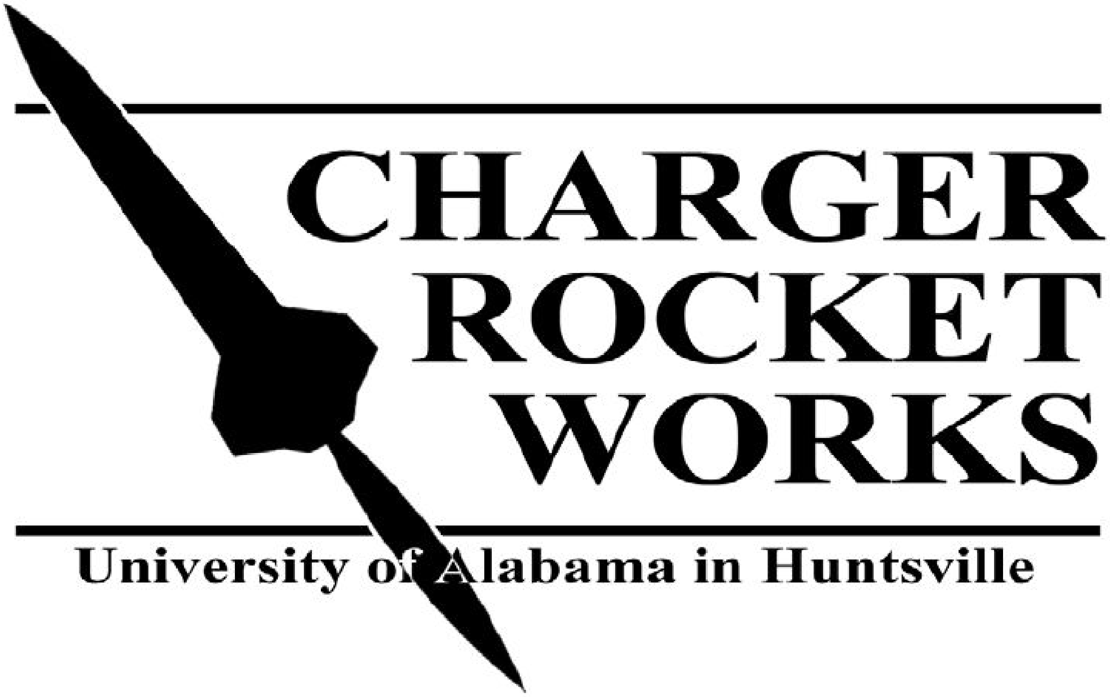

Preliminary Design Review

Student Launch Initiative Team

Fall 2008

I) Summary of PDR Report

Team Summary

Charger Rocket Works, a student led and operated product development and testing team based out of The University of Alabama in Huntsville in Huntsville, Alabama. The team is supported by:

Dr. Marlow Moser (NAR Certified Level 2)
Team Official/ Faculty Sponsor
Professor, Mechanical Engineering Department, UAH

Mr. William T. Bradshaw (Tripoli Certified Level 2)
Assistant Team Official, United States Army

Mr. Daniel Cavender (NAR certified Level 2)
Graduate Assistant, Engineer, Jacobs Engineering

Mr. Jason Winningham
Electronics Advisor, Electrical and Computer Eng. Department, UAH

Launch Vehicle Summary

The Charger Rocket Works USLI team has designed a rocket for the 2009 NASA USLI rocketry competition that has been shown in simulation to meet the requirements set forth. Charger Rocket Works has named the given design Osprey, in honor of the late Dr. Clark W. Hawk. Osprey will be approximately 9 feet 5 inches in length and will weigh roughly 33 pounds. In order to further develop the team members' skills in design and manufacturing, Charger Rocket Works has opted to utilize fewer commercially available components normally used in the construction of high power rockets. Such an example is shown in the team's choice of using carbon fiber filament wound airframe and fins that the team will personally design and manufacture. Osprey will use a fiberglass Ogive nosecone. The motor chosen for the given experiment is an Aerotech L850W. This particular motor produces an average of 1180 Newtons of thrust which has been shown in RockSim simulations to be plenty of thrust to meet the competition altitude of 5,280 feet above ground level (AGL). The projected center of gravity is 5 feet 5 inches from the tip of the nose cone, with the projected center of pressure being 6 feet 3 inches from the tip of the nosecone, giving a stability margin of 1.58 at launch.

Payload Summary:

For the 2008-2009 USLI competition, Osprey will attain two sets of experimental data while in flight. First, a Pitot Static probe that protrudes from the tip of the nosecone will measure and record dynamic pressure during flight. Also, the motor casing will be instrumented with strain gages and will be calibrated to measure the chamber pressure of the engine in flight. In addition to the two aforementioned experiments, the payload will consist of an RDAS (data acquisition system), a Global Positioning System (GPS), a magnetometer, and a video recorder to provide real-time visual data to the ground station as the rocket is in flight. 2-D accelerometers and magnetometers will record the flight path and rocket orientation.

II) Changes made since Proposal

Changes made to Vehicle Criteria

There were two major changes to the structural aspect of the vehicle since the proposal. One has been the choice of materials for the airframe and fins. At the time of the proposal, the team was debating over whether to use the standard fiberglass wound phenolic tube for the airframe and G10 fiberglass for the fins, or an intermediate modulus filament-wound carbon fiber for both the airframe and fins. After careful deliberation over the advantages of each material, the team has determined that the carbon fiber would be the ideal choice. The other major change to the structure of the vehicle is to use a window in the nose cone instead of the clear tip. This was done to better accommodate the pitot-static probe.

Changes made to Payload Criteria:

The major changes made to the payload of the rocket are the addition of a high-resolution video recorder and a Pitot Static probe. The video recorder will be a pendulum mounted device located inside the nose cone. The pendulum motion will allow the camera to pivot, and thus maintain a steady image regardless of nosecone orientation. The other important change is the Pitot Static probe which will protrude from the tip of the nosecone. The Pitot Static probe was implemented as a means of measuring the velocity in addition to the acceleration and altitude.

Changes made to Activity Plan:

To date, there have been no changes to the Activity Plan.

III) Vehicle Criteria

Selection, Design, and Verification of Launch Vehicle

Mission Statement

Charger Rocket Works seeks to further the knowledge of its participating students in rocketry and provide tangible engineering experience in a team environment. This will be accomplished through the USLI competition by seeking to build the best rocket possible and meeting all requirements within budgetary and time restraints.

Requirements

1. The rocket must carry a scientific payload and both must be recoverable and reusable.
2. A tracking device must be placed in the launch vehicle to allow for recovery of the rocket and payload after launch.
3. The target altitude for the rocket if 5,280 feet AGL measurable by an on-board Perfect Flight MAWD altimeter.
4. Vehicle preparation on launch day must not exceed 4 hours.
5. Data from the payload must be collected, analyzed, and reported using the scientific method.
6. Only commercially available, NAR approved motors shall be used in the launch vehicle.
7. A full scale launch must be performed prior to the competition launch to test vehicle stability and recovery systems.

Mission Success Criteria

1. Target altitude must be met without going over.
2. Launch must have a successful recovery.
3. All electronics and structure of the vehicle must survive for reuse.
4. All data must be recovered from flight computers and payload for analysis.

Major Milestone Schedule

Table 1. Major Milestone Schedule

Major Milestone Schedule		
Objective	**Start Date**	**End Date**
Project Initiation	August 15, 2008	
Basic Design	August 17, 2008	December 5, 2008
Proposal Due	October 8, 2008	
Workshop	October 10, 2008	October 11, 2008
Sub-Scale Launch 1	November 15, 2008	November 15, 2008
PDR Due	December 5, 2008	
Detailed Design	January 5, 2009	January 22, 2009
CDR Due	January 22, 2009	
CDR Presentations	January 28, 2009	February 6, 2009
Sub-Scale Launch 2	Pending	
Full Scale Launch 1	Pending	
Full Scale Launch 2	Pending	
FRR Due	March 18, 2009	
FRR Presentations	March 25, 2009	April 3, 2009
Rocket Fair	April 17, 2009	
USLI Launch Day	April 18, 2009	
PLAR	May 8, 2009	

System Level Design Overview

Subsystem Descriptions

Avionics

The avionics system will be designed for total rocket telemetry recording. The goal is to have the ability to plot a 3 dimensional graph of position and orientation versus time of the rocket trajectory and have redundancy in the system in case of hardware failure. This will require the use of many different sensors including two R-DAS flight computers, two 2-D accelerometers, a magnetometer, piezo-electric gyroscopes, a GPS receiver, high definition pendulum mounted video camera, video overlay controller, video transmitter, and a data transmitter. Before launch, each device will be properly calibrated and interfaced with the R-DAS computers. The system will then be completely assembled and rigorously tested to alleviate all possible errors. Each device in the avionics payload is described in more detail below.

R-DAS (Rocket-Data Acquisition System)

The R-DAS is a flight control computer that can be enabled to detect rocket liftoff and collect rocket telemetry data. It has an accelerometer (0-50g), pressure transducer measuring altitude, and ignition switches for deployment of the parachutes. It has EEPROM (Electronically Erasable Programmable Read Only Memory) that can hold between 115 to 462 seconds of telemetry depending on the number of data channels enabled and the data sampling rate. Six channels are available for data recording on each R-DAS. Two R-DAS computers will be required to control, record the data from all the sensors, and to allow for redundancy.

2-D Accelerometer

The 2-D accelerometer is a detector capable of measuring acceleration in two axes. The sensitivity of the sensor can be adjusted to measure between 5g and 50g. The accelerometer will be mounted in the nosecone perpendicular to the flight path. The two accelerometers will measure the horizontal motion of the rocket.

Magnetometers

The magnetometer can detect rocket spin angle and flight angle. The sensor outputs the rocket’s orientation in relation to the earth’s field vector. The spin angle of the rocket is the angle between the axis perpendicular to the rocket’s trajectory and the earth’s magnetic field vector. The flight angle is the angle between the rocket’s trajectory and the earth’s magnetic field vector.

Piezo-electric Gyroscope

The piezo-electric gyroscope will measure the rate of spin and this data will be used to smooth out flight path data acquired from the magnetometer and the accelerometers.

GPS Receiver

The GPS receiver is a standard GPS receiver with a high gain antenna. It contains on board FLASH memory allowing for more data collection on the RDAS. It can track three-dimensional position as well as velocity and can transmit position data if connected to a transmitter unit. The onboard camera is a small Sony camera with an effective pixel area of 500x582. It is a very small and lightweight camera that will work well for video recording. The video overlay controller overlays the GPS readings on the video feed from the camera. In conjunction with a video transmitter the launch team will know exactly were the rocket is at all times provided the transmission works. The video transmitter is a simple high frequency transmitter capable of transmitting video to a receiver over long distances. The data transmitter is a 900 MHz transmitter that can transmit up to 3 miles.

Pitot-Static Probe

The Pitot Static probe is a simple brass cylindrical stem that has a tube inside a tube. The Pitot Static tube measures the total pressure (or impact pressure) at the nose of the Pitot tube and the static pressure of the air stream at side ports. The difference of these pressures, the velocity pressure ($P_{dynamic}$) varies with the square of the airs velocity. Thus the air velocity may be expressed as:

$$V = \sqrt{\frac{2P_{dynamic}}{\rho}}$$

Where: V is the velocity, $P_{dynamic}$ is the pressure difference, and ρ is the gas density.
The figure below shows the basic idea of how the Pitot Static probe is configured except the rockets probe will be a straight probe protruding vertically from the nose cone tip.

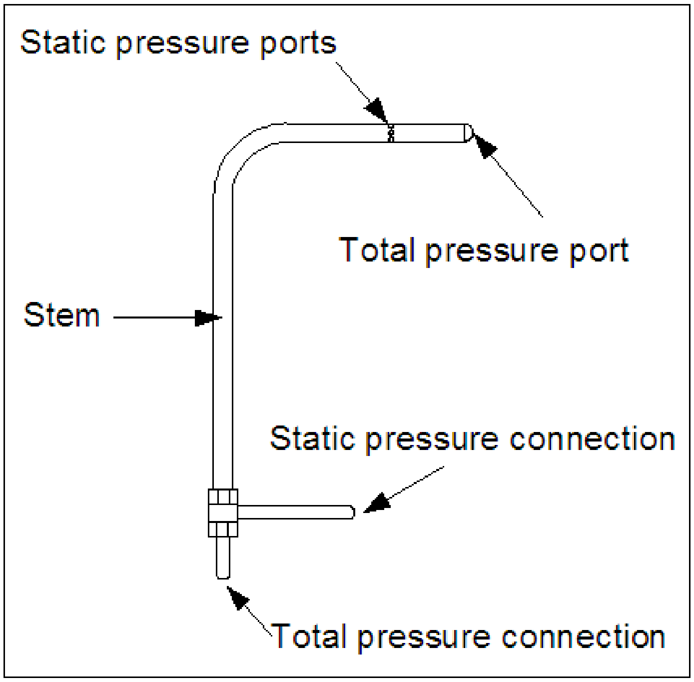

Figure 1. Pitot Static Probe

The testing of the operations of how the nose cone payload will operate has been conducted; and verification of the retraction of the Pitot Static probe was successful. The concern for a multiple flight rocket with a Pitot Static probe protruding from the tip of the nose cone and becoming damaged was one of the main focuses of the payload team. Testing methods of retracting the Pitot Static probe, and finding a reliable solution was the payload teams' focus for the sub-scale flight. During the building of the sub-scale the probe retraction was best done by having the probe secured in a horizontal direction but the vertical direction was free. The probes vertical direction was then able to move up and down allowing the Pitot Static probe to retract inside the protective nose cone. This method of retracting the probe proved to be simple and allowed for a more reliable system integration.

Propulsion

In order to select the proper motor to meet the given mission requirements, the team utilized the Rocksim software. A number of different motors were simulated with our given design and payload in order to find the motor that produces the correct amount of thrust to launch Osprey to the desired altitude of 5,280 ft. AGL. After numerous simulations, the team chose to utilize the Aerotech L850W. Rocksim predicted that the L850W would propel Osprey to an altitude of 5,300 ft. AGL.

Structures

The structure of the rocket will consist of three sections: the airframe, the nose cone, and the fins. The entire structure will be approximately 9 feet 5 inches long and 6 inches in diameter. The rocket's primary structural component will be its 6 inch diameter intermediate modulus filament wound carbon fiber airframe. The Ogive nosecone is constructed from light weight high strength fiberglass and weighs only 1.5 lbs. Several payload components will be housed in the nose cone, such as the high definition camera and the Pitot Static Probe. The four trapezoidal shaped custom made fins will be constructed of intermediate modulus plain weave carbon fiber.

Recovery

The recovery subsystem is designed to safely return the rocket back to the surface after the flight. The recovery system will employ a dual deployment method. At apogee, the rocket will separate via an electronically activated black powder charge. The two separated sections will be connected via a Kevlar shock chord. The separation of the rocket reduces aerodynamic efficiency and allows the rocket to fall at a decreased rate due to the increased drag of the two separated rocket sections. At a preset altitude, another electronically activated black powder charge will deploy the main parachute allowing the rocket to descend at a controlled rate. This method of deployment greatly reduces the recovery area because the main parachute deployment at a lower altitude greatly reduces drift.

Verification Plan

In order to ensure that Osprey will operate as designed, several verification tests need to be undertaken for each subsystem. Verification of operational readiness for each subsystem prior to launch ensures mission success with minimized risk and increased safety for the team, bystanders, and apparatus.

Avionics Verification

In order to verify adequate operation of the avionics, verification and testing will begin with the R-DAS. To ensure that the R-DAS will accurately detect the key deployment altitudes during flight, the R-DAS will be tested in a vacuum chamber. For the vacuum test, the R-DAS unit will be fitted with lights instead of the black powder charges. The pressure will be lowered and then equalized to simulate the ascent to apogee and then raised again to simulate the dual deployment descent. As the R-DAS senses the equalization in pressure of apogee, the light should turn on indicating a successful measurement. Likewise, when the R-DAS measures the exact rise in pressure for main parachute deployment, a secondary light will then turn on indicating a successful operation. This vacuum testing will significantly reduce the risk of deployment failure during flight. Verification and testing will continue with the 2-D accelerometer, magnetometer, and GPS. To ensure their proper function during the USLI competition, tests will be conducted by fitting the subscale model with the mentioned components and making several test flights. Post-flight data analysis will verify proper readings. By properly testing the 2-D accelerometer and ensuring that it properly measures the force of launch, the risk of proper and safe recovery of the rocket is reduced. The subscale test flights will also verify that the GPS not only tracks the three dimensional flight paths but will transmit the location for an easier recovery.

Propulsion Verification

Verification will also include testing of the propulsion system. Performance predictions are done using Rocksim software. A number of different motors were simulated with our given design and payload in order to find the motor that produces the correct amount of thrust to launch Osprey to the desired altitude of 5,280 ft. AGL. After numerous simulations, the team chose to utilize the Aerotech L850W. Rocksim predicted that the L850W would propel Osprey to an altitude of 5,300 ft. AGL. At least one full scale, full altitude test flight will be done prior to competition to ensure that theoretical data will match experimental.

Structures Verification

Since the airframe and fins will be deigned and built by Charger Rocket Works analysis will have to be performed to verify its ability to tolerate the various loads that it will witness during flight and recovery. Initial stress calculations will be done to determine the winding pattern and material type to be used. To further validate the endurance capability of the airframe and fins destructive and nondestructive tests will be applied. For destructive tests samples of the carbon fiber components will be put through tensile and compressive tests in order to confirm previous calculations. Nondestructive analysis will be completed utilizing Abacus for finite element analysis which will show the stress concentrations of the airframe and fins during flight. Charger Rocket Works will be able to attain more resourceful data through nondestructive tests conducted using Shearography. Shearography will produce three dimensional images of any voids or imperfections that will occur during the manufacturing of these parts. These tests will help ensure that after several flights the integrity of the airframe and fins will still be more than adequate to endure several more flights.

Recovery Verification

Charger Rocket Work’s Osprey is a two stage system that will utilize electronically ignited black powder driven pistons. Mock pistons have been built to simulate the ones used in flight. Powder charges of various weights will be tested in the mock pistons to determine the correct amount needed to separate the two stages. Once the amounts have been determined further testing occurs during flight tests. Flight tests will reveal how well the powder charges work and if the main chute operation is adequate and successful. The testing and validation of the recovery system will ensure that Osprey will be able to fly again another day.

The tables on the following pages give risk and failure mode effects, analysis, and mitigation.

Table 2. Risk and Mitigation Table

Risk and Mitigation Table			
Risk	**Probability**	**Impact**	**Mitigation**
Project Falls Behind	High	Deliverables submitted late; Project not completed.	Schedule project with adequate time margin.
Long Delivery of Parts	Low	Incomplete Osprey	Order parts early; Manufacture own parts.
Delayed Test Flights	Medium	Inadequate testing of system and subsystems.	Plan several dates for test flights.
Insufficient Personnel	Low	Too much work for too few people;Possible Incomplete project.	Involve several workers
Key Personnel Leave Project	Low	Extra work for each member; later delivery; incomplete project.	Produce backup personnel assignments.
Poor Leadership	Low	Disorganization; late submittals.	Elect strong leaders; establish organizational structure.
Procrastination Among Team Members	High	Late submittals; incomplete project.	Strong leadership; eager team members.
Osprey Over Project Cost Limit	Medium	Design changes	Proper budget planning; manufacture own parts;
Loose Monetary Support from UAH	Low	Fuding Insufficiencies;Project Cancelation	Have several funding sources.
Part Unavailability	Low	Design changes; Incomplete project.	Manufacture own parts; Incorporate standard parts in design.
Loose Manufacturing Contacts	Low	Loose ability to manufacture carbon fiber parts.	Gain multiple manufacturing contacts.
Lack of Necessary Tools	Low	Inability to build Osprey.	Budget for acquisition of tools; Solicit contributions.
Poor Worksmanship	Medium	Weak structure; unstable flight.	Proper guidance from experienced members/mentors.

Table 3. Failure Modes and Effects Analysis of Propulsion System

Failure Modes and Effects Analysis of Propulsion System

Function	Potential Failure Mode	Potential Effects of Failure	Failure Prevention
1	Motor ignitor fails to ignite.	Rocket does not fly.	Proper igniter selection and setup; proper power source.
2	Motor propellant fails to ignite.	Rocket does not fly.	Proper ignition system selection and setup.
3	Propellant ignites but causes explosion.	Destruction of motor casing; possible destruction of entire system.	Proper motor/propellant setup; adequate verification testing.
4	Propellant burns through motor casing.	Loss of thrust; loss of stability; destruction of system.	Verification testing of motor casing and propellant combinations; static fire tests.
5	Motor mounting fails and motor launches through rocket.	Destruction of all subsystems.	Proper motor mout construction; adequate load testing.
6	Propellant does not burn long enough.	Osprey will not reach desired height.	Proper propellant grain loading; multiple static fire tests.
7	Motor casing becomes dislodged during flight.	Osprey will not reach desired height; motor casing becomes dangerous projectile.	Proper motor retention.

Table 4. Failure Modes and Effects Analysis of Structures System

Failure Modes and Effects Analysis of Structures System			
Function	**Potential Failure Mode**	**Potential Effects of Failure**	**Failure Prevention**
1	Buckling of the airframe during flight.	Unstable flight; inability to reach target altitude.	Selecting suitable materials for a high powered rocket flight.
2	Premature nosecone separation.	Unstable flight; premature deployment; zippering of airframe.	Adequate selection and integration of nylon shear pins; proper shoulder diameter.
3	Premature airframe separation.	Unstable flight; catastrophic failure of all systems.	Adequate selection and integration of nylon shear pins.
4	Fin(s) flutter during flight.	Unstable flight; fin failure during flight.	Adequate materials and construction techniques.
5	Fin(s) break off during flight/landing.	Unstable flight; possible damage of engine mount.	Adequate materials and construction techniques.
6	Fin-can failure due to high temperatures.	Unstable flight; Fin can separation.	Proper mounting material and hardware.
7	Centering ring failure.	Unstable shift in stability margin; Damage to all subsystems; separation of fin can.	Proper centering ring diameter; proper construction techniques.
8	Bulkhead failure.	Unstable flight; damage to subsystems; unstable shift in stability margin.	Proper bulkhead diameter; proper construction techniques.
9	Launch button separation.	Improper flight trajectory; unstable flight.	Proper alignment and construction of launch buttons.

Table 5. Failure Modes and Effects Analysis of Recovery System

Failure Modes and Effects Analysis of Recovery System			
Function	**Potential Failure Mode**	**Potential Effects of Failure**	**Failure Prevention**
1	Parachute Breakaway	Loss of flight article	Design robust retention system.
2	Parachute Deployment Failure	Loss of flight article	Ground test deployment system.
3	Descent Rate Too High	Damage on landing; loss of flight article.	Use larger parachute; drop test flight hardware.
4	Parachute Melt	Damage on landing; loss of flight article.	Use flame retardant shroud; use piston deployment system.
5	Parachute Tear	Damage on landing; loss of flight article.	Inspect parachute material prior to launch preparation.
6	Parachute Tangle	Descent rate too high; damage on landing; loss of flight article.	Correctly pack parachute; ground test deployment system.

Table 6. Failure Modes and Analysis of Avionics/Payload System

Failure Modes and Effects Analysis of Avionics/Payload System			
Function	**Potential Failure Mode**	**Potential Effects of Failure**	**Failure Prevention**
1	R-DAS Miscalibrated	Early/Late parachute deployment; erroneous data collection.	Properly calibrate R-DAS.
2	R-Das Failure	Loss of flight article; loss of flight data.	Test R-DAS prior to flight; design a redundant system.
3	Dead Battery	Loss of flight article; loss of flight data.	Monitor charge of batteries.
4	Video Transmitter Failure	Video transmission failure.	Test to verify high-g operation.
5	GPS Unit Failure	Location transmission failure.	Test to verify high-g operation.

Charger Rocket Works is confident that its design will meet all requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with a more detailed design of Osprey.

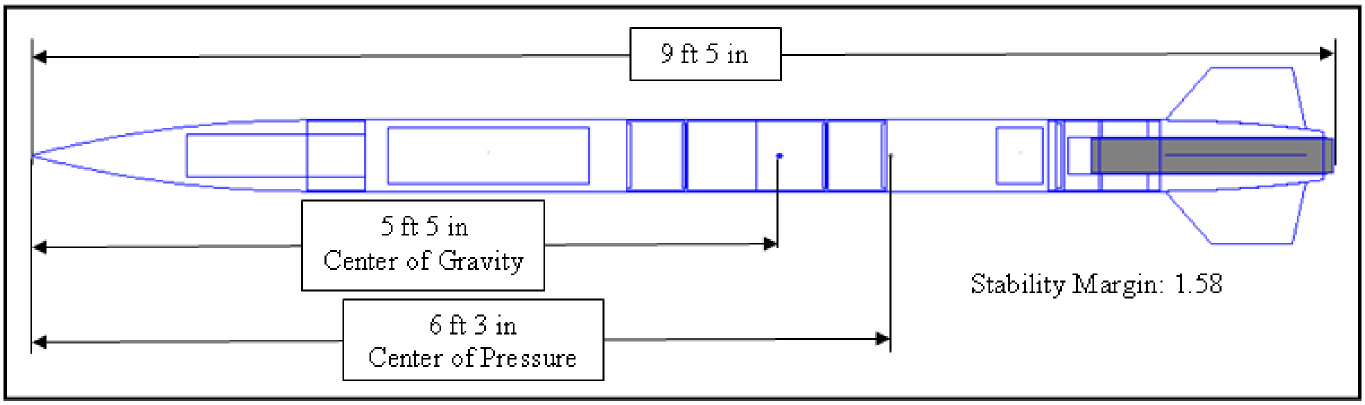

Figure 2. Schematic of Full Scale Osprey

Recovery Subsystem

The recovery system is designed to produce a safe and controlled landing of the vehicle. This system is critical for safeguarding the structure as well as the payload and avionics housed throughout the vehicle. This is also necessary in meeting the USLI requirement for a reusable launch vehicle. Osprey will consist of a dual deployment technique. The onboard avionics supports the recovery system and will include a Rocket Data Acquisition System (R-DAS) as well as a Perfectflite (miniAlt). Both the R-DAS and the Perfectflite contain event deployment capabilities, and each will be wired to the forward and aft ignition charges. Each flight computer will be programmed to produce drogue separation at apogee releasing the drag cord as well as deploying the main parachute at 600ft AGL. The redundancy of two flight computers provides increased assurance in Osprey's safe recovery.

At apogee the flight computers will generate drogue separation and release the drag chord. An electronic match ignition will set off a black powder charge and the aft end piston will be pushed forward separating the tail section from the aft airframe. A drag cord will connect the airframe and the tail section, and this will inherently disrupt the aerodynamics of the rocket. This separation will produce a decrease in Osprey's velocity, and will begin the descent phase.

Later in the descent phase at approximately 600 ft AGL of Osprey's flight, the flight computers will ignite the second black powder charge. When this charge fires, another piston will be pushed out of Osprey's upper airframe. In the process, the shock chord connecting the nose cone and main parachute will be ejected. Once the parachute inflates, Osprey will descend and land safely. The deployment process in its entirety can be seen below in *Figure 3. Flight and Recovery Process*. The Recovery system was successfully tested on Nov 16, 2008 when the subscale vehicle was launched and recovered safely from two separate flights. This system is taken from historical procedures utilized in past teams, and greatly reduces the recovery area. This system does add complexity to the vehicle however historical proven experiences deem this system reliable.

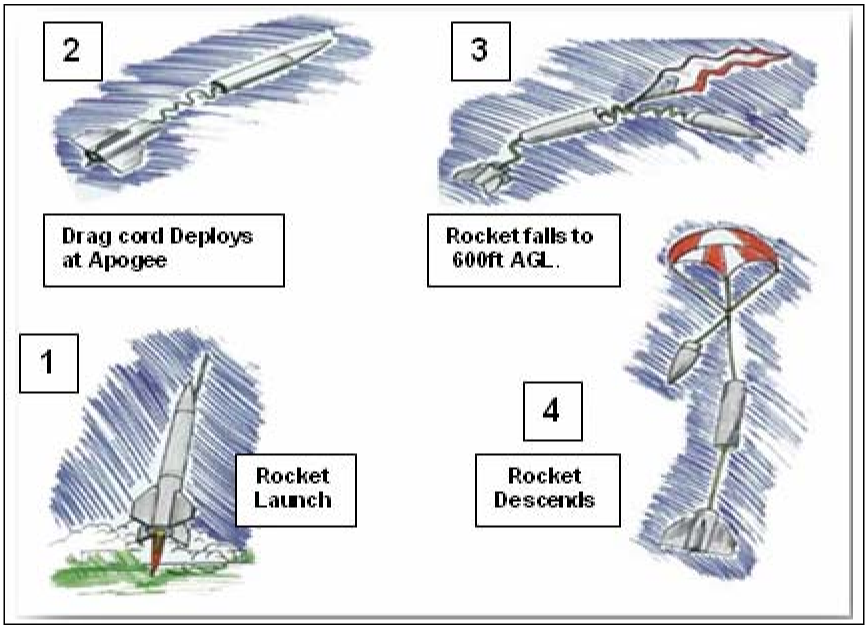

Figure 3. Flight and Recovery Process

The recovery system's deployment charges, shock cords, piston, interface components, and parachute must be tested for functionality and reliability. The deployment charges will need to be of sufficient size to overcome the shear pins and separate the rocket's forward and aft sections. The parachute must be of sufficient size to provide a gentle decent rate that safely ensures the intact recovery of the rocket and its scientific payload. The parachute diameter will vary between 60 and 72 inches, depending on the final weight of the full scale vehicle. The subscale vehicle utilized a 1 gram quantity of black gun powder FFF for the drogue and main separation. Osprey's structures are similar to that of last year's vehicle; this fact yields the preliminary quantity of black powder for the full scale vehicle. Last years vehicle utilized a drogue black powder quantity of 2.0 grams, and a main ejection quantity of 2.5 grams. This knowledge provides the team with a valid starting point, however testing and evaluation of this black powder measure will be tested to provide verifiable evidence for functionality in the full scale vehicle's flight. This is also important because of any dissimilar structural characteristics between last year's vehicle and Osprey. *Figure 4. Piston Deployment Schematic* below displays the team's historical recovery attachment scheme. This illustration outlines the required components compiled in the piston ejection system.

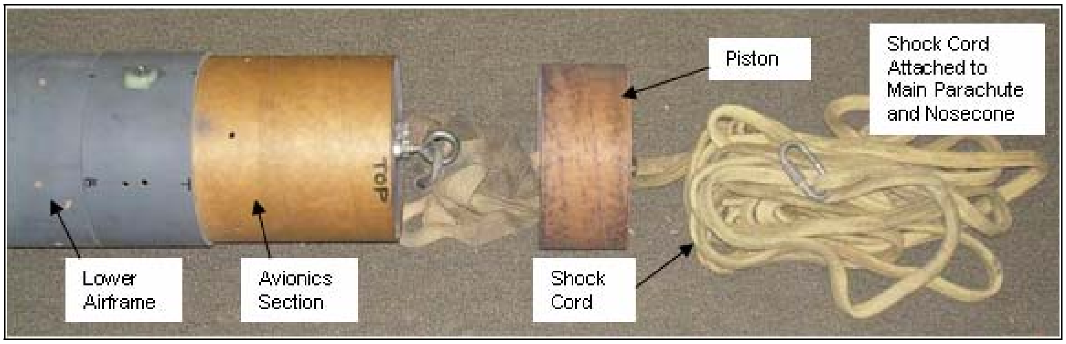

Figure 4. Piston Deployment Schematic

Mission Performance Predictions:

The Osprey must be propelled to a height of approximately 1 mile above ground level (AGL). The Osprey must not experience an acceleration of more than 8g due to structural uncertainties.

A model of the full scale rocket was created in Rocksim. The diameter of the model was 6 in with a span diameter of 17 in. The total length of the rocket was 9 ft 5 in with a center of gravity located at 5 ft 5 in from the nose and a center of pressure located at 6 ft 3 in from the nose. See *Figure 5. Full Scale Osprey Schematic*. The center of gravity was determined by the weight and location of each subsystem. A summary of the weight distribution is located in *Table 7. Osprey Weight Distribution.*

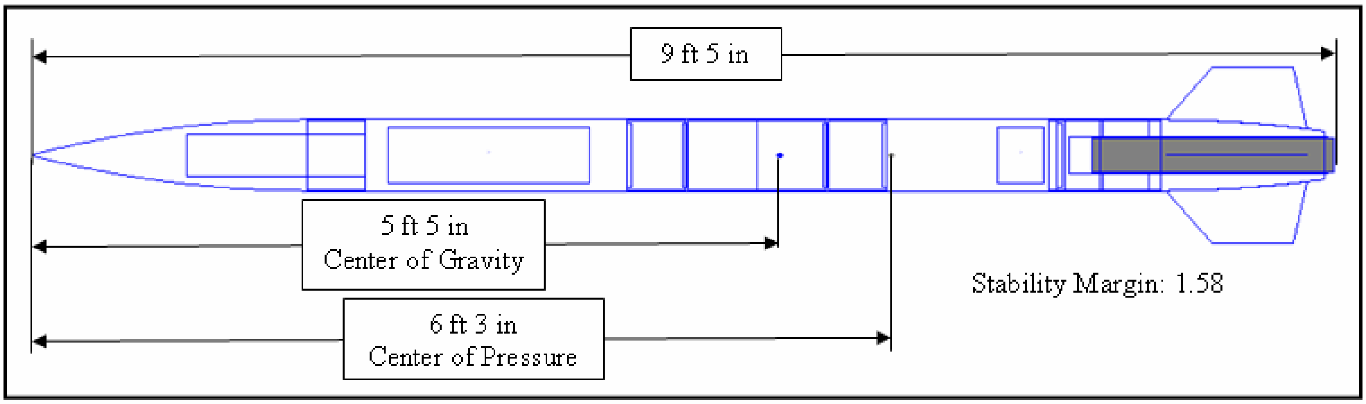

Figure 5. Full Scale Osprey Schematic

Table 7. Osprey Weight Distribution

Component Group	Weight (lbs)
Structures	15
Propulsion	10
Recovery	2
Avionics/Payload	6
Total	33

The Rocksim simulation was run for the model of the Osprey with a L850W motor. The velocity, altitude, and thrust can be seen in *Figure 6. Thrust, Velocity, Altitude vs. Time of Osprey*. The maximum altitude of the flight was approximately 5,300 ft which is close to the goal of 5280 ft (1 mile). The thrust profile for the simulated flight is also shown in *Figure 7. Thrust vs. Time of Osprey (4.75 seconds)*. In this figure, the duration of the burn can be seen more clearly. The burn will last for approximately 4 s and reach a maximum thrust of 1,190 N.

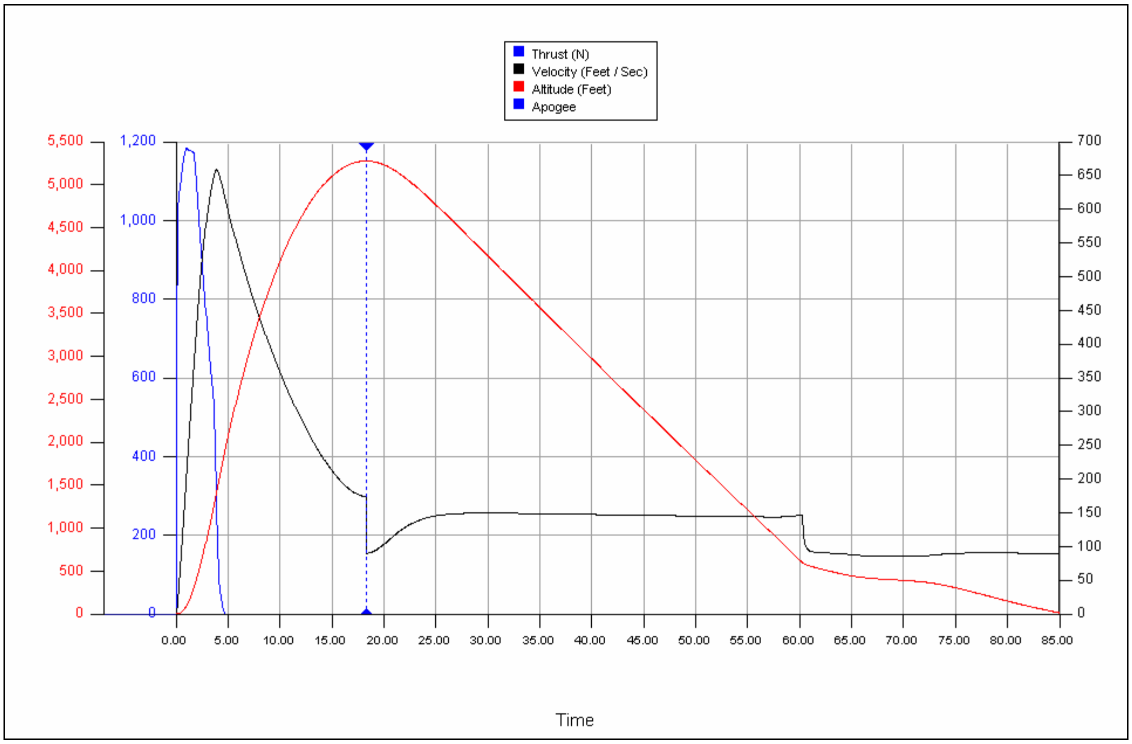

Figure 6. Thrust, Velocity, Altitude vs. Time of Osprey

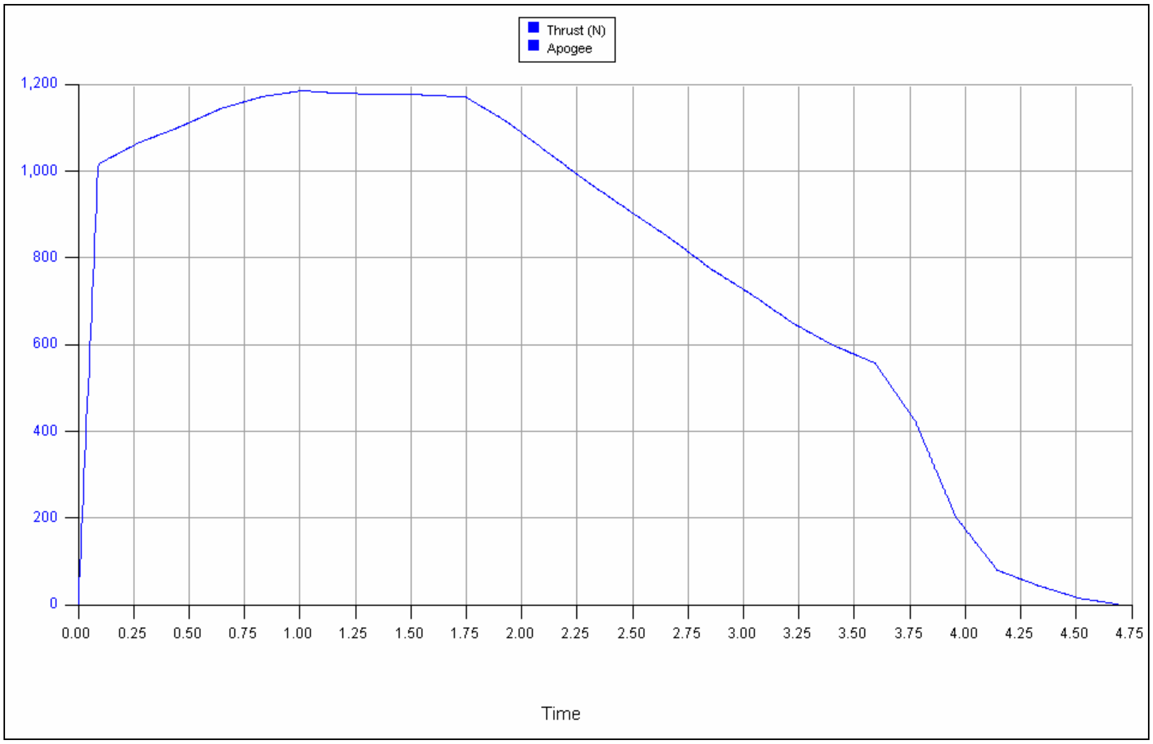

Figure 7. Thrust vs. Time of Osprey (4.75 seconds)

Payload Integration

The payload will easily integrate with the other subsystems. The payload and avionics teams have been collaborating with the recovery and structures teams in order to determine the size, weight and positioning of the payload within the rocket. The payload and avionics were slated to fit within the constraints of the University Student Launch Initiative (USLI) guidelines.. All of the subsystems collaborated to decide the positioning of each system and the positioning of the bulkheads. The scientific avionics payload which includes the Pitot Static Probe, pendulum video camera, 2-D accelerometers, and magnetometers will be positioned within the nosecone of the rocket.

Launch Operation Procedures

The launch system used for the rocket will be a rail launch system combined with launch lugs that will be attached to the side of the launch vehicle. The platform is comprised of an extruded aluminum launch rail mounted to a large and stable aluminum base.

The team will review system preparation requirements in advance of the launch and establish a “Technical Manual” for launch-prep operation. Safety oversight and launch procedures will be managed by the launch leader (project leader). The safety officer(s) will oversee all operations where danger might exist. Team leaders will supervise the preparation of their subsystem. Formal integration of subsystems will require launch leader oversight. An NAR or Tripoli member with appropriate certifications will oversee the assembly of Osprey’s propulsion system. This is a quality control measure to ensure that mission essential systems are in fact prepared for launch. All launch procedures are divided into systems along with the personnel required and are listed below.

A. Launch Leader

The role of the Launch Leader is to choreograph the preparations of all systems and serve as the point of contact for the team, the faculty advisors, the USLI personnel, and the range officer.

B. Payload Leader

The role of the Payload Leader is to oversee all aspects of the preparation and handling of *Ospreys* payload subsystems. He serves as a point of contact between the Launch Leader and the payload team. His endorsement is required on critical tasks before subsequent tasks can be performed.

C. Recovery Leader

The role of the Recovery Leader is to oversee all aspects of the preparation and handling of *Osprey’s* main avionics system. He serves as a point of contact between the Launch Leader and the recovery team. His endorsement is required on critical tasks before subsequent tasks can be performed.

D. Avionics Leader

The role of the Avionics Leader is to oversee all aspects of the preparation and handling of *Ospreys Avionics*. He serves as a point of contact between the Launch Leader and the payload team. His endorsement is required on critical tasks before subsequent tasks can be performed.

E. Structures Leader

The role of the Structures Leader is to oversee all aspects of the preparation and handling of *Osprey*. He will oversee the assembly of *Osprey* and the integration of each system. He serves as a point of contact between the Launch Leader and the structures team. His endorsement is required on critical tasks before subsequent tasks can be performed.

F. Checklists

The Checklists provided below are reviewed pre-launch for safety and risk mitigation.

Payload System Pre-Launch Checklist	**GO**
1a) Inventory of all payload equipment	____
1b) Inspect all payload equipment for safety and security	____
2) Inspect each RDAS and expansions for hardware security	____
3) Inspect batteries for hardware security	____
4) Inspect Magnetometers for hardware security	____
5) Inspect GPS for hardware security	____
6) Inspect each camera for cleanliness and hardware security	____
7) Inspect each payload carrier for hardware security	____
8) Inspect respective antennas for security	____
9) Inspect the deployable payload for fit	____
10) Inspect deployable payload parasail for hardware defects	____
11) Inspect deployable payloads second stage vehicle	____
12) Inspect each payload security separately	____
All Payload Equipment Is Secure	____

Payload Leader ____
Launch Leader ____

Hold for Avionics Systems Pre-Launch Checklist	**GO**
1) Insert Main Avionics into airframe and align holes	____
2) Check switch holes for proper positioning	____
3) Inspect static pressure ports for obstructions	____
4) Install rivets into rivet holes and secure	____
All Avionics Equipment Is Secure	____

Avionics Leader ____
Launch Leader ____

Recovery System Pre-Launch Checklist	**GO**
1) Inventory of all recovery equipment	____
2) Inspect all Kevlar fiber shock cords for safety and security	____
3) Hook drogue/shock cord to rockets fin and motor assembly	____
4) Hook opposite end of drag shock cord to bottom of Main Avionics / Payload assembly	____
5) Hook Parachute shock cord to nosecone	____
6) Hook opposite end of Parachute shock cord to top of Main Avionics/ Payload assembly	____
7) Inspect parachute for hardware defects and security	____
8) Visually inspect the main ignition charges for secure connection	____
9) Fold and load parachute into upper airframe	____
10) Fold remaining shock cord and load into upper airframe	____

11) Mount nosecone and align shear pin holes ____
12) Install shear pins in shear pin holes ____
Parachute Loading Complete ____

Recovery Lead ________________________________
Launch Lead ________________________________

GO
13) Visually inspect the drogue ignition charge fro secure connection ____
14) Fold drag shock cord and load into lower airframe ____
15) Mount lower airframe to motor fin assembly ____
16) Install shear Pins ____
Shock Chord Loading Complete ____

Recovery Leader ________________________________
Launch Leader ________________________________

Avionics System Pre-Launch Checklist **GO**
1) Inventory of all avionics equipment ____
2) Inspect all avionics equipment for safety and security ____
3) Verify correct wiring scheme for R-DAS #1 ____
4) Verify correct wiring scheme for R-DAS #2 ____
5) Verify correct wiring scheme for R-DAS #3 ____
6) Verify correct wiring scheme for R-DAS #4 ____
7) Verify correct wiring scheme for Perfectflite ____
8) Test R-DAS for proper orientation and configuration ____
9) Verify proper programming of each R-DAS ____
10a) Invert each payload to trigger the R-DAS listen for
R-DAS triggering and record 30 seconds worth of data ____
11) Recover data form 30 second test to laptop ____
12) Verify R-DAS main parachute configuration is correct ____
13) Verify R-DAS is activated by G-switch ____
14) Verify R-DAS appropriate channels are switched on ____
15) Verify R-DAS sample rate ____
16) Repeat for each R-DAS ____
R-DAS's Are Properly Configured ____

Avionics Leader ________________________________
Launch Leader ________________________________

17) Inspect main ignition wires from R-DAS and Perfectfllite ____
18) Visually inspect for proper connection to the junction
box on top of the Main Avionics/ Payload ____
19) Install main ignition charges ____
20) Inspect drogue ignition wires from R-DAS and Perfectfllite ____
21) Visually inspect for proper connection to the junction box
on top of the bottom Avionics/ Payload ____
22) Install drogue ignition charges ____
Recovery Charge Loading Complete ____

Avionics Leader ____
Launch Leader ____

Structural System Pre-Launch Checklist **GO**
1) Inventory of all structures equipment ____
2) Inspect fins for damage and security ____
3) Inspect motor assembly bulkheads, centering rings,
motor mounts and eye bolts for security ____
4) Inspect airframe for damage ____
5) Inspect nosecone centering ring and eye bolt for security ____
6) Inspect Launch Lugs for security ____
7) Inspect all structural components for proper fit ____
All Structures Hardware Is Secure ____

Structures Leader ____
Launch Leader ____

Safety and Environment (Vehicle)

The safety officers for Charger Rocket Works are Mr. Daniel Carter (Project Lead) and Mr. Eddie Jeffries (Assistant Project Lead). The safety officers will ensure that Charger Rocket Works designs, builds, and tests Osprey within the full scope of the University of Alabama in Huntsville's safety policies. A complete and detailed set of MSDS's are posted in the Charger Rocket Works clubhouse. Since Osprey will be constructed in Charger Rocket Works' clubhouse, environmental hazards were identified and mitigated. Some of these possible hazards are ventilation and the event of fire. The team will build, test, and launch Osprey while strictly adhering to NAR regulations. All students have been briefed in detail about these regulations. Such briefings include, but are not limited to:

- NAR certifications and how they pertain to the safety and procedures associated with the UAH USLI competition.
- The use of lightweight materials, such as wood, paper, rubber, plastic, and fiberglass for reasons of safety to the team and bystanders.
- The use of certified, commercially manufactured engines and the necessesity of keeping heat sources a safe distance away from any motor.
- The use of electrical launch systems and igniters that are fitted with safety interlocks and the importance of not arming the igniter until the rocket is on the pad.
- The proper procedures to be undertaken in the case of a motor misfire.
- Details concerning launch safety, including the use of a loud, audible countdown, enforcing a safe distance between the rocket and observers, and checking the stability of the rocket before flight. The team extensively utilizes the RockSIM software to ensure rocket stability.
- The importance of choosing a proper launch site with adequate dimensions for the planned flight, and the proper location of the launcher.
- The importance of using a proper recovery system which will ensure that all parts of the rocket are safely returned undamaged in reusable condition, and the importance of not attempting to recover the rocket from power lines, trees or any other hazard.

Potential failure modes that Osprey's structure could experience during flight are buckling of the frame, fin flutter or break off, centering ring or bulkhead failure, launch button separation, premature nosecone or airframe separation, and/or fin-can failure due to high temperatures.

IV) Payload Criteria

Selection, Design, and Verification of Payload Experiment

The rocket's avionics will have one of two tasks. In the center of the rocket a recovery avionics compartment will be solely responsible for firing the drogue and main charges. This compartment will contain a Perfectflite computer, which will record the official altitude, and an R-DAS flight computer. Both the R-DAS and the Perfectflite are connected to a single charge for redundancy. This compartment will be sealed except for two small holes to allow the pressure to equilibrate. These holes will be perpendicular to the direction of travel of the rocket to mitigate fluctuations in pressure caused by adverse pressure gradients. These holes will also be used for the "Remove Before Flight" pins that turn the recovery avionics on.

The nosecone and tail section of the rocket will contain additional flight computers for recording telemetry and payload data. The nosecone avionics will consist of an R-DAS connected to the Pitot Static probe, GPS receiver, camera, and video transmitter. The GPS data is also overlaid onto the video prior to being transmitted. The tail section will either use an R-DAS or a microcontroller and datalogger to record motor pressure data.

Payload Concept and Definition

The primary goal of the proposed payload is to collect data with respect to the measurements taken from the Pitot Static probe. Secondary goals include acceleration forces data in 3-D, video and GPS telemetry. If successful, it will be possible to map the payload from within the rocket – in 3-D -complemented with GPS positions. This will allow a possible 3-D model of the rocket throughout the flight. The level of difficulty for this project is considerably high; especially post flight data analysis of the Pitot Static probe, the pendulum video camera configuration, and the 3-D modeling. The creativity of the payload for the new rocket is that the pendulum action of the video camera will be able to get a full view of both the take-off and descent of the rocket through the entire flight. The pendulum action will be a challenge to manufacture and to maintain a reliable system for the multiple launches in the rockets lifespan. The method of retracting the Pitot Static probe is also challenge; however, a simple yet original design will correspond to an already tested reliable system.

Science Value

The data collected can then be compared to other data gathered from Recovery/Avionics computer system and scientific conclusions can be made from the data. Understanding the data gathered by all the Payload systems is the top priority of the Payload team. The primary scientific goal of the payload team is to understand the data collected from the Pitot Static probe. After the sub-scale rocket flight, a greater understanding of the data gathered was analyzed and was found to be very useful data measurements. The below data and analysis of data is shown below:

There were two sub-scale flights that were analyzed, one with a blunt tail section and one with a boat tail section. The Pitot Static probe data from each were converted to velocity and compared with the velocity that was integrated from the acceleration data recorded. Graphs from each flight are shown below.

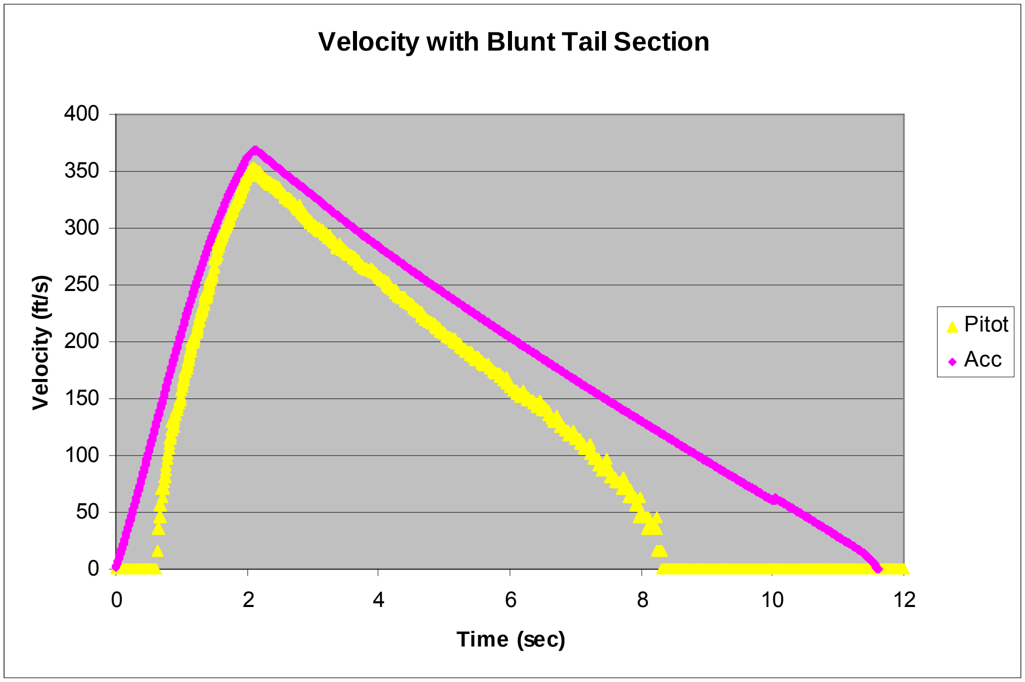

Figure 8. Velocity of Sub-Scale Osprey with Blunt Tail

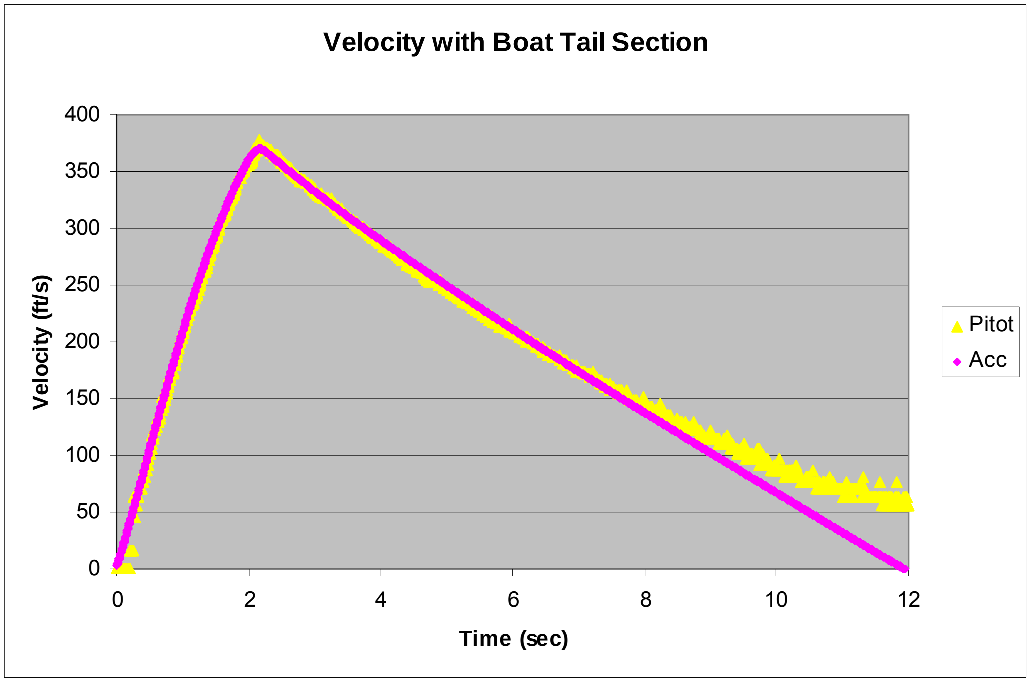

Figure 9. Velocity of Sub-Scale Osprey with Boat Tail Section

When the velocity from the Pitot Static probe is compared to the velocity integrated from the acceleration they are very similar. After comparing the two velocities the pitot static experiment was very successful in determining the velocity of the flight.

Below is the pressure transducer determination chart. It shows the predicted velocity given by the Propulsion Team and shows what pressure differences are to be expected during the predicted sub-scale flights. As seen, a pressure transducer that can take data calculations of a pressure difference within 0 to 2 psi would be sufficient.

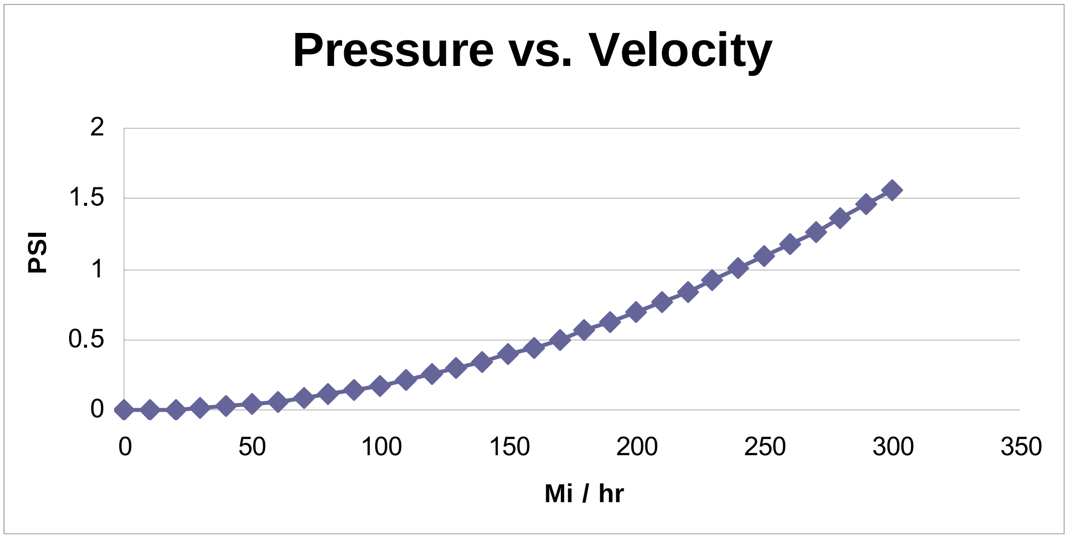

Figure 10. Pressure Transducer Determination Chart

The sub-scale flight data appeared to be correct however with any new instrumentation it's important to verify the data by calibrating it so the presented data is accurate. The below information shows the ideas behind calibrating the sub-scale Pitot Static probe.

Figure 11. Calibration of Pressure Transducer below shows how the pressure transducer was correctly calibrated.

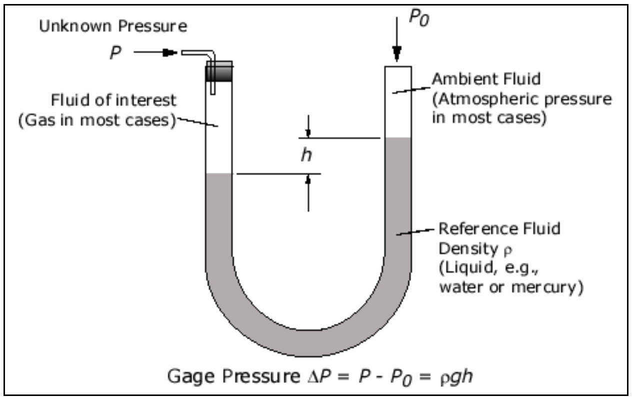

Figure 11. Calibration of Pressure Transducer

Figure 12. Pitot Calibration Data below shows the pressure and voltage linear relationship that was used to correctly translate the sub-scale data to read correct values.

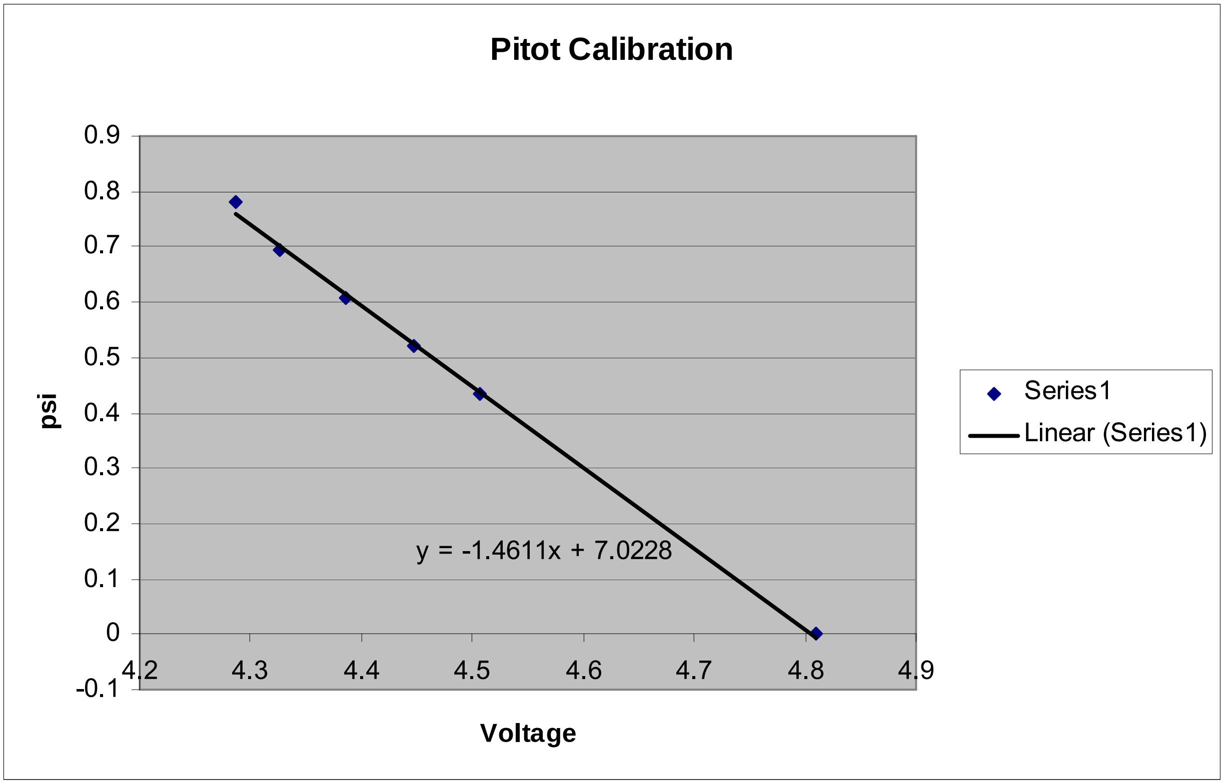

Figure 12. Pitot Calibration Data

The figure below shows the altitude differences between the Blunt and Boat Tail sections. The

Blunt Tail section was flown first and was on a timed drogue deployment which deployed at a greater altitude as seen in the figure. The second flight with a Boat Tail section was more successful with respect to the deployment of the drogue. The drogue deployed at a certain altitude as seen in Figure 13 with a quicker drop in altitude then the wrong time released drogue with the Blunt Tail section.

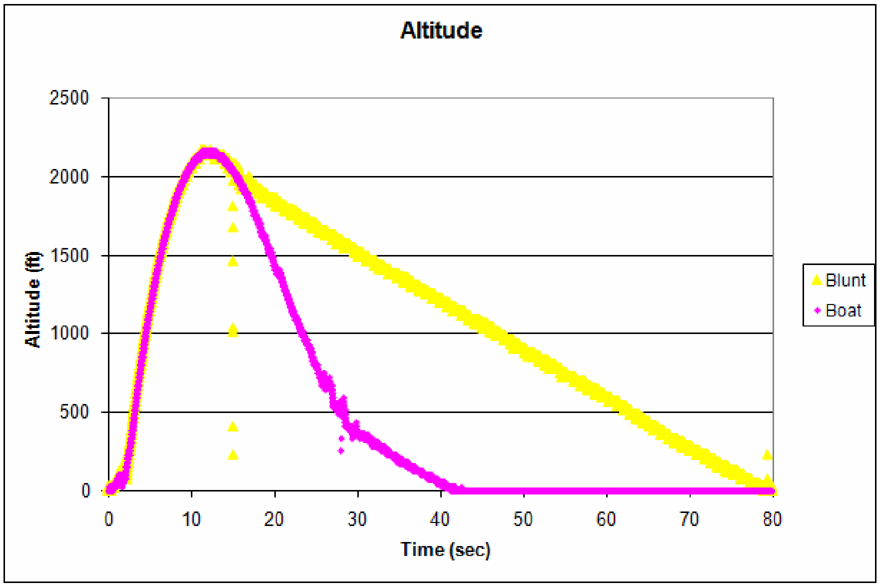

Figure 13. Altitudes of Sub-Scale Osprey with Straight and Boat Tail Sections

With the descent velocity of the rocket known, the Recovery Team will be able to do an in-depth analysis to ensure a successful recovery with minimal damage and minimal drift. *Figure 14. Acceleration of Sub-Scale Osprey's with Straight and Boat Tail Sections* shows the acceleration of the two different tail sections. The data shows that there is no significant advantage in using a boat tail section.

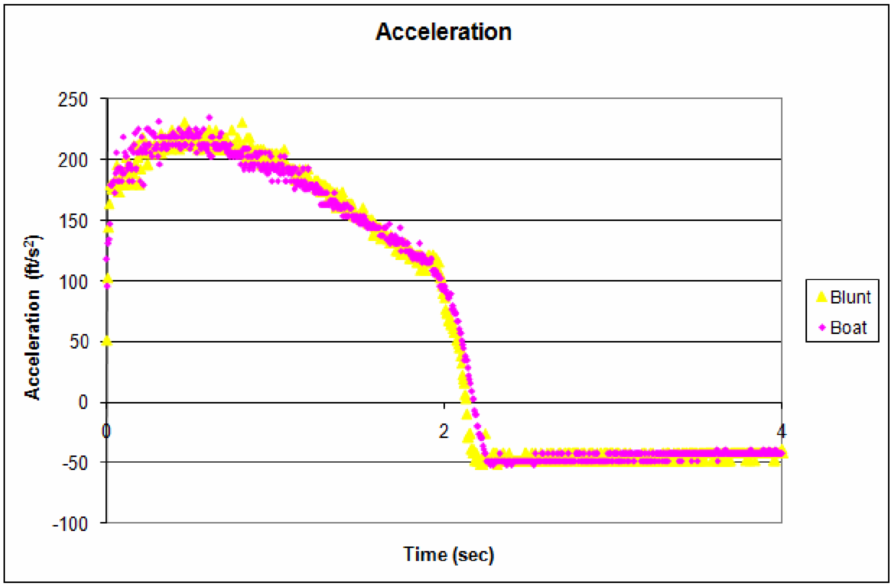

Figure 14. Acceleration of Sub-Scale Osprey's with Straight and Boat Tail Sections

The secondary scientific goal of Osprey is to actively collect data from all instruments. Upon flight the payload will transmit 3-D acceleration force data complemented with GPS positioning data. With accelerometers strategically placed throughout the payload package, a post data analysis will allow for 3-D modeling of the rocket's flight, complete with velocities and orientations. The 3-D modeling will be accomplished through Matlab and Simulink software.

Safety and Environment (Payload)

The safety officers for Charger Rocket Works are Mr. Daniel Carter (Project Lead) and Mr. Eddie Jeffries (Assistant Project Lead). The safety officers will ensure that Charger Rocket Works designs, builds, and tests Osprey within the full scope of the University of Alabama in Huntsville's safety policies. A complete and detailed set of MSDS's are posted in the Charger Rocket Works clubhouse. The team will build, test, and launch Osprey while strictly adhering to NAR regulations.

Pressure fluctuations inside the avionics compartment due to adverse pressure gradients can cause the Perfectfllite computer to detonate the drogue charge during ascent. To mitigate this failure mode the recovery avionics will be housed inside a sealed assembly with two holes on opposing sides that are perpendicular to the direction of travel. This assembly has terminal blocks on the exterior of each end connected to both the Perfectfllite and the R-DAS computers. This allows the recovery avionics to be tested before launch day and sealed up. Then during vehicle assembly on launch day, the drogue and main parachute charges are connected to the appropriate terminal block and inserted inside the vehicle frame. This system has worked flawlessly for at least three consecutive flights.

Shear pin placement and size must correspond to the sizing of the ejection charge. Also, there was some concern about the modifications made to the motor tube to mount a pressure transducer so it will not be used. Instead strain gages mounted on the outside surface of the motor tube will be used so that the motor tube remains unmodified. The modified motor will be used in static firings to calibration the strain gage systems.

V) Activity Plan

Table 8. Timeline Table

Timeline		
Objective	**Start Date**	**End Date**
Project Initiation	August 15, 2008	
Basic Design	August 17, 2008	December 5, 2008
Proposal Due	October 8, 2008	
Workshop	October 10, 2008	October 11, 2008
Sub-Scale Launch 1	November 15, 2008	November 15, 2008
PDR Due	December 5, 2008	
Detailed Design	January 5, 2009	January 22, 2009
CDR Due	January 22, 2009	
CDR Presentations	January 28, 2009	February 6, 2009
Sub-Scale Launch 2	Pending	
Full Scale Launch 1	Pending	
Full Scale Launch 2	Pending	
FRR Due	March 18, 2009	
FRR Presentations	March 25, 2009	April 3, 2009
Rocket Fair	April 17, 2009	
USLI Launch Day	April 18, 2009	
PLAR	May 8, 2009	

Rocket Weight & Budget Distribution Matrix

TEAM	Total Weight = 35 lbs	Total Budget	General Dimensions
Structures Carbon Airframe Carbon Fins Nose cone Centering rings motor tube misc **Total**	9 lb. 0.5 lb. 1.0 lb. 0.5 lb. 1 lb. 2 lb. **15 lb.**	$450 $175 $100 $50 $25 $200 **$1000**	9' long, 6" diameter, 1/8" thick
Propulsion motor hardware Propellant Total	**8 lb.**	$400 $250 **$650**	75mm, 24" long
Recovery Avionics Flight Computers Batteries Chute Shock cord Electric matches Misc **Total**	1 lb. 1 lb. 0.5 lb. 1.5 lb. 0.1 lb. 0.9 lb. **5 lb.**	$500 $100 $100 $40 $10 $100 **$850**	6" diameter, 24" long
Payload Flight computers Batteries GPS/Camera/transmitter Instrumentation **Total**	1 lb. 0.5 lb. 2.5 lb. 3 lb. **5 lb.**	$500 $100 $400 $1500 **$2500**	6" diameter, 24" long
Ground Support **Travel** **Subscale rocket** **Test Propellant**	N/A N/A	$1000 $1000 $500 500	N/A
Total	35 lb.	$5,000	

Outreach Summary

The UAH Student Launch Initiative Team for fall 2008 participated in many Outreach opportunities for the semester. Activities included two UAH Open House events in both of the months of October and November to meet and greet with incoming freshmen and their parents. SLI members visited Eva Elementary School in Morgan County to teach two classes of sixth grade student about various aspects of rocketry. Topics covered in the lesson included drag, propulsion, and stability. Several interactive demonstrations were used to drive home the material, see pictures below. The SLI team also participated in Astronomy Day in September on Monte Sano Mountain here in Huntsville. Astronomy Day is set aside for an exhibition of planetarium shows, telescope tours, and model rocket launches. Guest speakers were present for the exhibitions. Lastly, the UAH SLI team set up an exhibit for the Werner Von Braun Symposium at the Von Braun Civic Center that spanned a two day period. The main sponsors for the symposium included Boeing, Pratt & Whitney Rocketdyne, Lockheed Martin, Teledyne Brown Engineering, and ATK. The events for the symposium involved key note speakers and presentations involving progress on the Ares and Constellation programs, along with Huntsville and its involvement with the U.S space program. The SLI team had the opportunity to attend a dinner and exhibition showing their accomplishments in rocket design and test flight.

Figure 15. Charger Rocket Works Outreach

Figure 16. Charger Rocket Works Outreach

VI) Conclusion

Charger Rocket Works has a rocket design that will prove to meet the requirements of the competition within budget and time constraints. Preliminary efforts along with sub-scale testing have shown the team what areas need improvements and where the design is on target. Through further testing and refinements, the competition launch will be a success. Overall, the design meets all requirements with acceptable risk and within the cost schedule constraints and establishes a strong basis for the detailed design of Osprey.