Calvert Hall College High School UAV Team

Journal Paper

2013 AUVSI UAS Competition

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Team Members

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Figure 1: Skywalker 1900 (Before Painting)

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Abstract

This paper describes Calvert Hall College High School's entry in the UAS competition. In this, the team will use a modified Skywalker 1900mm with major changes in the wing, fuselage and undercarriage. This plane will be powered via two 5000mAh 3S 30C Lithium Polymer batteries. A 60A Turnigy Plush electronic speed control will power a 3536 size 1400kV brushless motor with a 9x6 APC propeller. The aircraft will use a 700TVL Sony CCD board camera with a stabilized pan/tilt system and a 3.6mm lens. A Lawmate 2.4GHz system is used to view live video from the Skywalker 1900. If deemed necessary, the aircraft can also use a single Samsung HMXU20 without a pan/tilt system. The aircraft will be autonomously controlled through its onboard ArduPilot Mega 2.5 (APM). The APM will provide telemetry gathered from its static and dynamic airspeed probes, GPS, barometer, gyros, accelerometers and temperature sensor to the ground through a 915MHz telemetry link. The Skywalker can be controlled manually through a 433MHz RangeLink long range system.

1 Introduction

1.1 Mission

The AUVSI Unmanned Aerial Systems (UAS) competition challenges undergraduate and high school teams to design, build and fly an autonomous vehicle through various waypoints while identifying targets of varying shapes, colors and sizes in real time. In this, the UAV must not only identify these targets, but remain inside a set no-fly zone without manual override. Further, the UAV should relay information from a 2.4 GHz Wi-Fi router to operators stationed on the ground. The vehicle must complete these tasks fully autonomously.

The team carefully reviewed these goals, and decided what could and couldn't be done. The team broke down the individual requirements, which allowed us to formulate solutions and answers for each goal, fine tuning the vehicle to complete them as efficiently as possible.

Learning from past experiences, the team decided to recycle what was known to work, instead of attempting to create a stable vehicle from scratch. This greatly reduced the risk of an unknown system failing and leaving us without a working vehicle. Because well-known electronics, hardware, and software were used it became possible to focus on smaller, though equally important details. In addition, when using familiar components, it is much simpler to fix problems than when using untested components.

The team devised a simple outline for this which presents the general guidelines followed when designing and building this drone.

- The onboard flight computer must be fully programmable and have built in error reporting. This is very important in such an advanced system, as it is entirely possible to have an integral fault that causes a crash, but goes unnoticed on the ground. If this system is completely open source, the team may be able to fix these errors, improve upon older code or simply adjust the code to the specifications that the team needs.

- The airframe will be durable and slow flying. The easiest way to achieve this is with a large, heavy, foam fuselage. An added benefit of such an airframe is the increased payload capacity, allowing the use of larger, higher capacity battery packs which lead to increased flight time.
- The vehicle will have a gimbaled camera mount, which allows for less in-flight course correction because the vehicle will not have to be pointing at the target to identify it.
- The air vehicle will have redundancies on all core systems so as to prevent a crash or navigation failure. This is critical in the case of one of the systems failing and causing loss of power, navigation or control resulting in mission failure.

1.2 Team Members and History

Calvert Hall's UAV team was formed in December of 2012 with the sole purpose of participating in the AUVSI UAS competition. As this is our first time entering in this competition, the team does not expect complete success this year, but hope it will serve as a learning experience for all of us. The team started working on the vehicle in March of 2013, and is still conducting numerous tests in order to achieve flight worthiness. The team is completely self-funded, and self-advised.

The team consists of five Calvert Hall students:

1. Stephen Hornish
2. Joshua Meek
3. Sean Nelan
4. Jack Robinson
5. Philip Swanson

2 Vehicle Overview

2.1 Vehicle Description and Engineering Approach

The air vehicle was designed to be big, stable, durable and able to carry a significant amount of weight without faltering. The vehicle is based off of a Skywalker 1900mm, but with significant changes in the wing and fuselage areas. These changes allow us to incorporate systems like the ArduPilot Mega autopilot system, multiple batteries, various electronics, and numerous redundancies such as backup power systems and GPS assisted attitude control.

One downside of this, however, is that these systems lead to a heavier plane. As stated before, the team anticipated this, and calculated that at maximum payload, the Skywalker 1900 will still be able to fly for over 30 minutes, and glide with a 10:1 glide slope should it need to. To further counter this problem, the wing has been redesigned to produce more lift at all speeds, although its airfoil is primarily meant for low speeds.

The airframe of the Skywalker is expanded polyolefin, or “EPO” foam. EPO is very rigid, but is able to accommodate minimal flexing in the event of a hard landing or crash. Running through most of this foam are carbon fiber tubes. These tubes provide more structural strength to key areas such as the boom, wings, and underbelly. EPO foam and carbon fiber are extremely light and only account for a small portion of the aircraft’s weight.

The Skywalker uses a Clark Y airfoil which has been slightly modified to produce more lift at slower speeds while maintaining stability at high speeds.

This plane is a pusher-prop, which means that the propeller is located behind the wing, and pushes the Skywalker 1900, instead of pulling from the front. With this, there will be no propeller interference in the video feed. Further, because this is a belly-landing plane, putting the propeller behind the wing, above the tail boom greatly reduces the risk of breaking a propeller.

This vehicle was designed specifically for FPV, or First Person View purposes in that it was made tail-heavy by default. Because of this, the Skywalker is able to tolerate a large frontal payload while maintaining a proper center of gravity.

To solve the issue of transporting this vehicle, the team has made the wing completely detachable. The entire 1900mm wing can be detached and reattached in a matter of seconds. The team found that the most efficient method to be through the use of rubber bands.

The Skywalker 1900 weighs 2500g under full payload, is 1180mm long and 1900mm wide (wingspan).

2.1 Propulsion

With the recent advancements in Lithium Polymer (LiPo) batteries, the team was able to utilize an electric propulsion system. This greatly reduces vibrations to sensitive components such as the magnetometer, accelerometers, GPS, camera and video transmitter that would be present if a gasoline propulsion system were used. Further, a gas engine has a tendency to spray an oil/fuel mix all over the wing, and requires a much heavier vehicle.

The motor that the team is using is a Turnigy Aerodrive SK3 3536 1400kv brushless out runner with a 9x6 APC propeller. The motor has a torque rating of 1400 revolutions per volt applied. This is substantially less than is typically used on a plane this size, however, this is intended. Because the team used a 9x6 APC propeller, the engine does not have to work as hard to spin the propeller as it would a typical propeller used on this plane, and thus achieves much better high-end efficiency without sacrificing battery life. Further, by using a faster-spinning propeller the team is able to greatly minimize vibrations that would otherwise result in skewed sensor data. This motor-propeller combination draws a maximum of 45 amps, which is handled by a 60 amp electronic speed controller (ESC). In using a 60 amp ESC, over a 45 or 50 amp ESC, the team is able to achieve a much greater power to mechanical energy conversion efficiency. This motor is able to produce 3.5kg of thrust at 540W. The vehicle can cruise at 6 amps, or 72 watts.

2.2 Power Systems

Our air vehicle utilizes two independent power systems. The first power system consists of two 11.1V 5000mAh LiPo batteries, capable of a continuous 150 amp discharge each. These batteries are connected in parallel to the vehicle's electronic speed control (ESC) and pass through the 3D Robotics Power Module, which supplies voltage and amperage draw information to the ArduPilot Mega (APM). They also feed two UBECs, which separately supply power to the APM and its extensions, and the Skywalker 1900's servos. The team concluded that should they try to use one UBEC to power the whole system, it would interfere with the magnetometer and cause skewed readings. On average, these batteries are able to provide a 30 minute flight time. If flown conservatively, these batteries can last up to 50 minutes in the air.

Secondly, the vehicle has an 11.1V 850mAh LiPo dedicated to the video systems. This battery only feeds the camera and video transmitter. By using a separate battery for this, the team was able to eliminate voltage fluctuations caused by motor power draw that result in video interference. This battery holds its charge in excess of one hour in the air.

There are three voltage converters onboard. The first is a 12V to 5.7V switching UBEC. This provides power to all of the servos onboard. The second is a 12V to 5V switching UBEC. This feeds the APM and its systems. The third is a 12V to 5.2V linear voltage regulator. While a linear voltage regulator is less efficient, it is necessary to use this for the video system, which cannot tolerate the high speed switching of a switching UBEC. Together, these provide us with a redundant, clean, and efficient power feed.

An RCTimer 90A power module monitors the voltage, amp draw and remaining mAh of the main flight battery, which could prove the most problematic in the event of a complete failure. This data is fed to the video feed and to ground station through the ArduPilot Mega's telemetry link.

2.3 Control Surfaces

This vehicle consists of four control surfaces, the rudder, elevator, ailerons, and flaps. All of these surfaces are powered by BEV-ES08MA 12g metal-geared servos that operate at 4.8V-6V (in this case 5.7V). These servos have 2kg.cm of torque, meaning that at one centimeter from their axis, the servo arm exerts 2kgs of force. Further, these servos move 60 degrees in one tenth of a second (0.1s). With this, the team achieved extremely responsive and powerful control surfaces.

Through experience, the team has learned that it is necessary to use these metal-geared servos on a plane of this size. Because this plane is capable of reaching speeds in excess of 60 miles per hour, it is very likely that a plastic servo's gears would completely strip should an emergency course correction be made. The team even looked into carbon-geared servos, but decided that tearing the control surface off of the Skywalker 1900 would be more likely than breaking metal-geared servos, and thus carbon gears were not necessary.

The team uses the rudder, ailerons and elevator throughout the entire flight, and use the flaps only for very slow flight (such as searching a small area), takeoff and landing.

2.4 Control Specifications

We are using a 13 channel RangeLink 433MHz UHF system for control. This is much more reliable than the common 2.4GHz system, which is prone to radio lockouts at distances over 1000 meters. This system is paired with a fully programmable Turnigy 9X. The team has flashed this transmitter with "ER9X" firmware, which allows us to set physical as well as logical switches, as well as the programming of up to 16 individual channels. This radio system has two power modes, 200mW "Low Power" mode, and 500mW "High Power" mode.

When under autonomous control, almost all ArduPilot Mega functions can be handled mid-flight through a 915MHz telemetry link. With this, the team will be able to direct the Skywalker 1900 to waypoints, as well as switch between flight modes on the fly.

3 Imaging System and Downlink

To accurately identify ground targets the team decided that they would need either multiple cameras on board, or the ability to "look around", or scan the area with a single camera system. There are many types of multiple camera systems, however only two methods seemed realistic for this competition. The first, and easiest way was to mount two stationary cameras, one high definition video recording device that the team would be able to review after the flight, and one standard definition video camera that would be continuously streaming down to the ground computers. While this proved very effective at identifying targets, it was unable to do so while in the air, and required us to review the film on the ground after the flight. This would take too long to remain within mission parameters. The second option was to make use of a "camera switcher", a device that allows the switching between video streams during flight. The team found that ultimately,

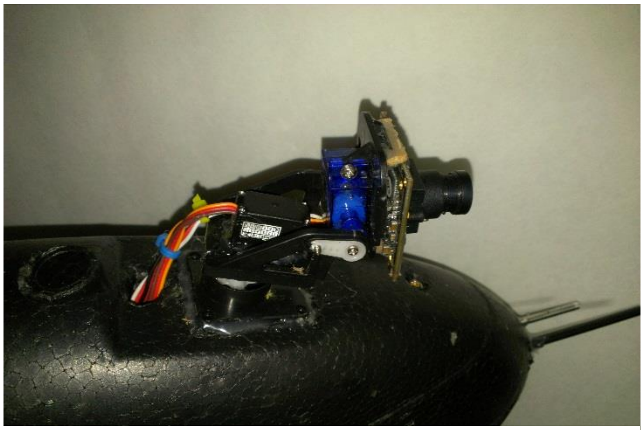

Figure 2: Pan-Tilt System

because the camera switcher only allows the user to switch between two feeds but only view one at a time, there was no advantage to having two cameras.

After extensive testing, the team decided to utilize a single camera imaging system. With this, the team is able to minimize the amount of different radio frequencies in use, and thus reduce risk of failure or interference. Had the team gone with multiple camera systems, they would have needed to have two or more video transmitters or a camera switcher. Either of these are not plausible; with multiple video transmitters it would be impossible to maintain minimum antenna separation while with a camera switcher we would still only be looking at one video feed at once, nullifying the use of the second camera.

However, because one camera cannot cover the area that multiple cameras would be able to cover on its own, the team has implemented a pan/tilt system that will allow us to direct the camera up/down and right/left. With this, the team will be able to maintain the viewing area of a double or triple camera system with one camera.

The team has decided though, to continue testing a single static high definition camera. In this configuration, the team would use a different search pattern to account for lack of the pan/tilt system. This pattern would be lower to the ground, and would have to search north to south and west to east, instead of solely north to south as this camera would not be able to turn sideways.

The advantage of using this camera configuration would be increased resolution. Because a PAL video downlink is only able to handle a maximum resolution of 540TV Lines, the 1080p camera footage would be lost. To handle this, analysis of the targets would be handled on the ground after the flight. The team will review the recorded video from the HD camera at the ground station. That is not to say that there will be no video downlink. The team will use a lower resolution downlink from the same camera to identify rough target location, GPS location, and the time the target was spotted. The team would then overlay this data with the HD video to obtain the exact properties of the target.

3.1 Camera

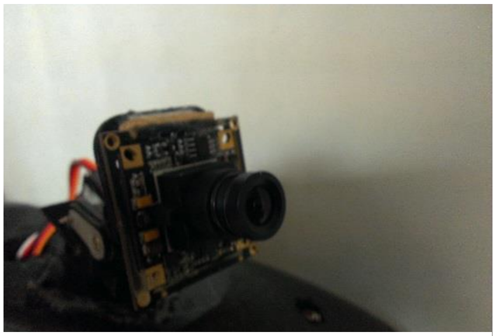

Figure 3: Sony Board Camera

After much testing, the team opted to use a Sony 1/3" CCD board camera. This camera has a resolution of 700 TV Lines, which amounts to 976x582 (Height x Width). Further, this camera is able to operate in night time conditions which, for our purposes, means it has the capability to accurately identify colors at all distances. Because this is a board camera, it weighs only 40 grams with a 3.6mm lens, and measures 38x38mm. Finally, the Sony board camera only uses 70mA (+/- 5mA).

The team has slightly modified the white balance settings of the camera to gain a better color representation of the surroundings. A 3.6mm lens produces 92 degree field of view, which means at 300 feet AGL, the area of view would be 471x628ft. Coupled with the 270x90 degree pan/tilt system, the Skywalker 1900 will have almost a 360 degree field of view.

The HD camera is a Samsung HMX-U20. This can record 1080p video at 30 frames per second, or 720p video at 60 frames per second. This camera has a 5.1mm lens, meaning at 300 feet AGL its field of view will be about 452x603ft. However, this is a static camera, so this will be its final FOV.

3.2 Pan-Tilt & Control

Our pan-tilt system is a simple design that implements two servos, one for pan, and one for tilt. With this, the team can use the ArduPilot to maintain a set orientation, or use a joystick on the ground to control the camera gimbal. The team is still in the testing phase, and have not decided whether to use manual or automatic control, but believe that it is possible to maximize simplicity through a manual camera search pattern. In this, the team will slowly pan the camera around the nose of the Skywalker 1900 until a target is spotted. The team will then take a picture of the target on the ground computer for further analysis, and continue with the manual search pattern.

Advantages to this are, aside from the ability to focus on a single target for an indefinite amount of time, the team can locate targets, and come back to them at a later point in the flight search pattern where they would have a better view. This would be enormously useful in the event that a target is spotted while the vehicle is directly above it, and is only able to obtain a momentary glimpse, but would be able to gain a better view on the next pass of the area.

4 Autonomous Systems

After much research into different autonomous systems, the team has selected the ArduPilot Mega. This board provides a completely open-source environment, and because of this, can be set up in many different configurations. This was very important to the team; most, if not all of the current autopilot systems on the market today are focused towards first person view (FPV) flight, instead of fully autonomous flight. With boards like the DJI Naza, Remzibi OSD, Eagle Tree and RangeVideo OSD you cannot program more than just a few waypoints, and cannot stream telemetry from the Skywalker 1900 to the ground. However, the ArduPilot Mega allows full customizability to support all of the functions the team needs to complete the mission.

One of these functions was the aforementioned use of telemetry. A telemetry link would allow us to maintain control of the Skywalker 1900 without using the radio controller, but through a laptop pc. Through this telemetry link the team can send and receive information about the drone’s current status, including interior temperature, air pressure, air and ground speed, altitude above ground and GPS location. With these, the team will be able to monitor the drone in real time, and make in-flight course corrections. This telemetry link will also allow us to view the course of the Skywalker 1900, and its position on a satellite map.

The autonomous system also needed to be able to handle an airspeed sensor, or a pitot tube. With this, the team will be able to accurately measure airspeed when in a dive, climb or during windy conditions. This is not possible through GPS. GPS, while giving an extremely precise ground speed reading, can only give a rough estimate of airspeed when the Skywalker 1900 is not level or during windy conditions.

The ArduPilot Mega is more than capable of tackling these tasks without requiring completely custom software, and breaking the budget. While there were other systems that may have been able to handle these requirements such as the 3D Robotics PX4 autopilot, these were much older and lacking in current support, thus the ArduPilot Mega was the final choice.

4.1 ArduPilot Mega

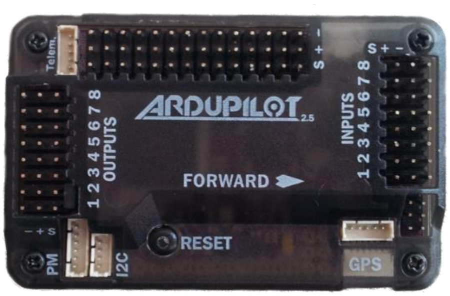

Figure 4: ArduPilot Mega

We have selected the ArduPilot Mega 2.5 (APM). This was released late last year, and features many improvements over the previous generation APM 1.0 and APM 2.0. This will be the main flight control board, and will guide the Skywalker 1900 through its various waypoints. This board is capable of allowing manual flight, autonomous flight and has the ability to switch between 6 different fully programmable flight modes.

The APM features Atmel's ATMEGA2560 processor, which is able to handle more calculations and data than its predecessor, the ATMEGA1280, which was equipped on the APM 1.0. The APM 2.5 also uses InvenSense's MPU-6000 six axis gyro and accelerometer with MEMS motion tracking for stability. This is a big improvement over the gyros and accelerometers of APM 1.0, which would eventually fall out of adjustment mid-flight, and put the Skywalker 1900 into a downward spiral. Another great improvement is Honeywell's HMC5883L-TR digital compass. This is much more accurate than previous generation APMs, thus the APM 2.5 is able to hold its heading with great precision over the course of long flights. Finally, the APM 2.5 incorporates an MS5611-01BA03 barometric pressure sensor. This is accurate to 10cm at any altitude.

The ArduPilot Mega will be receiving data from various sensors and transmitting this data to the ground station through a 3D Robotics 915MHz telemetry link. These sensors include: GPS, a pitot tube for airspeed and air pressure, a barometer, a 6-axis accelerometer & gyro, a temperature sensor and a 3-axis digital compass. Through these, it is able to measure a variety of parameters, the most exotic being wind speed, wind direction, temperature and drift across the x and y axis.

With the APM 2.5 comes the elimination of the "oil pan", or a separate board used for administrative processes, and a removable memory storage module. The APM 2.5 uses only one board and has 4MB of built in memory to store settings and parameters. A 500mA fuse is also included between the output and input rails of the APM 2.5, allowing the board to be protected should a power source fail or short circuit.

The team is powering the APM through two power supplies. The input rail of the APM is powered through a Turnigy 15A switching regulator. This regulator takes in 12v and feeds exactly 5.0v (>5.25v is dangerous to the MUX chip) to the APM and its satellites (GPS, 3DR Telemetry, airspeed sensor, receiver). The output rail is powered through a 7A switching regulator. This regulator takes in 12v and feeds 5.7v to the servos on the output rail of the APM. The team did this for two reasons, the first being that a single power supply solution is not as reliable as a dual power supply solution, and because the 3-axis compass can pick up interference from the electromagnetic field when using one power source. When using two, it is possible to separate the output rail from the input rail, and minimize interference. Both of these power supplies are completely separate, including separate grounds. They both use capacitors to minimize brown-outs (partial power loss 1-2ms) and voltage fluctuations in the lines providing power to the APM and the servos.

4.2 Ground Station

Our ground station consists of two computers. The first computer runs a Windows 7 environment and displays the telemetry data from the ArduPilot Mega with a 3DR Telemetry module. This module is “locked” to another air module which communicates to establish a telemetry link. This laptop will show the Skywalker 1900’s real-time position on a satellite image map. The team needed to use a Windows environment for this as neither OSX nor Linux natively supports Mission Planner, the program used to interact with the APM. The team did not want to install a program such as Crossover to OSX or Linux and risk a hiccup in the field. From this computer the team will be able to configure the APM, gimbal the camera, program waypoints and switch between flight modes.

The second computer is running a Macintosh OSX 10.7 environment, as the team found this to be the smoothest, most reliable and trouble free way to use the EasyCap Viewer device. This computer will be used for viewing and recording the aerial footage from the Skywalker 1900.

There will be three antennas on the ground station. These will be the radio control, telemetry, and video antennas. Each antenna will be suited for its purpose. The team is using an 8dbBi linear “patch” antenna for the video feed, but have started experimenting with a 2.4GHz ½-wavelength 8dBi Omni-directional antenna. With the patch antenna, the maximum video range is about 4 miles. With the Omni-directional, the range drops to about 1-2 miles, but when using the Omni, the Skywalker 1900 does not have to stay in front of the antenna as it would when using the patch antenna. However, experience shows that patch antennas on the receiver are still able to receive video from any direction in a 1000-foot radius.

The second antenna on the ground station is the telemetry antenna. This is a 915MHz ¼ wavelength linear dipole. Although greater range could be obtained through use of a directional patch antenna, this setup already has a range of over one mile, which is more than enough for our purposes.

The final antenna is a 433MHz ¼-wavelength dipole for the manual control link. This is not on the ground station, but mounted on the Turnigy 9x controller, which will be on the ground station with us. This controller will only be used for takeoff and landing, when the team will need manual control.

The team looked into circular polarization antennas as well for the video link. These would eliminate multipathing, which is known to happen around 5.8GHz. Although it may reduce the range of the 2.4GHz video link slightly, the change would only be a few percent, whereas with 5.8GHz it can be anywhere from a 20-90% reduction in video quality and range. Multipathing occurs when a signal bounces off a hard object (ground, tree or rock) and becomes “reversed”. These signals are picked up by linear polarized antennas very well, and can lead to a very choppy or degraded video stream. A circularly polarized antenna rejects multipathing because it only receives signals with the same type of polarization as its antenna (clockwise or counter-clockwise polarization). With circular polarization, when a clockwise wave meets the ground and becomes counter-clockwise, the receiver antenna will only pick up the clockwise signal, and not the multipath counter-clockwise signal.

In an effort to reduce glare in the field, the team has constructed “hoods” over the laptops which they hope will provide shade over the screen of the laptops.

5 Testing and Performance

5.1 Autopilot Testing

While the APM is a very simplified autopilot system, precautions still need to be taken. The team did not want to rush to guided waypoints on the first few flights, so started on the manual and stabilize modes for the maiden flight and the next few flights after that. Once proper flight characteristics were established, and the team confirmed a solid control link, they went into testing phase. In this, the team started with a basic box, then moved to more advanced waypoints. Throughout the tests the team quickly realized that it was necessary to adjust the gyro and accelerometer’s “gain” settings. These determine how rapidly and how powerfully the Skywalker 1900 adjusts to rolling, pitching, and conditions such as wind or turbulence. Once properly adjusted, the Skywalker 1900 was much more predictable and flew more smoothly. Aside from this, the Skywalker 1900 held altitude and position as expected.

When the team moved to GPS guided flight, they setup six flight modes, and looked for possible issues with each. If any errors were spotted, the Skywalker 1900 was brought back manually and adjusted so as to eliminate the errors. Below is a list of the six flight modes and an explanation of each.

- Manual: This passes the control inputs through the APM straight to the servos, giving the pilot direct control of the Skywalker 1900.
- Stabilize: This controls roll and pitch to keep the Skywalker 1900 going in a straight line. This mode does not utilize GPS.
- Fly by Wire (A): This mode, for example, will allow the user to roll to a 45 degree angle and let go of the control input. The ArduPilot Mega will then hold the Skywalker 1900 in this orientation, only leveling off if the user manually rolls the Skywalker 1900 the opposite direction.
- Loiter: This mode makes the Skywalker 1900 circle around a GPS location and hold altitude. When loiter is switched on, the Skywalker 1900 will set the GPS location to its current position and circle.
- Guided: This mode makes the Skywalker 1900 fly to the next pre-programmed GPS waypoint. Waypoints for guided mode can also be programmed while flying from the ground station.
- Return to Launch (RTL): This mode will make the Skywalker 1900 fly back to its launch position, or the position where the ArduPilot Mega was switched on and locked on to at least one GPS satellite. Upon arriving at launch, the Skywalker 1900 will circle overhead until a different flight mode is selected, or the Skywalker 1900 is taken over manually.

5.2 Airframe Testing

Again, the first tests of the Skywalker 1900 were done under manual control. Because we have flown a Skywalker 1900 in the past, we more or less knew what to expect. The first flight was done under turbulent conditions, and the next few under calm conditions. Through this, the team gained a better understanding of how the Skywalker 1900's performance differs between a calm and a windy day. These tests also helped us to properly calibrate the Skywalker 1900's hardware and control surfaces to maintain level flight without unwanted yaw, roll or pitch.

5.3 Ground Station and Communications Testing

Our ground station uses three antennas: telemetry, video and control. While these frequencies have been proven not to interfere with each other, devices such as laptops can produce radio noise. It is possible that this noise would be picked up by the ground antennas, and reduce the range. With this in mind, the team tested each system individually before testing them together in the hopes that if they noticed a diminished range after one system is turned on, it would be easy to deduce which system was causing that interference.

After the tests, the team has gathered that in optimal conditions the ranges are as follows:

- 433MHz Control (6dBi Omni): ~20 Miles (calculated from RSSI signal)
- 2.4GHz Video (8dBi Patch): ~4 Miles (at this point the video was greatly degraded)
- 915MHz Telemetry (6dBi Omni): ~1-3 Miles (different bit-rates give different ranges)

Further, at 1000 feet out the video signal is able to penetrate through two acres of forest or a house while providing enough clarity to maintain control.

5.4 Imaging System Testing

Aerial testing of both the pan/tilt system and static high definition system was done at 300ft AGL. During this time, the team worked to calibrate color accuracy as well as target distance. As stated before, both of these systems are still undergoing final testing. All of these tests were done under conditions that simulate the competition. This includes various speeds, search patters, and wind conditions.

The team found the biggest determining factor in the video quality to be vibrations from systems such as the motor and servos, as well as voltage fluctuations when throttle is applied. To counter this, the team placed the camera on the nose of the Skywalker 1900 to maximize the distance from the motor. The team also decided to use a separate 850mAh Lithium Polymer battery for the video systems to completely eliminate voltage fluctuations.

Figure 5: Skywalker 1900 on Approach for Landing

6 Radio Frequencies

The Skywalker 1900 uses three frequencies during operation. Through manual operation and with current antennas, the maximum range of this plane is about 3.5 miles, which is limited by the video link.

- 433MHz: RangeLink LRS System (Vehicle Control)

- 915MHz: 3D Robotics Telemetry Module
- 2.4GHz: Video Downlink

7 Safety Precautions

7.1 Power Systems and Airframe

To ensure safety in the event of a power system failure, the team has incorporated passive and active devices into the main and auxiliary power rails. A common cause of failure is voltage fluctuation which can lead to either a brown-out (temporary loss of power) or a voltage spike, which can destroy delicate circuits. The team has tackled both of these issues by placing capacitors along the main power rails of the system. These capacitors work to smooth out the power rails by "absorbing" voltage fluctuations. In the event of a temporary (1-2ms) loss of power, these capacitors will provide a buffer to keep all main systems operating smoothly.

Further, the Skywalker 1900 uses two independent power systems. The first system is dedicated to the camera, Minim-OSD, and video transmitter. This system incorporates an "LC" filter, or a capacitor with a Ferrite core on the main power lines. The LC Filter was designed by "Sanders" from "Team Black Sheep", Germany. The LC filter both minimizes noise and protects against brown-outs and voltage spikes.

The second system is dedicated to the main flight components. These include ESC, motor, servos, ArduPilot Mega (and its satellites) and the RangeLink control receiver. This circuit is split into three separate parts, all with a common ground. The first sub circuit feeds the ESC, which in turn supplies power to the motor. The second sub circuit provides power to the input rail of the ArduPilot Mega. This is a regulated 5.0V line. The third system provides power to the output rail of the APM, which then provides power to the servos. If one of these circuits should fail, another circuit takes over and will provide power until the Skywalker 1900 can land. All of these circuits are fused and have capacitors with Ferrite cores on all of the crucial rails.

7.2 ArduPilot Mega

As required, the ArduPilot Mega will terminate flight with full elevator, rudder and no throttle after three minutes, but will allow the safety pilot to do this manually as well from the controller. However, before it gets to that point the APM will implement its own safety measures. The APM uses "Geo Fencing". With this, if the Skywalker 1900 should fly outside of a pre-defined "no-fly zone," the APM will direct the Skywalker 1900 back to its home location, or a specified GPS waypoint. From there, it can be taken over manually and landed, or set to continue with its search pattern.