safety, Exp 12/13/18
  - Maintenance Awareness, Exp 12/5/19
  - Quality Practices & Measurement, Exp 5/7/19
  - Process & Production, Exp 4/30/20
- Vertical milling
- Arduino programming
- Basic circuitry
- Solidworks and Solidedge

Academic Projects

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Starting – Ending Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Robotics Competition</td>
<td>2012-14</td>
</tr>
<tr>
<td>UAH Honors College</td>
<td>2015-present</td>
</tr>
<tr>
<td>College of Engineering Dean’s list</td>
<td>2017</td>
</tr>
<tr>
<td>National Honors Society</td>
<td>2013-2015</td>
</tr>
<tr>
<td>4-H, Shelby County</td>
<td>2005-2015</td>
</tr>
</tbody>
</table>
Brooklyn K.  
Huntsville, AL  
US Citizen

**Education**

Bachelors of Science, Aerospace Engineering  
The University of Alabama in Huntsville

**Experience**

The Boeing Company  
Huntsville AL  
March 2017 – Current  
Design Engineer Intern

- Designer for several major structural layouts on NASA’s Space Launch System Upper Stage as a member of the Cryogenic Tank team.
- Worked with several different CREO design interfaces such as tubing, wiring, sheet metal, and solid structural parts.
- Obtained full design responsibility from concept creation and detail design to layout completion and drawing release in preparation for CDR.
- Completed professional training in the CAD environment, automatic parts list creation, and geometric dimensioning and tolerancing.

**Skills**

- Proficient in: PTC CREO 3.0/4.0, NX 8/11, Solid Edge ST8/ST9, CREO Simulate, Microsoft Office Suite, APDM, Arduino Microcontrollers
- Experience with: Patran/Nastran, MATLAB, MathCAD, developmental design processes for spaceflight application.

**Academic Projects**

**MAE 311 Arduino Project**  
Jan 2018 – May 2018

Worked alongside a group of peers, and successfully utilized the Arduino interface to design, build, and program a sensor for the Huntsville sewage plant that was water resistant and could digitally measure and plot sewage depth accurate to within a tenth of a decimal place.

**MAE 200 Airplane Project**  
Jan 2017 – May 2017

Used prior knowledge of aerodynamics to design, build, and test a self-propelled aircraft out of recycled materials with a small group of students. The plane had an elliptical wing structure mounted on an I-beam that provided an angle of incidence. The plane flew over 40ft and carried a payload 1/3 the weight of the aircraft.

**MAE 211 Moving Cad Project**  

Successfully designed, rendered, and drafted a watch assembly that could keep time correctly. The watch utilized several unique parts and motor powered gears designed in Solid Edge.

**NASA Protein Crystallization Project**  
Aug 2012 – May 2015

Studied the concepts and methods of protein crystallization using information and data provided by NASA. Successfully worked with the University of Alabama in Birmingham to produce protein crystals in different environments and in space. Won third place in the poster competition presenting the group’s results.
Erik K.  
Anchorage, AK  
US Citizen

**Education**

Bachelor of Science, Aerospace Engineering  
The University of Alabama in Huntsville

**Experience**

UAH Propulsion Research Center  
Huntsville AL  
May 2018 – Present  
Undergraduate Research Assistant

- Design, construct, and operate test systems for an orbital-class rocket
- Analyze data from tests
- Designed and helped construct the addition of a system to the PRC’s 2500 psi fluid facility, upgraded facility line diameter to 1”

**Skills**

- Programming – MATLAB, MATLAB GUI, C/C++, Excel, LabView
- Simulations – NASTRAN/PATRAN, ANSYS, OpenRocket
- Modelling – SolidEdge
- High Pressure Plumbing – Swageing, Operating a Pipe Bender, Calibrating Transducers
- Data Analysis – Statistical Analysis, Fourier Analysis
- Operating Shop Equipment – Drill Press, Power Saws, X-Winder, Soldering
- Red Cross CPR and First Aid Certified

**Academic Projects**

**ALFRED**  
January 2017 – September 2018

ALFRED was a high-altitude scientific instrument that flew with NASA on August 17, 2018. Its purpose was to test a concept for a sort of active radiation “shield” for x-ray telescopes. It contained an x-ray detector and some novel instrumentation that could detect when a particle event came from an undesirable direction and impacted the detector. If such an event occurred, the event would be removed from the data. I helped design its air-tight housing and its interface with the launch vehicle. I also helped program the ground station. Currently, I am helping analyze the collected data for the 2018 von Braun Symposium.

**Spaceport America Cup**  
August 2017 – Present

The goal of this project is to design and construct a liquid rocket from scratch. Work has been going on since the beginning of the last school year. While the team was still focused on competing in the 2018 Spaceport America Cup, I helped design the airframe of the rocket up to a PDR level and ran aerothermal simulations on the nose cone. The project proved far more complex and challenging than originally anticipated, so the team has refocused to hot firing its engine this year. I am the Ground Station Equipment lead, responsible for the cold flow testing system, the hot fire stand, the propellant storage and transportation systems, and the data acquisition and control systems.
Kyle D.
Huntsville, AL
US Citizen

Education

Bachelors of Science, Aerospace Engineering
The University of Alabama in Huntsville
Minor in Mathematics

Experience

None

Skills

- MATLAB Programming
- AutoDesk Inventor CAD Software
- Solid Edge CAD Software
- Arduino PLC Programming

Academic Projects

Rubber Band Airplane

Students were tasked with designing and developing an aircraft capable of carrying a minimum payload a predetermined distance on an aircraft styled out of rubbish. Members were required to analyze aircraft geometry and acquire constants and pressure curves using predeveloped software.

Arduino Measurement Project

Students were tasked with creating a calibrated measurement device using an Arduino PLC and were to report on device uncertainties. Members were required to divide tasks accordingly and write a comprehensive technical document detailing the project. An infrared tachometer was developed to be mounted onto a commercial mountain bike to log the revolutions and speed throughout a trial.
Marcus S.
Huntsville, AL
US Citizen

Education
Bachelors of Science, Aerospace Engineering The University of Alabama in Huntsville

Experience
Kratos Defense and Rocket Support Service August 2017 – Present
Huntsville, AL Aerospace Engineering Intern
- Develop and Test sUAS Ground Control Software
- Write post processing scripts for hypersonic CFD results
- Assist with miscellaneous software support

Skills
- MATLAB
- C/C++
- Embedded Programming
- Project Managment

Academic Projects
Spaceport America Cup Liquid Engine Development Team June 2017 – Present
Team member of the Space Hardware Club’s Spaceport America Cup liquid rocket team. Spaceport America Cup is the foremost university rocketry competition in the world. Our goal is to develop, test and fly a liquid fueled rocket engine on a vehicle to 30,000 feet carrying a 9 pound payload. As a member of the Engine Development team, I’ve assisted in heat modeling and mitigation, engine architecture, injector design, material selection, identifying instability and developing mitigation techniques.

Project Manager – Space Hardware Club Multistage Rocket August 2016 – September 2017
The primary goal for the project is to design, manufacture and fly a two staged rocket flying to ~30,000 feet by September 2017. As Project Manager, my responsibility is to facilitate the engineering team by managing budget, scheduling and feasibility.
Matthew J.
Huntsville, AL
US Citizen

Education
Bachelors of Science, Aerospace Engineering The University of Alabama in Huntsville

Skills
- Proficient in MATLAB, C++, Java, Python, and Linux
- Working knowledge in Solid Edge ST8, ST9, and ST10
- Working knowledge in Microsoft Office Suite

Academic Projects
Principles of Measurements & Instrumentation Project January 2017 – April 2017
Designed, built, and calibrated an outdoor weather station consisting of various sensors using an Arduino

Principles of Aeronautics & Astronautics Project January 2015 – April 2015
Designed, built, and flew a rubber band powered airplane made with only recycled materials

Elements of Spacecraft Design August 2017 – November 2017
Created an initial concept for an asteroid intercept and recovery mission which included an analysis of orbital maneuvers, subsystem requirements, and ROM mission cost estimate

Advanced Aerospace Structures and Materials August 2017 – November 2017
Designed a composite replacement for an existing aircraft structure and analyzed the viability of the replacement structure for given parameters and cost
Reid W.
Virginia Beach, VA
US Citizen

**Education**
Bachelors of Science, Aerospace Engineering  
The University of Alabama in Huntsville

**Experience**

<table>
<thead>
<tr>
<th>Employer</th>
<th>Topgolf</th>
<th>Starting – Ending Dates:</th>
<th>5/2018-8/2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Huntsville, Al</td>
<td>Position Title:</td>
<td>Facilities Associate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- Maintain Mechanical, Electrical, and Computer Systems
- Operate field cleaning machinery

<table>
<thead>
<tr>
<th>Employer</th>
<th>Mister Sparky</th>
<th>Starting – Ending Dates:</th>
<th>5/2017-8/2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Huntsville, Al</td>
<td>Position Title:</td>
<td>Apprentice Electrician</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- Wire homes/assist senior electricians

**Skills**

- SolidWorks Certification (CSWA)
- SolidEdge Proficiency
- Matlab and Simulink
- Patran/Nastran
- Arduino Programming/Data Collection
- Subsonic Wind Tunnel Operation
- CNC Machining
- 3D Printing
- Xfoil and Tornado
- Fritzing (Wiring Schematic/PCB Design)
- Microsoft Office programs
- GHS OSHA Certification
- First Aid CPR AED Certification

**Academic Projects**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Starting – Ending Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior Design Capstone Project</td>
<td>09/2014 – 05/2015</td>
</tr>
<tr>
<td>Rubberband Aircraft Project</td>
<td>02/2016 – 05/2016</td>
</tr>
<tr>
<td>Lidar Sewage Depth Arduino Sensor</td>
<td>02/2017 – 05/2017</td>
</tr>
</tbody>
</table>
Sakurako K.  
Kochi, Japan  
Japanese Citizen

**Education**

Bachelors of Science, Aerospace Engineering, The University of Alabama in Huntsville  
Minor in Astronomy,  
Russian language certificate

**Experience**

The National Space Science Technology Center  
Huntsville, Alabama  
May 2017 - Present  
Student Specialist II

- Research of Electrostatic charge and discharge by using Martian simulant grain to develop the knowledge for future human Mars exploration  
- Usage of Electrodynamic Balance in Dusty Plasma Lab under Marshall Space Flight Center  
- High voltage operation is required

**Skills**

- Basic proficiency in MATLAB, Microsoft Excel, and Solid Edge  
- Experience with Simulink, Arduino, LabView, and VirtualBox  
- Japanese (Native level), Russian (Conversational level)  
- Leadership skill in Student council president in Elementary, Junior high, and High school  
- Event management skill in annual Japanese festival at North Alabama Japanese Garden

**Academic Projects**

NASA Human Exploration Rover Challenge 2016 & 2017

This is competition that construct a human power moon buggy and race the course with various given objectives at Space and Rocket Center in Huntsville, U.S. Participation as a member of International Space Education Institute, Germany. The members are from Germany, Russia, Italy, India, Bolivia, and United Arab Emirates. The parts are transported from each country, and I mostly engaged in assembly of the moon buggy, and translation of documents from German to Japanese.
Tanner S.
Huntsville, AL
US Citizen

Education
Bachelors of Science, Aerospace Engineering  The University of Alabama in Huntsville

Experience
UAH Housing and Residence Life  July 2016-May 2018
Huntsville, Alabama  Resident Assistant
- Assisted residents with interpersonal problems
- Helped acclimate freshman residents to living away from home for the first time
- Work with fellow staff members to effectively tackle situations and create a beneficial team work environment

Skills
- Proficient in Microsoft Office
- Experience with: Solid Edge – MATLAB
- Simple, conversational understanding of French

Academic Projects
MAE 311: Project  January-May 2018
Assisted in the design and construction of a pitot probe for use in the nosecone of a high-powered rocket in order to measure pressure changes to calculate velocity. The probe was compared with data collected from a calibrated accelerometer and gyroscope in order to check for variance in the setup. The data was collected in real-time during tests done at ground-level through a wired connection to a DAQ. The final data was used to determine the accuracy of the constructed pitot probes.
Connor G.
Huntsville, AL
US Citizen

**Education**
Bachelors of Science, Aerospace Engineering The University of Alabama in Huntsville

**Experience**

- **Parsons Corporation**
  - Redstone Arsenal, AL
  - May 2018 – Present
  - Intern
  - Performed systems level modeling and simulation engineering support services to the Missile Defense Agency
  - Moved to BMDS TEAMS contract to directly provide support services to MDA’s Advanced Technology Research group

- **CRM Solutions, Inc.**
  - Huntsville, AL
  - May 2017 – Present
  - Intern
  - Performed high speed impact debris modeling in support of the NASA Space Launch System

**Skills**
- LS-DYNA and Abaqus/CAE Finite Element Codes
- Proficient in MATLAB Scripting and Programming, Microsoft Office
Andrew S.  
Huntsville, Alabama  
US Citizen

Education
Bachelor of Science, Aerospace Engineering  
The University of Alabama in Huntsville

Experience
Forest Draper Hardware  
Cartersville, GA  
May 2014-July 2016  
Warehouse Associate  
- Responsible for packing orders; checking-in, putting away, and organizing inventory  
- Modifying inventory for orders when needed

Mars Grill, U.S.S.R.C  
Huntsville, AL  
June 2018-August 2018  
Cook/Cashier  
- Responsible for cooking food, preparing food, and cleaning equipment.  
- Trained on cash register and as cashier.

Undergraduate Research Assistant  
Huntsville, AL  
September 2018-Present  
Research Assistant  
- Investigation of Active Flow Control with a focus on sweeping jet actuators under the guidance of Dr. Konstantinos Kanistras

Skills
- MATLAB  
- Solid Edge (CAD)  
- SolidWorks (CAD)  
- Additive Manufacturing  
- Sewing  
- Soldering  
- Building Computers  
- NASTRAN/PATRAN FEA

Academic Projects
One Month Project  
September 2015  
Introductory project for UAH Space Hardware Club (SHC) where new members design, build, and fly a small balloon payload with embedded systems on it while going through PDR, CDR, FRR, and PFR documentation in one month’s time. I was responsible for mechanical design and construction.

Mentor for One Month Project  
September 2016  
Mentor for new members of SHC’s One Month Project. I helped mentor a team of 6 new club members during the project by providing them with contacts within the club that could help them with their design, helping them directly with their design, keeping them apprised of presentation dates and deadlines, and assisting them during the balloon flight.
International CanSat Competition   November 2016 – June 2017

I was responsible for the mechanical design of the glider and container, as well as entirely responsible for the design and construction of the descent control system (DCS). The objective was to build a 0.5 kg payload which flew inside a rocket to a specific altitude. At this altitude a folding solar powered glider contained inside a 125mm diameter x 310mm long cylinder was deployed and descended a under a parachute before the container was opened and the folding glider was released.

Spaceport America Cup (SAC)

Annual competition held at Spaceport America in New Mexico where student teams compete to build rockets with solid, hybrid, or liquid propulsion systems to achieve a target apogee of 10,000 or 30,000 feet. SHC is building a liquid powered rocket that will hit 30,000 feet at apogee. I have been involved with multiple sub-teams during my time on this project:

SAC - Payload Team   September 2017 – September 2018

A 4.0 kg simulated Martian rover which deploys from the nosecone of the rocket at apogee and tumbles to 1,500 feet. At this point the rover deploys its own DCS and lands safely on the ground. It will then move around, drill a hole in the ground, and drop a simulated seed packet (based off the NASA VEGGIE system). It has been designed to transmit live first-person view video telemetry in addition to radio telemetry at ranges up to 10 miles. I was responsible for all the mechanical design work (which was very CAD intensive); design of the DCS, development and manufacturing of the DCS, implementation of the DCS, and testing of the DCS; and acted as system engineer to oversee the integration of all subsystems on the rover into a single coherent unit. This sub-team was my primary focus on SAC during my time on the project.

SAC - Ground Support Equipment   September 2017 – January 2018

GSE was responsible for transportation, fueling, assembly, and safety procedures involving the rocket on launch day. During my time on this sub-team I was responsible for almost all the design work of the portable launch stand for the rocket.

SAC - Recovery Operations Lead   October 2017 – January 2018

This sub-team existed briefly during the investigative period when the SHC team was considering designing, building, and testing a custom DCS for the liquid rocket. I was responsible for the design of the parachutes, their rigging and other recovery hardware, developing a manufacturing plan, developing a testing plan, and responsible for the testing. This sub-team was eventually eliminated due to time constraints and the decision by the team to use commercial off the shelf recovery systems.

SRAD Rocket Motor   August 2018 – Present

This is an SHC project with the objective of designing and test-firing a custom 75mm solid rocket motor. I am primarily responsible at this stage for designing the test stand.

UAH USLI   August 2018 – Present

Student lead senior design project where the students design, document, build, test, and fly a rocket capable of carrying either a rover or UAV payload to a mandated altitude.