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A DESIGN FOR A HIGH ALTITUDE FLIGHT TEST SYSTEM

By

Kristen Erin Wahlers

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Aerospace Engineering
in the Department of Aerospace Engineering

Mississippi State, Mississippi

May 2006

A DESIGN FOR A HIGH ALTITUDE FLIGHT TEST SYSTEM

By

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Small UAV's and flight vehicles in other atmospheres such as Mars are characterized by low Reynolds numbers. Low Reynolds number airfoil testing has been difficult to achieve and there are few centers that can accomplish this task. This study is an effort to develop a flight test system that will enable low Reynolds number tests to be performed with a simple glider design. The concept is to develop a high altitude glider that will be transported to altitudes reaching 100,000 feet or more by a helium filled balloon. At altitude, the glider will be released and will perform flight experiments as it descends. This region of Earth's atmosphere, 'near space' has the conditions desired for low Reynolds number testing as well as similar properties to the surface of Mars. With the knowledge gained from this experiment, a better understanding of accomplishing flight on Mars may be attained.

DEDICATION

To my family
and friends
who supported me

and in memory of
my grandmother,
Ruth Heiskell Kemmer McCall

ACKNOWLEDGEMENTS

I would like to thank Dr. Keith Koenig for being my guide and my guru. His ability to teach in ways only he could devise inspires me to constantly question and think of all possibilities. I want to thank him for mentoring me and taking me under his wing. I also want to thank Dr. David Bridges for his knowledge and understanding shown through his considerable editing most likely resulting in a new red pen. Dr. Greg Olsen also helped with editing as well as keeping me calm during stressful balloon launches and attempts at launches. Nathan King, Card Ratliff, and Devon Sanders were tremendous assets to the project whose efforts are greatly appreciated.

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CHAPTER I

INTRODUCTION

The possibility of flight and its advancement has driven people from the early beginnings of the Wright Brothers to the current exploration of space. We have fully entered into a society of flight dependency with the many commercial flights taken each day and the large number of satellites in space relaying much relied upon information. What about the sky in between, 'near space'? This region has lately become very popular to those seeking to continue space exploration, yet remains unoccupied for the most part. In this region, around 100,000 feet or more, the air density is quite thin yielding much lower Reynolds numbers. It is here where researchers can learn about air qualities similar to that on another planet, Mars. Most people of every nation are curious about what lies out in the vast unexplored regions of space. To travel, to explore, requires flight. The near space region of earth is a window into that arena of flight and is the focus of this thesis.

A design for a high altitude glider of relative simplicity is proposed. The idea is to have the glider perform near space flight at low cost. The concept is to use a helium filled weather balloon to transport the glider to an altitude around 100,000 feet. From this altitude the glider is released and its flight controlled remotely. The procedure, equipment, and design considerations required to perform such an experiment have been examined and are discussed herein.

1.1 Background

One of the more simplistic and inexpensive ways to test new and interesting aircraft has been to develop them as unmanned air vehicles (UAVs). In the 1970s, the National Aeronautics and Space Administration (NASA) began to build unpowered three-eighths scale versions of the F-15 to demonstrate its agility. NASA referred to them as remotely piloted research vehicles (RPRVs).[1] These drones were airlifted to high altitudes and released to glide back down. They were even outfitted with parachutes for recovery purposes. NASA then went on to produce radio-controlled drones which were used to test wing designs and control systems in their "Drones for Aerodynamic & Structural Testing (DAST)" program.[1] Over the years, UAVs have been utilized to study the aerodynamics and performance of potential fighter and other aircraft before their realization as full-scale prototypes. The same concept applies to this proposal. Through the observance of gliding flight in the near space flight regime, a better understanding of the aerodynamics required to achieve flight in similar regimes can be attained.

1.1.1 Previous Work

The most recent investigations into high altitude gliding flight have been made on both large and small scales. In 1992, NASA Dryden Flight Research Center carried out simulation studies of a balloon-assisted high altitude aircraft deployment.[2] In 1999 the center began the development of a sailplane to explore performance in a high-altitude, low-Reynolds-number flight regime based on the previous simulation studies.[3] Reynolds numbers were on the order of 200,000 to 700,000 at altitudes ranging from 70,000 feet to

100,000 feet. The sailplane was referred to as “APEX” after the APEX-16 airfoil designed for the mission by Mark Drela from the Massachusetts Institute of Technology. Pitot and static pressure measurements were to be taken to calculate the section lift and drag performance of the airfoil.

A similar high altitude project by Aurora Flight Sciences, the High Altitude Drop Demonstrator (HADD1), is a half-scale UAV prototype being developed for flight on Mars.[4] In 2002, this UAV successfully flew above 100,000 feet. Currently, the company is developing the full-size prototype, HADD2, for a risk reduction studies.

The sailplane proposed had a wingspan of 41.2 feet with an aspect ratio of 13.6 and was 22.7 feet long. The design gross weight was 600 pounds. The sailplane was to be released from a high altitude balloon tail-first at 108,000 feet and would require rocket assistance to transition to horizontal flight by 100,000 feet. As it descended to 70,000 feet, the sailplane would perform its test maneuvers directed by a remote pilot and airfoil measurements were to be recorded.

Design constraints included weight, experiment packaging and limited available off-the-shelf instrumentation with adequate range and accuracy capabilities at high altitudes. They were quite similar to some of the design constraints imposed on the current project. The program was selected to be part of a Revolutionary Concepts project by NASA in the spring of 2000. Unfortunately, the project was cancelled thus ending the APEX program.

After development of the present flight test system had begun, it was discovered that a Canadian group was attempting a similar venture.[5] They are currently developing a small self-guided high altitude glider to be released from a weather balloon, relying on an auto-pilot to trim itself as it falls. As the glider descends, navigation data, low resolution photos and pressure and temperature data are transmitted to the ground. The group has completed five launches and amazingly only lost the prototype in the most recent launch. The most recent descent experimented with a drogue chute to aid in the glider's recovery upon release. The chute did not help as desired but seemed to exacerbate problems and was cut away.

The Canadian glider effort is mainly focused on the electronics of the mission and not as much on the dynamics of the flight. The group states that its development is primarily for educational and recreational purposes and is not equipped for science-related payloads.

1.2 Motivation

The initial interest in the development of this project began as a result of learning of science experiments being conducted through high altitude ballooning and amateur ham radio. At the time, investigations into low Reynolds number scale effects were already being conducted by this researcher. (Scale effect refers to the dependence of the airfoil on the size and speed of the wing.) Also, with the present national interest in the development of a Mars aircraft, a high-altitude platform was greatly desired. Merging the two ideas seemed a perfect match: low Reynolds number testing in a high altitude, low Reynolds number environment.

Lower Reynolds number vehicles present a number of problems. Coefficients of lift and drag as well as the required angle of attack of the airfoil depend upon the Reynolds number. On the low end of the range of Reynolds numbers, the viscosity is a major concern. Viscous effects are quite large and cause high drag with limited maximum lift values. However, around a Reynolds number of 70,000, these effects do tend to improve the overall lift-to-drag ratio. Boundary layer behavior is a concern given that both separation and reattachment occur on a small section of an airfoil. Compressibility effects also begin to arise at higher altitudes with higher velocities.[6]

The Earth's atmosphere at the proposed release altitude of 100,000 feet has many similarities with the atmosphere near the surface of Mars. Although the surface density of Earth's atmosphere can be eighty times greater than that of Mars, depending on the time of year, the near space region of the Earth's atmosphere is exceptionally close. The surface density of the atmosphere of Mars is around 0.000039 slugs per cubic foot with an average temperature of -65 degrees Celsius (°C). The temperature can vary from 27 °C in the summer to -133 °C in the winter. The density of Earth's air at 100,000 feet is approximately 0.000031 slugs per cubic foot with an average temperature of -40 °C. The temperature at altitude on Earth may be less than that on the surface of Mars, but a glider will experience similar temperatures on the flight to and from altitude. Between approximately 36,000 feet and 80,000 feet the atmosphere contains an isentropic temperature gradient with an average temperature around -56 °C.

As a result of observation of the atmospheric similarities, it could be quite possible to achieve flight on Mars once flight in the near space region of Earth is accomplished. The present research is an effort to develop a flight test system for such atmospheric conditions.

CHAPTER II

SYSTEMS

This design of a high-altitude flight test system requires the combination of separate systems working together. In this case the ground system, balloon hardware, and the glider must work independently of one another, but need each other to fulfill the mission. Before an actual glider can be tested, the accuracy and dependability of equipment must be verified. The radios, circuits, and sensors that will operate the glider and obtain data are first flown in payloads. The success of the payloads will determine the success of the glider.

2.1 Ground

In every flight experiment, the ground system is as a basic necessity. Through launch tracking, control, and recovery the ground system is involved throughout the entire mission.

The ground system serves to organize the mission through flight planning and adhering to designated guidelines. The Federal Aviation Administration (FAA) has in place certain restrictions governing the use of all objects and aircraft within the United States airspace. The U. S. Federal Aviation Regulations (FAR) Part 101[7] pertaining to unmanned free balloons are the guidelines for this experiment. Part 101 mandates certain operating limitations, equipment requirements, and notification and tracking report requirements. The operating limitations refer to visibility concerns for the flight experiment. The flight is not to occur should the horizontal visibility be less than five miles and more than five-tenths cloud coverage. This section also restricts the use of such testing over crowded or congested areas for safety purposes.

The flight equipment must have the ability to employ two independent cut-down mechanisms to terminate the flight should it be deemed necessary. The payload or glider must also incorporate a device or material that reflects radar or causes an echo from surface radar.

Within 6 to 24 hours before a launch, the FAR requires specific information to be given to the FAA Air Traffic Control (ATC) facility closest to the launch site. The expected launch and landing date and time within thirty minutes of the actual time in addition to the proposed location of launch and landing must be determined. Given the atmospheric conditions of the day of the launch, there is available software on the internet that can forecast the trajectory of a dropped payload. The software, Balloon Track for Windows[8], outputs the geographical coordinates, burst altitude, and time to burst altitude, as well as the overall duration of the flight needed by the ATC facility. Specific information about the payload/balloon configuration itself such as length and diameter of the balloon, length of the trailing antenna and suspension device, and the weight of the payload must be reported. There should also be some sort of identification and contact information on the payload in the case of another party discovering the payload first. The equipment can then hopefully be retrieved.

The ATC facility is contacted an hour before launch to correct any changes in trajectory or payload that may have occurred since initial contact. Once the payload is launched, the ATC is immediately contacted with the exact time. The balloon’s position should be recorded at least every two hours and position reports given an hour before descent. If communication with the balloon is lost for any two hour period, the ATC facility is contacted with its last known position and must be notified if communication is regained. If the flight goes flawlessly, the ATC facility is finally notified when the flight has been completed.

For tracking the payload during flight as well as upon landing, a global positioning system (GPS) is employed on the package itself. If possible, the last known position of the payload box is used to locate the package on the ground. If the altitude reported is low, then it will be a fairly decent place to start recovery operations. Once on the ground, a Yagi directional antenna is employed due to disturbances and obstacles on the ground inhibiting the proper reception of the long range ham signal. The antenna connects to a ham radio on the ground that can receive the frequency continuously transmitted from the payload. As the antenna is pointed in different directions, an increasingly audible tone is emitted as the direction of the payload’s location is found.

The guidelines themselves impose some of the factors considered in the design process to be discussed later in this chapter. An individual payload package may not weigh more than six pounds. The total weight of packages that may be carried by one balloon is twelve pounds. Based on these guidelines, the high altitude glider with all of its components can not weigh more than six pounds.

2.2 Balloon

The balloon's systems with regard to the configuration for the initial flight tests as well as eventual glider applications are very important to the success of the experiment. A detailed plan of hardware selection and the tasks of the preliminary payload boxes are necessary first steps toward glider design. Once the payload boxes have successfully taken data, been tracked and recovered, the glider testing can begin.

2.2.1 Hardware

Transporting the payloads securely to altitude is not to be taken lightly. The parachute, the ropes used for attachment of the balloon, parachute and payload as well as all of the connections have to work properly for the safety of everyone on the ground and of the equipment. A very hard and unpredictable landing will occur if ropes get tangled in the parachute. Specifically, in the region where the proposed testing is to be performed, the danger of landing on major roads is a possibility. The untimely end of expensive radio equipment is not desirable when working with a tight budget.

The parachute chosen for this experiment is the R9C chute from Kytec Innovative Sports Equipment. It is commonly used in similar applications of high altitude ballooning and rocketry. It is made of rip-stop nylon with four tubular shroud lines to reduce tangling. The minimum weight of a payload for safe descent is six pounds with a maximum of twelve pounds. The actual weight of the parachute is 1.25 pounds which is heavier than desired for the glider but is on the safe side for initial payload drops.

A single quarter-inch diameter nylon chord is used to connect the payload to the parachute and the parachute to the balloon. This chord has a fifty-pound test limit and is kept intact and without knots as much as possible to retain the strength of the chord. Nylon is also preferred as possible cut-down mechanisms should be able to disconnect it from the balloon relatively easily.

The balloons available vary in size, implying a variation in attainable altitude and weight of payload that can be carried to altitude. The balloons are made of latex and must be handled carefully with cotton gloves to prevent oils from the hands from breaking down the latex. Balloons are classified according to mass. A range of balloons including the 600-gram, the 1200-gram, and the 2000-gram balloons have been acquired from the company Kaymont. Each of these has a bursting altitude of ninety-eight thousand feet or better. The larger mass balloons allow a higher attainable altitude and an increased payload. With payload testing, the burst altitude can be verified leading to the choice of the right balloon for the glider experiment.

2.2.2 Payload Boxes

The payload boxes provide a simple initial test bed for the systems needed on the glider. Instead of testing the glider and components at one time, the payload boxes allow each component desired on the glider to be flown and analyzed individually. The systems to be examined with the payload boxes include GPS tracking, cut-down mechanisms, glider controls, data collection, and photography capabilities. The reliability of the radio equipment should also be assessed.

In this flight test experiment, the use of ham radio equipment is necessary due to the great distance signals must travel to communicate with the system. However widely used by licensed practitioners, ham radio is still a new area to this author. The equipment as well as the terminology had to be thoroughly researched. A two-meter dual band radio has been determined to be the best for this application. The two-meter frequency allows for the range needed to communicate with the payload at 100,000 feet. Also, the dual band capability makes possible the transmission or receipt of more than one frequency. This is necessary to control both a glider and a cut-down mechanism. A Kenwood TH-D7AG radio has been chosen to fulfill these needs. One is used on a payload package to transmit the GPS coordinates obtained through the Garmin GPS 25-LVS sensor. As shown in Figure 2.1, an external antenna, the GPS with a lithium AA battery power supply and a radio are placed in the payload package.

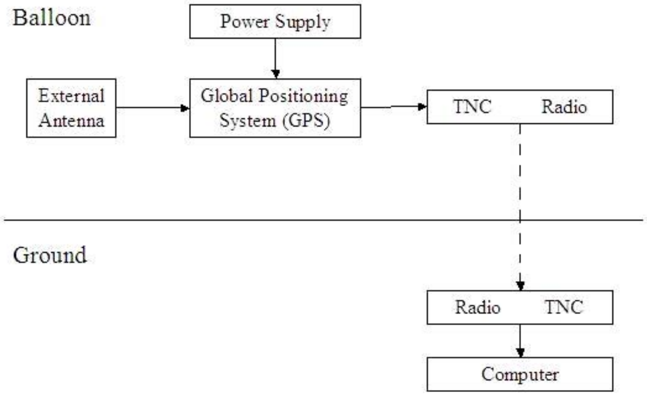


Figure 2.1 GPS Payload System Block Diagram

The antenna is connected to the GPS sensor to relay its position based on the positions of orbiting satellites. The GPS is capable of determining its position in 3 axes with a time stamp and updates its position constantly. The radio is then used to transmit the payload's position. The radio was chosen not only for its dual band capability, but also because it contains a built-in terminal node controller (TNC). A TNC acts as a radio-modem to transmit data in packets. The TNC translates the GPS data into a digital audio signal which can then be transmitted to another radio on the ground. Another Kenwood TH-D7AG is used on the ground to translate the digital audio signal back to data readable by computer. Mobile external antennas are also used on the ground to strengthen the receipt of the signal. When used in combination with a computer mapping system, the payload can be tracked across the country. The mapping system chosen for this application is Delorme's Street Atlas 2006©. The data are input into the mapping software visually displaying the location of the payload. The ground tracking system uses this location to home-in on the payload.

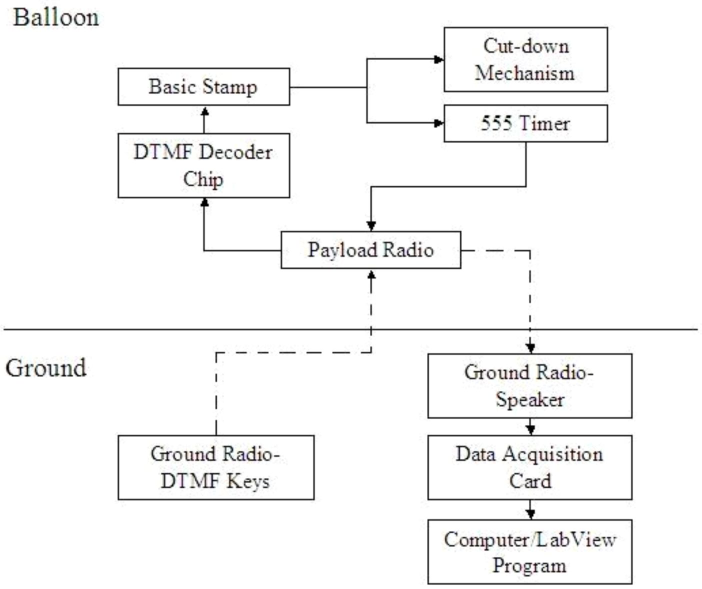


Figure 2.2 Measurement and Mechanism Operation Systems Block Diagram

The cut-down mechanism and the temperature data collection are combined in the same payload package and use the same controlling circuit. The payload system requires a dual-tone multifrequency decoder chip (DTMF), a Basic stamp, an astable 555 timer, and a ham radio as shown in the diagram of Figure 2.2.

DTMF refers to the audio signals generated from the depression of buttons on a touch-tone telephone. The DTMF decoder chip receives DTMF signals from the speaker output of the payload radio. The payload radio was an Alinco DJ-S11T chosen for its dual band capabilities as well as a built-in speaker. The speaker output of the radio is wired to a section of the DTMF chip. As DTMF tones are sent from another Kenwood ground radio, the Alinco receives the tones and outputs the tones into the decoder. The decoder then processes the tones through a low pass filter to remove any anomalies and then determines if the correct sequence of tones have been given to signal the microcontroller. If so, then it processes the tones into signals corresponding to four digits to be sent to the Basic stamp. For this application, only the touch-tones corresponding to the digits 1, 3, 5, 7, 9, *, A, and C are utilized.

The Basic stamp is programmed to receive the signals and determine the digits and their order. The stamp is to accept the commands that activate either the cut-down mechanism or the astable 555 timer. The first digit must be C to be recognized and then the state is set to 1. States 2 and 3 must be recognized as the digits * and 9, respectively. The stamp currently determines the command by the last digit received. The cut-down mechanism is activated by digit 1 and the 555 timer activated by digit 3. The system can be very versatile with slight changes to the programming of the stamp. Several commands can be added with the remaining digits in the fourth state as well as changing the digits recognized by the program and set to the second and third state.

When the DTMF tones for the digits C*91 are given, the pin connected to the cut-down mechanism circuit is set to “high” sending a 5V signal to the circuit. The signal bridges a connection between the ground and a 9V battery power source. Nichrome wire is attached between the ground and the battery. The voltage sent through the wire causes it to heat up rapidly. The payload boxes and parachute are suspended from the balloon with nylon rope wrapped with the nichrome wire in a section just above the parachute. As the wire heats, it burns through the rope cutting the parachute and payload boxes free.

The astable 555 timer outputs a square wave. Because this is a wave with sharp transitions between high and low, is it not stable in any state. The frequency of the wave is a function of two resistors and a capacitor. This 555 timer uses a variable resistor to measure the surrounding temperature. For every one degree Celsius the temperature increases, the resistance decreases by 3.8%. As the temperature changes over the course of the flight, the resistance will change causing a corresponding frequency to be output. A LabView program has been developed to read the frequency and compute the resistance and the corresponding temperature after a desired time interval. The frequency is output from the 555 timer to the payload radio. The payload radio then transmits the frequency to the ground radio which routs the frequency through the speaker output. The speaker output is connected to a data acquisition card which converts the signal into readable data for a computer. The computer attached to the data acquisition card reads the data with the LabView program to calculate the temperature. The program then inputs a time stamp on the data and saves. The DTMF tones for C*93 can be sent to the payload radio at any given time to request the Basic stamp to initiate the 555 timer and output a frequency.

Another option available is to provide the payload boxes and glider with photography capabilities. A film or video camera can record images of the glider's ascent and descent. Photos can be taken at specific intervals during a flight. A simple 35-mm camera can easily be altered to capture a photo when triggered by a voltage signal. Once connected to a timing circuit, the camera can be given the signal at specific time intervals over the duration of the flight. The main difficulty would be in gathering real-time video footage. To constantly download video data requires a large bandwidth. This necessitates expensive and bulky equipment which is in opposition to the intent of the experiment. Since photography is not necessary to the glider's successful operation, to include it is a secondary issue. As long as the weight of the glider does not exceed 6 pounds and the required control, power, and communication systems still function properly, then the capability of photography might be added.

2.3 Glider

2.3.1 Design Considerations

Before design of any aircraft can begin, the constraints and mission objectives must be fully outlined. The development of a simple, low-cost glider to provide aerodynamic properties in the near space region of Earth is the goal. The central design considerations for this endeavor are weight and equipment restrictions, cost effectiveness, and a major contribution of the wing on the aircraft. In order to perform airfoil studies with the aircraft at altitude, a large wing would provide the main contribution of lift and drag allowing for a more simplified analysis. A glider allows for the wing to be the main focus of this experiment as well as allows for exchangeable wings for airfoil studies. By simplifying the aircraft to a major wing structure and minimal lift and drag contributions from the remainder of the aircraft, a more accurate lift and drag analysis of the vehicle can be completed. This implies that the overall structural weight of the aircraft must be minimal. Although minimal, the structure must still maintain the radio equipment securely and safely. To adhere to budget restrictions, the radio equipment itself is off-the-shelf except the circuit boards controlling the glider, cut-down mechanisms and data measurements that can be built more cheaply than can be purchased. The radio equipment must have adequate range and accuracy for the altitude desired as well as be able to operate in the low temperatures experienced through the flight. It is the size and shape of the radio equipment that will contribute to the shape the overall aircraft.

2.3.2 Wing: Airfoil Selection

An objective of the flight test system was to make the wing the main focus of the aircraft in order to investigate the effects of low Reynolds numbers. In recent years, due to the increased interest and development of UAVs, a large number of airfoils have been designed to operate at low Reynolds numbers. A performance database of over 180 low Reynolds number airfoils has been compiled at the University of Illinois Urbana-Champaign by Michael Selig, Paul Gush, and Kian Tehrani.[9] Of these airfoils, the Wortmann FX63-137 for low Reynolds numbers has been noted by the United States

Navy and other agencies as an optimal candidate.[10] Originally designed for sailplane use, this airfoil also appears to have an adequate amount of available data from multiple researchers.

Bastedo and Mueller[11] have investigated the tendency of the airfoil's zero-lift angle of attack to shift to less negative values as the Reynolds number decreases. This shift also produces the maximum lift coefficient at higher angles of attack. The wing of the glider will be positioned at a positive angle of incidence to aid in the pull out recovery of the aircraft. Figure 2.3 is a representation of the Wortmann FX63-137 airfoil.

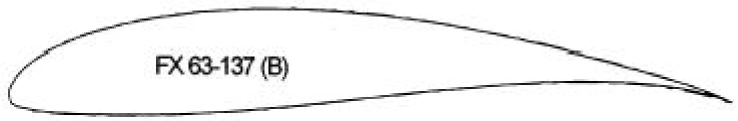


Figure 2.3 Wortmann FX63-137 Airfoil Section

A span of 6 feet and a chord of 12 inches were chosen to maintain the wing as the focus of the aircraft and will be used in the stability analysis.

2.3.3 Longitudinal Stability and Control

The tail of the glider is designed to have enough control authority over the aircraft at the high speeds it will experience as it descends from the balloon yet allow for the wing to remain the main contributor. The sizing of the tail surface is also dependent upon the overall structural weight. The moment arm created by the position of the tail is limited by the material weight and length of the fuselage. A NACA 0015 has been selected for its symmetry and a manufacturable thickness. The effects of low Reynolds numbers on the wing are already great and would be more so in the case of a smaller tail. Therefore, the same chord length of one foot will also be chosen for the both the horizontal and vertical tail surfaces. The tail will have a horizontal span of one foot and have a moment arm of 2.5 feet.

For static longitudinal stability of the aircraft, the derivative of pitching moment with respect to the angle of attack must be negative.

$$\frac{\partial C_m}{\partial \alpha} < 0 \tag{2.1}$$

The pitching moment at zero angle of attack must also be positive in order to trim and stabilize the aircraft.

$$C_{m_0} - C_{m_{\alpha=0}} > 0 \tag{2.2}$$

The sizing parameter values for tail and wing incidence, center of gravity position, tail surface area, and moment arm are used to determine values for Cm_α and Cm_0.[12] The coefficient of pitching moment curves over a range of angle of attack are plotted in Figure 2.4 and the results for the sizing parameters are listed in Table 2.1.

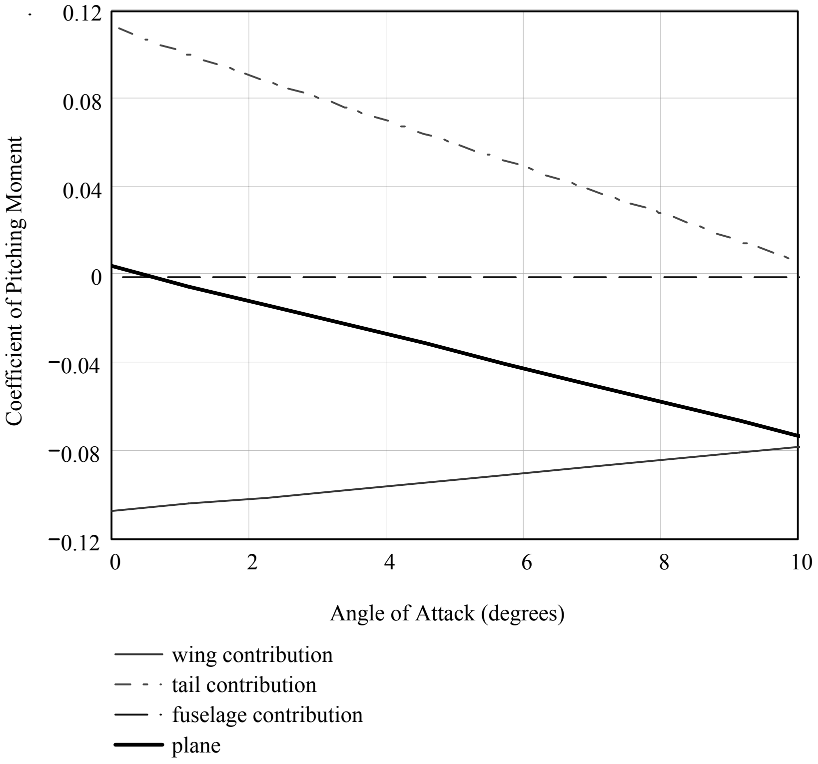


Figure 2.4 Longitudinal Stability Characteristics

Table 2.1 Longitudinal Stability Geometries

Parameter	Value
Tail Moment Arm	30.12 inches
Incidence of Wing	2 degrees
Incidence of Tail	1 degree
Span of Horizontal Tail	12 inches
Chord Length of HT	12 inches
Center of Gravity (X_{cg}/c)	0.30
Trim Condition	1.29 degrees
Static Margin (percent)	18

2.3.4 Lateral Stability and Control

Once the horizontal tail service has been sized, the size of the vertical tail surface is then determined. To achieve directional stability, a positive yawing moment coefficient, $C_{n\beta}$, is desired to restore the airplane to its equilibrium state.[12]

$$C_{n_\beta} = \frac{\partial C_n}{\partial \beta} > 0 \tag{2.3}$$

A plot of the yawing moment coefficient as a function of the span of the vertical stabilizer for a fixed chord length of 12 inches is shown in Figure 2.5. This figure was examined to obtain an optimal value.

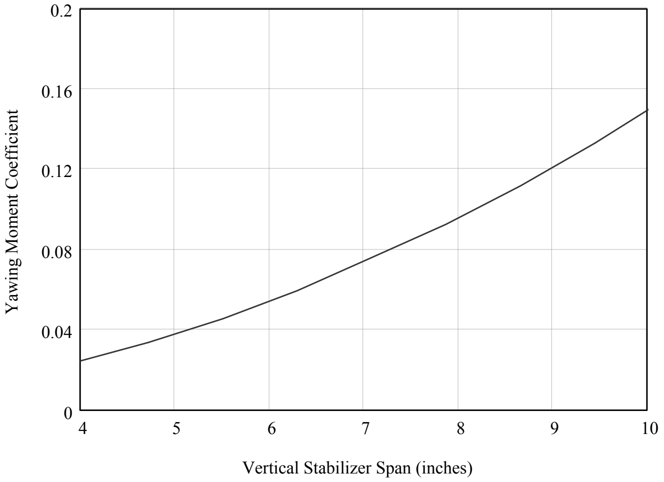


Figure 2.5 Lateral Stability Characteristics

The span of the vertical tail was chosen to be 10 inches and a chord of 12 inches to provide ample rudder authority and display good 'weathercock' properties.

2.3.5 Fuselage

The fuselage of the glider will be a minimal casing surrounding the equipment inside the aircraft. The shape will be a traditional blunt cone in the front and tapering off in the rear. A foam block will be sanded and shaved to shape extending slightly ahead of and behind the wing. The foam will be sheeted in a light layer of fiberglass to provide some protection to the radio equipment in the event of a harsh landing. Some foam will be extracted leaving a layer on the glass to act as insulation for the equipment. This fiberglass pod will connect to a rod extending the length of the glider. The rod will provide the structure of the fuselage and will allow for some movement in the tail placement should that be necessary after further testing. Several configurations of this structure are examined for weight savings and attachment feasibility in Section 2.3.9.

2.3.6 Control Systems

Out of the glider’s total weight of six pounds, three pounds are allotted for the systems necessary to control the aircraft and store any data collected. The systems needed to control the aircraft include the mechanisms which activate the control surfaces on the glider, such as the elevator, rudder, and ailerons. The glider will need three micro servos for the control surfaces. Several micro servos have been investigated to determine which will produce enough torque to control the glider’s surfaces. Suitable choices typically weigh around an ounce per servo. The servos can be operated with a five-meter or ham model aircraft radio.

The glider will need a ham radio configuration that combines GPS tracking capabilities with data collection. To reduce the amount of information transmitted down to the ground, only the GPS system will be transmitted and the rest stored onboard for later retrieval. Much progress had been made in the GPS sensing field that will be most helpful in this endeavor. The Massachusetts Institute of Technology has developed a method to control aircraft using a single antenna GPS system based on pseudo-attitude.[13] Pseudo-attitude control requires the flight path angle relative to the local horizontal and a pseudo-roll angle which is based on the known aircraft and gravitational accelerations. Essentially, as the aircraft moves through the air, its position coordinates are recorded and time-stamped about once per second. From this, the change in position of the aircraft on each axis allows for the derivation of its ground velocity and acceleration. All that is required on the glider is a GPS sensor, antenna, and a radio with a built-in TNC. Through the transmission of the signal to another TNC-capable radio on the ground, position coordinates can be converted to readable data with a data acquisition card and relayed to a laptop computer. A program has already been created in LabView which has the ability to visually display the pseudo-attitude with a gimble. The glider would be piloted based on the gimble display. An onboard rate-gyro will store the observed accelerations and angular rates of the glider for post-processing of the data.

2.3.7 Parachute

A parachute is needed on the glider for recovery purposes. The parachute is a back-up should problems arise after release and will aid the glider’s descent as it reaches the surface. The glider is designed for the flight conditions at 100,000 feet and will have some difficulties as it reaches the lower altitudes. The parachute will be placed internally in the back of the fuselage. The search for the actual point of attachment will be conducted in a series of tests from a tethered release.

The R9C parachute used in the payload box flights is 20% of the total weight of the glider and cannot be used. The same manufacturer also produces a 68 inch parachute, the R7C. This parachute has a maximum weight limit of 8 pounds and only weighs 0.35 pounds. With this 28% weight reduction, the parachute can easily be placed onboard.

2.3.8 Flight Mechanics

An aspect of the aircraft's flight that has been investigated is the glide, specifically a spiral glide. A sailplane in a turning glide will have a load factor *n* greater than 1 and a negative specific energy P_s. Based on zero acceleration in an equilibrium glide, the specific energy reduces to just a function of the vertical velocity.[14] From equation 2.4, it can be determined that the rate at which the potential energy due to height is lost is equal to the rate at which drag does work as in equation 2.5. The descent itself will provide the energy necessary to overcome the drag.

$$P_s \cdot V = -q\left[\frac{C_{D0}}{W} S + k\left(\frac{n}{q}\right)^2 \cdot \frac{W}{S}\right] \tag{2.4}$$

$$W \cdot \frac{dh}{dt} = -D \cdot V \tag{2.5}$$

In the plane of the glide, the component of lift available to act against weight depends on the roll angle.[13] Equation 2.6 will reduce to equation 2.7.

$$L \cdot \cos(\phi) = W \cdot \sin(\theta) \tag{2.6}$$

$$\cos(\phi) = \frac{\cos(\theta)}{n} \tag{2.7}$$

However, the component available radially does not depend on flight path angle as shown in equation 2.8.

$$\frac{W}{g} \cdot \frac{V^2}{r} = L \cdot \sin(\phi) \tag{2.8}$$

Assuming weight is equal to lift in this instance, equation 2.8 can reduce to equation 2.9 in which the glider is again influenced by roll angle.

$$\frac{V^2}{g \cdot r} = n \cdot \sin(\phi) \tag{2.9}$$

This is explained visually through Figure 2.6 from left to right. The glider on the left is a planform view in the negative z direction with the lift vector positive up. The glider in the middle is pitched 45 degrees down, tilting the lift vector forward. The glider on the right depicts the lift vector as the glider is rolled about the body axis.

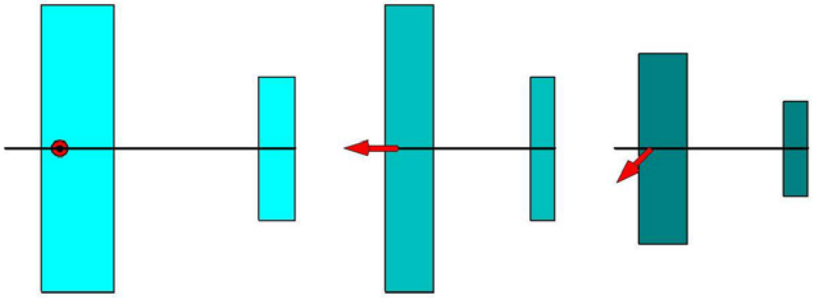


Figure 2.6 Spiral Glide Planform View in the Negative z Direction

Based on the above equations, the glide angle, roll angle, lift coefficient, and turn radius are examined to determine which value of each will produce the most efficient spiral glide. Using the equation for a level equilibrium maximum range glide, shown in equation 2.10, a C_{D0} of 0.03, and a k of 0.0758, a range of Mach numbers has been chosen.

$$V = \sqrt[4]{\frac{k}{C_{D0}}\left(\frac{2W}{\rho S}\right)^2} \tag{2.10}$$

By plotting each as a function of wing loading, a wing loading of 3 pounds per square foot is chosen to be representative of the glider in flight. Figures 2.7, 2.8, 2.9 and 2.10 are plots of the characteristics investigated at 90,000 feet. This information will give insight as to what the pilot might expect at altitude.

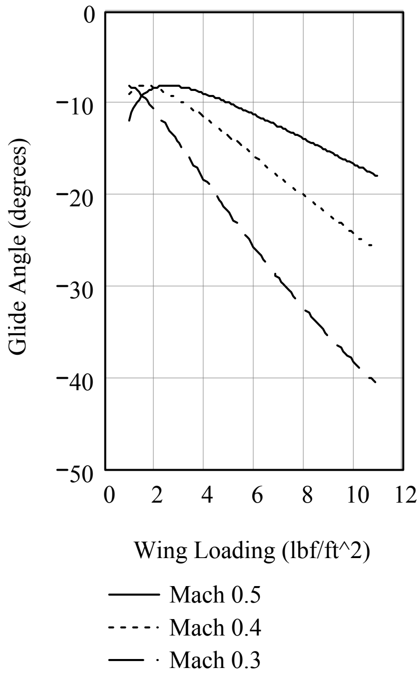


Figure 2.7 Effect on Glide Angle

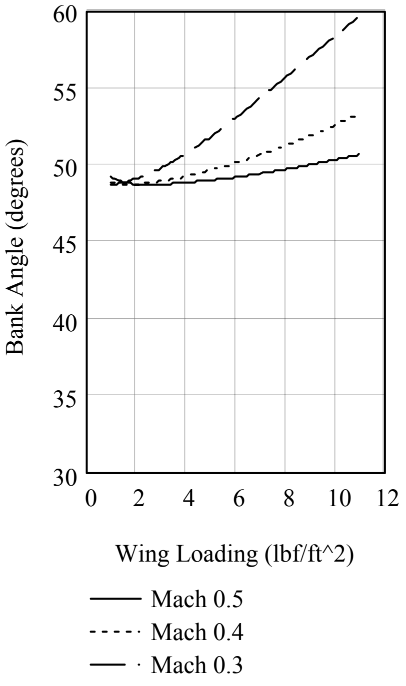
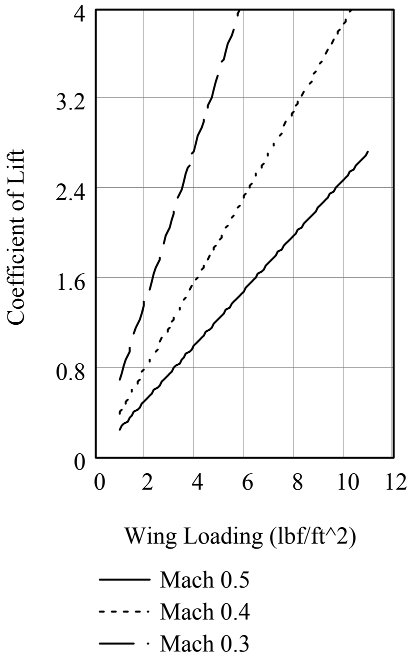


Figure 2.8 Effect on Bank Angle



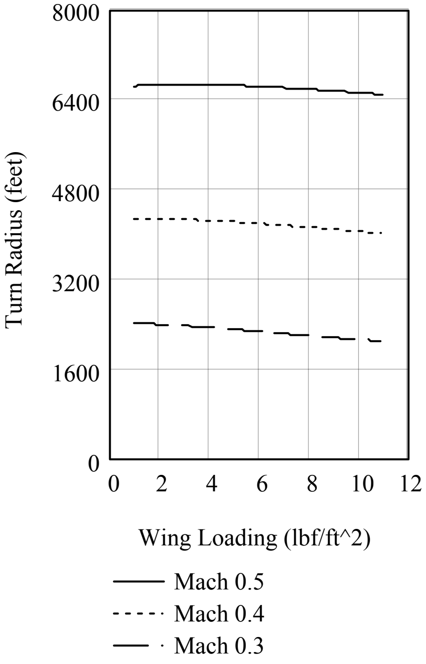


Figure 2.9 Effect on Lift Coefficient

Figure 2.10 Effect on Turn Radius

Even though the speeds used in the calculations are high, the dynamic pressure is still low due to the altitude and the wing loadings are still viable. As the speed increases, the turn radius becomes quite large and the required lift coefficient decreases. A large common bank angle of 49 degrees is observed at all three speeds. The glide angle tends to consistently plateau at -8 degrees independent of the wing loading yet becomes more negative as the speed is decreased. In order to fly at a lower speed, the glide angle would have to be quite steep.

2.3.9 Construction

The design constraints imposed on the glider suggest a light-weight vehicle yet one that is durable and strong enough to handle the acceleration during pull out the glider will experience. When considering materials, light weight and strength are characteristics of composite materials. The experience with and understanding of composite materials has grown at Mississippi State University through the Raspet Flight Research Laboratory over the past thirty years with some recent experimentation by student design teams. A simple and effective method of constructing a foam-and-reinforced-carbon wing with glass overlay has been refined by the Aerospace Engineering Department's Society of Automotive Engineering Heavylift team. The wing uses a "D"-shaped foam core with a unidirectional carbon strip to increase the load capacity of the wing. The method involves a process using a hot-wire CNC machine to cut out computer-aided drawings of foam wing cores for most airfoils. The machine sends a current through a wire heating it enough to melt through high density foam. The wire is strung between arms of a computer-operated machine which has the ability to move in two axes. The portion of the wing from the leading edge to roughly the quarter-chord is cut away from the rest of the wing. The D shape is wrapped in fiberglass with a small strip of unidirectional carbon over the trailing end and covered in resin. The shape is then connected back to the rest of the wing, wrapped in another sheet of fiberglass and again covered in resin. A peel-ply material is then wrapped around the wing to aid in removal of the bleeder material used to soak up excess resin placed on top of the peel-ply. The wing is placed on a flat surface in a vacuum bag with the leading edge against a straight edge to ensure the wing does not warp. Suction is placed on the bag and left for at least eight or more hours before removal of the peel-ply and bleeder. The wing can be replicated easily and quickly. The tail sections of the glider can be produced in the same manner.

A minimal fuselage for the aircraft is desirable for calculations to ensure that the wing is the main contributor to the aircraft. Composite as well as aluminum tube and C-channel sections have been considered. A weight model of the materials used to build the plane has been created to ensure the structural weight of the glider does not exceed three pounds. Different variations for a four-foot fuselage have been calculated and the results obtained are listed in Table 2.2.

Table 2.2 Comparison of Fuselage Weights

Material	Configuration	Area (in^2)	Weight (lb)
Carbon	Tube-square 2 in.	0.938	1.273
	C-channel	0.688	0.934
Fiberglass	Tube-square 2 in.	0.938	2.143
	C-channel	0.688	1.571
Aluminum	C-channel	0.486	2.334

A C-channel configuration will weigh the least for any of the materials studied and will also provide a good surface for the attachment of the tail surfaces and the equipment in the fuselage. The carbon C-channel weighs the least with the aluminum C-channel far beyond consideration. Although the fiberglass channel may weigh 60% more than the carbon, the cost of the materials must also be taken into account. A two-inch by eight-foot square tube of carbon costs nearly \$350 compared to \$35 for a fiberglass tube of the same dimensions. The additional weight of the fiberglass channel can be accepted should testing prove it suitable for the mission. The approximate 1.5 pounds of structural weight remaining will be enough for foam wing and tail sections as determined from the weight model.

CHAPTER III

TESTS TO DATE

3.1 First Tethered Payload Drop

In order to validate the design of the glider and its components as well as determine certain aspects of the flight, thorough testing must be done before proceeding. As of now, four separate tests have been performed: two tethered payload drops, a pressure test and a launch. The first test was a simple tether of a mock payload package suspended from a parachute and released from a balloon at 100 feet altitude. Although this test was simple, several factors had to be taken into consideration.

The first to be considered was the proper inflation of the balloon. For initial testing a small 600-gram balloon was used and re-used for tethered drops. The balloon was laid out upon a sheet so that the ground would not cause a small prick in the latex. Again, soft gloves were used when the balloon was handled due to the possibility of oils in the hands breaking down the latex. Three-eighths inch diameter tubing was inserted into the opening of the balloon and cinched with cable ties to secure it. The other end of the tubing was attached to an air regulator screwed onto the helium tank. The air regulator indicated the amount of helium flowing into the balloon. After a significant amount of helium filled the balloon, a small fish scale was attached to the end of the balloon. The balloon was allowed to pull on the scale freely to determine the amount of lift the balloon was creating. As other researchers have previously documented, two more pounds than the payload weight is required to sufficiently lift the payload off the ground.[15] The finished payload was approximately five pounds, so a total of seven pounds of lift were required. Once the balloon was filled, the tubing was removed and the end of the balloon was wrapped around a carabineer and tied back to itself using cable ties to prevent the helium from escaping. The tether rope was secured on the carabineer to hold onto the balloon more safely. From the carabineer was hung a ring from which the payload and parachute were suspended as shown in Figure 3.1.

Figure 3.1 Balloon Tether Configuration

The design of the payload package was to be uncomplicated, as its use was only needed in early tethered testing. A five-gallon aluminum container was cut open on the side to allow for placement of the flight data recorder, the power supply, and a release mechanism. The flight data recorder used was produced by Eagle Tree Systems and was purchased for the Mississippi State University Aerospace Engineering Department's design teams. A piece of insulation foam was shaped, cut, and glued to the side of the container. From this protrusion was placed the flight data recorder's pitot probe. For this experiment, it recorded the current altitude, temperature and velocity of the payload's flight. A standard 4.8 volt nickel cadmium battery powered the data recorder and the release mechanism. The flight data recorder was assembled and wrapped in furniture foam to protect it upon impacting the ground. The entire experimental package is shown in Figure 3.2. The release mechanism for the tethered tests was a radio-controlled servo placed in the payload with a razor blade attached to the servo arm. A hole was drilled in the bottom of the container adjacent to the servo mount, a screw put through the hole, and a nut secured the screw. A ball bearing was attached at one end to the screw leaving the free end to fasten to the fifty-pound test fishing line. The fishing line ran through the container out a pre-manufactured hole up to the balloon.

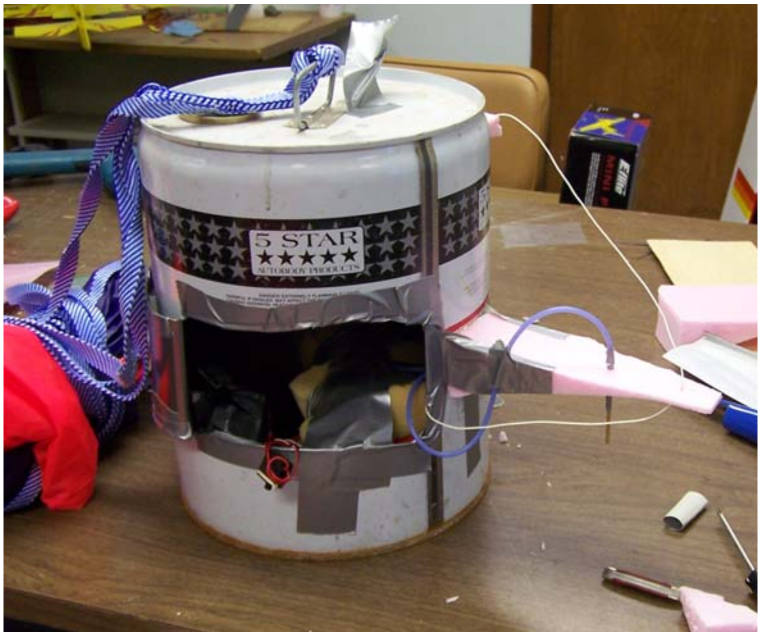


Figure 3.2 Initial Payload Container

Figure 3.3 Release Mechanism

The release mechanism was a key factor in the design of the suspension system. The mechanism setup is shown in Figure 3.3. The fishing line from the payload was secured to a ring from which the balloon was tied by means of a carabineer. Also secured on the ring was a six-pound-test fishing line attached to the top loop of the parachute. Once tension was placed on the line, the servo was triggered and the razor blade easily cut through the fifty-pound-test fishing line. As the payload fell, the parachute lines leading from the payload fully extended opening the parachute. This created a sudden jerk on the six pound test line at the top of the parachute, causing the line to break and the parachute and payload to drift down freely.

The first tether test was a success overall. The release mechanism worked extremely well without any problems. The configuration of the balloon, parachute and payload suspension did not get tangled in any way. The flight data recorder managed to collect some good data with fluctuations in the speed. Inflating the balloon proved to be more difficult than previously thought due to the number of times the lift was measured. Each time lift was measured, the tubing was removed so that the balloon could be safely secured and the fish scale attached. New procedures would be needed to make this part of the experiment more efficient. From this point, similar suspension configurations and release mechanisms could be used and tested further.

3.2 Second Tethered Drop

Once the configuration of the suspension device was determined, the focus was turned to the development of the payload box and its contents. The structure of the payload box needed to be lightweight and rigid as well as thick enough to keep the contents of the box insulated from the extreme cold temperatures experienced at high altitudes. For this reason, white bead and pink insulation foam were chosen. A hexagonal shape was designed for the box to encompass all of the necessary equipment. The box in Figure 3.4 was 9 inches tall by 8 inches wide by 3/4-inch thick without the end caps. The end caps were 1.5 inches thick and recessed into the box three quarters of an inch leaving 7.5 inches of height for radio equipment. A 3/4-inch panel for equipment attachment was made to fit snuggly in the box diagonally across two corners. This way the electronics were secured to the panel separately and inserted into the box when launching the payload. The more dense pink insulation foam was used for the walls of the box and the white bead foam for the end caps and inner panel.

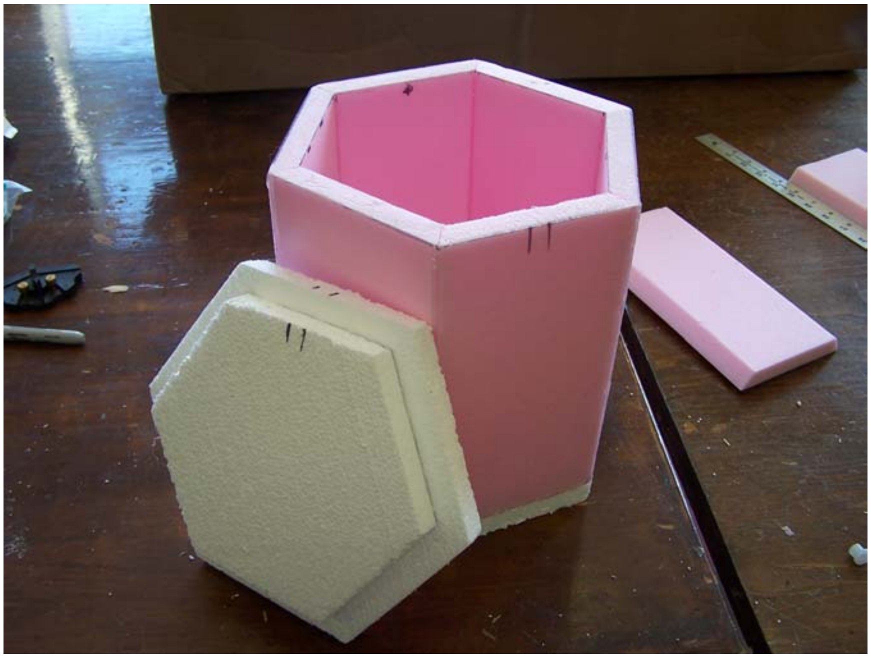


Figure 3.4 Payload Box

Each side panel of the box was cut using a table saw and then glued together with low-temperature hot glue. Many adhesives were researched and the low-temperature hot glue was determined to not become brittle at high altitudes in the colder temperatures as well as to be generally easy to work with. The outline of the box was then traced and then cut to form end caps. An end cap was then hot-glued to the bottom of the box leaving the top open for later equipment placement.

Next, the box needed some outside covering to provide additional protection from any trees or brush that the payload might impact upon descent. A covering called monokote which can be purchase in any hobby store was used. In order to also adhere to FAA regulations and guidelines[7], the monokote was chosen in chrome and neon orange colors to be seen adequately. The monokote was cut slightly larger than the size of each side panel. After peeling off the back clear layer, the monokote was placed onto the foam and smoothed out using a hot iron. The monokote adhered to the foam through the use of the iron. The same process was used to cover the end caps as well and is shown in Figure 3.5.

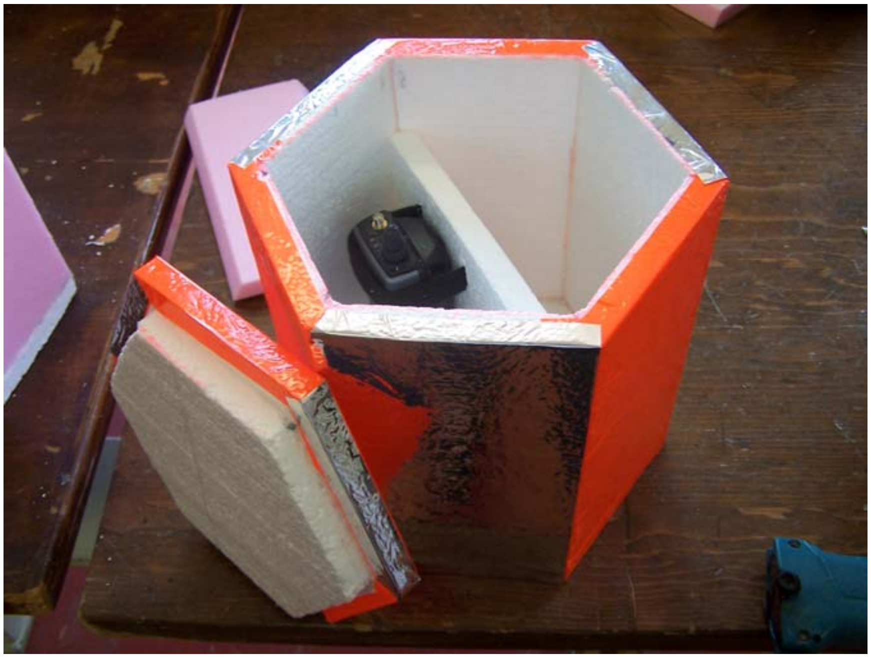


Figure 3.5 Covered Payload Box

The payload boxes also needed to be suspended from the parachute while still insulating the radio equipment from the cold air. Two basic options included cutting holes in the box to string rope through which would allow cold air in and attaching rope to the outside of the box which would increase the chance for payload detachment. It was decided to string rope through the box but to encapsulate the rope in tubing. Holes in the end caps were cut large enough for two 10.5 inch lengths of three-eighths-inch-diameter tubing to be inserted and hot-glued. Then quarter-inch-sized rope was inserted through one tube, pulled out underneath the box, and then run back through the other tube. Washers and knots in the string were placed at each end of the tubing to keep the box from shifting along the string.

Once the structural design of the box was completed, the ham radio equipment was tested. Two boxes were built: one box to hold the GPS equipment and radio, the other to hold the temperature equipment, radio, and cut-down mechanism. The equipment was placed on the diagonal foam reinforcement and sealed inside each box. The payload boxes were suspended by rope from the parachute. The cut down mechanism tested in this tethered drop was different from the one discussed in Chapter 2. Electrical current was to be sent through wires to a strand of nichrome wire wrapped around a length of rope causing the nichrome wire to get hot and burn through the rope. The wires ran from the temperature payload box up to the top of the parachute where it was connected to the balloon by rope.

This system was tested with another tethered flight. Again, the balloon was inflated with helium and flown to a height of 100 feet. By entering in the correct sequence of numbers through the ground radio, the command ‘C*91’ was given for the nichrome wire to burn. Unfortunately, the rope was not cut and the tether was pulled down.

This experiment successfully tested the GPS payload package as well as obtained temperature readings as it floated up and was pulled down. The payload boxes had not been dropped therefore their structural resilience was not fully known. There were also several possible problems with the cutting mechanism. Either the power supply was not producing enough voltage or the nichrome wires had crossed thus shorting the system. The cutting mechanism and payload boxes would need further testing.

3.3 Pressure Test

Known difficulties in the balloon inflation process led to further testing of the balloon itself. A test was desired to determine the mass of helium required to inflate the balloon in order to more accurately determine the resulting lift of the inflated balloon. The actual pressures experienced by the balloon during inflation and the resulting balloon diameters could be obtained and used to determine the balloon’s mass at those particular instances. First, however, a proper fill mechanism was needed in order to improve inflation procedures.

A simple mechanism was developed from PVC pipe and brass air hose fittings shown in Figure 3.6. The pipe with the same diameter as the neck of the balloon was inserted into a screw cap fitting with an outlet on the side. A brass air hose fitting was screwed into the outlet. The air hose fitting used was determined by the three-eighths inch tubing already being used to fill the balloon. The tubing was then firmly attached to the mechanism and helium tank. The neck of the balloon could be securely fastened onto the PVC pipe and be held down during inflation and lift measurements.

Figure 3.6 Balloon Inflation Device

As the supply of air was more abundant than helium as well as free of charge in the Patterson Laboratory, it was chosen to substitute air for helium. The density of the gas was the only changing factor. In order to record pressure data inside the balloon, a slender brass pitot tube was fastened to the PVC pipe and slid inside the balloon. The pitot tube was attached to a water manometer to record the pressure. The balloon was placed in between a stationary wall and a movable wall. The experimental set-up is shown in Figure 3.7. As the balloon was filled, the movable wall was positioned next to the largest portion of the balloon. The distance from one wall to the other was recorded as the balloon's diameter. The diameter was recorded at four positions and corresponding pressure data taken at each. The results are found Table 3.1.

Figure 3.7 Balloon Pressure Measurement

Table 3.1 Determination of Mass

Diameter (in)	Pressure (psi)	Mass of Air (kg)	Mass of Helium (kg)
63.5	1.66	2.69	0.39
76.5	2.24	4.71	0.69
96.25	2.08	9.37	1.37
120	1.56	18.16	2.65

In the third pressure recorded, a drop in the pressure was noticed. The latex began to relax allowing the walls of the balloon to stretch more freely easing the pressure. By the fourth pressure recorded, the balloon expanded to a point where the latex no longer experienced a strong pressure difference.

3.4 Launch of Payloads

The last test to date was an actual launch of the temperature and GPS payload packages. The same payload boxes from the earlier tethered test were used with the same radios controlling the temperature circuit and GPS equipment. The cut-down mechanism used was the nichrome wire method. It had been re-wired and the circuit proved to work by burning through the same nylon rope that would be used in the launch. For both the payload boxes and cut-down mechanism this would be an in-flight trial test.

Several items were reviewed before launch in an attempt to ensure the safe recovery of the payload boxes. Accurate weight estimates of the payload boxes and their contents were taken to allow for the correct amount of helium to be used in the balloon. The ham radio call signs being used were reviewed to properly relay communication and data updates with the payload boxes. The payload boxes also needed to be properly secured and as air-tight as possible to protect the equipment from the cold temperatures. The boxes were to be hot-glued around the tubing and taped shut. Apart from the payloads, the equipment needs and the responsibilities of the recovery team and FAA regulations were discussed.

On the day of the launch, the Balloon Track program predicted that the balloon would ascend from the North Farm launch site to an altitude of 119,000 feet heading towards Florence, Alabama with a flight duration of 157 minutes. The team assembled at 8:00 a.m. to prepare the payload boxes and to ensure all processes were functioning properly. The boxes were secured shut and labeled clearly with contact information should they not be recovered by the team. The balloon was then inflated using the PVC pipe device connected to the tank regulator using three-eighths-inch tubing. The device was also attached to one end of a fish scale while the other end was secured to a weight preventing the balloon from rising. While the balloon was being inflated with helium, the person holding the balloon checked the reading from the fish scale. Once a seven-pound lift force was observed, the tank was shut off. The set-up is shown in Figure 3.8.

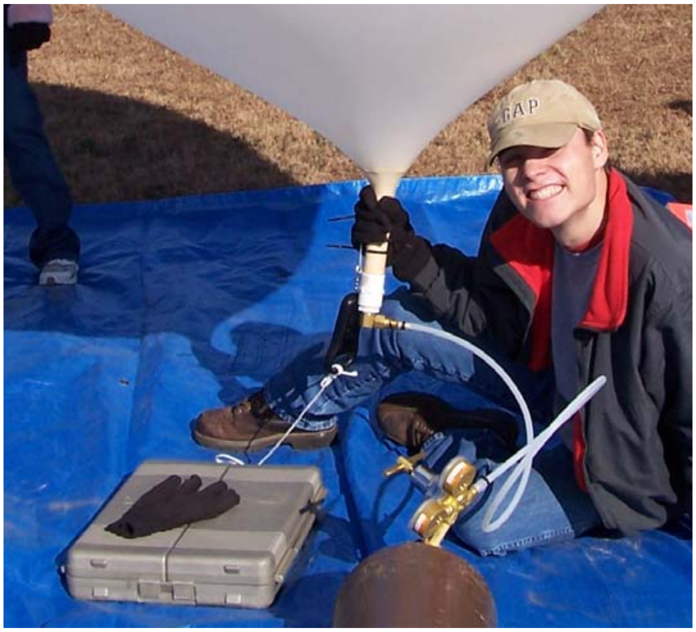


Figure 3.8 Balloon Inflation Configuration

From this point, the two payload boxes were strung together using a single nylon rope as described in Section 3.2 and shown in Figure 3.9. Once the boxes were connected to each other and the parachute, another rope was used to connect the parachute to the balloon. It was on this section of rope that the wires from the cut-down mechanism were run. The wires were intertwined through the rope and then wrapped with electrical tape to prevent the wires from loosening during the flight.

Figure 3.9 Payload Box Connection

The team was ready for launch at approximately 10:00 a.m. after having contacted the ATC facilities in both Memphis, Tennessee and Atlanta, Georgia thirty minutes earlier. In order to keep the payload boxes and parachute from an unnecessary scrape across the ground where damages could occur during launch, they were held above ground as seen in Figure 3.10. As the balloon was released and tension reached the lines, each item was released individually.

Figure 3.10   Balloon Launch Configuration

Upon launch, the team divided and used two vehicles to begin monitoring the ascent of the balloon. Both GPS data and temperature readings were being received by the radio equipment on the ground. Following the GPS coordinates, the vehicles traveled north towards Aberdeen, Mississippi. On the way, the GPS data was not being received regularly with the last coordinates obtained indicating a northeasterly flight direction before GPS communication was lost. However, the temperature circuit continued to output readings, although these were inconsistent with predicted readings. Unfortunately, no readings are available to document due to the unintentional premature shut down of the recording computer. The team split in Aberdeen, with one group driving towards Amory, MS and the other towards Sulligent, AL. The group driving north had the only Yagi antenna. The team stopped at intervals to get a direction with the antenna. The Yagi readings indicated the payload packages were heading east. The team drove eastward to join the other. It was believed that the payloads descended during this time period and were on the ground. The Yagi directional antenna could not get a signal. This had to be due to the payloads being out of a reasonable search area and to the tremendous number of obstacles in its path on the ground. The ATC facilities were contacted with the information. An approximate position could not be obtained from the ATC facilities since they were not actively recording the payload's position. The vehicles continued to drive around both Mississippi and Alabama listening to the ground radios for a signal from the payload boxes. At the end of the day, the payload boxes were not recovered.

Upon review of the launch, several factors were identified that could have contributed to the failed recovery. The GPS could have had a connection loosen during flight and foam in the box protecting the equipment may have jostled the connection. The cold air may have seeped in around the area where the radio antenna protruded out of the box. Another Yagi directional antenna in the other vehicle would have allowed the team to triangulate the balloon's position once the GPS contact was lost. The radio signaling the circuit controlling both temperature data acquisition and the cut-down mechanism was thought to have been used to prematurely cut down the payloads. More testing was obviously needed.

It was determined that a contingency plan was needed should this situation arise again. Once GPS signal is lost, the cut-down mechanism should be implemented to give the recovery team a more accurate region to search. Also, the chase team should already be near the predicted landing site of the payloads. The team would be in a better position to adapt to changes in the flight path and ready to recover a cut-down flight. In any event, the addition of an emergency transmitter locator would be useful and should be investigated.

CHAPTER IV

CONCLUDING REMARKS

4.1 Follow-up Testing

The failed recovery of the payload boxes indicated that certain tests were necessary before another launch could occur. The equipment, power supplies, and cut-down mechanism were among those areas in need of investigation.

The temperature range of all the equipment will undergo cold testing. The minimum temperatures that the radios and circuits can withstand need to be verified against manufacturers' recommendations. The payload box containing the equipment will be placed on a rack in a cooler. Solid carbon dioxide, also known as dry ice, will be placed along side the payload box in the cooler. The coldest air temperature that could possibly be experienced is around -56°C. The boiling point of dry ice is -78°C. The cooler will be vented until the appropriate temperature is reached. If the equipment cannot adequately withstand these temperatures near that, some sort of heat source must be placed inside the payload containers. Small athletic heat patches have been suggested.

The power supplies of the radios and cut-down mechanisms were never tested for longevity. The lithium batteries were chosen for their endurance yet the exact time frame was not known. Also, the circuitry for the cut-down mechanism will most likely be reconfigured to an automated relay and tested thoroughly for consistency.

Before another launch, the equipment will first be operated on an airplane. The airplane can aid in validating the range of the radios obtaining the GPS and temperature data. This will help minimize the chance for loss of equipment.

4.2 Additional Steps

Moving forward with glider preparations, the next area of interest is examining the behavior of a glider released from a tether. A practice glider was purchased until construction of the proposed glider begins. The glider is a Great Planes Spirit Elite ARF (almost ready to fly) sailplane with a two-meter wing span and an empty weight of three pounds. The glider is equipped with an elevator, rudder, flaps and ailerons. The fiberglass fuselage and basswood built-up wing sections are pre-manufactured. The wing also has a Selig/Ashok Gopalarathnam SA7035 airfoil. The orientation of the tethered glider will be varied: attachment from the nose, the tail, the top of the wing and the bottom of the fuselage. The release behavior of each will then be assessed to determine which will be optimal for the safe pull-out of the glider. The current cut-down mechanism can also be examined with the possibility of exploring new release mechanisms.

4.3 Project Advantages

The flight test system proposed is a relatively simple yet effective way of exploring the ‘near space’ region of earth’s atmosphere. There is great potential with a glider and the current test platform. High altitude balloons can be launched fairly easily, weather permitting. Once enough trial flights are completed, the testing platform should prove to be quite reliable. Different airfoils can be used on the interchangeable wing. The data collection systems on the glider can advance over time. The addition of pressure taps to the wing may be a possibility. The aerodynamic data acquired could possibly be received during the flight. This would require more equipment resulting in a higher cost to obtain the necessary bandwidth for transmission. A waiver could possibly be attained from the FAA should the need for an increase in weight arise. For now, simplicity is the key and it will continue to be the main focus of this concept.

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