

**FINAL DESIGN REPORT**

**HIGH ALTITUDE GLIDER**

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**with MAEs:**

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## **PREFACE**

The work described in this report covers the contributions of David Becker and Nicholas Palumbo to the High Altitude Glider project, collaborated on with the mechanical engineers listed on the title page. Any work done by the mechanical engineers that David Becker and Nicholas Palumbo did contribute to is not covered in this report. This report is solely focused on their work as part of the Electrical and Computer Engineering Capstone Design class.

## **ABSTRACT**

Our High Altitude Glider project had us collaborate with mechanical engineers to create an effective glider that could withstand high altitude conditions, while still being able to autonomously guide itself and collect data. The glider will be dropped from a weather balloon at 60,000 feet and use an autopiloting system to lead itself back to a location to be recovered.

The scope of the systems included the autopilot and all associated components, as well as mechanisms for detaching the glider from the weather balloon in a reliable way. The autopilot we chose is the ArduPilot Mega 2.6, which allows for high levels of customization as well as access to a well-established ground control software in Mission Planner. Through use of RFD900 radio modems, we can communicate over long ranges from Mission Planner to the glider, sending mission commands and altering parameters if necessary, in addition to receiving live data from the glider. The ArduPilot is connected to 5 servos for controlling the plane and to a remote control receiver that will allow us to take manual control of the plane once it is low to the ground to make a safe landing. A barometer and air speed sensor are attached for data collection. There are primary and secondary detachment mechanisms to ensure that the plane detaches successfully. The first is simply a servo activated by the autopilot which causes a mechanical release of the balloon from the glider. The secondary consists of a 555 monostable timer circuit, which induces an output current through a resistor after an adjustable amount of time, based on resistance and capacitance. The resistor heats up and melts through the string attached to the glider, causing it to drop from the balloon.

Unfortunately, as of April 16th, 2014, we were not cleared by the FAA to fly in class B airspace. We are currently engaged with administrators to find a way to fly, either in a different location or at a different altitude. In the meantime, we attempted a low altitude flight to allow us to have some kind of air time. This flight was mostly successful; the detachment mechanism, communication, and all systems functionality were demonstrated to be functional. However, due to the low altitude the glider detached at, the glider did not have time to level itself out well and achieve an appropriate speed. Thus, we were forced to take manual control of the glider, and it crashed during our attempt to land it at an unfortunately high speed.

All other tests, including environmental chamber testing and detachment testing were satisfactory. The glider and its systems were demonstrated functional at -60°C. In addition, we proved that the primary detachment would activate at any set altitude and that the secondary detachment activated at any set time. Some things we would hope to achieve in the future regarding the abilities of our glider include optimizing communication range, adding temperature and humidity sensors to collect meteorological data, and finding a better way to insulate the batteries to ensure their proper function without overheating.

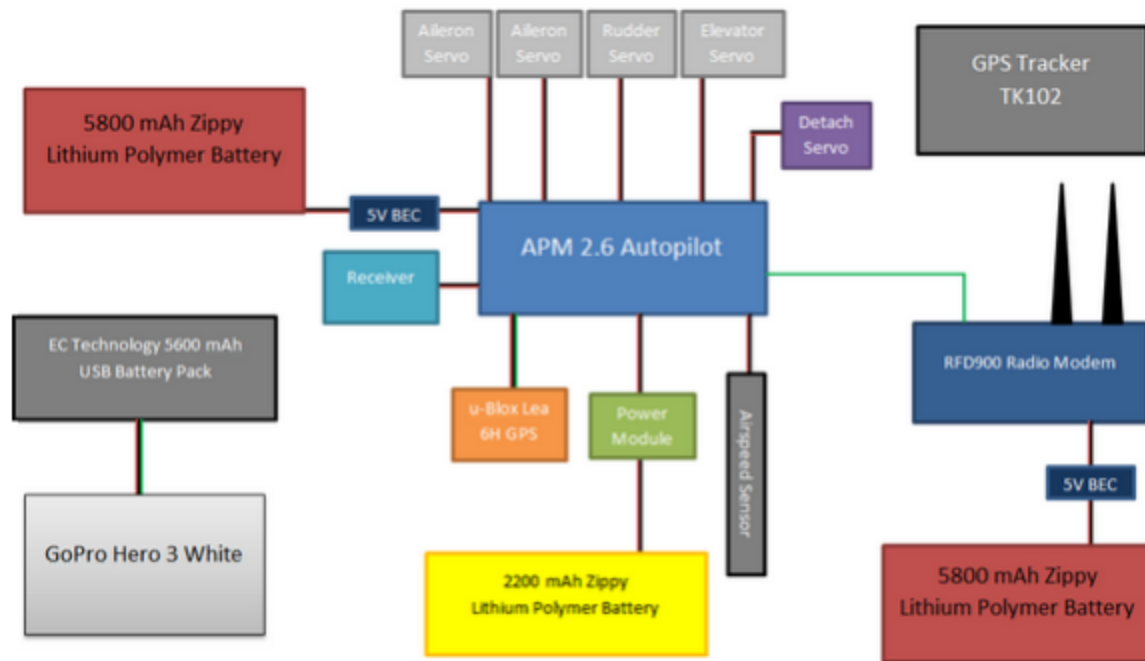
## OVERVIEW

Though mankind has been capable of flight for over a century, exploration of the upper atmosphere still presents difficulty. The problems associated with high altitude data collection include costs, accessibility to materials, and reliability. The most common vehicle for high altitude research is the weather balloon--which is widely accessible, but not necessarily reliable. Commonly, a payload containing data acquisition hardware known as a radiosonde will be attached to the balloon, flown to a desired altitude, released, and parachuted back to the ground. Unfortunately, the final stage of this process can lead to both losses in equipment and data because the parachute will be at the mercy of weather conditions. In fact, less than 20% of the launched radiosondes are recovered at all to be refurbished and reused [1]. The estimated cost of each launch is around \$250; each weather station typically launches two radiosondes a day [2]. Hence, the development of a cost-effective and reliable method of returning a payload to its owner would greatly mitigate the risks associated with high altitude data collection. An excellent solution is the development of an autonomous glider that can perform the desired data acquisition and pilot itself to a specified landing point for retrieval. Since the glider is autonomous, it would be able to respond to wind conditions and control its descent, allowing it to safely land in a designated pick-up zone.

Ultimately, our goal was to conceive, design and execute a multidisciplinary project with the objective of creating a high altitude glider capable of autonomous guidance and data acquisition. The final product should be re-usable, cost effective, and reliable under the intense conditions associated with high altitude flight. This glider will open up the upper atmosphere for exploration on a budget, allowing for multiple commercial uses in addition to providing an advanced high altitude platform to sailplane enthusiasts.

## METHODS

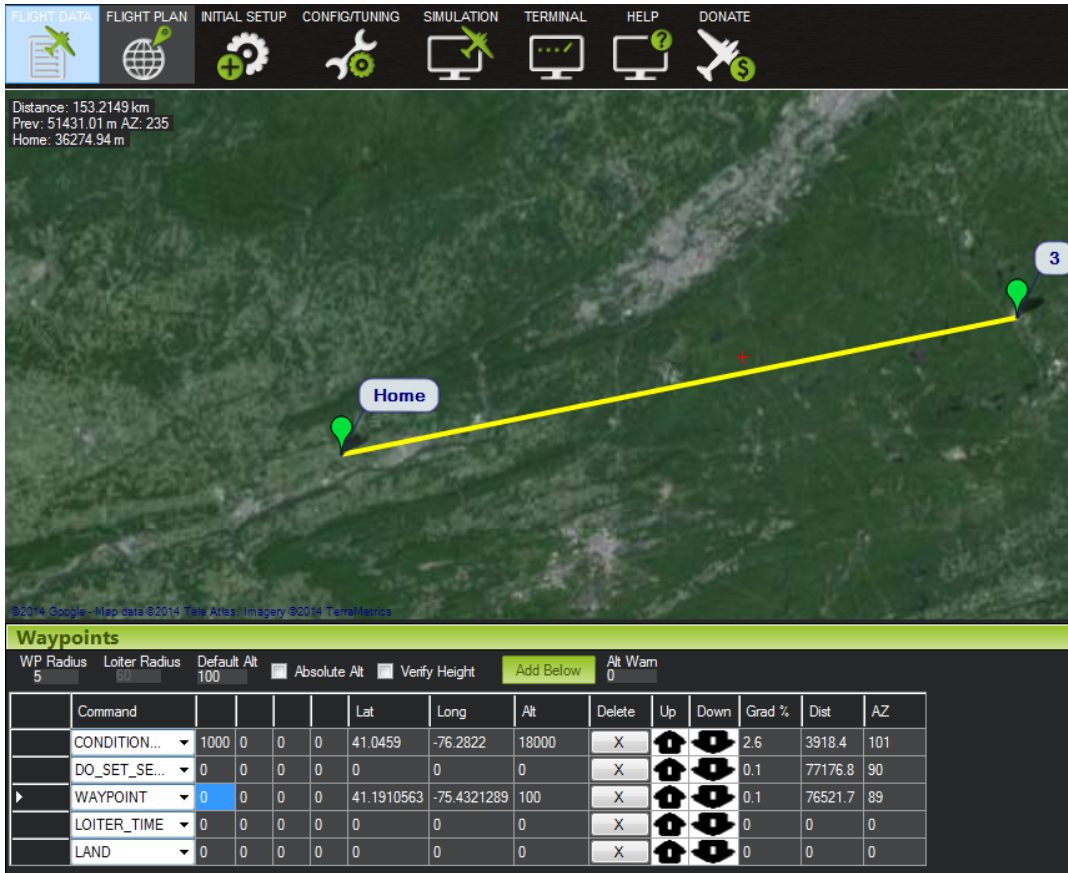
All our major system components required little assembly independently, but needed to be interconnected. However, the layout is relatively simple. The ArduPilot sits stationary and in line with the GPS in the plane aligned with the center of gravity. The GPS/compass interface directly with the ArduPilot, whose data is transmitted to us through the RFD900 modem, also connected into the ArduPilot. We had previously considered trying to program the autopilot to transmit the data to us via a cell phone to save on money, but it was deemed to be too convoluted for an ultimately inefficient and cumbersome system, so we switched to the modems, with a GPS Tracker as a backup. To read all of the data from the autopilot, the ground station computer used the Mission Planner software.



**Systems Diagram**

### Flight Plan

A key component of this project was programming the logic and mission for the glider to follow. The basic outline of this was using a conditional altitude command first. As soon as the glider reaches 60,000 feet, the 'Do Set Servo' command was used to trigger the detachment servo, thus dropping our plane. From here, a waypoint located by our launch site is the primary guidance mechanism for the plane to follow. Once it reaches the launch site, it is programmed to loiter above for a specified amount of time to give us a chance to take manual control and land the plane using the remote control. After the specified time, if no manual control is enacted, the plane is set to take advantage of the airspeed sensing and altitude capabilities to perform an autonomous landing. With a valid telemetry connection during the flight, we can update waypoints and any parameters or flight modes that we desire in real time. This is dependent on having a live connection with the autopilot through the radio modems. A sample flight plan is shown in the screen capture below.



**Sample Flight Plan Screen for Glider**

## Communication

After some range testing with the modems, even though it could not be done in complete line of sight representative of the realistic scenario, we were not one hundred percent confident that telemetry would be maintained throughout the entire flight. There were several fixes that were instituted to deal with this possible dilemma. The first is obtaining a higher gain ground station antenna. With the use of a 900MHz 9dBi gain yagi antenna shown below, the signal from the plane can be focused back to us by pointing the yagi antenna at the plane. In order to transmit a strong signal on the ascent, a diversity scheme was used within the plane to eliminate interference. Two 3dBi gain half wave omnidirectional (transmit equally in all directions perpendicular to axis of antenna) 900Mhz antennas were oriented in the plane facing 90 degrees apart to ensure the signal was being transmitted in every direction. The RFD900 supports diversity switching, meaning it will send the data through the antenna with a stronger signal. It also uses frequency hopping to take advantage of its entire frequency range (902-928 Mhz), finding the clearest, strongest transmission range.



### **9dBi Yagi and 3dBi Omnidirectional Half Wave Dipole Antenna Ground Station Setup**

Just in the case of telemetry failure or intermittent connection, we added an entirely independent GPS tracker which transmits the location of the glider via cellular network. We chose just to use a GPS tracker as our backup telemetry as it is not absolutely critical that all other data is transmitted live to us--the autopilot can navigate entirely autonomously. However, locating it is absolutely necessary. The GPS tracker is installed with a SIM card connected to AT&T networks. From a preconfigured authorized number, the GPS location can be requested through text or phone call via specific commands. The geolocation, battery life, and speed will be returned in a text through the GSM or GPRS transmission band (two most common texting transmission systems). It also supports continuous tracking (sending updates every requested time interval indefinitely). This system was tested by having members of the team carry the tracker with them wherever they went around town, and the system succeeded with great accuracy and an impressive battery life of over 6 hours continuous texting.

### **Power**

A necessary aspect of this project was making sure there was complete system compatibility and power management. Due to the fact that the autopilot, GPS, radio modem, servos, and receiver all operated on 3.3 to 5 Volts and Lithium Polymer batteries come in cells of 3.7 Volts each, we were forced to use 7.4 Volt LiPo batteries and regulate them down to 5 Volts. For the autopilot system, this was done with a native APM power module, capable of regulating the voltage input and monitoring the current and nominal capacity of the battery. For the servo power and radio modem power, each powered by a 5800 mAh battery, a 5 Volt BEC (Battery Eliminator Circuit) was used. These devices work on the simple principle of dissipating power with an internal load and passing along only the desired voltage. While this leads to higher efficiency than similar solutions like switching regulators, the power dissipated is done so in the form of heat, a valuable asset within our fuselage in the cold temperatures, especially since the batteries do not generate as much heat as in more common high

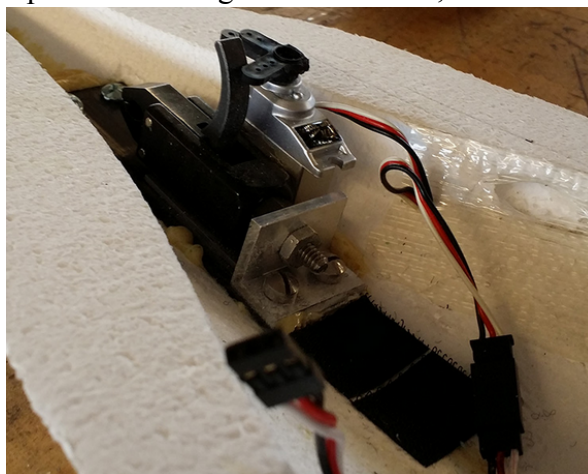
current draw applications. We also needed to create various extenders for the servos to ensure that they could reach the ArduPilot from the wings and tail. This was done by stripping the servo wires down (including the ground, +5V, and signal wires) and crimping pins and male/female terminals onto the pins. The servos were embedded into the foam of the plane and the wires were run through the carbon fiber tubes connecting the wings and tail to the fuselage. All servo wires were twisted within the fuselage in order to eliminate noise from the power signals which would otherwise cause unwanted servo jitter.

### **Mechanical Control**

In total, five servos will be connected to the autopilot. Two servos control the ailerons in the wings, one controls the rudder, one controls the elevators, and one will control the primary detachment mechanism. This amounts to three output channels being used on the autopilot, since the ailerons utilize the same signal and still move in opposite directions (desired) due to their mirrored installation. Splitting this signal was accomplished with a simple Y-servo splitter cable. The servos are controlled by the ArduPilot but can also be controlled manually by a remote control transmitter through a receiver in the plane, also connected to the ArduPilot. All tests on both automatic and manual control were successful.

### **Detachment**

Our primary release mechanism will be an Allen Bow Release and a servo because of its durability in supporting heavy loads, ability to release with very little force, and inexpensive components. Out of all of the potential detachment mechanisms this one was the most reliable and simplistic. The flaws encountered with the other mechanisms included weight issues and unreliable execution. Our final design for the primary release underwent a series of technical issues. Originally we planned on using a solenoid because of the low power requirement to activate it, but we were unable to find a solenoid capable of fulfilling the requirements of having the required pull of 14 mm yet still being small. A linear servo was also considered but due to complications interfacing it with the Ardupilot we opted for the same type of servo used by the systems team since it had already been successfully tested. The original design involved connecting a bar between the servo and the trigger. However, a simpler design was conceived in which the servo arms would be oriented so that one arm would prevent the trigger from firing and then when rotated 100 degrees the other arm would activate the trigger. This design was ultimately chosen because it eliminated the intermediary step between the servo and the trigger. This mechanism is inside of the fuselage behind the main wing. The primary release will be the activated by the GPS connected to the Ardupilot when the glider reaches 60,000 feet.

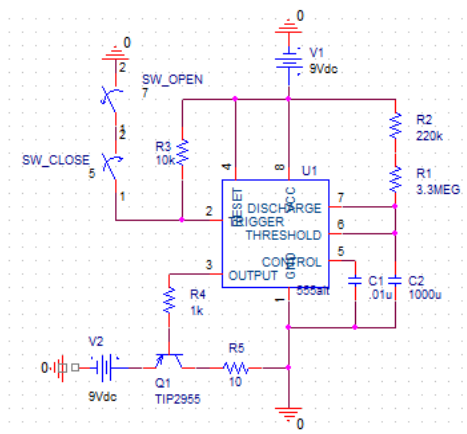


**Primary Detachment Mechanism**

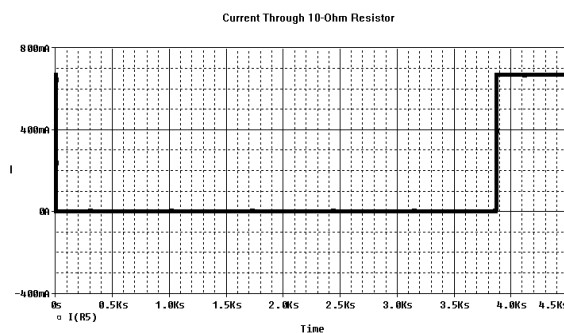


The secondary release mechanism will be a wire melting technique because it was proven to work for another group that attempted a similar feat. The original design was to use a Nichrome wire to melt through the rope. However, after a series of tests during which the Nichrome wire was unreliable at low temperatures, a 10 ohm resistor was chosen. The 10 ohm resistor will be attached outside of the fuselage where it will not impede the rope's movement should the primary release prove successful. The secondary release will be activated by a timer circuit based on the ascent time calculation for when 75,000 feet is reached. At that point the circuit, powered by a 9 Volt battery, will produce a power output of roughly 8.1 Watts which should burn through the rope in a short time. The secondary release is completely independent from the first; it relies on a separate mechanism and will be activated by a different measurement, so it will detach the glider even if the whole primary release system malfunctions.

The secondary release is also activated separately from the ardupilot, in case it somehow fails. The release runs off of a 555 timer circuit, which runs a current from the battery through the resistor after a certain amount of time, pending on resistor and capacitor values. It is set to activate 1 hour, 4 minutes, and 32 seconds after release, roughly 15 minutes after the glider reaches 60,000 feet, which is when the primary release should activate. This correlates to height of about 75,000 feet, well below the maximum height of the balloon of 110,000 feet. The resistor and break away wires leading to it are also attached to the rope above the resistor so that when it burns through the rope it breaks away and flies away with the balloon leaving nothing trailing behind the glider.



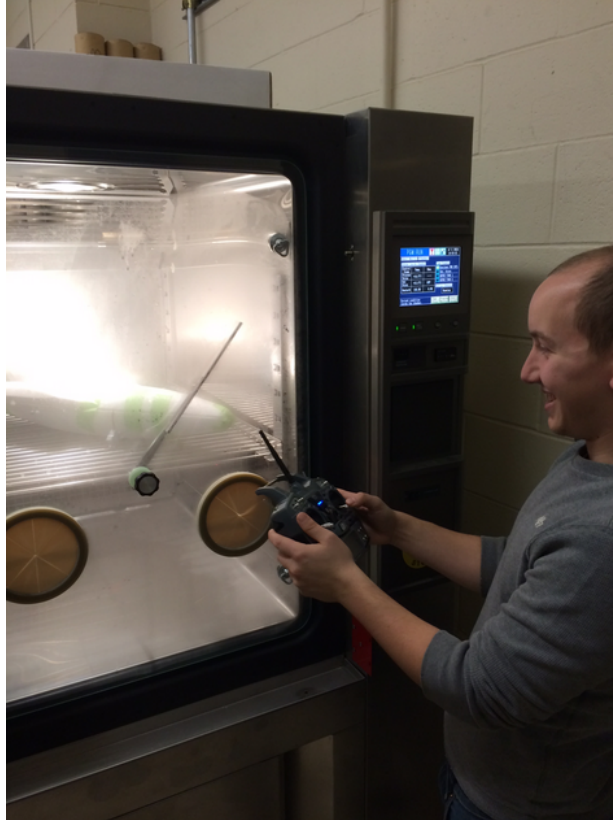
**555 Circuit Diagram**



**Current Running Through Detachment Resistor Over Time**

## TESTING AND DESIGN CHANGES

The major concern for the systems was operational ability at extremely high altitudes and cold weather. We conducted a test on the entire system, sealed inside the fuselage of the glider, within the environmental chamber, which can alter temperature and humidity. We created a profile of temperature drop as altitude increases and simulated it with the environmental chamber. Even with the external temperature at  $-60^{\circ}\text{C}$ , and the internal temperature of the fuselage reaching  $-25^{\circ}\text{C}$ , the systems all still functioned perfectly. The only failure was a servo, left outside of the glider, that was no longer able to function once it hit  $-35^{\circ}\text{C}$ . However, the servos will be in motion as they rise through the atmosphere; we redid the test with a moving servo, and it worked all the way down to  $-60^{\circ}\text{C}$ .



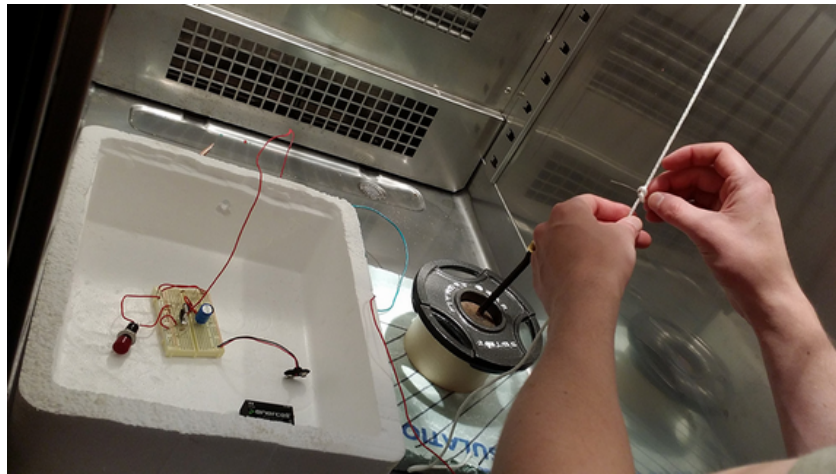
**Environmental Chamber with Fuselage Inside for Temperature Testing**

Another concern that was addressed was the stability of all of the systems within the fuselage. The GoPro is pressure squeezed into its slot at the front of the plane and held in place by the batteries, which are velcroed to the bottom and held in by foam wedges on the side and the top hatch. These were the most crucial pieces to keep in one place as they affect the center of gravity on each axis and could potentially rip out other wires if not secured. Every other system was velcroed down in its respective place (velcro secured with Foam-Tac glue), and plywood and balsa supports were incorporated to relieve stress on wires and provide more walls to keep the batteries stationary.

To ensure the reliability of both of the release mechanisms, tests were performed under various conditions. The allen bow release in the primary detachment mechanism would carry the weight of the entire glider, which would be a maximum of six pounds. The design specifications rated it up to 60 lbs,

which we confirmed through our own force testing. Each component of the base platform was chosen because of its strength to weight characteristics. Our prototype release mechanism consisted of an aluminum base, but to minimize weight the final release mechanism was mounted on a carbon fiber base. After performing various load tests we are confident of the ease in which this release mechanism performed.

Testing for the secondary release mechanism proved to be very time consuming due to the length of each test. Initially tests were performed at room temperature with a simple battery and Nichrome wire setup. The wire was wrapped around the rope for a clean sever when a current was applied. This setup worked reliably at room temperature. However when attempted in the cold chamber at  $-25^{\circ}\text{C}$ , or the temperature inside of the fuselage with all the systems running, the circuit failed. Subsequent tests in which the batteries were outside of the cold chamber led us to discover the major problem that alkali batteries only function down to  $-20^{\circ}\text{C}$ . Further testing with the battery outside of the cold chamber showed that the circuit was still unreliable because the Nichrome wire was not reaching the temperatures necessary for melting the rope. This led us to switch out the Nichrome wire with a 10 ohm resistor, which was more reliable when tested at room temperature. Due to shifting of the resistor during subsequent tests we realized that we needed a way to maintain a longer contact with the rope. This led us to tie a pretzel knot around the resistor using the rope. Then when tested in the cold chamber, it successfully melted through the rope with the battery on the outside.



**Secondary Detachment Setup Inside Environmental Chamber**

The time delay circuit also gave difficulties in testing because of the length of the tests. For small time delays the system worked with marginal error, but for longer time delays the system gave difficulties. We believe that these were attributed to the batteries not sustaining their charge for the hour long tests that were performed since we were being economical and reusing batteries. When we used new supplies the system became more reliable which led us to be able to perform successful full tests in the cold chamber with the 10 ohm resistor. To overcome the issues with the battery freezing at low temperatures we researched other batteries, but the corresponding increase in cost was not justifiable. So instead we tested batteries wrapped in various hand/foot warmers to determine if they would work. We found that two foot warmers or two hand warmers wrapped around the battery were sufficient in insulating the battery. For our final tests in the cold chamber we used a styrofoam cooler to approximate




the shape and insulation of the fuselage. Using a thermocouple we found that the addition of the insole foot warmers did not increase the ambient temperature inside of the fuselage so the other systems would not be affected by the additional heat source. However the battery itself produced a lot of contact heat so it will be placed away from the more delicate components. Condensation was also produced on the circuits when brought quickly to room temperature from -60C. However, further tests that more accurately represented the actual temperature change during descent showed that the condensation effects were negligible.

Originally the rope was to be released through a small hole in the top of the glider but because of the desire for a vertical detachment the rope will be released from the tail. A plastic tube of smaller diameter than the carbon rod tail was attached inside the tail so that the rope would have an unimpeded exit from the craft and avoid the wires for the secondary release mechanism and the servos controlling the tail. In the interest of reducing causes for error with the secondary release, a polypropylene rope will be used to attach the glider to the balloon for its characteristics of being strong while having a very low melting temperature. The knot used to attach the balloon to the primary release will be a bowline knot. This knot is used in rescue operations due to its high payload capacity. The knot will be located inside of the tube and testing has been done to ensure that it will slide out easily. After various configurations during testing the resistor will be attached to the rope outside of the glider. The main issue we encountered was the resistor losing contact with the rope during the melting phase leading to rope ends fusing back together. To overcome this, the resistor will be located inside of a pretzel knot to maximize the contact surface. Should the primary release prove successful the resistor for the secondary release is attached via clips that will detach from the circuit and with the resistor remaining attached to the rope. If the primary fails and the secondary releases successfully the resistor will be attached to the rope above the cutoff point so that the resistor will float away with the balloon and break the circuit. This was done so that the battery does not continue to give off a charge, thereby heating up, and potentially raise the temperature inside the pod above the working temperature of the other systems.

## COMPONENT SELECTION AND COST ANALYSIS

The first step in designing the systems of our glider was determining what we required from them. We wanted imaging, autopiloting, GPS location, communication, power, and mechanical motion (to control the wings, rudder, etc.). Once we had determined this, we could move onto actual selection for each component--deciding what product to use based on cost, reliability, weight, and effectiveness at achieving what we need.



### Imaging

Camera	Pros	Cons
<p>Go-Pro</p> 	Has been used in similar situations	High Cost, Heavy, Short Battery Life
<p>iShot OD Color Micro Camera</p> 	Full HD, Light Weight	Not in price range
<p>Canon PowerShot SX260 HS</p> 	Cheap, Easy to Program	Never been used under these conditions

From the beginning, there was really only one standout choice for the camera. While there were alternatives at lower costs, the Go-Pro Hero is the tried and true camera for these types of projects. It's small, high quality, and has been successfully used in the past at extremely high altitudes and extremely cold temperatures. We mounted this into the bottom of the glider, with the body of the camera inside the fuselage and the lens embedded into the actual body, exposing it just enough to leave it unobstructed. Its



orientation allows it to capture video towards the earth’s horizon on ascent, and footage looking straight down at the earth on descent. This was in contrast to the original idea of having it facing 45 degrees between the plane’s forward and down facing direction, as this would not have adequately captured the full range of its possible view.

## Autopilot

Autopilot	Pros	Cons
<p data-bbox="203 541 462 577">Ardupilot Mega 2.6</p> 	<p data-bbox="618 541 1003 653">Open source, highly used and reliable, supports all necessary functions</p>	<p data-bbox="1031 541 1291 577">Relatively high cost</p>
<p data-bbox="203 863 414 898">UAV DevBoard</p> 	<p data-bbox="618 863 938 898">Cheap, more lightweight</p>	<p data-bbox="1031 863 1430 974">Does not come with all gyroscopes, magnetometers, or altimeters; more coding needed</p>

The autopilot for our glider was selected as the Ardupilot Mega 2.6 (APM). While we did consider using a UAV DevBoard, it lacks the innate support available to us through an APM. The UAV DevBoard lacks the built-in sensors and well-supported firmware provided by the APM. The ArduPilot has everything we need: in-flight stabilization, waypoint navigation, and programmable control over all our other devices. Ultimately, the Ardupilot is at the center of our entire system. It controls the servos via its native autopiloting software, utilizing its built in gyrometer, accelerometers, magnetometer, altimeter, and the GPS unit detailed in the next paragraph. In addition, an airspeed sensor was purchased to aid in the glider’s autopiloting functions by taking into account stagnation and dynamic pressure. It also was programmed to communicate via a modem with our computer on the ground. The computer on the ground monitors the glider using the open source Mission Planner software which is readily available and highly customizable.

## GPS

GPS	Pros	Cons
Media Tek MT3329 	Comes with Ardupilot, Low Cost	Shuts off at 60k ft.
uBlox Lea-6H 	Works up to 164k ft.	High Cost

As our GPS, we originally thought to choose the out-of-box MediaTek GPS included with the ArduPilot Mega 2.6. However, we determined that based on our flight plan (particularly the aspect of the maximum altitude that we'd reach), we would need to upgrade. The uBlox Lea-6H was chosen, as it is not too expensive and functions up to 164,000 feet and  $-40^{\circ}\text{C}$ , which is more than enough for our flight.

## Batteries

Based on power requirements, we chose several different batteries to power their respective system subset. We used 6 hours as our goal for up-time, based on the airframe team's flight time calculations and a built in safety factor. For the four main servos, which each require an expected average of 250mA, we went with the Zippy 5800mAh 7.4V LiPo (Lithium Polymer). For the transmission modem, we will be using another 5800mAh, as it alone requires 800mA at maximum 1 Watt transmission power. Drawing less total current at a max of approximately 300mA, the Ardupilot, GPS, receiver, airspeed sensor, and detachment servo (one time current draw) will be powered by a smaller Zippy 2200mA battery. Finally, the GoPro camera requires its own dedicated battery, the EC Technology 5600 mAh USB Battery- this raises its capacity from 1050mAh to 6650mAh, which is almost 6.5 times greater.



A decision to increase battery life was made in case the actual glide time exceeds the team's initial estimations, which may be due to unforeseen winds or the possibility of overestimations in the drag forces. Also, although the systems compartment is insulated and generates its own heat, the extremely

low temperatures may adversely affect battery life so it would be best to overestimate the amount of battery life needed. The changes made from the preliminary design concept are as follows: Instead of the two 3700 mAh batteries which would yield approximately 4.5 hours (one for the 4 servos and one for the modem), two 5800 mAh batteries will be used to get closer to 6.5 hours of power. In order to scale up the autopilot/GPS battery to match the new flight time, a 2200mAh battery will be used to increase its capacity to an estimated 7.33 hours. Overall, these changes will only increase the size of each larger battery by 1.5 cm in length and by 3 cm in length for the smaller battery. The total addition in weight will be 7 oz (200 g), and the cost for the added battery life is \$30 total. This is a small trade off for ensuring the glider will not lose power in the event that the flight time is longer than expected.


### Servos

We are using five BMS-380MAX Micro Servos: one for each aileron, one for the elevator, one for the rudder, and one to activate our primary detachment mechanism (explained in the next section). The servos were chosen because they will provide enough torque to move their respective control surfaces with the calculated drag forces and lift required. They also were small enough to be embedded into our glider.

### Communication

Communication	Pros	Cons
<p>Motorola Razr</p> 	<p>Ability to interface with Arduino to send texts with location to ground.</p>	<p>No constant communication with glider.</p>
<p>RFD 900 Modem Bundle</p> 	<p>Air to ground communication</p>	<p>High Cost</p>



<p>Mini GPS Tracker TK102</p> 	<p>Standalone, Long Battery Life, Low cost</p>	<p>Does not include altitude, Relies on AT&amp;T coverage.</p>
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For communication, we had initially decided use a Motorola phone as a backup telemetry system, controlled by the ArduPilot, to text us coordinates from the GPS periodically. This was because the cost was very low. However, we decided that this would slow down the autopilot and introduce unnecessary complexity, so we decided the RFD Modems were sufficient to communicate between our ground station and our glider. In addition, as a backup form of geolocation, a cellular-based GPS tracker was put into the glider to ensure that if telemetry failed, we would still be able to locate the glider. The tracker is installed with a SIM card, and will respond to specific commands from known phone numbers with its GPS location, battery life, and speed.

### **Overall Cost**

The cost for our project is very straightforward. All the materials and components used have no direct environmental impact and can be easily obtained. The costs for each individual aspect are as follows:

#### **Glider**

Carbon Rod - \$80.21  
Carbon Strips - \$17.94  
Expanded Polystyrene Foam with milling expenses - \$1200.00  
Monokote - \$15.00  
Fiberglass - \$79.95  
Weather Balloon - \$122.00  
Helium - \$131.40

#### **Systems**

Allen 153 Adult Caliper Release - \$15.00  
RFD 900 Modem Bundle - \$209.95  
BMS-380MAX Micro Servo - \$8.95 per servo  
Mini GPS Tracker TK102 - \$35.00  
uBlox Lea-6H - \$79.99  
Ardupilot Mega 2.6 - \$159.99  
GoPro HERO3 - \$199.99

This gives us a total cost of \$2355.37. However, most of this is a single time investment;

because the glider is capable of landing itself and being fully recovered, the only recurring cost for each flight is the cost of the balloon and helium. When compared with the typical cost of launching a radiosonde, \$250, [2] one notices that they are almost identical. So without increasing costs at all, the glider allows for a much broader coverage of areas--whereas the radiosonde only covers a small, linear area (the area it drops through), the glider can be maneuvered to cover large areas or to explore interesting areas as data is found in real time.

## CONCLUSION

### Summary of Work Done

The Aero subteam has finalized the updated dihedral design for greater stability and has remodeled the fuselage to achieve a lower body drag coefficient and accommodate optimized packaging of internal systems. Carbon rods are to be used as armatures to provide more rigidity in the wings as well as create a stronger connection between the wings and the fuselage. The control surfaces were designed to balance agility and necessary servo torque based on calculated velocity profiles for the flight and will be manufactured separately from balsa wood. Theoretical work included modeling the airfoil and pod into a lumped drag coefficient, allowing for drag forces to be calculated across different velocities and altitudes. These results were verified using CFD analysis.

In summary for the detachment subteam, both the primary and secondary release mechanisms were designed, manufactured, tested, and redesigned to account for any sources of error. Since the mechanisms are completely independent of each other, should there be a failure in any components comprising the primary release mechanism, the secondary will not be affected. Both mechanisms also do not interfere with the performance of the other systems. The 555 circuit controlling the secondary release mechanism was tested under various cold weather scenarios with the main issue being the condition of the battery. A recommendation for future production is to acquire a battery capable of withstanding low temperatures without the aid of hand warmers. This substitution could save space and weight inside the fuselage. A further recommendation for future testing would be to perform more organized testing keeping most variables constant so that unsuccessful tests could be attributed the experimental variables. The potential launch locations were determined from FAA guidelines and using a balloon tracking software. Because of the length of time required to identify these locations it is recommended that these locations are determined as early as possible for future tests.

All systems have been purchased or manufactured. They were interconnected either using native wiring or via soldering the necessary connections. The servos, after being ensured to function at the low temperatures, were embedded into the external parts of the glider to control the ailerons, elevators, and rudder. The servo that controls the primary detachment remains inside the glider since it will not be constantly in motion and therefore is much more likely to fail at low temperatures. Weaknesses of the systems include the antennae; we were unable to determine optimal antenna orientation and range testing indicated some weaknesses. However, it is difficult to test range on the ground due to obstructions and interference whereas in-flight, we will have an essentially unobstructed line of sight with the glider. All other testing, however, was successful- including functionality tests inside the environmental chamber and system power time tests; we are confident that the glider will be able to conduct itself autonomously even in the case of lost telemetry.

The team's high level goals included monitoring the weight contributions of each subteam to ensure the glider was not too heavy for the balloon payload, monitoring the budget to ensure any design modifications would be reflected in the total part costs, and communicating with the FAA to pinpoint potential launch locations. Our final design meets both the weight budget and the monetary allotment for the components, with no compromises made for performance or reliability.

### **Test Flight Results**

On April 18th, 2014, we attempted a test flight of our glider at an altitude of 1,000 feet. For the most part, we were able to establish the successful function of our systems. The detachment was activated at the correct height and released the glider in a clean fashion. Throughout the brief flight, we maintained communication with the glider and received live data on its airspeed, location, etc. However, as the glider had been designed to drop from a much higher altitude, there was not enough time for it to level itself out and find an appropriate speed to glide at. Thus, it was approaching the ground at a concerning speed, and we felt the need to take manual control of it to try to pull up and land it ourselves. Unfortunately, it was still moving too quickly during the attempted landing and crashed. Damage was done to the body of plane and some of the systems, but we were able to mostly recover the aircraft.

### **Final Thoughts**

Although the test flight did not go as planned, we still have faith in our product as a legitimate solution to upper atmospheric exploration and data collection. We have proved its operation at low temperatures, the detachment is perfectly functional, and all communication was successful with the craft. Although we never were cleared by the FAA for a full flight, we will hopefully eventually be able to bypass this constraint and use our glider as it was meant.

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