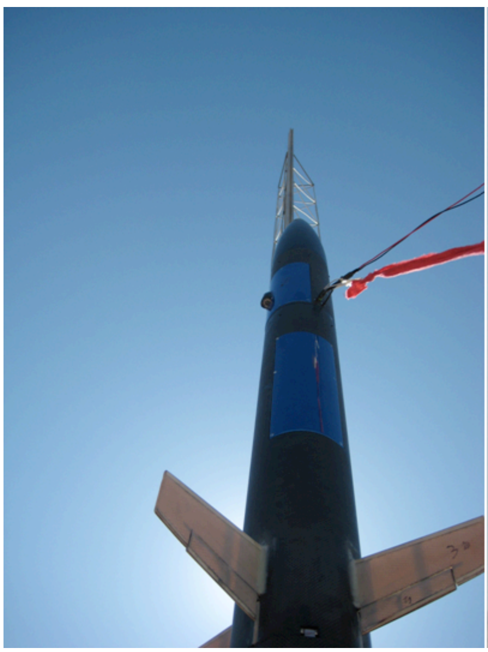
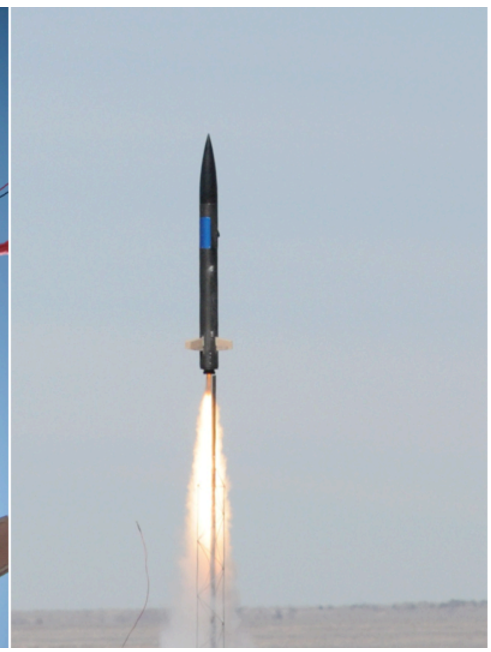
Chimaera
Experimental Hybrid Rocketry

2010-2011 NASA University Student Launch Initiative Proposal

Utah State University Chimaera Project

October 1, 2010

Contents

1 School Information **4**

2 Facilities and Equipment **5**

3 Safety **6**

3.1 Vehicle Safety and Mission Assurance . . . 6
3.2 Material Handling . . . 7
3.3 Explosives Permits . . . 7
3.4 Purchase, Shipping, Storing, and Transport of Motor . . . 7
3.5 Launch Site Safety . . . 7
3.6 HARA Regulations . . . 8
3.7 Level II Certification . . . 8

4 Technical Design **8**

4.1 Technical Design Overview . . . 9
4.2 Projected General Vehicle Dimensions . . . 10
4.3 Structural Design . . . 11
4.3.1 Load Analysis . . . 11
4.3.2 Airframe Design . . . 11
4.4 Aerodynamics . . . 12
4.4.1 Analytical Aerodynamics Estimation . . . 13
4.4.2 Wind Tunnel Testing . . . 15
4.5 Propulsion . . . 16
4.5.1 Propulsion System Overview . . . 16
4.5.2 Main Motor Selection . . . 16
4.5.3 Cold Gas Booster . . . 16
4.5.4 Propulsion Systems Technology Readiness Level . . . 17
4.5.5 Propulsion Testing and Integration . . . 17
4.6 Rocket Performance Simulation . . . 17
4.7 Recovery System Overview . . . 19
4.7.1 Recovery System Design . . . 20
4.7.2 Parachute Sizing and Load Determination . . . 22
4.7.3 Recovery Control . . . 23
4.7.4 Pre-flight Testing . . . 23
4.8 Avionics and Guidance . . . 24
4.8.1 Flight Computer . . . 24

4.8.2 Instrumentation . . . 24
4.8.3 Telemetry . . . 25
4.9 Scientific Payload . . . 25
4.9.1 Objectives . . . 25
4.9.2 Plume Affects on Aerospike Nozzle Performance . . . 25
4.9.3 Energy Management . . . 26

5 Educational Engagement 26
5.1 Community Support . . . 26
5.2 Outreach . . . 27

6 Project Plan 28
6.1 Estimated Cost . . . 28
6.2 Mass Budget . . . 29

7 Returning Team Information 29

A High Power Rocket Safety Code 31

B Contact Information 32

C Material Safety Data Sheets 33

D Hunstville Area Rocketry Association Safety Regulations 69

E Rocket Motor Candidates 71

F Work Schedule 73

G Resumes 74

H Bibliography 89

1 School Information

School:	Utah State University
Project Title:	Chimaera
Rocket Name:	Javelin
Official:	Dr. Steven Whitmore
Team Instructor:	Dr. Steven Whitmore
Assistant Team Instructors:	Shannon Eilers[a],Zach Peterson[a], Matt Wilson[a]
	Bowen Masco[b], Nate Erni[c]
Chief Engineer:	Richard P.[d]
Assistant Chief Engineer:	Colin W.[d]
Systems Engineer:	Jamie W.[d]
Safety Officer:	Kyle H.[d]
NAR Section:	Utah Rocket Club (UROC)
NAR Section Contact:	Tim Boschert

Table 1: 2010-2011 USLI team members and responsibilities.

Students Involved	Responsibilities
Andrew B.[e]	Propulsion
Annika J.[d]	Recovery, Outreach, Solid Modeling
Colin W.[d]	Assistant Chief Engineer, Flight Mechanics
Craig B.[d]	Website, Controls
Jamie W.[d]	Systems Engineer, Outreach, Controls
Joshua K.[d]	Propulsion
Josue R.[d]	Structures, Simulation
Kyle H.[d]	Safety Officer, Simulation
Mansour S.[d]	Propulsion, Simulation, Controls
Nathan M.[f]	Avionics, Controls
Richard P.[d]	Chief Engineer, Structures, Flight Mechanics
Ryuichi Y.[d]	Flight Mechanics, Recovery, Simulation
Samuel M.[d]	Modeling, Controls, Procurement, Simulation
Stewart H.[f]	Avionics, Controls

[a]Graduate Research Assistant, Mechanical and Aerospace Engineering
[b]Graduate Research Assistant, Computer Science
[c]Graduate Research Assistant, Electrical Engineering
[d]Undergraduate, Mechanical and Aerospace Engineering
[e]Graduate Student, Mechanical and Aerospace Engineering
[f]Graduate Student, Electrical Engineering

The Utah State University (USU) Chimaera team is competing in this year's NASA USLI competition a completely new team of students. To work more effectively, the team is broken into smaller groups, each with their own function, as shown in figure 1.

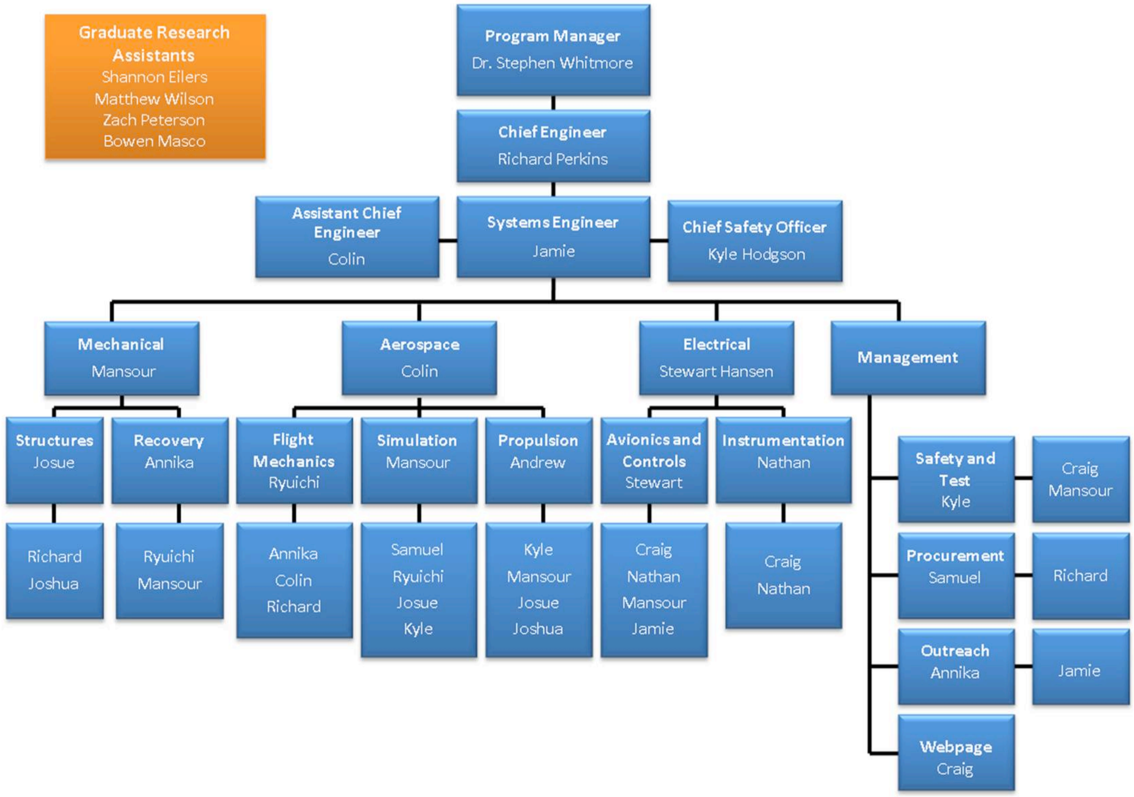


Figure 1: 2010-2011 USU Chimaera Team work breakdown structure.

2 Facilities and Equipment

Utah State University (USU) has been successfully building and launching rockets since the mid-1980s. This gives the 2010-2011 USU Chimaera team a rich collection of resources that can be leveraged to safely design, build, and test the Javelin. Since 2003, USU has launched five separate high powered rockets, two of which were over 20 feet long and were intended for flights greater than 100,000 feet. Because of these designs, previous USU Chimaera teams have succeeded in USLI competitions over the past four years.

USU is equipped with a large suite of industry-standard engineering software, including MATLAB/Simulink, Solid Edge, FLUENT, and MathCAD. In addition, the team has inherited a large library of commercial and student-created simulations that will aid in accurately modeling the rocket. Missile DATCOM, developed by the US Air Force, will provide tools for the preliminary analysis of the design. Utah State also possesses a wind tunnel that will provide data on aerodynamics of the rocket body. A motor test bed consisting of a motor test stand and the necessary sensors will be used to acquire motor characterization data. A launch platform has already been built and is available for the team, as shown in figure 2.

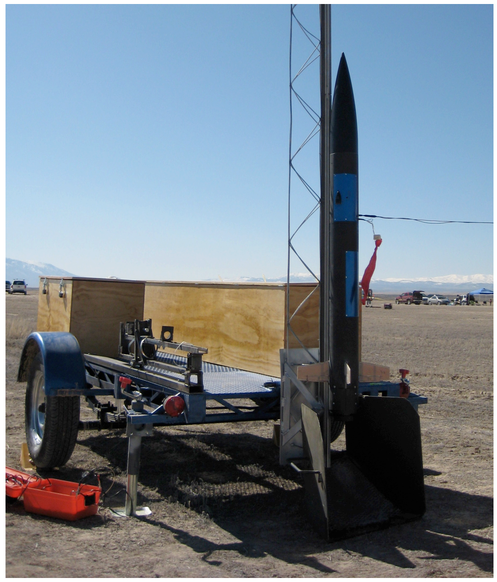


Figure 2: Chimaera mobile launch platform.

The team has access to a machine shop, complete with a CNC mill, lathes, welders, band saws, and other metal shaping equipment. This shop is staffed by full-time university employees, including a professional machinist, Mike Morgan, who is on-call for student designed projects. A composites laboratory with an autoclave and composites lay-up facility is also available. The team has a dedicated design lab containing spare rocket parts, rocket construction sleds, test instrumentation, a vacuum mixer, and archives of previous rocket designs. A rapid prototyping machine is also available on the campus.

Conference rooms are available on campus to allow for direct video conferencing and offsite communications. These rooms are capable of hosting WebEx teleconferences and include web cameras, speakerphones, broadband internet, and appropriate presentation software. A dedicated web site will be online which will include current team information, a team picture, and other relevant data. Subversion (SVN) software is used by the team. The USU Chimaera team will comply with all aspects of the Architectural and Transportation Barriers Compliance Board's Electronic and Information Technology (EIT) Accessibility Standards.

3 Safety

3.1 Vehicle Safety and Mission Assurance

The 2010-2011 USU Chimaera Team plans to build on the rich history of safety established by years of experience building and testing amateur and high-power rockets at USU. The current team has inherited an extensive list of materials and procedures that has led to the safe and successful launch of many rockets. The safety protocols and launch procedures will be adopted with little if any modification.

The Safety Officer, Kyle H., is responsible for ensuring that the team's safety plan is followed. The USU Chimaera team is aware of and compliant with all the National Association of Rocketry (NAR) requirements outlined in Appendix A. Contact information for USU Environmental, Health, and Safety personnel, as well as the Utah Rocket Club (UROC) contact person is listed in Appendix B.

3.2 Material Handling

A solid rocket motor containing Ammonium Perchlorate Composite Propellant (APCP) will be used by USU in the USLI competition. Solid motors use compounds which have strict storage, handling, and transportation requirements. The team has access to facilities capable of storing APCP motors and other low explosives according to applicable laws, as outlined in Section 3.4. All students will be briefed on the risks associated with the propellant to ensure safe preparation and launch practices.

Black powder and electric matches will be used for recovery deployment. Material Safety Data Sheets (MSDS) for potentially hazardous construction materials are included in Appendix C. As other potentially hazardous materials are encountered, an MSDS for each will be obtained and made readily available in the areas where the materials are present.

3.3 Explosives Permits

Because the rocket design will include black powder charges, electric matches for recovery deployment, and an APCP motor, a low explosives permit is necessary. A Low Explosives User's Permit (LEUP) has been obtained through the Bureau of Alcohol, Tobacco, and Firearms (BATF) by Dr. Stephen Whitmore, the team instructor. The permit in Appendix C expires in March 2011. The team will renew or obtain a new permit before that time in order to remain compliant to all safety codes and regulations.

3.4 Purchase, Shipping, Storing, and Transport of Motor

National Fire Protection Association (NFPA) 1127 and safety codes of both the National Association of Rocketry (NAR) and the Tripoli Rocketry Association (TRA) require that high-power motors be sold only to or possessed by certified users. This certification may be granted by a nationally recognized organization to individuals over 18 years of age who demonstrate competence and knowledge in handling, storing, and using such motors. High-power motors include all motors above F-class, and all motors that use metallic casings, including reloadable motors, regardless of power class.

The USU USLI rocket design will include an L-class, reloadable rocket motor. Currently only NAR and TRA offer the certification required to use this type of motor. High-power rocket motors contain highly flammable substances, such as black powder or ammonium perchlorate, and are considered to be hazardous materials or explosives for shipment purposes by the U.S Department of Transportation (DOT). The DOT regulations concerning shipment of hazardous materials is contained in the Code of Federal Regulations (CFR) Title 49, Parts 170-179. These regulations specify that it is illegal to send rocket motors by commercial carriers, or to carry them onto an airliner except under exact compliance with these regulations. NFPA 1127 Section 4.19 contains the storage requirements of motors over 62.5 grams. High-power rocket motors, motor reloading kits, and pyrotechnic modules are to be stored at least 7.6 m (25 ft) from smoking, open flames and other sources of heat.

Propellant for high-power rocket motors is subject to the storage requirements of 27 CFR 55. This states that propellant shall be stored in a type 3 or 4 indoor magazine, and that no more than 23 kg (50 lb) of propellant shall be stored in one location. The magazine shall be painted red and have the words "explosive-keep fire away" in white block letters at least 76 mm high on the top of the box. The motor must be stored without the ignition element installed. The vehicle used for transportation will not be left unattended with black powder or APCP inside it. No open flame or smoking will be allowed within close proximity of the vehicle containing the magazine. The magazine will be strapped down securely to the floor with fire resistant material. The doors of the vehicle leading to the magazine will be locked at all times. A CO_2 or foam extinguisher along with the MSDS sheets and the contact information of the safety officer and the designated personnel will be made available to the driver and the attendant accompanying the driver. A first aid kit for minor burns will also be made available in the vehicle. Whenever possible, rocket motors and black powder will be bought near the launch site to help mitigate the hazards involved in transporting these materials.

3.5 Launch Site Safety

Before launch day the student team will receive training in hazard recognition and accident avoidance. On the day of launch the safety officer will conduct a systems safety check on the motor, payload, and recovery. A pre-launch briefing will be conducted with the team before each launch. The recognized hazards will be discussed, as well as methods for mitigating the hazards. Each launch site will be controlled by the local NAR section. The test launches will be overseen by the Utah Rocketry Club (UROC), while the Huntsville Area Rocketry Association (HARA) will regulate the competition launch. High-power rocket launches must comply with local, state and federal regulations. The Federal Aviation Administration (FAA) has specific laws governing the use of airspace during high-power rocket launches, as specified in 14 CFR 101. The local NAR section controlling the launch must notify the local FAA Air Traffic Control facility of the details of the launch. It is the responsibility of each rocket's operator to ensure that the launch is conducted within the operating limitations outline in 14 CFR 101.23.

3.6 HARA Regulations

Each member of the USU Chimaera team will sign a consent form, verifying that each understands the following: 1) HARA will conduct range safety inspections of each rocket before it is flown The USU Chimaera team will comply with the inspection determination. 2) The HARA Range Safety officer has the final say on all rocket safety issues, and has the ability to deny the launch based on safety reasons. 3) If the team is in noncompliance with the safety and mission assurance, the rocket will not be launched. The consent form can be found in Appendix D.

3.7 Level II Certification

To purchase and use high power rocket motors, an individual must be certified by either the NAR or the TRA. The certification is designed to ensure that the high power motors are being used only for the purpose for which they were designed. There are three different levels of certification; Level II certification allows for the use of J-, K- and L-class motors. The certification process is designed to allow the candidate to demonstrate their understanding of the basic physics and safety guidelines that govern the use of high power rockets. Level II certification requires that one construct, fly and recover a high power rocket in a condition that it can immediately be flown again (Level I), as well as pass a written exam that tests knowledge of rocket aerodynamics and safety. The required pass rate for this test is a 90% score. Shannon Eilers, a graduate research assistant working with the team, has previously obtained Level II certification. For the 2011 USLI competition, Kyle H. and Colin W. plan to receive Level II certification through the TRA on October 16, 2010. The certifications will be done through the Utah Tripoli Prefecture, with the assistance of UROC. Tim Boschert, the Tripoli Prefect, has agreed to oversee the administration of the written and flight tests. The Level II certified persons will ensure that all members of the USU Chimaera team are aware of the risks of high-powered rocket launches, and will help create a safe launch environment.

4 Technical Design

The Utah State Chimera Rocket Team competing in this year's NASA USLI competition is almost a completely new team of students. To more work more effectively, the team has broken up into temporary smaller teams, each with a primary function. A program-wide milestone plan has been developed, as shown in figure 3.

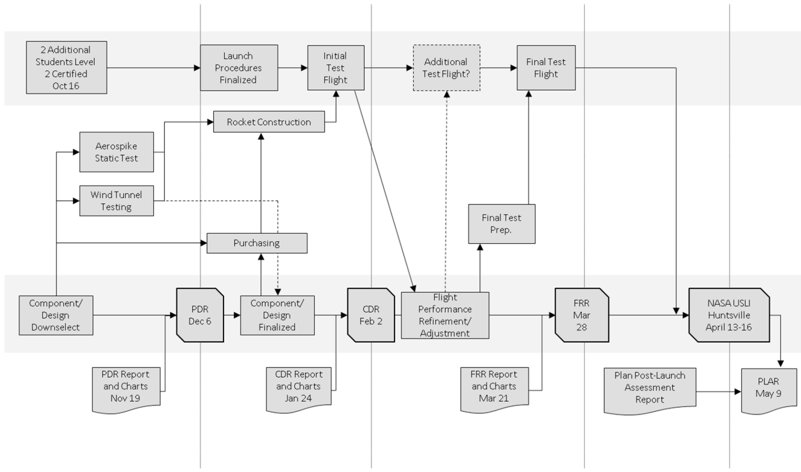


Figure 3: Program-level mission milestone map.

4.1 Technical Design Overview

The 2010-2011 USU Chimaera Team will mainly be using an L-class solid propellant motor to launch the rocket so that the Javelin's altitude dispersion envelope, or the altitude variance the rocket may experience to a certain confidence level, is always below the one mile target altitude. The energy management system, consisting of two novel two-dimensional linear aerospike nozzles and associated equipment, will provide additional thrust at predetermined waypoints in order to boost the rocket to the desirable altitude. This process will be controlled using a robust, time-optimal energy management control algorithm. This algorithm will use multiple different variables to calculate how much cold gas propellant should be used, such as acceleration, velocity, and orientation of the rocket. This system will be used as a thrust augmentation system to augment the energy level of the Javelin. Control surfaces, either on the fins or on the rocket body, may be employed in case too much energy is added. The Concept of Operations is shown above in figure 4:

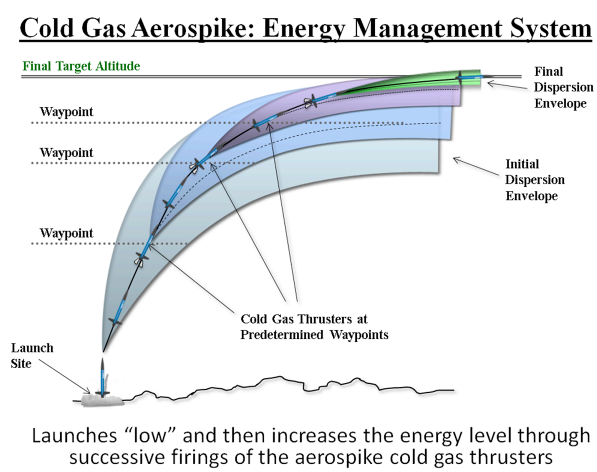


Figure 4: Concept of operations for the cold gas aerospike energy management system.

The aerospike nozzle will be used as the main part of the scientific payload. We will be gathering in-flight pressure data on the aerospike nozzle in the exhaust plume. After the flight we will continue to analyze the data collected to optimize the rocket even more for future launches.

The components of the rocket will be discussed in the following sections outlining how the rocket will be optimized for stability, reliable performance, and successful recovery. Each of the components is essential in having a successful rocket flight.

4.2 Projected General Vehicle Dimensions

Table 2 summarizes the projected dimensions and principle vehicle specifications:

Table 2: Projected vehicle dimensions.

Structures		Recovery	
Length of the rocket:	5.95 ft (1.81 m)	Parachute type:	Elliptical
Maximum diameter of the rocket:	5.5-7 in (14-17.8 cm)	Drogue chute diameter:	2 ft (61 cm)
Clean mass:	20-25.4 lb (9-11.5 kg)	Main chute diameter:	8 ft (244 cm)
Nosecone Length:	22.8 in (60 cm)	Aerodynamics	
Body tube material:	Carbon fiber or Blue Tube 2.0	Nosecone type:	Tangent ogive
		Fin root chord:	4 in (10.2 cm)
Body tube legth:	4.08 ft (1.24 m)	Fin span	6 in (15.1 cm)
Propulsion		Avionics	
Solid Rocket Motor Diameter:	54 or 75 mm	CPU:	Gumstix Overo Fire
Impulse:	3000-4500 N-s	IMU:	Microstrain 3DM-GX2
Cold gas aerospike propellant:	CO2 or HPA	Communications:	CPU built-in wifi
		Instrumentation:	PerfectFlite MIniAlt/WD

The primary dimensions for this rocket are derived from previous USLI designs developed by the Chimaera program at Utah State. The major uncertainty at this point in the design is the width of the main body tube. This diameter will be driven by the final motor selection.

Currently a detailed investigation is being performed to determine the appropriate motor size for the vehicle design. This investigation is enabled by a student-built 3-degree of freedom ballistic simulation. The preference is to select a 54-mm diameter motor design to reduce the overall vehicle size and weight; but there are a limited number of motors in the size that provide sufficient impulse, and a larger 75-mm motor may be required to accomplish the design objectives. The final motor-selection trade study is anticipated for completion by mid-October.

Similarly, a trade study is being performed to select the appropriate components for the cold-gas augmentation system. This design will leverage a wide variety of components commercially available for "paintball" applications. Both carbon dioxide (CO_2) and high-pressure air (HPA) designs are being considered. The CO_2-based designs are more volumetrically compact, but have a higher overall system weight when compared to the HPA components. This design trade study is also scheduled for completed by mid-October.

The recovery system will use dual-deployment, with dual initiation-redundancy for each deployment stage (drogue/main). The proposed parachute sizes are based on previous USLI designs. The actual chute characteristics will be defined by a trade study to be performed following the final motor and cold-gas system component selection. The initial closed sizing calculations will be performed using the closed-form solution provided by Pflanz's method. These sizing calculations will be verified by direct simulation.

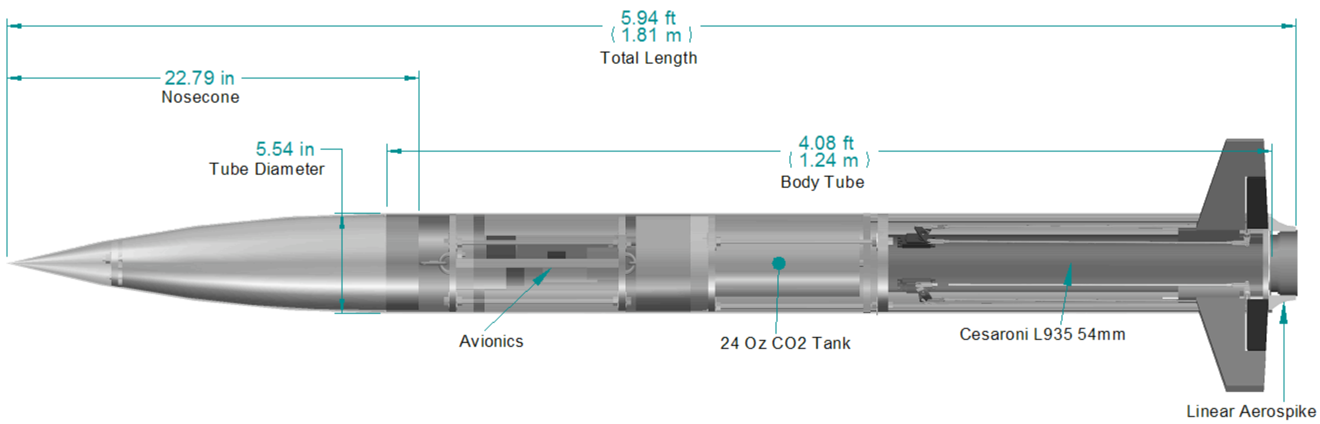


Figure 5: Schematic of projected vehicle dimensions.

4.3 Structural Design

The structures team will provide an affordable and durable rocket body and will accurately track mass position in the Javelin. To meet this objective all the following will be investigated: support structure, positioning of the payload components, selection of nose cone, selection of materials, and mass estimate. The 2009 Chimaera team's work suggests that increased accessibility to the rocket's payload and avionics bays is necessary, so larger access doors will be designed on the rocket.

4.3.1 Load Analysis

Load events that will be considered include: Transportation, Pre-launch, Launch, Ascent, Parachute Deployment, Descent, and Landing. In considering the load events, the primary loads considered will be loads transmitted along the structure from motor and cold gas thrust, acceleration loading, aerodynamic forces acting on the fins, recovery load due to parachute deployment, and landing loads acting on the fins and main body. The structural team will use analysis techniques, such as finite elements analysis, to verify the structural integrity of the rocket and compute all the required loads and safety factors as necessary.

4.3.2 Airframe Design

Taking into account aerodynamics, materials selection, manufacturing, and cost; the airframe will be built with either a 5.5 in (14.0 cm) or 6.0 in (15.2 cm) tube, along with the necessary bulkheads and stringers. To accommodate the aerospike, additional room may be needed in the aft portion of the case. This will be done either by using the smaller 54 mm diameter L- class motor (as opposed to a 75 mm L-class motor) or by employing a boat-tail flair the aft section. Figure 6 an the airframe being considered for the design. Both options will be investigated as possible solutions for accommodating the aerospike cold gas thrust augmentation system.

Figure 6: Potential design for rocket.

Two types of materials will be considered for the airframe, carbon fiber and Blue Tube 2.0. Carbon fiber tubing is very popular in rocketry because of its strength, light weight, and machinability. Blue Tube 2.0 is a new product that is highly abrasion resistant and able to withstand 10 g. Table 3 shows a comparison of these two materials for a 5.5 in diameter and 48 in long tube, which will be useful in deciding the final material. More research will be done on these two materials in order to choose the final material to be used for the airframe. There is also a possibility of using both of these materials for different parts of the rocket body.

Table 3: Airframe material comparison.

Material	Tensile Strength (MPa)	Density ($\frac{g}{cm^3}$)	Price ($\frac{\$}{48\ in}$)
Blue Tube 2.0	110.3	1.20	54.95
Carbon Fiber	4000	1.75	140

4.4 Aerodynamics

The proposed launch and energy management strategies require a good overall working knowledge of the vehicle aerodynamics. These properties will initially be calculated using analytical methods, and then verified via wind tunnel and flight-testing. Collected results from the three methods will be used to establish uncertainty models. These uncertainty models will be used to insure that the design hardware can achieve the mission objectives, and also insure that the maximum altitude limit of 5600 ft above ground level (AGL) cannot be exceeded. Figure 7 shows the process the USU Chimaera team will follow.

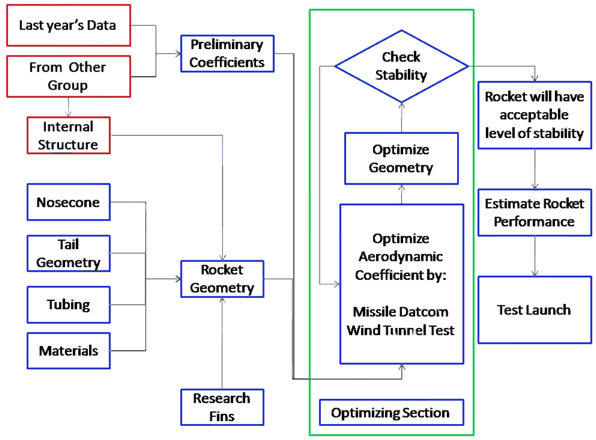


Figure 7: Aerodynamics mission milestone map.

4.4.1 Analytical Aerodynamics Estimation

The initial vehicle aerodynamic coefficients, primarily lift-coefficients, drag coefficient, and Pitching Moment Coefficient will be calculated and tabulated as a function of the vehicle angle of attack using the United States Air Force (USAF) Missile DATCOM program. The USU Chimaera team has access to Missile DATCOM, which is an industry-standard computer code developed for the USAF, and allows a wide variety of axi-symmetric and non-axi-symmetric rocket configurations to be rapidly analyzed. Missile DATCOM is a high-level aerodynamic design tool which has the predictive accuracy suitable for preliminary design, and the capability for the user to easily substitute methods to fit specific applications. Missile DATCOM output files can be directly imported into the USU-built dynamic simulations used to perform the launch analysis.

The Javelin will require a certain level of aerodynamic stability for successful flight. For designing stability of the rocket, a suitable stability criteria will be picked up first. In order to determine the stability of the rocket, the rocket's center of pressure distance aft of the center of gravity and the rocket diameter are measured. These two measurements give the static margin of the rocket. In general, having a static margin of at least 1.0 is a good rule of thumb for rocket stability. As the center of mass of the rocket is fixed by structural and spacial constraints, the primary design variables for stability are the size, shape, and location of the fins. In practice, the location of the fins is also specified by the location of a boat-tail. There is an optimum size and shape of fin that will minimize energy lost due to drag and weight over a given profile. Rocket stability calculated by analytical methods will be verified by wind tunnel testing.

In order to design fins, an understanding of the possible failure modes that could occur with the rocket and how to fix or minimize the likelihood of those failures is required.

Table 4: Possible modes of failure for stability design.

Failure Mode	Reaction	Likelihood	Remedy
Rocket becomes unstable	Loss of control Rocket could crash	Low	Confirm accurate center of mass location. Perform wind tunnel testing to check stability.
Rocket becomes over-stable	Rocket will nose too far into the wind	Moderate	Ensure that the speed of the rocket leaving the launch rail is large enough and measure the affects of fin size on stability.
Lack of strength of fins	Fins break on impact	Moderate	Redesign fins to have enough strength.
Inaccurate prediction of drag	Rocket may not reach apogee	Low	Revise simulator aerodynamic drag result.

4.4.2 Wind Tunnel Testing

In order to verify the aerodynamic data that will be obtained from Missile DATCOM and other analytical tools, wind tunnel testing will be performed at Utah State University to compare the drag coefficient acting on the rocket at various angles of attack. To achieve accurate results from wind tunnel tests, the model used in this test must have geometric, kinematic and dynamic similarities to the full-scale rocket. Table 6 shows how the team plans on achieving these conditions.

Table 6: Similarity criteria for wind tunnel testing.

Name of Similarity	How to Acheive Similarity
Geometric	Create a scale model of the actual rocket
Kinematic	Fluid flow direction should be the same.
	Magnitude of the flow around the model should be proportional to the flow around the actual rocket.
Dynamic	Match Reynolds number on model with the one on the rocket.

A small model of the rocket will be created using a rapid prototyping machine on campus in order to complete this testing. A Pitot probe will be placed in the wind tunnel downstream of the rocket model as shown in figure 8. This probe will collect pressure data to determine the velocity of the flow. Drag coefficient will be obtained by the equation

$$C_d = \frac{F_d}{\frac{1}{2}\rho V^2 A_{ref}} \quad (1)$$

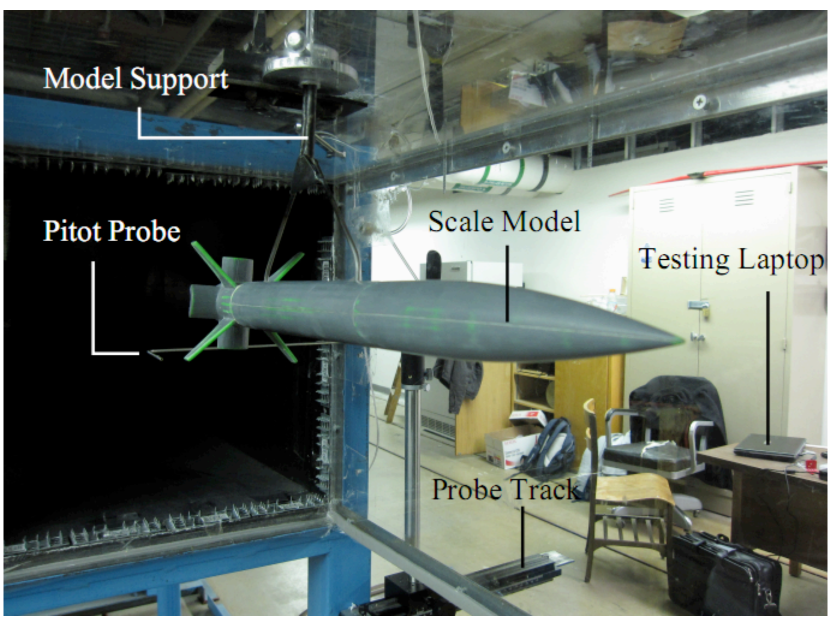


Figure 8: 2009 wind tunnel test.

Figure 9: 2008-2009 Utah State University USLI team rocket model for wind tunnel testing.

4.5 Propulsion

4.5.1 Propulsion System Overview

The propulsion subsystem will consist of a main solid rocket motor and a supplementary cold gas booster. The solid rocket motor will provide most of the impulse needed to reach one mile AGL. The purpose of the cold gas thruster is to add the remaining impulse.

Based on the impulse requirements of past rocket projects, an impulse range of 2500 - 4800 N-s for the main motor will be considered, which is within the impulse range of a large selection of L-class motors. More constraints, such as maximum allowable altitude and gravitational forces, will be applied based on flight and design requirements in order to narrow down the number of motor options.

4.5.2 Main Motor Selection

One parameter that will be constrained in order to limit the number of motors is motor diameter. Standard 54 or 75 mm motors are common in the L-class range. A diameter less than 54 mm will not provide enough motors to choose from in the desired impulse range, while a diameter larger than 75 mm will increase structural mass, as well as force the design to use a bigger motor tube to accommodate the aerospike nozzles. The increase in drag could potentially negate the added impulse. The Javelin will use a 54 or 75 mm, L-class motor.

Restraining the solid motor to an L-class, 54 or 75 mm diameter motor considerably reduces the number of motors that meet all other design and flight requirements. As more constraints are imposed on the rocket motors, the list will be refined to a smaller sample size. The manufacturer's flight performance data of the motors will be input into simulations to verify thrust curve data. The simulation will also determine the amount of additional impulse from the cold-gas thruster needed to reach one mile, if any. Those that clearly exceed one mile and use no cold gas are eliminated. Also, the motors that will fall short of one mile even after using all of the cold gas available will be eliminated. The motors available for further analysis after considering all specified constraints are shown in Appendix E.

The best motor for the current design will be chosen using the data gathered from the simulations as well as a decision matrix. The decision matrix will be used to consider the advantages and disadvantages of each motor, assigning a weighing factor to each. The motor that has the best score and that exhibits the best performance in the simulations will be selected as the best choice.

4.5.3 Cold Gas Booster

In addition to selecting the motor, the propulsion team will design the delivery system for the cold gas propellant. This will involve selecting a propellant type, propellant container, regulator, and a flow valve. The predominant options for propellant are CO_2 or high pressure air (HPA). Both are readily available from the paintball industry in pressure vessels that store between 0.4 and 40 oz. of propellant, depending on the gas. Figure 10 shows a typical paintball CO_2 tank. The availability of such a wide range in tank sizes significantly reduces the cost of propellant containment.

Figure 10: Typical 40 oz. CO_2 paintball tank.

More research will be conducted on the differences between CO_2 and HPA, as well as on the gas flow valve and regulator. Once a system is chosen, the parts will be ordered and tested to confirm their performance and subsystem testing of the fuel delivery system will begin.

4.5.4 Propulsion Systems Technology Readiness Level

Because cold gas thrusters are commonly used for attitude control on spacecraft, the Technology Readiness Level (TRL) of such systems is TRL 9 according to the "Definition of Technology Readiness Levels" . This means the system has been proven through multiple successful mission operations. CO_2 and HPA tanks and associated hardware have also been successfully tested within the paintball industry, but to use the hardware as an energy augmentation system would decrease the TRL to 5 or 6. At TRL 5, a system has had "basic technology elements integrated with reasonably realistic supporting elements." This means that although the gasses aren't intended for energy augmentation, they will perform properly in this capacity.

4.5.5 Propulsion Testing and Integration

With the optimum motor chosen, the testing phase of the project will begin. This includes verifying the motor performance specifications provided by the manufacturer. Motor testing will include test firings, which will yield thrust and impulse data. This new data will be input into the simulations and create a more accurate simulation for the rocket's flight. Once the motor has been tested and the cold gas fuel delivery system completed, the propulsion subsystem will be ready to integrate into the rocket for system level tests.

4.6 Rocket Performance Simulation

The team will develop a deterministic and stochastic simulation to predict the flight path of the rocket using simulation tools such as MATLAB/Simulink and LabVIEW. A simple, deterministic, three degree of freedom (3-DOF) simulation has already been created in MATLAB/Simulink to predict the behavior of the motor that will be installed in the rocket. The simulation takes into account aerodynamic drag and launch rail characteristics. For verification a second simulation has been developed in LabVIEW to compare the results with Simulink. Figure 11 shows the mission milestones of the simulation development process.

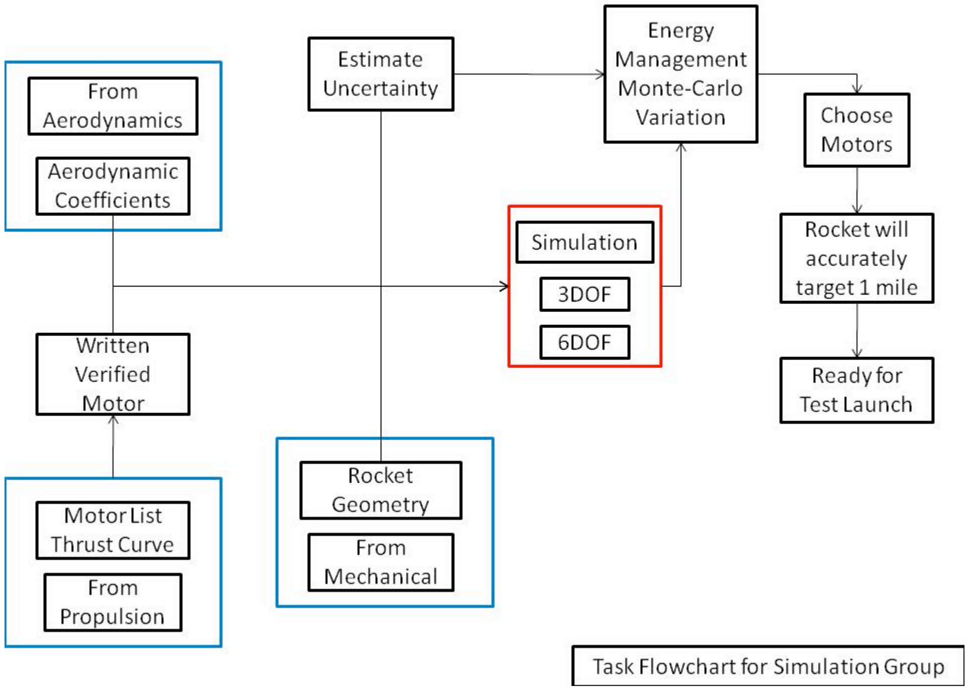


Figure 11: Simulation development mission milestone map.

Each team member will write their own 3-DOF simulation in order to gain understanding and experience with the simulation process. The RockSim software, favored in model rocketry, will be used to compare the data from Simulink and LabVIEW to verify that the projections are realistic. RockSim software cannot be altered for the desired aerodynamic calculations or any additional parameters that will need to be accounted for, so it will be used solely for verification. An energy augmentation system component will be incorporated into the 3-DOF simulation in order to more accurately predict the behavior of the rocket during flight.

In order to simulate the rocket behavior using a specific motor, a thrust profile needs to be obtained for each motor. Thrustcurve.org[1] provides thrust curves for most of the L-class motors shown in Appendix E. The first narrowing criteria in the simulation is maximum altitude. Gravitational forces on the rocket are also considered. The maximum force must not exceed 15 g. Drag coefficient was assumed for the simulation, based on the reference area of the 2008-2009 USU Chimaera team's rocket. The reference area of the Javelin was held constant ($A_{ref} = 0.016$ m^2), and the drag coefficient was changed for each motor size (0.38 for 54 mm, 0.57 for 75 mm).

The LabVIEW simulation accounts for thrust augmentation, assuming CO_2 as the cold gas with 200 N of thrust. The altitude constraint in selecting a motor for use with thrust augmentation is 1608-1610 m. MATLAB/Simulink simulates the AMW L777 without augmentation. The altitude constraint in selecting a motor for use without thrust augmentation is 1450 – 1550 m. Figure 12 indicates that AMW L777 did not fit within the constraint requirements. This motor will be discarded from the final selection.

Figure 12 shows the performance of the AMW L777 according to the flight simulations, using the specified clean mass. The chosen launch angle was 85°. The mass of the thrust augmentation system is added to the clean mass as part of the payload. The clean mass of the entire rocket is approximated to be 8.93 kg. Clean mass is defined as the mass of the airframe without the motor casing and propellant.

[1] http://www.thrustcurve.org

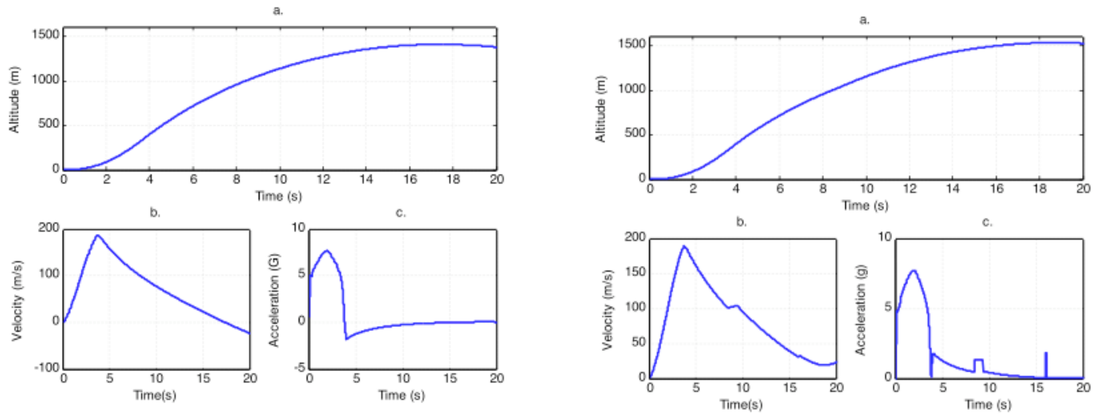


Figure 12: MATLAB/Simulink simulation output for AMW L777, 75 mm Left: without augmentation. Right: with augementation : a) altitude profile, b) velocity profile normal to earth, c) acceleration along length of rocket.

Figure 13 illustrates that Cesaroni L1276 did reach the constraint criteria with a maximum altitude of 1452 m in the MATLAB/Simulink. This motor will be included for further simulation. Using the same motor to simulate the profile in LabVIEW the maximum altitude is 1609 m, which is very near one mile.

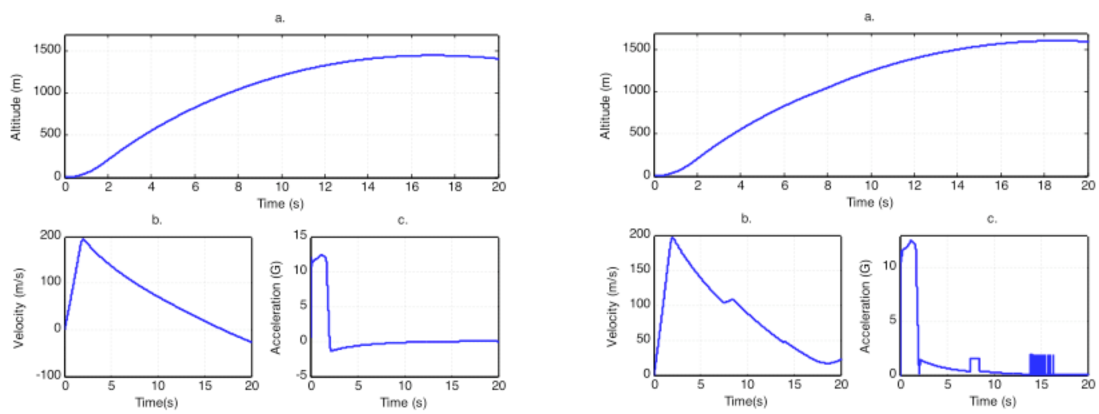


Figure 13: Simulation ouput for Cesaroni L1276 54 mm: a) altitude profile, b) velocity profile normal to earth, c) g-loads experienced by the rocket

Once the configuration is determined and the motor selection is narrowed, a more complicated and sophisticated simulation will be developed, or adapted from previously developed codes, and Missile DATCOM will be used to help calculate the aerodynamic properties. Monte Carlo analysis will be introduced to account for random variables that will occur during the flight.

4.7 Recovery System Overview

The objective of the recovery team is to develop a system that will allow the rocket to land safely within the outlined recovery zone while maintaining the integrity of the rocket. The recovery design will be a dual deployment, with the initial parachute deploying at apogee. The drogue parachute will minimize drift as the rocket descends, and a main parachute, released at several hundred meters above ground level, will slow the descent to an appropriate landing velocity. A recovery profile is shown in figure 14.

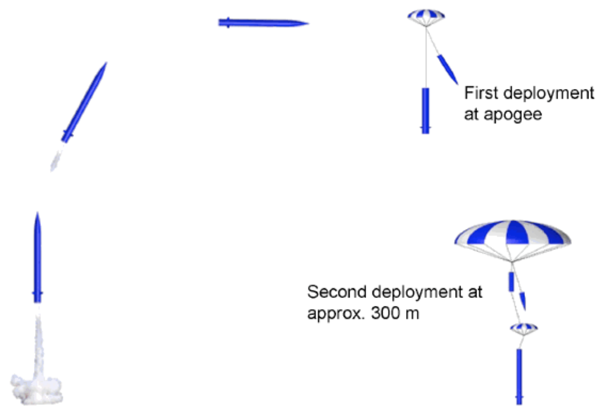


Figure 14: Recovery system performance profile.

4.7.1 Recovery System Design

A milestone map outlining the design process of the recovery system is shown in figure 15. A simple, proven design has been chosen in order to best meet the constraints of the project and will reduce the number of extraneous parts and overall mass. A proven design will increase predictability and reliability of the system. Elliptical parachutes will be used because of their common use in hobby rocketry, which makes them more accessible than other styles.

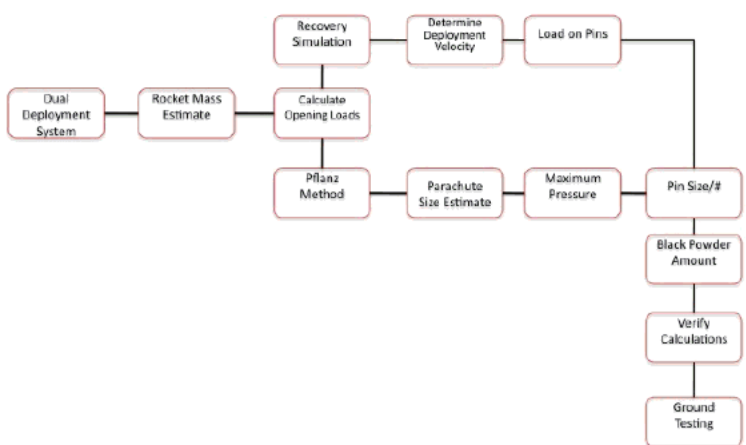


Figure 15: Recovery system mission milestone map.

The avionics bay, where the recovery system electronics are housed, will be attached to the airframe and nose cone using shear pins. Black powder will be used as ejection charges for the separation of the airframe. Black powder involves a high risk of heat damage to other system components, but will be prevented through careful packing procedures. Burn retardant material will be used on the harnesses, and no heat-sensitive components will be touching the charges. A summary of other possible failure modes and the team's proposed solutions are outlined in table 7.

Table 7: Recovery system risk analysis.

Failure Mode	Design Location	Likelihood	Proposed Solution
Tangled Parachute Lines	Packing Procedures	High	Properly fold parachutes so lines will not cross on deployment
Torn Parachute	Opening Load	Low	Minimize opening loads, inspect housing to avoid snag points
Burned Parachute	Charges, Packing Procedures	High	Surround heat-sensitive parachute components in protective material and ensure charges are placed such that they do not touch unprotected areas.
Charge Failure	Charges	Moderate	Use redundancy in avionics. Store black powder in a dry environment. Check e-match wires for continuity.
Rocket Separation Failure	Shear Pins, Charges	Moderate	Use redundancy in avionics. Apply appropriate charge sizes.
Parachute Separation	Opening Load	High	Use harness materials capable of withstanding opening loads.
Excessive Drift	Parachute Size, Descent Rate	Moderate	Correctly size parachute, accurately predict descent rates.
Airframe Damage	Charges, Opening Loads, Descent Rate	Moderate	Accurately predict opening loads and charge sizes.

The primary controller for the recovery system will be a PerfectFlite altimeter backed up by an R-DAS altimeter. When either system detects that the rocket has reached apogee, it will ignite an electric match, which will fire the charge, releasing the drogue parachute. The drogue parachute will deploy as the avionics bay separates from the main airframe. When the rocket has descended to a target altitude several hundred meters above ground level, as measured by the altimeter, the flight computer will fire the main parachute charge. The main parachute will release as the nose cone separates from the avionics bay.

A redundant, secondary control system will be provided by an R-DAS altimeter. The ejection charges will be wired to both altimeters. For easy access to the parachute ejection charges, the avionics section will be placed between the parachutes. Connections from the avionics package will detach when the charges fire to allow for smooth separation from the adjacent sections. Electric matches will be oriented and secured to maintain connection during flight. For additional safety, warning lights will be placed on the rocket to indicate if the flight computer is sending a signal to the charges before they are armed. A block diagram of the parachute connections is shown in figure 16.

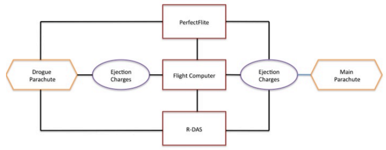


Figure 16: Parachute connections configuration

4.7.2 Parachute Sizing and Load Determination

Load Determination The main challenge in designing a dual deployment recovery system is correctly sizing the parachutes to meet the goal of safe recovery while minimizing in-flight drift and parachute opening loads. The maximum stress the airframe must withstand is minimized when the loads from the drogue and main parachutes are equal. The drogue parachute must also be sized to produce a descent rate between 50 and 100 ft/s, and the main parachute must slow the descent to between 17 and 22 ft/s. The main parachute size is dependent on the mass of the rocket. The process of determining the size of the parachutes will be repeated as the optimization of the rocket design progresses.

The Pflanz method will be used to determine parachute opening loads. First, the inflation time, t_f, will be found with the equation

$$t_f = \frac{n_c D_0}{V_{op}^{0.85}} \tag{2}$$

where n is the canopy fill constant, D_o is an assumed drogue parachute diameter, and V_{op} is the velocity of the rocket when the parachute opens. The canopy fill constant for an elliptical parachute is four. The inflation time will be used to determine a ballistic parameter,

$$A_b = \frac{Z_{m_d} g}{(C_d S)_p \rho V_p t_f} \tag{3}$$

where m_d is the mass of the rocket, S is the parachute surface area, C_d is the drag coefficient and ρ is the atmospheric density at deployment altitude. The opening force reduction factor, X_1, will be determined using the ballistic curve found in figure 17. The opening force can then be determined from the equation

$$F_p = (C_d S)_p q_1 C_x X_1 \tag{4}$$

where q_1 is the dynamic pressure and C_x is the opening coefficient. The opening force will cause stress on the shear pins, connecting the nose cone to the avionics section, which will be sized to withstand the stress. Terminal velocity will then be calculated from

$$V_t = \sqrt{\frac{Z M_d g}{\rho (C_d S)_p}} \tag{5}$$

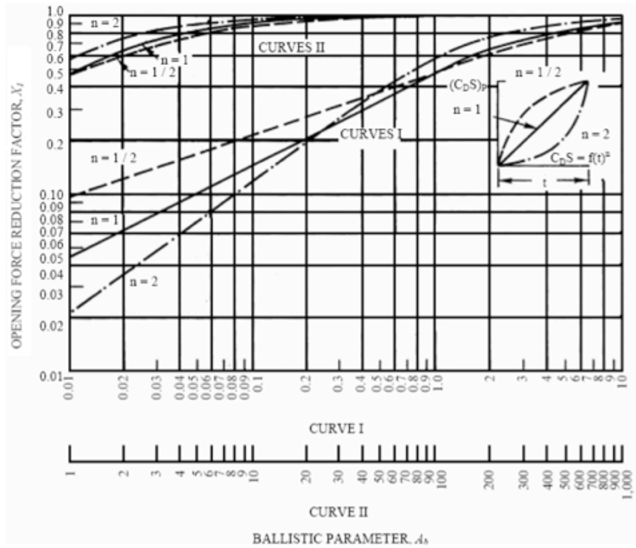


Figure 17: Ballistic curve for determining X_1.

Once the terminal velocity of the rocket with the drogue parachute deployed, and the required size of the main parachute are found, the peak opening load of the main parachute will be calculated using the same iterative process that was used to find the opening load of the drogue parachute.

Recovery Simulations The flight simulator used in development for previous rocket designs will be updated or rewritten to include the descent phase of the rocket's flight. Monte Carlo analysis will be employed, including parameters for wind conditions, parachute diameters and deployment altitudes, in order to establish a range of possible drift distances. Wind profiles will be obtained from EarthGRAM, an atmospheric model developed by NASA. Including wind profiles in the Monte Carlo analysis will make it possible to more accurately determine an appropriate landing footprint.

4.7.3 Recovery Control

When the PerfectFlite detects that the rocket has reached apogee it will ignite an electric match, which will fire the charge deploying the drogue parachute. When the rocket has descended to a target altitude several hundred meters above ground level, the flight computer will fire the main parachute charge. A redundant secondary control system will be provided by the flight altimeter, and there will be a tertiary system in the form of a manual override through the RS-232 modem connection. For easy access to the parachute ejection charges, the avionics section will be placed in between the parachutes. Connections from the avionics package will detach when the charges fire to allow for smooth separation from the adjacent sections. Electric matches will be oriented and secured to maintain connection during flight. For additional safety, warning lights will be placed on the rocket to indicate if the flight computer is sending a signal to the charges before they are armed.

4.7.4 Pre-flight Testing

Pre-flight testing will be performed on the recovery system in order to ensure the systems are functioning properly. Charges will be set off manually on the ground to verify that the nose cone and avionics section will separate and the parachutes will clear the housing without snagging or tangling. This will also test the packing method. The flight altimeter and computer will be placed in a chamber that will simulate small, varying altitudes. As the pressure is adjusted, the components should detect apogee and signal for the drogue parachute deployment. The pressure will continue to be raised until the estimated altitude for main parachute deployment is reached, when a signal is be sent to the electric matches. Axial loads will be applied to the nose cone and avionics section to ensure that the shear pins will prevent premature separation during flight.

4.8 Avionics and Guidance

The avionics of the rocket will monitor the flight of the rocket and its projected path to aid in successfully completing the mission. Software will be written for the flight computer to maintain and monitor the movements of the rocket. The design procedure for testing is outlined in figure 18. The avionics package will take measurements from the instrumentation on board, run guidance algorithms using the data acquired, and log the data for later analysis. The data measurements taken during flight will be sent via an industry standard IEEE 802.11 G wireless telemetry link to the ground station, where a member of the team will monitor the flight.

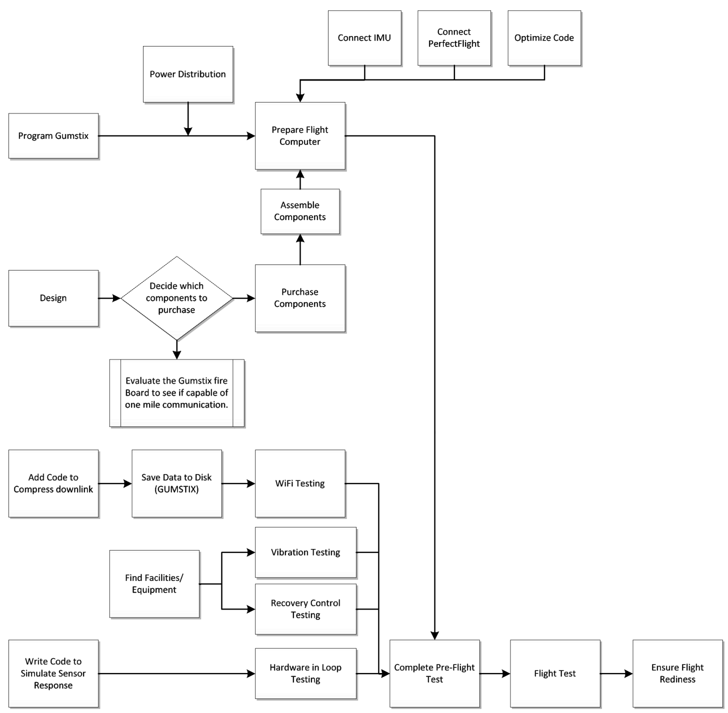


Figure 18: Avionics milestone map.

4.8.1 Flight Computer

The Gumstix Overo Fire Com or the Overo Air will be used to control the avionics. These have been chosen because they are small, light, and have powerful processors to get the desired data from the flight. They also provide Wi-Fi or Bluetooth connections for tracking the rocket. The flight computer will also monitor the various on board instrumentation and will take calculated measurements of the progress of the rocket and make estimates of its height capabilities.

4.8.2 Instrumentation

The Inertial Measurement Unit (IMU) that will be used for flight measurements is the Microstrain 3DM-GX3. It contains three gyroscopes, three accelerometers, a magnetometer that will be used to account for gyroscopic drift during flight, and a thermocouple that is used to measure the different temperatures the rocket is exposed to during flight. These sensors provide flight data to the computer in order to run attitude control and guidance algorithms. The rocket design will also include a PerfectFlite MiniAlt/WD (PF), an AED Electronics R-DAS Tiny, and some additional pressure transducers. The PF will measure the altitude of the rocket from launch to recovery, and send the data to the flight computer. The data will then be used by the energy management algorithms of the science payload. The altitude data will also be used by the recovery system to deploy the drogue parachute. The R-DAS will act as a redundant altimeter if the PF fails. The R-DAS will provide the capability to log data recorded during the flight by the additional pressure transducers. The R-DAS will be used In order to increase the ability to safely and effectively recover the vehicle. This will aid in the successful deployment of the recovery system. The additional pressure transducers installed in the rocket will measure flight data from the aerospike environment. That data will be relayed via the flight computer to the ground terminal, and possibly stored in the onboard memory of the R-DAS.

4.8.3 Telemetry

The Gumstix Overo Fire has a built in Wi-Fi system which will be tested to ensure it can maintain adequate connectivity at a distance of at least one mile; this will be done using a modem with a signal enhancer to see if the signal strength is adequate to reach the requirement. If the Overo fails then a modem transmitter with both a low gain and high gain antenna will be used to maintain the necessary connectivity.

4.9 Scientific Payload

4.9.1 Objectives

The 2010-2011 USU Chimaera team will incorporate a truncated linear aerospike design with the goal of accomplishing two objectives; 1) Acquire pressure measurements of the exhaust plume along the aerospike during flight, and 2) test the feasibility of using an aerospike nozzle as part of an energy management system. The science payload for the rocket will serve as an energy management/thrust augmentation system. The payload was chosen for its ease of integration given the limited space, applicability to the industry, and the chance to collect data that has not yet been collected. Although the concept of the aerospike nozzle has been around for over 50 years, no significant flight data has been gathered. Test engines have been developed for various NASA-funded projects such as the X-33 and Saturn II vehicles, but the programs were canceled before test flights could verify the science. Rocketdyne also conducted some tests during the 1960s, but abandoned the aerospike with the close of the Apollo program.

4.9.2 Plume Affects on Aerospike Nozzle Performance

One of the advantages of aerospike nozzles over traditional bell nozzles are their ability to compensate for altitude. Because of unconstrained flow on the outboard side, the pressure at the end of the spike will always equilibrate to ambient pressure. This means less drag loss on the rocket, and more efficient and predictable thrust according to the equation

$$F_{thrust} = \dot{m} * V_e \tag{6}$$

where F_{thrust} is the thrust, $\dot{m}$ is the mass flow rate of the cold gas, and V_e is the exit velocity. Figure 19, which was developed by Rocketdyne in 1999 for the X-33 aerospike nozzle, shows altitude compensation.

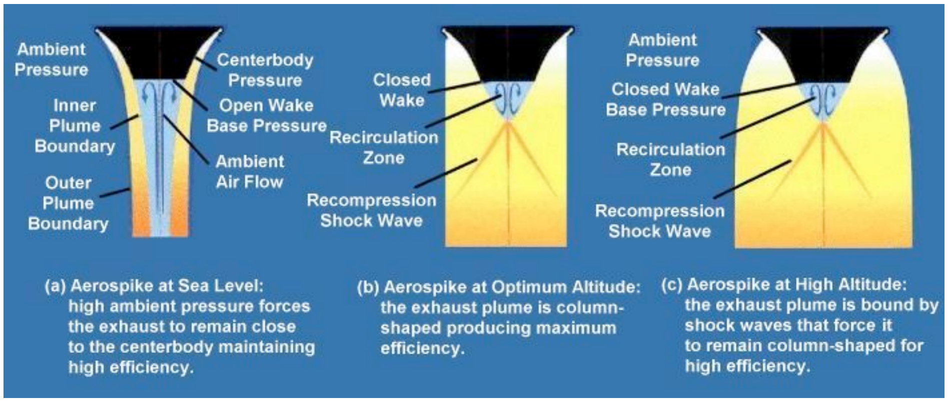


Figure 19: Altitude compensation for aerospike nozzle .

There are cases where the cross-flow will impinge on the aerospike due to compression waves caused by pressure differences. These waves tend to travel down (aft) the spike as altitude increases and pressure decreases. Transducers on the aerospikes will measure the pressure changes as the waves propagate, giving the first meaningful in-flight measurements of the plume effects ever.

For optimal conditions in an aerospike, these compression waves would occur past the end of the spike. Some challenges arise when a spike is truncated like the linear aerospike planned for the 2010-2011 USU Chimaera team design. The aerospikes flying on the Javelin are designed such that a compression wave will travel the length of the spike during flight. As the rocket ascends the team will use pressure measurements along the length of the spike to verify this actually occurs.

4.9.3 Energy Management

The primary purpose of incorporating the aerospike nozzle in this year's rocket design is to serve as a closed loop energy management system. A Kalman filter may be employed as part of this system. The flight computer will take acceleration measurements and estimate the current position of the rocket. Then that position will be compared with a prediction of what the energy state of the rocket should be to reach the desired altitude. If the current estimate falls short of the predicted state, the aerospike will fire to add enough energy to the rocket to reach the desired altitude. A new predicted energy state is calculated, and the process is repeated. Because of the increases in efficiency over the traditional nozzle, the aerospike can fit into a smaller space with less added mass to the rocket while still providing the needed impulse to make the energy management system work.

5 Educational Engagement

It is very important to the USU Chimaera rocket team at USU to have support from the community. Rocket design is a senior project, but the team could not be successful without the immense support and encouragement they receive from the University, interested companies and individuals, and students throughout Cache Valley.

5.1 Community Support

As the reputation of the Chimaera program has spread, the Utah State rocket team has been offered monetary support from several sponsors. The Space Dynamics Laboratory has asked the USU Chimaera team for help in numerous outreach events. The 2010-2011 team has already co-hosted an event on campus this year, in which more than 150 students participated in a hands-on rocket experience. In October they will join with SDL in an event for 200 elementary school students. SDL has offered $5000 toward the development of the rocket.

The team has also received monetary and physical support from NASA Exploration Systems Mission Directorate (ESMD), Rocky Mountain Space Grant Foundation, and Total Impulse Rocketry.

The team is heavily supported and encouraged by the College of Engineering. The team will also solicit funds from the Associated Students of Utah State University (ASUSU) for travel funds. ASUSU sets aside funds for groups on campus engaged in extracurricular educational programs.

5.2 Outreach

Figure 20: Young child with 2008-2009 USU Chimaera team's Pike rocket.

The purpose of Utah State's outreach program is to promote interest in math, science, and engineering education throughout the next generation of young minds. The Utah State team intends to conduct various outreach programs at local schools and in the community in the coming months. One event has already taken place, and several more are in the planning stage.

In an effort to bring the community closer to the project, each child that is affected through the team's outreach program this year will have the opportunity to fly with the rocket. The name of each child they work with will be placed on a flash drive, attached to the rocket, and sent one mile into the atmosphere, "almost to space," as one excited first grader said. This unique opportunity gets even the most disinterested children excited about rockets, space, and what the team is doing.

Aggie Child Day Care Each year, Utah State University holds an activity day on campus for faculty and their families. The USU Chimaera team, in conjunction with SDL, provided an activity booth for the event. Members of the rocket team displayed rocket and lunar lander designs from past USU teams, and talked to children ages 3-15 about rockets, space, and research at USU. With assistance from team members, kids had the opportunity to launch water bottle rockets. Those interested could answer questions about rockets to earn a free water bottle, supplied by SDL. Figures

Figure 21: Aggie Child Day Care event.

Logan High School MESA Club MESA (Math, Engineering, and Science Achievements) is a club designed to introduce women and minorities to the world of math and science, and provide them opportunities to excel in these areas. In November, the USU Chimaera team will visit the Logan High School club. The first week, the students will hear a presentation about rockets and NASA, and they will design and launch their own water bottle rockets.

Hillcrest Elementary School Science Club

On the first Wednesday of every month the USU rocket team will present a hands-on lesson to the Hillcrest Elementary school science club. The club consists of approximately 30 third through fifth grade students who are selected by their teachers to attend because they excel in math and science.

Boy Scout Troop 1 Rocketry is a subject in which boy scouts have the chance to earn a merit badge. The team will host an activity with Troop 1, a local Boy Scouts of America troop, in which they will teach the young boys about rockets and basic aerodynamics and flight principles, and then have them build and launch their own model rockets.

Other School and Community Outreach Several other activities are in the planning stage, including participation in a middle school career day and various MESA club visits. Once they are solidified, activities will be held, similar to those described above.

6 Project Plan

A Gantt chart is currently being maintained for the USU USLI Chimaera rocket team on the team website. The chart lists all critical milestones established by the USLI competition, as well as internal milestones that must be reached in order to design, build, and fly a rocket capable of competing in the competition. A Gantt chart current as of September 30, 2010 can also be found in Appendix . Two of the other project details being tracked by the 2010-2011 USU Chimaera team are an estimated cost of the current design and an estimate of the mass of the current design.

6.1 Estimated Cost

In order to successfully build the rocket and attend the competition, the team will be receiving funds in the form of donations from the institutions listed in table 8. The received amount is expected to be split into two parts: approximately one half will cover the cost of hardware, testing and certifications, and the other will be reserved for future travel and transportation related expenses.

Table 8: Projected income and expenses.

Donations		Expenses	
Space Dynamics Lab	$5,000	Rocket hardware	$5,000
American Institution of Aeronautics and Astronautics	$2,000	Testing and certifications	$3,500
Associated Students of Utah State University	$400	Travel and transportation	$8,400
College of Engineering	$5,000		
Exploration Systems Mission Directorate	$4,500		
Total	$16,900		$16,900

6.2 Mass Budget

Mass prediction for the Javelin is a necessary milestone for the design and selection process. Consequently, the USU Chimaera team must adhere to a strict mass budget and communicate proficiently within the team in order to accurately track any addition of mass into the design of our rocket. As show in Figure below, design, selection, and performance of both the primary solid motor and the secondary payload systems will be greatly determined on how well the Chimaera rocket team can predict the total rocket mass for the USLI competition. Furthermore, accurately predicting mass will assist in creating more practical data during various flight simulations in order to solidify the design of the Javelin. The chart in figure 22 is a projected breakdown of each sub-system for the Chimaera rocket design listing mass subtotals and a grand total of 9.614 kg, excluding the mass of the solid motor.

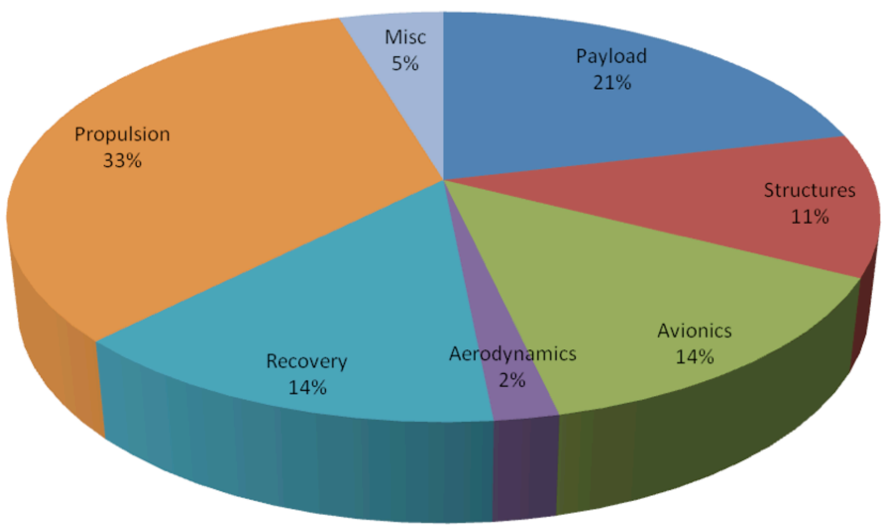


Figure 22: Mass budget comparision.

7 Returning Team Information

The USU Chimaera rocket program has a solid reputation for building and launching rockets at the USLI competition, and involving students in the design and fabrication process. USU also recognizes opportunities provided by the NASA USLI competition and encourages students to take advantage of this opportunity. In order to achieve this goal, USU is implementing NASA's USLI rocket competition as a project alternative for senior design class. This alternative allows students from mechanical, electrical, and aerospace engineering to work together as a team to successfully compete in the USLI competition, apply their education, and earn credits for graduation. To ensure the research and success of the Chimaera program at USU, Dr. Stephen A. Whitmore, Chimaera's program director and a professor in the Mechanical and Aerospace Engineering department, diligently mentors students with his NASA career expertise, providing highly valuable insight concerning the design of the Chimaera rocket according to NASA's USLI regulations. Shannon Eilers, a research graduate working with Dr. Whitmore, has a long history of involvement with the Chimaera project (including being an instructor in previous years). He advises students by drawing from experience gained during previous years of successfully competing in the USLI competition. Such a successful past has built strength and confidence within the engineering community for the Chimaera rocket program, and continues to provide research opportunities for future students interested in rocketry.

Student enthusiasm for the USU Chimaera rocket design team continues to grow. During the 2007-2008 school year, there were sixteen undergraduate students and two graduate students on the team; this year the class has thirteen undergraduate students and one graduate student. Success and continual student interest in the Chimaera rocket project is the result of community outreach as well as the performance of USU's 2008-2009 Chimaera team at the NASA USLI competition. After their successful competition, the rocket team shared their experiences with various junior-level classes to encourage students to join the project. To help ensure continued support from the community and attempt to ensure that all involved knew they were vital in the team's success at the NASA USLI competition the team gave special thanks to all of the faculty and companies who assisted them. This enthusiasm and support creates an excellent foundation at USU for future students to continue to receive hands-on experience through the Chimaera rocket program.

Due to the successes of previous Utah State Chimaera teams in the USLI competition, this year's Chimaera rocket team has lofty standards to reach. The Javelin will build on the test, analysis, and simulation legacy left by previous USU teams; but will bring a completely new energy management concept to the design. The pulsed-thrust application offers a real opportunity to research, apply, and test cutting-edge control algorithms. The linear aerospike nozzle augmentation thrusters are an application of advanced technology that has never been flight-tested. The in-flight pressure measurements will be the first time that plume cross-flow measurements have been obtained flight for a two-dimensional aerospike configuration. Utah State University is leading the way in aerospace research, and the 2010-2011 Chimaera team is proud to continue that legacy.

A 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. If my rocket has on- board ignition systems for motors or recovery devices, these will have safety interlocks that interrupt the current path until the rocket is at the launch pad.

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 no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table, and that a means is available to warn participants and spectators in the event of a problem. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable.

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 detector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 if the rocket motor being launched uses titanium sponge in the propellant.

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, 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.

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

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.

B Contact Information

Rachel Curry	Chemical Hygienist	(435) 797-7423	rachell.curry@usu.edu
Eric Jorgensen	Asst. Director, Environmental Affairs (DOT Issues)	(435) 797-2856	ericj@cc.usu.edu
Raymond Cartee	Director of Research Firms	(435) 797-2209	
Tim Boschert	Tripoli Utah Prefect	(801) 274-8076	tboschert@utah.gov

C Material Safety Data Sheets

Material Safety Data Sheet
(MSDS-BP)

PRODUCT IDENTIFICATION	
Product Name	BLACK POWDER
Trade Names and Synonyms	N/A
Manufacturer/Distributor	GOEX, Inc. (Doyline, LA) & various international sources
Transportation Emergency	**800-255-3924 (24 hrs — *CHEM • TEL*)**

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 handled and used following approved 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. 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				
Material or Component	**%**	**CAS No.**	**TLV**	**PEL**
Potassium nitrate[1]	70-76	007757-79-1	NE	NE
Sodium nitrate[1]	70-74	007631-99-4	NE	NE
Charcoal	8-18	N/A	NE	NE
Sulfur	9-20	007704-34-9	NE	NE
Graphite[2]	Trace	007782-42-5	15 mppct (TWA)	2.5 mg/m^3
N/A = Not assigned NE = Not established				

[1] Black Powder contains either potassium nitrate ***or*** sodium nitrate in the percentages indicated. Black powder ***does not contain both***.

[2] Not contained in all grades of black powder.

PHYSICAL DATA	
Boiling Point	N/A
Vapor Pressure	N/A
Vapor Density	N/A
Solubility in Water	Good
Specific Gravity	1.70 - 1.82 (mercury method) ◆ 1.92 - 2.08 (pycnometer)
PH	6.0 - 8.0
Evaporation Rate	N/A
Appearance and Odor	Black granular powder. No odor detectable.

HAZARDOUS REACTIVITY	
Instability	Keep away from heat, sparks, and open flame. Avoid impact, friction, and static electricity.
Incompatibility	When dry, black powder is compatible with most metals; however, it is hygroscopic, and when wet, attracts 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). Gases produced may be toxic if exposed in areas with inadequate ventilation.
Polymerization	Polymerization will not occur.

FIRE AND EXPLOSION DATA	
Flashpoint	Not applicable
Auto ignition temperature	Approx. 464°C (867°F)
Explosive temperature (5 sec)	Ignites @ approx. 427°C (801°F)
Extinguishing media	Water
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 5000 feet (1 mile) if explosives are heavily encased. Division 1.1 Explosives (not heavily encased): Evacuate the area for 2500 feet (½ mile) if explosives are not heavily encased. Division 1.1 Explosives (all): Consult the *2000 Emergency Response Guidebook, 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, regulations, 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.
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, induce vomiting immediately by giving two glasses of water and sticking finger down throat.
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 cleanup 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.
Respiratory	None
Eye	None
Gloves	Impervious rubber gloves.
Other	Metal-free *and* non-static producing clothes

SPECIAL PRECAUTIONS

- Keep away from friction, impact, and heat. 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		
Proper shipping name	Black powder	
Hazard class	1.1D	
UN Number	UN0027	
DOT Label & Placard	DOT Label	EXPLOSIVE 1.1D
	DOT Placard	EXPLOSIVES 1.1
Alternate shipping information	Limited quantities of black powder may be transported as "Black powder, flammable solid" pursuant to U.S. Department of Transportation Exemption DOT-E 8958.	

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 and independent laboratories, it is given without warranty or representation that it is complete, accurate, and can be relied upon. *OWEN COMPLIANCE SERVICES, INC.* has not attempted to conceal in any manner the deleterious aspects of the product listed herein, but makes no warranty as to such. Further, *OWEN COMPLIANCE SERVICES, INC.* 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:

David W. Boston, President
OWEN COMPLIANCE SERVICES, INC.
12001 County Road 1000
P.O. Box 765
Godley, TX 76044
Telephone number: 817-551-0660
FAX number: 817-396-4584

MSDS prepared by:

David W. Boston
Original publication date: 12/08/93
Revision date: 12/03/03

MSDS

SECTION 1 – Chemical Product and Company Identification

J-B Weld Company

P.O. Box 483
1130 Como Street
Sulphur Springs, TX 75482
Tel: (903) 885-7696
Fax: (903) 885-5911

PRODUCT NAME:	**JB Weld Epoxy Steel Hardener**
PRODUCT CODE:	**(48008), 48105, 48155, 48171**
SYNONYM/CROSS REFERENCE:	**Epoxy Steel Hardener**
SCHEDULE B NUMBER:	**3214.10.0090**

SECTION 2 – Hazard Identification

OVEREXPOSURE EFFECTS:
ACUTE EFFECTS:
EYES: Contact with eyes can cause severe irritation, possible irreparable eye damage.
SKIN: Contact with skin can cause irritation, (minor itching, burning and/or redness), Dermatitis, defatting may be readily absorbed through the skin.
INHALATION: Inhalation of vapors can cause nasal and respiratory irritation, dizziness, weakness, fatigue, nausea, headache, possible unconsciousness and/or asphyxiation. Aspiration of material into lungs may result in chemical pneumonitis which can be fatal.
INGESTION: Ingestion can cause gastrointestinal irritation, nausea, vomiting, diarrhea.

PRIMARY ROUTES OF EXPOSURE: skin, inhalation

SECTION 3 – Composition, Information or Ingredients

INGREDIENTS	**WGT%**	**CAS #**
Furfuryl Alcohol	1-5%	98-00-0
Calcium Carbonate	5-10%	1317-65-3, 471-34-1
Non-fibrous Talc	15-25%	14807-96-6
Barium Sulfate	20-30%	7727-43-7
Aminophenols	1-5 %	Mixture
Polyamide Resin	15-25%	68410-23-1
Titanium Dioxide	1-5%	13463-67-7

SECTION 4 – First Aid Measures

INHALATION: If inhaled, remove victim from exposure to a well-ventilated area. Make them comfortably warm, but not hot. Use oxygen or artificial respiration as required. Consult a physician.
SKIN: For skin contact, wash promptly with soap and excess water.
EYES: For eye contact, flush promptly with excess water for at least fifteen minutes. Consult a physician.
INGESTION: If ingested, do not induce vomiting. Give victim a glass of water. Call a physician immediately.

MSDS

SECTION 5 – Fire-Fighting Measures

FLASH POINT: >200°F/93°C Seta Flash Closed cup
LOWER FLAMMABLE LIMIT %: N/E
UPPER FLAMMABLE LIMIT %: N/E
FIRE EXTINGUISHING MEDIA: Carbon Dioxide, Dry Chemical, Foam
SPECIAL FIRE FIGHTING PROCEDURES: Fight like a fuel oil fire. Cool fire exposed containers with water spray. Firefighter should wear OSHA/NIOSH approved self-contained breathing apparatus.
UNUSUAL FIRE AND EXPLOSION HAZARD: Closed containers exposed to high temperatures, such as fire conditions may rupture.

SECTION 6 – Accidental Release Measures

SPILLS, LEAK OR RELEASE: Ventilate area. Remove all possible sources of ignition. Avoid prolonged breathing of vapor. Contain spill with inert absorbent.

SECTION 7 – Handling and Storage

STORAGE AND HANDLING: Use with adequate ventilation. Avoid contact with eyes and skin. Avoid breathing vapors. Do not store the product above 100°F/38°C. Do not flame, cut, braze weld or melt empty containers. Keep the product away from heat, open flame, and other sources of ignition. Avoid contact with strong acids, alkalis, and oxidizers.

SECTION 8 – Exposure Controls and Personal Protection

INGREDIENTS	CAS #	TLV/PEL
Calcium Carbonate	1317-65-3 471-34-1	ACGIH TWA 10 mg/m^3 OSHA PEL 15 mppcf
Non-fibrous Talc	14807-96-6	ACGIH TWA 2 mg/m^3 OSHA PEL 20 mppcf
Barium Sulfate	7727-43-7	ACGIH TWA 10 mg/m^3 OSHA 15 mg/m^3 Total dust OSHA 15 mg/m^3 Respirable dust
Aminophenols	Mixture	N/E
Polyamide Resin	68410-23-1	N/E
Titanium Dioxide	13463-67-7	ACGIH TWA 10 mg/m^3 OSHA PEL 20 mg/m^3
Furfuryl Alcohol	98-00-0	ACGIH TWA 10 ppm

RESPIRATORY PROTECTION: If component TLV limits are exceeded, use NIOSH/MSHA approved respirator to remove vapors. Use an air-supplied respirator if necessary.
VENTILATION: Use adequate ventilation in volume and pattern to keep TLV/PEL below recommended levels. Explosion-proof ventilation may be necessary.
PROTECTIVE GLOVES: To prevent prolonged exposure use rubber gloves; solvents may be absorbed through the skin.
EYE PROTECTION: Safety Glasses or goggles with splash guards or side shields.
OTHER PROTECTIVE EQUIPMENT: Wear protective clothing as required to prevent skin contact.

ACTION 9 – Physical and Chemical Properties

APPEARANCE: White Paste
SPECIFIC GRAVITY: 1.78
VAPOR PRESSURE (mmHG): Heavier than air
BOILING POINT: N/Av
VAPOR DENSITY: Heavier than air
EVAPORATION RATE (Ethyl Ether = 1): Slower than Ethyl Ether
VOLATILES BY WEIGHT:
SOLUBILITY IN WATER: None
VOC: Grams/Liter = 72
Lbs/Gallon = 0.6

SECTION 10 – Stability and Reactivity

STABILITY: Stable
CONDITIONS TO AVOID: Open flames, sparks, heat, electrical and static discharge.
INCOMPATIBILITY MATERIALS TO AVOID: Strong acids, alkalis, oxidizers.
HAZARDOUS DECOMPOSITION PRODUCTS: Carbon Dioxide, Carbon Monoxide, and Carbon.
HAZARDOUS POLYMERIZATION: Will not occur.

SECTION 11 – Toxicological Information

CHRONIC EFFECTS:
Overexposure to this material has apparently been known to cause the following effects in lab animals: Eye, skin, lung, and central nervous system damage.

CARCINOGEN: YES __ NO X
TERATOGEN: YES __ NO X
MUTAGEN: YES __ NO X

SECTION 12 – Ecological Information

NOT A MARINE POLLUTANT

SECTION 13 – Disposal Considerations

WASTE DISPOSAL: Dispose of in accordance with local, state, and federal regulations.

SECTION 14 – Transport Information

For Ground Transport: In USA
Not Regulated

For Air Transport:
Not Regulated

For Ocean Transport:
Not Regulated

MSDS

SECTION 15 – Regulatory Information

CALIFORNIA PROPOSITION 65:
Trace amounts of some chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm may be present in this product.

SECTION 313 SUPPLIER NOTIFICATION:
This product contains the following toxic chemicals subject to the reporting requirements of the Emergency Planning and Community Right-To-Know Act of 1986 and 40 CFR 372:

CHEMICAL NAME	CAS	% BY WGT

N/Ap

This information must be included in all MSDS that are copied and distributed for this chemical.

SECTION 16 – Other Information

HMIS RATING:			
	Health	2	4 = Extreme
	Fire	1	3 = High
	Reactivity	1	2 = Moderate
			1 = Slight
			0 = Insignificant

Personal Protection - See Section VIII

ABBREVIATIONS

IARC	= International Agency for Research on Cancer
ACGIH	= American Conference of Governmental Industrial Hygienists
NIOSH	= National Institute of Occupational Safety and Health
TLV	= Threshold Limit Value
PEL	= Permissible Emission Level
DOT	= Department of Transportation
NTP	= National Toxicology Program
N/AV	= Not Available
N/AP	= Not Applicable
N/E	= Not Established
N/D	= Not Determined

MSDS

PREPARED BY: **J-B Weld Company**

P.O. Box 483
1130 Como Street
Sulphur Springs, TX 75482
Tel: (903) 885-7696
Fax: (903) 885-5911

DATE REVIEWED: February 6, 2009
DATE REVISED: February 6, 2009
REVISION: New Format

The information in the Material Safety Data Sheet has been compiled from our experience and from data presented in various technical publications. It is the user's responsibility to determine the suitability of this information for the adoption of the safety precautions as may be necessary. We reserve the right to revise Material Safety Data Sheets from time to time as new technical information becomes available. The user has the responsibility to contact the Company to make sure that the MSDS is the latest one issued.

J-B Weld Company

P.O. Box 483
1130 Como Street
Sulphur Springs, TX 75482
Tel: (903) 885-7696
Fax: (903) 885-5911

SECTION I - IDENTIFICATION OF PRODUCT

PRODUCT NAME:	JB WELD - EPOXY STEEL RESIN
PRODUCT CODE:	(48009), 48102, 48153, 48170
SYNONYM/CROSS REFERENCE:	Resin Solution
SCHEDULE B NUMBER:	3506.91.0000

SECTION II - HAZARDOUS INGREDIENTS

INGREDIENTS	WGT%	CAS #	TLV/PEL
Calcium Carbonate	40-50%	1317-65-3	ACGIH: TWA 10 mg/m^3 OSHA: PEL 15 mppcf
Iron Powder	10-20%	65997-19-5	ACGIH TLV 15 mg/m^3 OSHA: PEL 15 mppcf
Epoxy Resin	30-40%	25068-38-6	N/E
Aromatic Hydrocarbons	1-5 %	64742-94-5	N/E

SECTION III - PHYSICAL DATA

APPEARANCE: Dark gray or black smooth paste
SPECIFIC GRAVITY: 1.80
VAPOR PRESSURE (mmHG): N/Av
BOILING POINT: N/E
VAPOR DENSITY: Heavier than air
EVAPORATION RATE (Ethyl Ether = 1): Slower than Ethyl Ether
VOLATILES BY WEIGHT: N/D
SOLUBILITY IN WATER: Not Soluble
VOC: Grams/Liter = Nil
Lbs/Gallon = Nil

SECTION IV - FIRE AND EXPLOSION DATA

FLASH POINT: >200°F/ 93°C Seta Flash Closed cup
LOWER FLAMMABLE LIMIT %: N/E
UPPER FLAMMABLE LIMIT %: N/E
FIRE EXTINGUISHING MEDIA: Carbon Dioxide, Dry Chemical, Foam
SPECIAL FIRE FIGHTING PROCEDURES: Fight like a fuel oil fire. Cool fire exposed containers with water spray. Firefighter should wear OSHA/NIOSH approved self-contained breathing apparatus.
UNUSUAL FIRE AND EXPLOSION HAZARD: Closed containers exposed to high temperatures, such as fire conditions may rupture.

SECTION V - HEALTH HAZARD/TOXICOLOGICAL PROPERTIES

OVEREXPOSURE EFFECTS:

ACUTE EFFECTS:

EYES: Contact with eyes can cause irritation, redness, tearing, blurred vision, and/or swelling.
SKIN: Contact with skin can cause irritation, (minor itching, burning and/or redness), Dermatitis, defatting may be readily absorbed through the skin.
INHALATION: Inhalation of vapors can cause nasal and respiratory irritation, dizziness, weakness, fatigue, nausea, headache, possible unconsciousness and/or asphyxiation. Aspiration of material into lungs may result in chemical pneumonitis which can be fatal.
INGESTION: Ingestion can cause gastrointestinal irritation, nausea, vomiting, diarrhea.

CHRONIC EFFECTS:
Overexposure to this material has apparently been known to cause the following effects in lab animals: skin sensitization, respiratory system irritation.

CARCINOGEN: YES _____ NO __X__
TERATOGEN: YES _____ NO __X__
MUTAGEN: YES _____ NO __X__

PRIMARY ROUTES OF EXPOSURE: skin, inhalation, eyes

FIRST AID:

INHALATION: If inhaled, remove victim from exposure to a well-ventilated area. Make them comfortably warm, but not hot. Use oxygen or artificial respiration as required. Consult a physician.
SKIN: For skin contact, wash promptly with soap and excess water.
EYES: For eye contact, flush promptly with excess water for at least fifteen minutes. Consult a physician.
INGESTION: If ingested, do not induce vomiting. Give victim a glass of water. Call a physician immediately.

SECTION V I - REACTIVITY DATA

STABILITY: Stable
CONDITIONS TO AVOID: Open flames & heat. .
INCOMPATIBILITY MATERIALS TO AVOID: Strong acids, alkalis, oxidizers.
HAZARDOUS DECOMPOSITION PRODUCTS: Carbon Dioxide, Carbon Monoxide and Carbon.
HAZARDOUS POLYMERIZATION: Will not occur.

SECTION VII - SPILL AND DISPOSAL PROCEDURE

SPILLS, LEAK OR RELEASE: Ventilate area. Remove all possible sources of ignition. Avoid prolonged breathing of vapor. Contain spill with inert absorbent.
WASTE DISPOSAL: Dispose of in accordance with local, state, and federal regulations.

SECTION VIII - PROTECTION INFORMATION

RESPIRATORY PROTECTION: If component TLV limits are exceeded, use NIOSH/MSHA approved respirator to remove vapors. Use an air-supplied respirator if necessary. With general ventilation, does not require a respirator.
VENTILATION: Use adequate ventilation in volume and pattern to keep TLV/PEL below recommended levels.
PROTECTIVE GLOVES: To prevent prolonged exposure use rubber gloves; solvents may be absorbed through the skin
EYE PROTECTION: Safety Glasses or goggles with splash guards or side shields.
OTHER PROTECTIVE EQUIPMENT: Wear protective clothing as required to prevent skin contact.

SECTION IX - HANDLING AND STORAGE PRECAUTIONS

STORAGE AND HANDLING: Use with adequate ventilation. Avoid contact with eyes and skin. Avoid breathing vapors. Do not store the product above 100®F/38®C. Do not flame, cut, braze weld or melt empty containers. Keep the product away from heat, open flame, and other sources of ignition. Avoid contact with strong acids, alkalis and oxidizers.

SECTION X - ADDITIONAL INFORMATION

SHIPPING INFORMATION: Please comply with DOT regulations in USA

HMIS RATING:	Health	2	4 = Extreme
	Fire	1	3 = High
	Reactivity	1	2 = Moderate
			1 = Slight
			0 = Insignificant

Personal Protection - See Section VIII

CALIFORNIA PROPOSITION 65:

Trace amounts of epichlorohydrin, a chemical known to the State of California to cause cancer, are present in this product. However, given the low level and application of this product, typical uses do not constitute a significant risk under the standard.

SECTION 313 SUPPLIER NOTIFICATION:

This product contains the following toxic chemicals subject to the reporting requirements of the Emergency Planning and Community Right-To-Know Act of 1986 and 40 CFR 372:

CHEMICAL NAME	CAS	% BY WGT

Not Applicable

THIS INFORMATION MUST BE INCLUDED IN ALL MSDS THAT ARE COPIED AND DISTRIBUTED FOR THIS CHEMICAL

ABBREVIATIONS

IARC = International Agency for Research on Cancer
ACGIH = American Conference of Governmental Industrial Hygienists
NIOSH = National Institute of Occupational Safety and Health
TLV = Threshold Limit Value
PEL = Permissible Emission Level
DOT = Department of Transportation
NTP = National Toxicology Program
N/AV = Not Available
N/AP = Not Applicable
N/E = Not Established
N/D = Not Determined

PREPARED FOR: **J-B Weld Company**

P.O. Box 483
1130 Como Street
Sulphur Springs, TX 75482
Tel: (903) 885-7696
Fax: (903) 885-5911

REVIEWED ON	May 17, 2004
SUPERSEDES	March 1, 2003
REVISION	Format

The information in the Material Safety Data Sheet has been compiled from our experience and from data presented in various technical publications. It is the user's responsibility to determine the suitability of this information for the adoption of the safety precautions as may be necessary. We reserve the right to revise Material Safety Data Sheets from time to time as new technical information becomes available. The user has the responsibility to contact the Company to make sure that the MSDS is the latest one issued.

5-MINUTE EPOXY GEL RESIN

This product appears in the following stock number(s):
14240 14240G 14265 6206 DA052 DA221 DA240

Last revised: 06/10/04
Printed: 7/2/2004

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Tradename: 5-MINUTE EPOXY GEL RESIN

Product Identifier: EPOXY RESIN

General use: This information applies to the resin component of the two-part kit; handle freshly-mixed resin and hardener as recommended for the hardener. After curing, the product is not hazardous.

Chemical family: Epoxy resin

MANUFACTURER

ITW Devcon
30 Endicott St.
Danvers, MA 01923

EMERGENCY INFORMATION

Emergency telephone number
(CHEMTREC): (800) 424-9300
Other Calls: (978) 777-1100

2. COMPOSITION/INFORMATION ON INGREDIENTS

HAZARDOUS CONSTITUENTS **Exposure limits**

Constituent	Abbr.	CAS No.	Weight percent	ACGIH TLV	OSHA PEL	Other Limits
Bisphenol A diglycidyl ether resin	DGEBPA	25068386	70-90	n/e	n/e	n/e
Phenol, polymer with formaldehyde, glycidyl ether		28064144	10-20	n/e	n/e	n/e

"TLV" means the Threshold Limit Value exposure (eight-hour, time-weighted average, unless otherwise noted) established by the American Conference of Governmental Industrial Hygienists. "STEL" indicates a short-term exposure limit. "PEL" indicates the OSHA Permissible Exposure Limit."n/e" indicates that no exposure limit has been established. An asterisk (*) indicates a substance whose identity is a trade secret of our supplier and unknown to us.

3. HAZARDS IDENTIFICATION

Emergency Overview

Appearance, form, odor: viscous liquid with little odor.

WARNING! Eye and skin irritant. Potential skin sensitizer.

Potential health effects

Primary routes of exposure: ☒ Skin contact ☐ Skin absorption ☒ Eye contact ☐ Inhalation ☐ Ingestion

Symptoms of acute overexposure:

Skin: Moderate irritant. Contact at elevated temperatures can cause thermal burns which may result in permanent damage. May cause skin sensitization (itching, redness, rashes, hives, burning, swelling).

Eyes: Moderate irritant (stinging, burning sensation, tearing, redness, swelling). Contact at elevated temperatures can cause thermal burns which may result in permanent damage or blindness.

Inhalation:
The low vapor pressure of the resin makes inhalation unlikely in normal use. In applications where vapors (caused by high temperature) or mists (caused by mixing) are created, breathing may cause a mild burning sensation in the nose, throat and lungs.

Ingestion:
Acute oral toxicity is low. May cause gastric distress (nausea, vomiting, diarrhea).

Effects of chronic overexposure:
Prolonged or repeated skin contact may cause sensitization, with itching, swelling, or rashes on later exposure.

Carcinogenicity -- **OSHA regulated: No** **ACGIH: No** **National Toxicology Program: No**
International Agency for Research on Cancer: No
Cancer-suspect constituent(s) : None

Medical conditions which may be aggravated by exposure:
Preexisting eye and skin disorders (e.g. eczema). Development of preexisting skin or lung allergy symptoms may increase.

Other effects:
See section 11.

4. FIRST AID MEASURES

First aid for eyes:
Flush eye with clean water for at least 20 minutes while gently holding eyelids open, lifting upper and lower lids. Get immediate medical attention.

First aid for skin:
Immediately remove contaminated clothing and excess contaminant. Flush skin with water for at least 15 minutes. Wash thoroughly with soap and warm water. Consult a physician if irritation develops.

First aid for inhalation:
Remove patient to fresh air. Administer oxygen if breathing is difficult. Get medical attention if symptoms persist.

First aid for ingestion:
Do NOT induce vomiting. Rinse mouth out with water, then sip water to remove taste from mouth. Never give anything by mouth to an unconscious person. If vomiting occurs spontaneously, keep head below hips (if sitting) or to the side (if lying down) to prevent aspiration. Get medical attention.

5. FIRE FIGHTING MEASURES

Extinguishing media:

- ☐ Water
- ☒ Carbon dioxide
- ☒ Dry chemical
- ☒ Foam
- ☐ Alcohol foam

Flash Point (°F): >400 **Method:** PMCC

Explosive limits in air (percent) -- **Lower:** n/d **Upper:** n/d

Special firefighting procedures:
Material will not burn unless preheated. Do not enter confined space without full bunker gear. Firefighters should wear self-contained breathing apparatus and protective clothing. Cool fire exposed containers with water.

Unusual fire and explosion hazards:
Heating above 300 deg F in the presence of air may cause slow oxidative decomposition and above 500 deg F may cause polymerization. Personnel in vicinity and downwind should be evacuated.

Hazardous products of combustion:
When heated to decomposition it emits fumes of Cl- , carbon monoxide, other fumes and vapors varying in composition and toxicity.

6. ACCIDENTAL RELEASE MEASURES

Spill control:
Avoid personal contact. Eliminate ignition sources. Ventilate area.

Containment:
Dike, contain and absorb with clay, sand or other suitable material.

Cleanup:
For large spills, pump to storage/salvage vessels. Soak up residue with an absorbent such as clay, sand, or other suitable material and dispose of properly. Flush area with water to remove trace residue.

Special procedures:
Prevent spill from entering drainage/sewer systems, waterways, and surface waters. Collect run-off water and transfer to drums or tanks for later disposal. Notify local health authorities and other appropriate agencies if such contamination occurs.

7. HANDLING AND STORAGE

Handling precautions:
Avoid contact with skin, eyes, or clothing. Wash thoroughly with soap and water after using and particularly before eating, drinking, smoking, applying cosmetics, or using toilet facilities.
Launder contaminated clothing and protective gear before reuse. Discard contaminated leather articles.
Handle mixed resin and hardener in accordance with the potential hazard of the curing agent used. Provide appropriate ventilation/respiratory protection against decomposition products (see Section 10) during welding/flame cutting operations and to protect against dust during sanding/grinding of cured product.

Storage:
Store in a cool, dry area away from high temperatures and flames.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering controls

Ventilation :
Use ventilation that is adequate to keep employee exposure to airborne concentrations below exposure limits (or to the lowest feasible levels when limits have not been established). Although good general mechanical ventilation is usually adequate for most industrial applications, local exhaust ventilation is preferred (see ACGIH - Industrial Ventilation). Local exhaust may be required for confined areas (see OSHA 1910.146).

Other engineering controls :
Have emergency shower and eye wash available.

Personal protective equipment

Eye and face protection:
Chemical goggles if liquid contact is likely, or Safety glasses with side shields.

Skin protection:
Chemical-resistant gloves (i.e. butyl) and other gear as required to prevent skin contact.

Respiratory protection:
None needed in normal use with proper ventilation. In poorly ventilated areas use NIOSH approved organic vapor cartidge respirator for uncured resin, dust/particle respirator during grinding/sanding operations for cured resin, or fresh airline respirator as exposure levels dictate (see OSHA 1910.134).

9. PHYSICAL AND CHEMICAL PROPERTIES

Specific gravity:	1.1-1.3	**Boiling point (°F):**	>500
Melting point (°F):	n/d	**Vapor density (air = 1):**	>1
Vapor pressure (mmHg):	0.03 mm Hg at 171 °F	**Evaporation rate (butyl acetate = 1):**	<<1
VOC (grams/liter):	0	**Solubility in water:**	Negligible
Percent volatile by volume:	0	**pH (5% solution or slurry in water):**	neutral
Percent solids by weight:	100		

10. STABILITY AND REACTIVITY

This material is chemically stable. Hazardous polymerization will not occur.

Conditions to avoid :
Open flame and extreme heat

Incompatible materials:
Strong Lewis or mineral acids, strong oxidizing agents, strong mineral and organic bases (especially primary and secondary aliphatic amines).

Hazardous products of decomposition:
Oxides of carbon; aldehydes, acids and other organic substances may be formed during combustion or elevated temperature (>500 deg F) degradation.

Conditions under which hazardous polymerization may occur:
Heat is generated when resin is mixed with curing agents; Run-a-way cure reactions may char and decompose the resin, generating unidentified fumes and vapors which may be toxic.

11. TOXICOLOGICAL INFORMATION

Acute oral effects: LD50 (rat): Not available.

Acute dermal effects: LD50 (rabbit): Not available.

Acute inhalation effects: LC50 (rat): Not available. Exposure: 4 hours.

Eye irritation:
Not available.

Subchronic effects:
No data available.

Carcinogenicity, teratogenicity, and mutagenicity:
1) MUTAGENICITY: Liquid resins based on diglycidyl ether of Bisphenol A (DGEBPA), have proved to be inactive when tested by in vivo mutagenicity assays. These resins have shown activity in in vitro microbial mutagenicity

screening and have produced chromosomal aberrations in cultured rat liver cells. The significance of these tests to man is unknown. 2) CARCINOGENICITY: Recent 2-year bioassays in rats and mice exposed by the dermal route to DGEBPA yielded no evidence of carcinogenicy to the skin or any other organs. This study clarifies prior equivocal results from a 2-year mouse skin painting study, which were suggestive, but not conclusive, for weak carcinogenic activity. 3) The International Agency for Research on Cancer (IARC) concluded that DGEBPA is not classifiable as a carcinogen (IARC group 3), that is human and animal evidence of carcinogenicy is inadequate.

Other chronic effects:

Prolonged or repeated skin contact may cause sensitization, with itching, swelling, or rashes on later exposure. Studies have shown bisphenol A diglycidyl ether resin to cause allergic contact dermititis.

Toxicological information on hazardous chemical constituents of this product:

Constituent	Oral LD50 (rat)	Dermal LD50 (rabbit)	Inhalation LC50 4hr, (rat)
Bisphenol A diglycidyl ether resin	11.4 g/kg	>20 ml/kg	no deaths
Phenol, polymer with formaldehyde, glycidyl ether	> 5000 mg/kg	> 6000 mg/kg	> 1.7 mg/L

'n/d' = 'not determined'

12 ECOLOGICAL INFORMATION

Ecotoxicity:

No data available.

Mobility and persistence:

No data available.

Environmental fate:

No data available.

13. DISPOSAL CONSIDERATIONS

Please see also Section 15, Regulatory Information.

Waste management recommendations:

If this resin becomes a waste, it would not be a hazardous waste by RCRA criteria (40CFR 261). Dispose of according to applicable federal, state, and local regulations. Incineration is the preferred method of disposal.

14. TRANSPORT INFORMATION

Proper shipping name: Non-regulated
Technical name : N/A
Hazard class : N/A
UN number: N/A
Packing group: N/A
Emergency Response Guide no.: N/A
IMDG page number: N/A
Other: N/A

15. REGULATORY INFORMATION

U.S. Federal Regulations

TSCA
All ingredients of this product are listed, or are exempt from listing, on the TSCA inventory.

The following RCRA code(s) applies to this material if it becomes waste:
None

Regulatory status of hazardous chemical constituents of this product:

Constituent	Extremely Hazardous*	Toxic Chemical**	CERCLA RQ (lbs)	TSCA 12B Export Notification
Bisphenol A diglycidyl ether resin	No	No	0.0	Not required
Phenol, polymer with formaldehyde, glycidyl ether	No	No	0.0	Not required

*Consult the appropriate regulations for emergency planning and release reporting requirements for substances on the SARA Section 301 Extremely Hazardous Substance list.

**Substances for which the "Toxic Chemical" column is marked "Yes" are on the SARA Section 313 list of Toxic Chemicals, for which release reporting may be required. For specific requirements, consult the appropriate regulations.

For purposes of SARA Section 312 hazardous materials inventory reporting, the following hazard classes apply to this material: - Immediate health hazard -- Delayed health hazard -

Canadian regulations

WHMIS hazard class(es) : D2B
All components of this product are on the Domestic Substances List.

16. OTHER INFORMATION

Hazardous Materials Identification System (HMIS) ratings:	Health	Flammability	Reactivity
	2*	1	1

The information and recommendations in this document are based on the best information available to us at the time of preparation, but we make no other warranty, express or implied, as to its correctness or completeness, or as to the results of reliance on this document.

5-MINUTE EPOXY GEL HARDENER

This product appears in the following stock number(s):
14240 14240G 14265 5348 5368 DA052 DA221 DC048

Last revised: 08/12/02
Printed: 7/2/2004

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Tradename: 5-MINUTE EPOXY GEL HARDENER

General use: The following information applies to the hardener component of the two-part kit and to freshly mixed resin and hardener. After curing, 5-Minute Epoxy Gel is not hazardous.

Chemical family: Polymercaptan/polyamine mixture

MANUFACTURER

ITW Devcon
30 Endicott St.
Danvers, MA 01923

EMERGENCY INFORMATION

Emergency telephone number
(CHEMTREC): (800) 424-9300
Other Calls: (978) 777-1100

2. COMPOSITION/INFORMATION ON INGREDIENTS

HAZARDOUS CONSTITUENTS

Exposure limits

Constituent	Abbr.	CAS No.	Weight percent	ACGIH TLV	OSHA PEL	Other Limits
Mercaptan amine blend		*	30-50	n/e	n/e	n/e
Polymercaptan curing agent		*	50-60	n/e	n/e	n/e

"TLV" means the Threshold Limit Value exposure (eight-hour, time-weighted average, unless otherwise noted) established by the American Conference of Governmental Industrial Hygienists. "STEL" indicates a short-term exposure limit. "PEL" indicates the OSHA Permissible Exposure Limit."n/e" indicates that no exposure limit has been established. An asterisk (*) indicates a substance whose identity is a trade secret of our supplier and unknown to us.

3. HAZARDS IDENTIFICATION

Emergency Overview

Appearance, form, odor: Viscous, amber liquid with Mercaptan odor.

WARNING! Eye, skin and respiratory irritant. Potential skin sensitizer. Overexposure may cause delayed lung effects.

Potential health effects

Primary routes of exposure: [X] Skin contact [ ] Skin absorption [X] Eye contact [X] Inhalation [ ] Ingestion

Symptoms of acute overexposure:

Skin: Can cause severe irritation, especially on prolonged contact. Potential sensitizer.

Eyes: Causes severe irritation with possible permanent damage and even blindness.

Inhalation:
Considered slightly toxic. Can cause irritation of respiratory tract. Over exposure to fumes or vapors may cause delayed lung injury and chemical pneumonia.

Ingestion:
Slightly toxic. May cause fatigue, muscle weakness, gastrointestinal irritation, nausea, vomiting and diarrhea.

Effects of chronic overexposure:
Prolonged or severe overexposure to DMP vapor can cause delayed lung damage and chemical pneumonia. Prolonged or repeated contact with this material may cause skin sensitization.

Carcinogenicity -- **OSHA regulated: No** **ACGIH: No** **National Toxicology Program: No**
International Agency for Research on Cancer: No
Cancer-suspect constituent(s) : None

Medical conditions which may be aggravated by exposure:
May aggravate existing skin, eye, and lung conditions.

4. FIRST AID MEASURES

First aid for eyes:
Flush eye with clean water for at least 15 minutes while gently holding eyelids open. Get immediate medical attention.

First aid for skin:
Remove contaminated clothing and shoes. Wash thoroughly with soap and warm water. Consult a physician if irritation develops.

First aid for inhalation:
Remove patient to fresh air. Provide oxygen if breathing is difficult. Consult a physician if symptoms persist.

First aid for ingestion:
Do not induce vomiting. Give large amounts of water followed by milk if available. Consult a physician.

5. FIRE FIGHTING MEASURES

General fire and explosion characteristics:
Class IIIB.

Extinguishing media:
☐ Water ☒ Carbon dioxide ☒ Dry chemical ☒ Foam ☐ Alcohol foam

Flash Point (°F): >200 **Method:** PMCC

Explosive limits in air (percent) -- **Lower:** n/d **Upper:** n/d

Special firefighting procedures:
Firefighters should wear self-contained breathing apparatus and protective clothing in confined areas. Cool containers with water spray.

Unusual fire and explosion hazards:
Toxic smoke and vapors may form during combustion.

Hazardous products of combustion:
Oxides of carbon, oxides of sulfur, oxides of nitrogen.

6. ACCIDENTAL RELEASE MEASURES

Spill control:
Avoid personal contact. Eliminate ignition sources. Ventilate area.

Containment:

Dike, contain and absorb with clay, sand or other suitable material.

Cleanup:

For large spills, pump to storage/salvage vessels. Soak up residue with an absorbent such as clay, sand, or other suitable material and dispose of properly. Flush area with water to remove trace residue. Clean-up waste water should be placed in appropriate containers for proper disposal.

Special procedures:

Prevent spill from entering drainage/sewer systems, waterways, and surface waters. Collect run-off water and transfer to drums or tanks for later disposal. Notify local health authorities and other appropriate agencies if such contamination occurs.

7. HANDLING AND STORAGE

Handling precautions:

Avoid contact with skin, eyes, or clothing. Wash thoroughly with soap and water after using and particularly before eating, drinking, smoking, applying cosmetics, or using toilet facilities.
Launder contaminated clothing and protective gear before reuse. Discard contaminated leather articles.
Handle mixed resin and hardener in accordance with the potential hazard of the curing agent used. Provide appropriate ventilation/respiratory protection against decomposition products (see Section 10) during welding/flame cutting operations and to protect against nuisance dust during sanding/grinding of cured product.

Storage:

Store in a cool, dry area away from high temperatures and flames. Keep container tightly closed when not in use.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering controls

Ventilation :

General mechanical ventilation is adequate for occasional use. For prolonged or repeated use, local exhaust is recommended.

Other engineering controls :

Have emergency shower and eye wash stations available.

Personal protective equipment

Eye and face protection:

Safety glasses with sideshields or chemical goggles.

Skin protection:

Chemical-resistant rubber (for example, neoprene, butyl rubber or nitrile) gloves and other protective gear as needed to prevent skin contact.

Respiratory protection:

None needed in normal use with proper ventilation. In poorly ventilated areas use NIOSH approved organic vapor cartidge respirator for uncured resin, dust/particle respirator during grinding/sanding operations for cured resin, or fresh airline respirator as exposure levels dictate (see OSHA 1910.134).

9. PHYSICAL AND CHEMICAL PROPERTIES

Specific gravity:	1.13	**Boiling point (°F):**	n/d
Melting point (°F):	n/d	**Vapor density (air = 1):**	n/d
Vapor pressure (mmHg):	<<1 at 70 °F	**Evaporation rate (butyl acetate = 1):**	n/d
VOC (grams/liter):	0	**Solubility in water:**	Negligible
Percent volatile by volume:	0	**pH (5% solution or slurry in water):**	9.5
Percent solids by weight:	100		

10. STABILITY AND REACTIVITY

This material is chemically stable. Hazardous polymerization will not occur.

Conditions to avoid :
Open flame and extreme heat.

Incompatible materials:
Strong oxidizing agents.

Hazardous products of decomposition:
Oxides of carbon, oxides of sulfur, oxides of nitrogen.

Conditions under which hazardous polymerization may occur:
Heat is generated when resin is mixed with curing agents; Run-a-way cure reactions may char and decompose the resin, generating unidentified fumes and vapors which may be toxic.

11. TOXICOLOGICAL INFORMATION

Acute oral effects: LD50 (rat): Not available.

Acute dermal effects: LD50 (rabbit): Not available.

Rabbit: Severe irritant;

Acute inhalation effects: LC50 (rat): Not available. Exposure: 0 hours.

Eye irritation:
Rabbit: Severe irritant.

Subchronic effects:
No data.

Carcinogenicity, teratogenicity, and mutagenicity:
No data.

Other chronic effects:
No data.

Toxicological information on hazardous chemical constituents of this product:

Constituent	Oral LD50 (rat)	Dermal LD50 (rabbit)	Inhalation LC50 4hr, (rat)
Mercaptan amine blend	n/d	n/d	n/d
Polymercaptan curing agent	n/d	n/d	n/d

'n/d' = 'not determined'

12 ECOLOGICAL INFORMATION

Ecotoxicity:
No data.

Mobility and persistence:
No data.

Environmental fate:
No data.

13. DISPOSAL CONSIDERATIONS

Please see also Section 15, Regulatory Information.

Waste management recommendations:
If this material becomes a waste, it would not be a hazardous waste by RCRA criteria (40CFR 261). Dispose of according to applicable federal, state, and local regulations.

14. TRANSPORT INFORMATION

Proper shipping name: Non-regulated
Technical name : N/A
Hazard class : N/A
UN number: N/A
Packing group: N/A
Emergency Response Guide no.: N/A
IMDG page number: N/A
Other: N/A

15. REGULATORY INFORMATION

U.S. Federal Regulations

TSCA
All ingredients of this product are listed, or are exempt from listing, on the TSCA inventory.

The following RCRA code(s) applies to this material if it becomes waste:
None

Regulatory status of hazardous chemical constituents of this product:

Constituent	Extremely Hazardous*	Toxic Chemical**	CERCLA RQ (lbs)	TSCA 12B Export Notification
Mercaptan amine blend	No	No	0.0	Not required
Polymercaptan curing agent	No	No	0.0	Not required

*Consult the appropriate regulations for emergency planning and release reporting requirements for substances on the SARA Section 301 Extremely Hazardous Substance list.

**Substances for which the "Toxic Chemical" column is marked "Yes" are on the SARA Section 313 list of Toxic Chemicals, for which release reporting may be required. For specific requirements, consult the appropriate regulations.

For purposes of SARA Section 312 hazardous materials inventory reporting, the following hazard classes apply to this material: - Immediate health hazard -- Delayed health hazard -

Canadian regulations

WHMIS hazard class(es) : D2B
All components of this product are on the Domestic Substances List.

16. OTHER INFORMATION

Hazardous Materials Identification System (HMIS) ratings:	Health	Flammability	Reactivity
	3*	1	1

The information and recommendations in this document are based on the best information available to us at the time of preparation, but we make no other warranty, express or implied, as to its correctness or completeness, or as to the results of reliance on this document.

AD

MSDS# CO01

AGA

AGA GAS, INC. (216) 642-6600
6055 ROCKSIDE WOODS BLVD
P.O. BOX 94737
CLEVELAND, OH 44101-4737

DISTRIBUTED BY: PIONEER MANUFACTURING CO.
4529 INDUSTRIAL PARKWAY
CLEVELAND, OH 44135
TELEPHONE: 800-877-1500

MATERIAL SAFETY DATA SHEET

No. 015

PRODUCT NAME Carbon Dioxide (CO2 CYLINDER)	**CAS #** 124-38-9
TRADE NAME AND SYNONYMS Carbon Dioxide; Carbonic Anhydride	**DOT I.D. No.:** UN 1013
CHEMICAL NAME AND SYNONYMS Carbon Dioxide	**DOT Hazard Class:** Division 2.2
	Formula CO_2
ISSUE DATES AND REVISIONS Revised January 1995 CONFIRMED AS CURRENT ON: 6-6-00	**Chemical Family:** Carbonate

HEALTH HAZARD DATA

TIME WEIGHTED AVERAGE EXPOSURE LIMIT

5,000 Molar PPM; STEL = 30,000 Molar PPM (ACGIH 1994-1995). OSHA 1993 PEL (8 Hr. TWA) = 5,000 Molar PPM .

SYMPTOMS OF EXPOSURE

Inhalation: Low concentrations (3-5 molar %) cause increased respiration and headache.

Eight to 15 molar % concentrations cause headache, nausea and vomiting which may lead to unconsciousness if not moved to open air or given oxygen.

High concentrations cause rapid circulatory insufficiency leading to coma and death.

TOXICOLOGICAL PROPERTIES

Carbon oioxide is the most powerful cerebral vasodilator known. Inhaling large concentrations causes rapid circulatory insufficiency leading to coma and death. Chronic, harmful effects are not known from repeated inhalation of low (3-5 molar %) concentrations.

Carbon dioxide is not listed in the IARC, NTP or by OSHA as a carcinogen or potential carcinogen.

Persons in ill health where such illness would be aggravated by exposure to carbon dioxide should not be allowed to work with or handle this product.

RECOMMENDED FIRST AID TREATMENT

PROMPT MEDICAL ATTENTION IS MANDATORY IN ALL CASES OF OVEREXPOSURE TO CARBON DIOXIDE. RESCUE PERSONNEL SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS.

Inhalation: Conscious persons should be assisted to an uncontaminated area and inhale fresh air. Quick removal from the contaminated area is most important. Unconscious persons should be moved to an uncontaminated area, given assisted respiration and supplemental oxygen. Assure that vomited material does not obstruct the airway by use of positional drainage. Further treatment should be symptomatic and supportive.

FOR CHEMICAL EMERGENCY
Call INFOTRAC
1-800-535-5053
24 Hrs. per day, 7 days per week

MATERIAL SAFETY DATA SHEET

Prepared to U.S. OSHA, CMA, ANSI and Canadian WHMIS Standards

1. PRODUCT AND COMPANY INFORMATION

CHEMICAL NAME; CLASS: AIR

SYNONYMS: Medical Air, Breathing Air, Compressed Air
CHEMICAL FAMILY NAME: Non-Flammable Gas
FORMULA: Not applicable.

NOTE: Air may be either compressed, atmospheric air, or a mixture of 21% oxygen and 79% Nitrogen
NOTE: Air may be supplied by pipeline.

	Document Number: 10003
PRODUCT USE:	Breathing, purging or general analytical or synthetic chemical uses.
MANUFACTURED/SUPPLIED FOR:	AIR LIQUIDE
ADDRESS:	2700 Post Oak Drive Houston, TX 77056-8229
EMERGENCY PHONE:	CHEMTREC: 1-800-424-9300
BUSINESS PHONE:	
General MSDS Information:	1-713/896-2896
Fax on Demand:	1-800/231-1366

2. HAZARD IDENTIFICATION

EMERGENCY OVERVIEW: Air is a colorless, odorless gas. The main health hazards associated with exposure to this gas are related to the high pressure. Contact with rapidly expanding gases from a cylinder that is suddenly released can cause frostbite to exposed skin or damage to eyes. Air is generally considered non-flammable, however, Air will support combustion. A moderate cylinder rupture hazard exists when Air, which is under pressure, is subject to heat or flames.

2. HAZARD IDENTIFICATION (Continued)

SYMPTOMS OF OVER-EXPOSURE BY ROUTE OF EXPOSURE: The most significant route of over-exposure for air is by inhalation at elevated or reduced pressure.

INHALATION: Air is non-toxic and necessary to support life. Inhalation of Air in high pressure environments, such as underwater diving or hyperbolic chambers can result in symptoms similar to over-exposure to pure oxygen. These symptoms include tingling of the fingers and toes, abnormal sensations, along with impaired coordination and confusion. Decompression sickness, "bends", is possible following rapid decompression.

CONTACT WITH SKIN or EYES: Contact with rapidly expanding gases (which are released under high pressure) may cause frostbite. Symptoms of frostbite include change in skin color to white or grayish-yellow. The pain after contact with liquid can quickly subside. Contact with the rapidly expanding vapors released the high pressure cylinder may cause freezing of the eye. Permanent eye damage or blindness could result.

HEALTH EFFECTS OR RISKS FROM EXPOSURE: An Explanation in Lay Terms. Over-exposure to Air may cause the following health effects:

ACUTE: The most significant hazards associated with air is the pressure hazard.

CHRONIC: There are currently no known adverse health effects associated with chronic exposure to this gas.

TARGET ORGANS: ACUTE: None. **CHRONIC:** None.

3. COMPOSITION and INFORMATION ON INGREDIENTS

CHEMICAL NAME	CAS #	mole %	EXPOSURE LIMITS IN AIR					
			ACGIH-TLV		OSHA-PEL		NIOSH	OTHER
			TWA ppm	STEL ppm	TWA ppm	STEL ppm	IDLH ppm	ppm
Air (compressed, atmospheric)	132259-10-0	100%	There are no specific exposure limits applicable to air.					
Mixed Air is a mixture of gases. The primary components of air, and the approximate concentration of each component, are listed below.								
Nitrogen	7727-37-9	79%	There are no specific exposure limits for Nitrogen. Nitrogen is a simple asphyxiant (SA). Oxygen levels should be maintained above 19.5%.					
Oxygen	7782-44-7	21%	There are no specific exposure limits for Oxygen.					

This material is classified as hazardous under OSHA regulations in the United States and the WHMIS in Canada.

NE = Not Established. NIC = Notice of Intended Change See Section 16 for Definitions of Terms Used.

NOTE: ALL WHMIS required information is included in appropriate sections based on the ANSI Z400.1-2004 format. This product has been classified in accordance with the hazard criteria of the CPR and the MSDS contains all the information required by the CPR.

4 FIRST-AID MEASURES

As the opportunity for injury from exposure to Air is limited to inhalation of Air in high pressure environments, such as underwater diving or hyperbolic chambers, the first-aid measures would be for over-pressure accidents, or rapid decompression-induced decompression sickness. In the event of such accidents, seek immediate and qualified medical attention.

In case of frostbite, place the frostbitten part in warm water. DO NOT USE HOT WATER. If warm water is not available, or is impractical to use, wrap the affected parts gently in blankets. Alternatively, if the fingers or hands are frostbitten, place the affected area of the body in the armpit. Encourage victim to gently exercise the affected part while being warmed. Seek immediate medical attention.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: A knowledge of the available information suggest that over-exposure to Air is unlikely to aggravate existing medical conditions.

RECOMMENDATIONS TO PHYSICIANS: Treat symptoms and reduce over-exposure if air is breathed in high pressure environment, (i.e. illness associated with decompression, bends, or caisson disease). Decompression equipment may be required.

5. FIRE-FIGHTING MEASURES

FLASH POINT: Not applicable.
AUTOIGNITION TEMPERATURE: Not applicable.
FLAMMABLE LIMITS (in air by volume, %):

Lower (LEL): Not applicable.
Upper (UEL): Not applicable.

FIRE EXTINGUISHING MATERIALS: Non-flammable. Air will support combustion of flammable materials. Use extinguishing media appropriate for surrounding fire.

Water Spray: YES	Carbon Dioxide: YES	Dry Chemical: YES
Halon: YES	Foam: YES	Other: Any "ABC" Class.

UNUSUAL FIRE AND EXPLOSION HAZARDS: Air does not burn; however, cylinders, when involved in fire, may rupture or burst in the heat of the fire.

Explosion Sensitivity to Mechanical Impact: Not Sensitive.
Explosion Sensitivity to Static Discharge: Not Sensitive.

SPECIAL FIRE-FIGHTING PROCEDURES: Incipient fire responders should wear eye protection. Structural fire-fighters must wear Self-Contained Breathing Apparatus and full protective equipment. If possible, shut-off the flow of Compressed Air supporting the fire. Immediately cool the cylinders with water spray from maximum distance. When cool, move cylinders from fire area, if without risk.

6. ACCIDENTAL RELEASE MEASURES

LEAK RESPONSE: Uncontrolled releases should be responded to by trained personnel using pre-planned procedures. Proper protective equipment should be used. In case of a release, clear the affected area, protect people, and respond with trained personnel. Minimum Personal Protective Equipment should be **Level D: safety glasses.** Locate and seal the source of the leaking gas. If this does not stop the release (or if it is not possible to reach the valve), allow the gas to release in-place or remove it to a safe area and allow the gas to be released there.

If leaking incidentally from the cylinder or its valve, contact your supplier.

7. HANDLING AND STORAGE

WORK PRACTICES AND HYGIENE PRACTICES: Air intended for breathing must conform to CGA Standard G-7 (Compressed Air for Human Respiration) and Standard G-7.1, American National Standard Commodity Specification for Air. All other sources of compressed air must be treated as unfit for human consumption until tested for conformance with these standards.

STORAGE AND HANDLING PRACTICES: Compressed gases can present significant safety hazards. Store cylinders away from heavily trafficked areas and emergency exits. Post "No Smoking or Open Flames" signs in storage or use areas.

SPECIAL PRECAUTIONS FOR HANDLING GAS CYLINDERS: Protect cylinders against physical damage. Store in cool, dry, well-ventilated, fireproof area, away from flammable or combustible materials and corrosive atmospheres. Store away from heat and ignition sources and out of direct sunlight. Do not store near elevators, corridors or loading docks. Do not allow area where cylinders are stored to exceed 52 °C (125 °F). Isolate from incompatible materials including flammable materials. (see Section 10, Stability and Reactivity) for more information), which can burn violently. Use only storage cylinders and equipment (pipes, valves, fittings to relieve pressure, etc.) designed for the storage of Air. Do not store cylinders where they can come into contact with moisture. Cylinders should be stored upright and be firmly secured to prevent falling or being knocked over. Cylinders can be stored in the open, but in such cases, should be protected against extremes of weather and from the dampness of the ground to prevent rusting. Never tamper with pressure relief devices in valves and cylinders. The following rules are applicable to situations in which cylinders are being used:

Before Use: Move cylinders with a suitable hand-truck. Do not drag, slide or roll cylinders. Do not drop cylinders or permit them to strike each other. Secure cylinders firmly. Leave the valve protection cap in-place (where provided) until cylinder is ready for use.

During Use: Use designated CGA fittings and other support equipment. Do not use adapters. Do not heat cylinder by any means to increase the discharge rate of the product from the cylinder. Use check valve in discharge line to prevent hazardous backflow into the cylinder. Do not use oils or grease on gas-handling fittings or equipment.

After Use: Close main cylinder valve. Replace valve protection cap (where provided). Mark empty cylinders "EMPTY".

NOTE: Use only DOT or ASME code cylinders. Close valve after each use and when empty. Cylinders must not be recharged except by or with the consent of owner.

7. HANDLING AND STORAGE (Continued)

PROTECTIVE PRACTICES DURING MAINTENANCE OF CONTAMINATED EQUIPMENT: Follow practices indicated in Section 6 (Accidental Release Measures). Make certain application equipment is locked and tagged-out safely. Always use product in areas where adequate ventilation is provided.

STANDARD VALVE CONNECTIONS FOR U.S. AND CANADA: Use the proper CGA connections, DO NOT USE ADAPTERS:

THREADED:	0-3000 psig	CGA 346 (alternative 590)
	3001-5500 psig	CGA 347
	5501 - 7500 psig	CGA 702
PIN-INDEXED YOKE:	0-3000 psig	CGA 950 (medical use)
ULTRA HIGH INTEGRITY:	1160	

8. EXPOSURE CONTROLS - PERSONAL PROTECTION

VENTILATION AND ENGINEERING CONTROLS: None needed.
RESPIRATORY PROTECTION: None needed.
EYE PROTECTION: Safety glasses. If necessary, refer to U.S. OSHA 29 CFR 1910.133 or appropriate Canadian Standards.
HAND PROTECTION: Wear gloves when handling cylinders of this product. If necessary, refer to U.S. OSHA 29 CFR 1910.138 and appropriate Standards of Canada.
BODY PROTECTION: Use body protection appropriate for task. Safety shoes are recommended when handling cylinders. If a hazard of injury to the feet exists due to falling objects, rolling objects, where objects may pierce the soles of the feet or where employee's feet may be exposed to electrical hazards, use foot protection, as described in U.S. OSHA 29 CFR 1910.136.

9. PHYSICAL and CHEMICAL PROPERTIES

GAS DENSITY @ 21.1°C (70°F) and 1 atm: 0.07493 lb/ ft^3 (1.2 kg/m^3)
FREEZING/MELTING POINT @ 10 psig: -216.2°C (-357.2°F)
SOLUBILITY IN WATER, Vol/Vol at 0°C (32° F): 0.0292
SPECIFIC GRAVITY (air = 1) @ 21.1°C (70°F): 1
EVAPORATION RATE (nBuAc = 1): Not applicable.
MOLECULAR WEIGHT: 28.975
pH: Not applicable.
EXPANSION RATIO: Not applicable.
ODOR THRESHOLD: Not applicable.
SPECIFIC VOLUME (ft^3/lb): Not applicable for Air; 13.8 (for Nitrogen)
VAPOR PRESSURE @ 21.1°C (70°F): Not applicable.
COEFFICIENT WATER/OIL DISTRIBUTION: Not applicable.
APPEARANCE, ODOR AND COLOR: This product is a colorless, odorless gas.
HOW TO DETECT THIS SUBSTANCE (warning properties): There are no unusual warning properties associated with a release of this gas.

10. STABILITY and REACTIVITY

STABILITY: Normally stable in gaseous state. Compressed Air which contains excess oxygen may present the same hazards as Liquid Oxygen and could react violently with organic materials, such as oil and grease.
DECOMPOSITION PRODUCTS: None.
MATERIALS WITH WHICH SUBSTANCE IS INCOMPATIBLE: Fuels may form explosive mixtures in air.
HAZARDOUS POLYMERIZATION: Will not occur.
CONDITIONS TO AVOID: Contact with incompatible materials, as listed above. Avoid exposing cylinders to extremely high temperatures, which could cause the cylinders to rupture.

11. TOXICOLOGICAL INFORMATION

TOXICITY DATA: There are no specific toxicology data for Air.
SUSPECTED CANCER AGENT: Air is not found on the following lists: FEDERAL OSHA Z LIST, NTP, CAL/OSHA, IARC, and there fore is not considered to be, nor suspected to be a cancer-causing agent by these agencies.
IRRITANCY OF PRODUCT: Not applicable.
SENSITIZATION OF PRODUCT: Air is not a skin or respiratory sensitizer.
REPRODUCTIVE TOXICITY INFORMATION: Listed below is information concerning the effects of Air on the human reproductive system.

Mutagenicity: Air is not expected to cause mutagenic effects in humans.
Embryotoxcity: Air is not expected to cause embryotoxic effects in humans.
Teratogenicity: Air is not expected to cause teratogenic effects in humans.
Reproductive Toxicity: Air is not expected to cause adverse reproductive effects in humans.

11. TOXICOLOGICAL INFORMATION (Continued)

A mutagen is a chemical which causes permanent changes to genetic material (DNA) such that the changes will propagate through generation lines. An embryotoxin is a chemical which causes damage to a developing embryo (i.e. within the first eight weeks of pregnancy in humans), but the damage does not propagate across generational lines. A teratogen is a chemical which causes damage to a developing fetus, but the damage does not propagate across generational lines. A reproductive toxin is any substance which interferes in any way with the reproductive process.

BIOLOGICAL EXPOSURE INDICES (BEIs): Biological Exposure Indices (BEIs) do not exist for Compressed Air.

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL STABILITY: This gas will be dissipated rapidly in well-ventilated areas.

EFFECT OF MATERIAL ON PLANTS or ANIMALS: No adverse effect is anticipated to occur to plant-life, except for frost produced in the presence of rapidly expanding gases.

EFFECT OF CHEMICAL ON AQUATIC LIFE: No evidence of an adverse effect of air on aquatic life is currently available.

13. DISPOSAL CONSIDERATIONS

PREPARING WASTES FOR DISPOSAL: Waste disposal must be in accordance with appropriate Federal, State, and local regulations. Return cylinders with any residual product to Air Liquide. Do not dispose of locally.

For emergency disposal, secure the cylinder and slowly discharge the gas to the atmosphere in a well-ventilated area or outdoors, away from all sources of ignition.

14. TRANSPORTATION INFORMATION

THIS COMPRESSED AIR IS HAZARDOUS AS DEFINED BY 49 CFR 172.101 BY THE U.S. DEPARTMENT OF TRANSPORTATION.

PROPER SHIPPING NAME: ..... Air, compressed
HAZARD CLASS NUMBER and DESCRIPTION: 2.2 (Non-Flammable Gas)
UN IDENTIFICATION NUMBER: ..... UN 1002
PACKING GROUP: ..... Not applicable.
DOT LABEL(S) REQUIRED: ..... Non-Flammable Gas
NORTH AMERICAN EMERGENCY RESPONSE GUIDEBOOK NUMBER (1996): 122
MARINE POLLUTANT: Air is not classified by the DOT as a Marine Pollutant (as defined by 49 CFR 172.101, Appendix B).

TRANSPORT CANADA TRANSPORTATION OF DANGEROUS GOODS REGULATIONS: This gas is considered as Dangerous Goods, per regulations of Transport Canada. The use of the above U.S. DOT information from the U.S. 49 CFR regulations is allowed for shipments that originate in the U.S. For shipments via ground vehicle or rail that originate in Canada, the following information is applicable.

PROPER SHIPPING NAME: Air, compressed
HAZARD CLASS NUMBER and DESCRIPTION: 2.2 (Non-Flammable Gas)
UN IDENTIFICATION NUMBER: UN 1002
PACKING GROUP: Not Applicable
HAZARD LABEL(S) REQUIRED: 2.2 (Non-Flammable Gas)
SPECIAL PROVISIONS: 42
EXPLOSIVE LIMIT & LIMITED QUANTITY INDEX: 0.12
ERAP INDEX: None
PASSENGER CARRYING SHIP INDEX: None
PASSENGER CARRYING ROAD OR RAIL VEHICLE INDEX: 75
MARINE POLLUTANT: Compressed Air is not a Marine Pollutant.

15. REGULATORY INFORMATION

ADDITIONAL U.S. REGULATIONS:

U.S. SARA REPORTING REQUIREMENTS: Compressed Air is not subject to the reporting requirements of Sections 302, 304 and 313 of Title III of the Superfund Amendments and Reauthorization Act.

U.S. SARA THRESHOLD PLANNING QUANTITY: Not applicable.

U.S. TSCA INVENTORY STATUS: Air is listed on the TSCA Inventory.

U.S. CERCLA REPORTABLE QUANTITIES (RQ): Not applicable.

OTHER U.S. FEDERAL REGULATIONS:

- Air USP is regulated by the FDA as a prescription drug.
- Air does not contain any Class I or Class II ozone depleting chemicals (40 CFR part 82).
- Air is not subject to the reporting requirements of Section 112(r) of the Clean Air Act.
- Air is not listed as a Regulated Substance, per 40 CFR, Part 68, of the Risk Management for Chemical Releases.
- Air is not listed in Appendix A as a highly hazardous chemical, per 29 CFR 1910.119: Process Safety Management of Highly Hazardous Chemicals.

CALIFORNIA SAFE DRINKING WATER AND TOXIC ENFORCEMENT ACT (PROPOSITION 65: Compressed Air is not on the California Proposition 65 lists.

U.S. STATE REGULATORY INFORMATION: Air is not covered under the following specific State regulations:

Alaska - Designated Toxic and Hazardous Substances: No.
California - Permissible Exposure Limits for Chemical Contaminants: No.
Florida - Substance List: No.
Illinois - Toxic Substance List: No.
Kansas - Section 302/313 List: No.
Massachusetts - Substance List: No.
Minnesota - List of Hazardous Substances: No.
Missouri - Employer Information/Toxic Substance List: No .
New Jersey - Right to Know Hazardous Substance List: Air.
North Dakota - List of Hazardous Chemicals, Reportable Quantities: No.
Pennsylvania - Hazardous Substance List: No.
Rhode Island - Hazardous Substance List: No.
Texas - Hazardous Substance List: No.
West Virginia - Hazardous Substance List: No.
Wisconsin - Toxic and Hazardous Substances: No.

ADDITIONAL CANADIAN REGULATIONS:

CANADIAN DSL/NDSL INVENTORY STATUS: Compressed Air is included in the DSL Inventory.

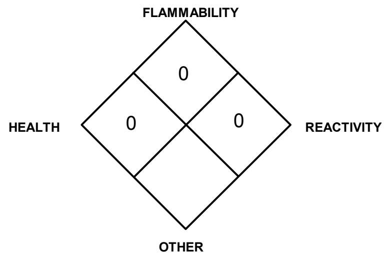
CANADIAN ENVIRONMENTAL PROTECTION ACT (CEPA) PRIORITY SUBSTANCES LISTS: Compressed Air is not on the CEPA Priorities Substances Lists.

WHMIS CLASSIFICATION: Compressed Air is categorized as a Controlled Product, Hazard Class A, as per the Controlled Product Regulations.

OTHER CANADIAN REGULATIONS: Not applicable.

16. OTHER INFORMATION

NFPA RATING



HAZARDOUS MATERIAL IDENTIFICATION SYSTEM

HEALTH HAZARD	(BLUE)	0
FLAMMABILITY HAZARD	(RED)	0
PHYSICAL HAZARD	(YELLOW)	0

PROTECTIVE EQUIPMENT

EYES	RESPIRATORY	HANDS	BODY
	SEE SECTION 8		SEE SECTION 8

For Routine Industrial Use and Handling Applications

Atmospheric air that is compressed is composed of the following gases:

Nitrogen:	78%
Oxygen	21%
Argon	0.9%

Compressed air is also synthetically produced by mixing 79% nitrogen and 21% oxygen.

MIXTURES: When two or more gases or liquefied gases are mixed, their hazardous properties may combine to create additional, unexpected hazards. Obtain and evaluate the safety information for each component before you produce the mixture. Consult an Industrial Hygienist or other trained person when you make your safety evaluation of the end product. Remember, gases and liquids have properties which can cause serious injury or death.

Further information about Air can be found in the following pamphlets published by: Compressed Gas Association Inc. (CGA), 4221 Walney Road 5th floor, Chantilly, VA 20151-2923. Telephone: (703) 788-2700.

G-7	*"Compressed Air for Human Respiration"*
G-7.1	*"American National Standard Commodity Specification for Air"*
P-1	*"Safe Handling of Compressed Gases in Containers"*
AV-1	*"Safe Handling and Storage of Compressed Gases"*

16. OTHER INFORMATION (Continued)

PREPARED BY:

CHEMICAL SAFETY ASSOCIATES, Inc.
PO Box 3519, La Mesa, CA 91944-3519
619/670-0609

Fax on Demand: 1-800/231-1366

D Hunstville Area Rocketry Association Safety Regulations

Huntsville Area Rocketry Association Safety Regulations

As a member of the Utah State University Chimaera Rocket team I, ___________________________
(print name)
understand that the Huntsville Area Rocketry Association (HARA) will regulate all aspects of launch site safety on the day of the competition launch, and I agree to abide by the following regulations:

1. HARA will provide range safety inspections of each rocket before it is flown and the USU team will comply with said inspection determination.

2. The HARA Range Safety Officer has the final say on all rocket safety issues, and has the ability to deny the launch based on safety reasons.

3. If the team is in noncompliance with the safety and mission assurance, the rocket will not be launched.

____ ________________
Signature Date

E Rocket Motor Candidates

ID	NAME	Mfr. Designation	BRAND NAME	Diameter (m)	Length (m)	Ave. Thrust (N)	Max Thrust (N)	Total Impulse (N*s)	Isp(sec)	Total Weight (kg)	Prop. Weight (kg)
1	KBA L2300	L2300G	L2300G	0.054	0.728	2191.39	2930.02	2737.05	213.05	2.63	1.13
2	Loki L780	L780-SF	L780-SF	0.076	0.498	783.3	995	3006		3.5	1.8
3	Aero Tech L339	L339N	L339N	0.098	0.302	316.5	445.5	3042.9		3.21	1.796
4	Kosdon L585	L585DH	L585DH	0.076	0.495	608.6		3093.8			1.93
5	AMW L777	WT-75-3500	L777WW	0.075	0.497	774.5	1000.2	3136.6	181.49	3.699	1.762
6	Cesaroni L935	3147-L935-P	Pro54-6GXL 3147L935 Imax	0.054	0.649	932.3	1582.7	3076.5	180.84	2.542	1.7347
7	Loki L480	L480-LR	L480-LR	0.075	0.498	500	567.3	3200	179.91	3.538	1.814
8	GR L789	L789RT	L789RT	0.075	0.497			3251.8		3.378	1.796
9	GR L425	L425WC	Gorilla Rocket Motors	0.075	0.497	424.6	756.2	3375.4	196.68	3.502	1.75
10	Kosdon L630	L630S	L630S	0.076	0.495	643.6		3429.9			1.661
11	AMW L900	RR-75-3500	L900RR	0.075	0.497	907	1173.5	3440.91	198.12	3.6	1.77
12	AMW L1111	ST-75-3500	L1111ST	0.075	0.497	1107.55	1398.33	3477.7	215.97	3.517	1.642
13	Aero Tech L1150	L1150R	L1150R	0.075	0.53	1102.23	1309.7	3488.55	172.24	3.674	2.065
14	Kosdon L1175	L1175F	L1175F	0.076	0.495	1205.1		3567.1			1.667
15	GR L1150	L1150WC	Gorilla Rocket Motors	0.075	0.497	1148.98	1757.05	3573.33	208.22	3.502	1.75
16	GR L985	L985GT	L985GT	0.075	0.498			3580		3.632	1.875
17	Loki L930	L930-LW	L930-LW	0.076	0.499	883.38	1123	3533.5	198.59	3.538	1.814
18	Cesaroni L995	3618-L995-P	Pro75 3618-L995-P	0.075	0.486	952.1	1280	3618	184.84	3.59	1.996
19	AMW L1060	GG-75-3500	L1060GG	0.075	0.497	1065.5	1298.3	3622.6	192.52	3.939	1.919
20	Aero Tech L850	K850W	L850W	0.075	0.531	756.7	1184.8	3694.98	182.44	3.67	2.065
21	AMW L1080	BB-75-3500	L1080BB	0.075	0.497	1087.37	1257.91	3686.19	218.92	3.592	1.717
22	Aero Tech L1520	L1520T	L1520T	0.075	0.518	1567.8	1765.3	3715.9		3.651	1.854
23	Cesaroni L800	3757 L800-P-U	Pro 75L800-P-U	0.075	0.486	795.48	1285.54	3722.84	211.49	3.511	1.795
24	Cesaroni L890	3762 L890-P	Pro75 L890 Smoky Sam	0.075	0.53	894.65	1151.8	3694.92	141.06	4.346	2.671
25	Loki L1482	L1482-LB	L1482-LB	0.076	0.497	1485.67	1758.62	3862.73	217.14	3.538	1.814
26	Aero Tech L1390	L1390G	L1390G	0.075	0.53	1390		3949		3.879	1.973
27	Cesaroni L1355	4025-L1355-P	Pro75 4025-L1355-P	0.075	0.621	1238.46	1750	4025	133.43	4.962	3.076
28	GR L1065	L1065BL	L1065BL	0.075	0.787	1065.5	1931.9	4209.7		5.363	2.693
29	Aero Tech L1170	L1170FJ	L1170FJ	0.075	0.665	1141	1489	4232		4.99	2.8
30	Loki L1400	L1400-LW	L1400-LW	0.054	0.736	1421.44	1906.38	2842.88	207.07	2.54	1.4
31	Cesaroni L1030	2788 L1030-P	Pro54 L1030	0.054	0.649	1028.55	1539.44	2781.21	186.82	2.338	1.52
32	Cesaroni L640	2772-L640-P	2772-L640-P	0.054	0.649	554.444	1540	2772.22	218.63	2.244	1.293
33	Cesaroni L990	2771-L990-P	Pro54 2771-L990-P	0.054	0.649	953.34	1625	2764.69	198.96	2.236	1.147
34	Cesaroni L730	2765 L730-P	Pro54 L730-P	0.054	0.649	732.947	1216.59	2763.21	208.56	2.247	1.351
35	Cesaroni L1276	L1276RR-P	AMW/ProX L1276	0.054	0.728	1237.17	1495	2703.21	186.88	2.96	1.475
36	AMW L1300	BB-54-2550	L1300BB	0.054	0.728	1297.91	1586.74	2672.02	207.36	2.5454	1.314
37	Cesaroni L985	2665 L985-P	AMW/PRO 2665L985-P	0.054	0.728	996.381	1483.94	2678.27	210.89	2.572	1.295
38	KBA L1400	L1400F	L1400F	0.054	0.728	1402.07	1992.89	2637.77	215.53	2.502	1.248
39	KBA L1000	L1000S	L1000S	0.054	0.728	960.255	1310.24	2592.69	203.21	2.325	1.301

F Work Schedule

G Resumes

Richard Perkins
873 Law Dr., Brigham City, UT 84302
Phone: (435) 553-5197
E-mail: professorluticor@gmail.com

Objectives: **Find a meaningful work or a summer internship summer 2011 prior to grad school**

Real-life problem solving
Meaningful work assignments
Coaching from experienced Engineers

Education: Major: **Mechanical Engineering** Senior at Utah State University: 3.89 GPA

Minor: Mathematics and Russian

Related course work:

Thermo-fluids	Structural	Computational	Motion/Data/Production
Heat and Mass Transfer	Machine Design	Num. Computation Methods	Advanced Dynamics
Thermodynamics	Solid Mechanics	FORTRAN Programming	Instrumentation/Measurements
Fluid Mechanics	Material Science	Solid Modeling	Manufacturing Processes
Compressible Fluids	Rocket Syst. Design	Finite Element Methods	Vibrations

Skills:

- Excellent writing abilities
- Self-starter
- Ability to meet deadlines
- Can work long hours
- Excellent stand-up presentation skills
- Can read, write, and speak Russian as a second language
- Abaqus, NX Thermal, FEMAP, Fortran, Mathcad, MS Office

Activities:

- NASA USLI Rocket Competition – Chief Engineer
- Tau Beta Sigma (Engineering Honor Society)
- USU Jazz Orchestra and Combo – Lead Trombone
- Big Band Swing Club council member and team performer
- Russian study – including Russian translation

Recognition:

- Academic Excellence (College of Engineering)
- News Writer of the Month (Utah Statesman)
- A-pin Recipient (Two consecutive semesters of 4.0 GPA)
- USU Presidential Scholarship
- Don Burger Band Scholarship Recipient
- Eagle Scout

Work Experience:

- **Structural/Thermal Analyst (Intern)** at ATK Space Systems in Promontory Utah (2010)
  Used various analysis tools to analyze the structural capabilities of a composite structure.
  Analyzed the transient temperatures incurred in the pad stabilization bracket during ascent
- **Insulation Design Engineer (Intern)** at ATK Space Systems in Promontory Utah (2009)
  Included: new process development, test design, data analysis, bond-line interaction research

Full-time summer position working on the insulation in the RSRM and Constellation motors

- **News Writer**, “Utah Statesman” USU university paper, Logan (Sept. 08 to Apr. 09)

2163 E RYAN • FRESNO CA • 93720
(559)970-0737 • CESSNA152TANGO@YAHOO.COM

COLIN WHITE

OBJECTIVE

Seeking to fill an entry-level full-time position servicing aircraft with a desire to work in a dynamic environment.

SUMMARY OF QUALIFICATIONS

- *FAA Airframe and Powerplant License, Number 2877155*
- *Hands on experience with aircraft airframes and PT-6, Alison 250, and TPE 331 turbine powerplants*
- *Leadership experience as a cadet in the United States Air Force Reserve Officers Training Core*
- *Micro Gravity Research Team Member*
- *Hands on experience in construction*
- *Hands on experience in Cube Sat satellite fabrication*

EDUCATION

2006-Present, Utah State University, Logan Utah

- *Currently enrolled in the Mechanical/Aerospace Engineering program, 3.0 GPA*

2005-2006, State Center Community College District, Fresno Calf.

- *Underwent pre-engineering undergraduate course work*

2003-2005, Reedley College, Reedley Calf.

AS Degree in Aviation Maintenance Technology

- *Underwent two year Airframe and Powerplant certification program.*

AWARDS AND CERTIFICATIONS

- *Eagle Scout*
- *CPR/First-Aid/AED(Automated External Defibrillator)*
- *Transfer Student Scholarship winner.*
- *Full Ride United States Air Force Scholarship Recipient*
- *Rocky Mountain Space Grant Consortium Summer Fellowship Recipient*
- *Recipient of the America Legion Scholastic Excellence Medal*

EMPLOYMENT

Pool Service Technician - Fresno Pool Chlor

- *Chemical analysis of pool water samples. Developed attention to detail, communication, ability to follow complex testing instructions, and in-field equipment repair skills. (2/05-8/06)*

Concrete Finisher – Storage Builders Inc.

- *Finishing of large concrete surfaces including walls in a construction team environment. Developed mechanical ability, teamwork, communication, and attention to detail. (8/04-2/05)*

Assembler – Lowe's Home Improvement Warehouse

- *Responsible for the assembly of store products for sale and display. Display and general store maintenance. Developed team work and positive customer service attitude.(8/07-11/07)*

KYLE HODGSON

253 ½ North 200 East APT 4 Logan, UT 801-244-3431
k.hodgson@aggiemail.usu.edu

EDUCATION:

B.S., Mechanical and Aerospace Engineering May 2011
Utah State University

A.S., General Studies May 2004
Salt Lake Community College

- Two year degree obtained in one year while maintaining a high GPA

RELEVANT SKILLS:

- **SECRET Security Clearance**
- Software: Matlab, Labview, Simulink, Solid Edge, Fortran, I-DEAS, NX-6, Mathcad, STK, Microsoft Office Suite (Word, PowerPoint, Excel, Access), Windows
- Passed FE Exam (October 2009)
- Quick learner; Excellent multi-tasking abilities; promoted quickly at other jobs
- Able to work well under stressful conditions, including deadlines and pressure from supervisors
- Incredible interpersonal skills; able to diffuse tense situations and calm troubled nerves
- Good problem solving skills; able to work long, arduous hours with little outside motivation
- Capable of managing and supervising others

VOLUNTEER WORK AND RESEARCH:

Team Member, Get-Away Special Research Team, USU, 2007-2010

- Space experiment flown on NASA's Vomit Comet in June 2010
- Worked with the Space Dynamics Lab to design and build a cubesat
- Spent time working in the machine shop milling out parts for the cubesat on a CNC mill

National Guard Member, Utah National Guard, 2008-Present

- Monthly training is tailored to prepare for leadership positions in the US Army upon graduation from college
- Concurrently enrolled in ROTC where additional leadership skills are developed

Volunteer, North Dakota, South Dakota, United States, 2004-2006

- Travelled the two states helping in retirement homes and hospitals
- Spent four months in an office setting organizing the maintenance of over 50 vehicles and 55 apartments

WORK HISTORY:

Manufacturing Engineer Intern	ATK, Promontory, UT
Design Engineer Intern	ATK, Promontory, UT
Cabinet Maker	Utah State University, Logan, UT
Construction Laborer	Intermountain Cleaners and Construction Inc., Salt Lake City, UT
Waiter	Texas Roadhouse, Taylorsville, UT

Annika Jensen

175 E 700 N Logan, UT 84321 • 435-512-5022 • annidude@gmail.com

---

Education

BS Mechanical/Aerospace Engineering (Math/German Minors) **December 2011**
Utah State University, Logan, Utah
• Maintain a 3.45 GPA while working part-time
• Awarded Presidential Scholarship **2007-Present**

Work Experience

Engineering Assistant **March 2009-Present**
Space Dynamics Laboratory/Utah State Research Foundation
• Data Management, Design Assistant, Technician Assistant

Customer Service Representative **June 2005-Aug 2008**
Domino's Pizza
• Managed store on day shifts
• Satisfied unhappy customers
• Daily interaction with the public

Leadership

• Society of Women Engineers (SWE) **2007-Present**
Section President, Utah State University Current
Collegiate Leadership Coaching Committing, Region B Current
Region Collegiate Representative, Region B 2009-2010
Section Secretary, Utah State University 2008-2009
• Rotary, International Youth Representative **2006-2009**
• Team Leader, Astro Camp **2007-2008**
• Led team building activities and taught lessons for youth, ages 9-15

Communication

• Written and communication skills developed as Features Editor for high school newspaper
• Conversational German language skills; proficient reading and writing German
• Gained public speaking skills through presentations to large and small groups of varied ages
• Developed excellent customer service skills through daily interaction with the public

Computer

• Proficient in Solid Edge and Fortran
• Used InDesign to produce newspaper layouts
• Proficient in Word, Excel and PowerPoint

Honors

• Richard and Moonyeen Anderson Scholarship Recipient
• First place, Voices Competition, Utah Sate University, 2008

SAMUEL E. MOSQUEA

8531 Mountain View Towers, Logan, UT, 84321 - samuelmosquea@gmail.com - 435.214.0284

EDUCATION

Utah State University, Logan, UT
Bachelor of Science in Mechanical Engineering, *Expected graduation date: 5/2011*
-*Academic Excellence Award*: *February 20, 2009*

Instituto Politécnico Loyola, San Cristóbal, Dominican Republic
Associate of Science in Industrial Electricity Technology, *2006*

EXPERIENCE SUMMARY

Vietnam, China, and Korea - Utah State University 6/2010-7/2010
Business Study Abroad
Visited multiple technology-based corporations, and analyzed them from the cultural, financial, operational, and human resources perspectives.

Autoliv - Initiators Tremonton Facility, Utah 11/2009 - 6/2010
Mechanical/Controls Engineering Intern
Provided solutions to a wide variety of mechanical and automation engineering problems through engineering design. The major focus of my designs was on solid mechanics (SolidWorks).

Dr. Jim Powell, Math and Stats Professor - Utah State University, Logan, Utah 9/2009 - 12/2009
Linear Algebra & Differential Equations Grader
Graded Homework and exams for the class MATH 2250 (Fall '09).

Dr. Ning Fang, Engineering Professor - Utah State University, Logan, Utah 8/2009 - 12/2009
Dynamics Teaching Assistant
Provided supplemental instruction for the class ENGR 2030, *Engineering Dynamics* (Fall '09).

Dominican Oil Refinery (a former Royal Dutch Shell Company) 5/2009 - 8/2009
Reliability Engineering Intern
Participated in the supervision of the installation and repair of mechanical seals of centrifugal pumps. Also responsible for updating the technical information database (J.D. Edwards) of safety relief valves, couplings, mechanical seals, valves, and manometers.

Dr. Ning Fang, Professor. Utah State University, Logan, Utah 1/2008 - 5/2009
Machining Research Assistant
Helped a postdoctoral researcher to prepare and execute metal cutting experiments on a CNC lathe. The experiments mostly dealt with the formation of Built-up Edge when cutting aluminum alloys.
Machining Theory Grader
Graded homework, computer simulations, and lab assignments for the class MAE 5650*, Machining Theory and Applications* (Spring 2008).

Consorcio Tecnologico del Caribe (Consulting Engineers), Dominican Republic 8/2006 - 8/2007
Automation Technician
Programmed and intalled PLC's and sensors to control the heating and air conditioning systems of the Hilton Hotel of Santo Domingo. Also identified, updated and reallocated components of the electrical control panel of the cement packaging machine (Siemens S5) of Cementos Mexicanos of the Dominican Republic. Simultaneously provided technical assistance to a wide variety of companies including Breweries, food production, and Bio-analysis organizations. Also, assisted with the calibration and certification (acc. to NIST) of various instrumentation devices.

Craig C. Broome

625 S. 500 W. (801) 644-2180
Brigham City, UT 84302 craigcbroome@gmail.com

Mechanical Engineering Position

Education

Utah State University – Logan, UT *Graduate May 2011*

- Pursuing a Bachelors degree in Mechanical Engineering
- Passed the Fundamentals of Engineering Exam

Weber State University – Ogden, UT December 2007

- Associates Degree in General Education 3.22 GPA

Professional Experience

Computer Quality Assurance Analyst June 2007 - February 2009
Flying J Inc. Corporate Offices Ogden, UT

- Project lead working with 2-3 other employees
- Designed test plans to adequately test web pages and database programs
- Worked with business users, programmers and other testers to find errors and problems with the design and finished program expectations
- Managed testing of computer software programs and test all relevant updates
- Evaluated outputs and debugged the current computer programs to find errors
- Used VB Script, Unix, and obtained an understanding of Java programming languages
- Evaluated different testing methods and create improved ways of testing more thoroughly
- Used networking abilities and automated testing to better test applications on multiple computers simultaneously

Electronic Assembly Technician July 2006 - June 2007
Richards Manufacturing Farr West, UT

- Built electrical components for military aerospace systems (F15, and minuteman missile protection)
- Analyzed different types of drawings including AutoCAD drawings, freehand drawings, and Solid Works drawings
- Worked with members of a team to complete the tasks assigned within the time limits specified

Technical and Language

Technical: Solid Edge, MATLAB, MathCAD, AutoCAD, VB Script, and FORTRAN
Language: German, Fluent

Service/Leadership

German Speaking Volunteer, Frankfurt Germany December 2003 – December 2005

- Worked hard to help others through service activities and progress toward specific goals
- Held various leadership positions supervising six to eight other volunteers
- Attained verbal and written fluency in German, including public speaking skills

Joshua Kingsford

55 N. 400 E.
Brigham City, UT 84302
Evening Phone: (801)391-4985
Email: joshuakingsford@hotmail.com

Career Objective:

Seeking an internship position in **Mechanical Engineering** by utilizing my **strong leadership, analytical, and communication skills** combined with my concurrent education at Utah State University.

Education:

Utah State University (2006-Present)
Graduation Date: May 2011
Major: **BS Mechanical Engineering w/ Aerospace Emphasis**
Minor: Japanese
Study Emphasis: **Thermodynamics, Heat & Mass Transfer, Fluid Mechanics, Aerodynamics**
GPA: 3.0

Specialize Skills:

Technical:
- **Software:** FORTRAN 95/2003, MathCAD, Solid Edge 3-D, Microsoft Office 2007
- **Infrastructure:** Network, PC Hardware, System Administration

Languages: Japanese.

Affiliations:

National Honors Society:	Honor Student
Boy Scout of America:	Eagle Scout
Wal-Mart Logistics:	Associate of the Month, Commendation 2009

Work Experience:

Wal-Mart Distribution Center: — Reserve Stocker — 09/2005-Present

As a Reserve Stocker, I am accountable for organizing, breaking down, and replenishing outbound grocery product. Furthermore, I deploy the ability to move and handle products at a high velocity pace which must be completed safely within tightly scheduled time frames. Team work, communication, and alertness to surroundings is absolute for successful completion of assigned goals.

Valley Market Grocery: — Butcher/Grocery Clerk — 04/2003-09/2005

I was responsible and accountable for organizing, stocking, and sanitizing of grocery related items. As grocery clerk/butcher, I was in charge of cutting and preparing meat, cleaning meat department tools, in addition to sanitizing the department.

Wolf Creek Resort: — Maintenance Laborer — 04/1999-09/2003

I served 3 seasons on the golf course maintenance crew for Wolf Creek. My primary responsibilities included landscaping, operating maintenance vehicles (trucks, tractors, and lawnmowers), trimming grass, and planting new sod.

Volunteer Experience:

Nagoya, Japan Mission: — District Leader — 03/2001-03/2003

As **District leader**, my primarily responsible was organizing, managing, and leading missionaries within my assigned district. Furthermore, I set up training meetings related to achieving goals, and trained missionaries to more effectively time on a daily basis. Due to my success as a District Leader, I was promoted to First Counselor of the Branch Presidency in Shingu, Japan.

References:

Craig Schang — Hill Air Force Base (309 MXW/QPE)
Phone Number: (801)721-5039
Email: Craig.Schang@HILL.af.mil

Lee Sawley — Federal Aviation Administration
Phone Number: (801)388-5511
Email: lsaw17@hotmail.com

Justin Anderson — Wal-Mart Distribution Center
Phone Number: (435)744-4000

Mansour Sobbi

204 Moen Hall, Logan, Utah 84321
(208)-410-7365
mansour_sobbi@yahoo.com

EDUCATION

College of Southern Idaho, ID
Associate in Mechanical Engineering **2006-2008**
GPA: 3.35

Utah State University, UT
B.S. Mechanical & Aerospace Engineering **2009-2011**
GPA: 3.54

RELATED EXPERIENCE

- Communication
- Calculus
- Differential Equations (ODE)
- Linear Algebra
- Numerical Methods
- Thermodynamics
- Heat and mass Transfer
- Fluid Mechanics & Compressible Fluids
- 2-D AutoCAD
- Solid Edge
- Dynamic of Space flight
- Dynamic system and Controls

WORK EXPERIENCE

- McDonalds – on the grill
- Lamb Weston
- Discovery Research Group – As an interviewer
- Design a shell and tube heat exchanger

PROGRAMING EXPERIENCE

- FORTRAN95
- MATHCAD
- MATLAB & SIMULINK
- C++
- Microsoft office

LANGUAGES

- Persian(Farsi) – native language
- German – lived five years in Germany
- English

Nathan V. Madsen

nathan.v.madsen@gmail.com
361 East 800 North
Logan, UT 84321
435-363-4678

OBJECTIVE

- Electrical Engineering student competing in USLI competition.

SUMMARY

- Proficient in Microsoft Office suite, experience with spreadsheets and access databases, software installation/troubleshooting
- Experience programming in C and C++ using Microsoft Visual Studio and Matlab

EXPERIENCE

Jan 2008 – Oct 2008 — Customer Service/Technical Support — Convergys--Logan, UT

- Receive inbound customer calls and complaints, resolve issues, and troubleshoot faulty internet connectivity issues.
- Met goals regarding call length, and issue resolutions, provide quality customer service while adhering to company guidelines.

Dec 2001 – Dec 2007 — Specialist Section Expediter — United States Air Force

- Stationed at Cannon AFB, NM; Kunsan AB, South Korea; Shaw AFB, SC
- Supervise 62 technicians responsible for troubleshooting and repairing avionics systems on 20 F-16 C/D aircraft valued in excess of $700M.
- Team leader on elusive flight control malfunction…identified/replaced faulty flight control panel with no further malfunction recurrences.
- Led unit transition to new Link-16 system on 27 F-16 aircraft...handpicked to brief 20 FW commander, 20 MXG commander, and distinguished visitors on system functionality.

EDUCATION

Utah State University

Electrical Engineering Major (Sr.) — Expected graduation: Fall 2011

-

Embry Riddle Aeronautical University

Professional Aeronautics Major — Transfer to Utah State University

- Maintained GPA of 3.5

Community College of Air Force

AAS - Avionics Systems Technology — April 2008

Josue S. Ricsi

CAMPUS:
204 Moen Hall
Logan, UT 84321
(208) 450-9097
josue.ricsi@aggiemail.usu.edu

PERMANENT:
PO Box 3825
Ketchum, ID 83340
(208) 725-2283
jric06mit@yahoo.com

EDUCATION:

Associates of Engineering, May 2008
College of Southern Idaho, Twin Falls, Idaho

Bachelors of Science, Mechanical Engineering. August 2008-Present
Utah State University, Logan, Utah.
Expected graduation: May 2011

Notable Courses Taken:

Thermodynamics I, II	Fluid Mechanics
Advanced Dynamics	Heat and Mass Transfer
Mechanics of Solids	Dynamics of Space Flight
Compressible Fluid Flow	Finite Elements of Solid Mechanics
Vibrations	Rocket Systems Design

RELATED EXPERIENCE: Design a shell and tube heat exchanger

COMPUTER SKILLS:

Mathcad	Microsoft Office
Matlab/Simulink	Fortran
C++	STK (Satellite Tool Kit)
Solid Edge	

ACTIVITIES & COMMUNITY SERVICE:

- Member of Engineering Club, 2006-2008
- Member of Math Club, 2006-2008
- Math Tutor, 2006-2008
- Member of Society of Hispanic Professional Engineers, 2009-present
- Member of ASME, 2009-present

Ryuichi Yamamoto

204 Moen Hall, Logan, Utah 84321
Phone: 435-764-8825
E-mail: georgelade922@mail.goo.ne.jp

Education

BS/MS Mechanical & Aerospace Engineering (2007-Present) — Graduation Expected: December 2011
Aerospace Emphasis
Utah State University, Logan, Utah — GPA: 3.96

- **Related Courses Taken:**

Thermodynamics	Numerical Methods	Advanced Dynamics
Fluid Mechanics	Linear Algebra	Differential Equations
Heat&Mass Transfer	Aerodynamics	Control Systems
Dynamics of Space Flight		Compressible Fluid Mechanics

Technical Skills/ Languages

- **Programming Skills**

Fortran	MathCAD	MATLAB/SIMULINK
Microsoft Office	Ruby	

- **Languages**
  Japanese (Native Language)
  English

Extracurricular Activities

USU Rocket Club (2007 to 2009)
Work as Helping Staff at 3rd Intercollegiate Rocket Engineering Competition, 2008, Green River, Utah

International Student Council (2008 to 2009)
Work at international events in Utah State University (International Banquet, Mr. and Ms. International, Tip-Toe into Asia)

Awards/Scholarships/Society

National Society of Collegiate Scholars	2008-Present
USU A-pin Award	2009
Golden Key International Honour Society	2009-Present
USU Mechanical & Aerospace Engineering Outstanding Pre-Professional	2009
USU Mechanical & Aerospace Engineering Outstanding Junior	2010
Tau Beta Pi, Engineering Honor Society	2010-Present
USU Sophomore Scholarship	2008-2009
Questar Scholarship	2009-2010
MAE Departmental Scholarship	2009-Present

Stewart Hansen

755 E. 700 N. #5B, Logan, UT 84321
Phone: (208) 705-8015, Email: stew.hansen@aggiemail.usu.edu

Objective: Gain assistance in finishing degree in Electrical Engineering with an internship position.

Skills: C++ Programming, Verilog, Ladder Logic, PSpice, Assembly Language, MATLAB, Construction, Carpentry, Electrician, Excellent Customer Service, Work well in groups / excellent team player.

Education: Senior in Electrical Engineering studies at Utah State University.

Credits: 93 Undergraduate GPA: 3.53 (4.0 scale)

Achievements & Honors or Organizations:

Eagle Scout, Ranger Award, Venturing Gold, Duty to God, Technical and Professional, National Honor Society, LDS Mission, a member of IEEE (*Institute of Electrical and Electronics Engineers*)

Professional Experience:

May 2009-Present — **Rocky Mountain NASA Space Grant Consortium,** Logan UT

- Designed weather station interpreter and analog to TTL translator
- Programmed PLC's (Programmable Logic Controllers)
- Manage the Aggie Observatory
- Research assistant Aerospike research

Dec. 2007-Aug. 2008 — **Qwest Corporation,** Logan UT

- Customer Service and Sales Associate (CSSA)
- Helped customers save money
- Presented products to customers that needed them

Sept. 2007-Dec. 2007 — **Axtell Taylor GM,** Preston ID

- Detailed used vehicles to look like new
- Vehicle transporter as needed by sales representative
- Minor vehicle repairs and paint touch-ups

June 2003-Aug. 2003 — **BSA Aspen Ridge Campground,** Preston, ID

- Emergency Preparedness Trainer
- Campground maintenance
- Senior Staff

References Available Upon Request

James R. Wilson

736 E 900 N Apt 13 Logan, UT, 84321
T (775) 482-4931 em.jam.wil@gmail.com

EDUCATION

B.S. Mechanical Engineering, Aerospace Engineering Emphasis, Spring 2011 **GPA: 3.69 out of 4.00**

Utah State University, Logan, Utah

Koch Scholar, Jon M. Huntsman School of Business, Utah State University, Spring 2009

RELATED SKILLS AND EXPERIENCE

Research and Projects

- Completed an individual conceptual design of a glass lamp independent of previous lamp designs; developed manufacturing processes for production, performed cost-analysis, and built 3-D models of the lamp in Solid Edge; presented a technical report.
- Used Satellite Toolkit (STK) to create a simulation of a lunar landing as part of a team working on a contract from the Jet Propulsion Laboratory's Autonomous Landing and Hazard Avoidance Technology (ALHAT) program.
- Created Fortran codes for root-finding, numerical integration, and linear algebra applications.
- Created a simulation in STK showing a lunar fly-by of a satellite; presented work to group of over 200 people at recruitment event for Utah State University.
- Part of a team that modeled a fully-operational dune buggy using Solid Edge and made technical presentation to a group of peers.
- Researched and designed infrared proximity sensor circuit with one other student; wrote technical report.

Computer Experience

- Certified in Satellite Toolkit (STK)
- Windows and MacOS X
- Microsoft Office suite, including PowerPoint, Excel, and Word
- Fortran 95
- Intermediate skill in Solid Edge, MATLAB, HTML, JavaScript

Teamwork

- Has led teams in school and community projects
- Good team player, brings enthusiasm into every assignment and project.
- Follows instructions well.
- Applies knowledge and creativity to every task.
- Excellent interpersonal and communication skills

SERVICE/LEADERSHIP

- Eagle Scout, 2005
- Volunteer, Church Service Representative, Washington DC, 2006-2008
- Tutor for high school students, Nye County (Nevada) School District, 2004-2005

H Bibliography

- Singh, T. & Vadali, S. R. 1994. Robust Time-Optimal Control: Frequency Domain Approach. Journal of Guidance, Control and Dynamics, 17(2), 346-353.
- Singh, T. 1996. Effect of Damping on the Structure of the Time-Optimal Controllers. Journal of Guidance, Control and Dynamics, 19(5), 130-134.
- Liu, S-W., & Singh, T. 1997. Robust Time-Optimal Control of Nonlinear Structures with Parameter Uncertainties. ASME Journal of Dynamics Systems, Measurement and Control, 119(4), 743-748.
- Knacke, T. W., "Parachute Recovery Systems Design Manual," Para Publishing, 1992. ISBN-09155126853.
- Whitmore, Stephen A., Hurtado, Marco O., and Rivera, Jose A., Rivera, and Jonathan W. Naughton, "A Real-Time Method for Estimating Viscous Forebody Drag Coefficients," AIAA-2000-0781, Jan. 2000, 38th AIAA Aerospace Sciences Meeting and Exhibit, January 10–13, 2000, Reno, Nevada.
- Whitmore, Stephen A., Naughton, Jonathan W., and Sprague, Stephanie, "Wind- Tunnel Investigations of Blunt-Body Drag Reduction using Forebody Surface Roughness," AIAA-2001-0252, January 2001. 39th Aerospace Sciences Meeting and Exhibit, January 8-11, 2001, Reno, NV.
- Blake, W. "Missile DATCOM, User's Manual – 1997 FORTRAN 90 Revision," AFRL-VA-WP-TR-1998-3009. Wright Patterson Air Force base, Ohio, 1998.