AUVSI SEAFARER Engineering Journal Paper
UAV Gilman : Gilman School - Apex

Abstract

The AUVSI SEAFARER Competition challenges undergraduate and high school students to design, build, and use an Unmanned Aerial System (UAS) for use in a simulated search-and-rescue mission. This system is required to fly autonomously through waypoints and ideally, takeoff and landing while providing actionable intelligence and delivering supplies. UAV Gilman has designed Apex to takeoff, land, and navigate waypoints autonomously using an 3DRobotics PIXHAWK autopilot system while streaming video with a Flytron FM10X camera with 10x optical zoom. Apex

streams video from the FM10X to the ground station using a 1.258 Ghz video transmitter. The system's other RF communication system is a 915 Mhz transceiver radio to both send down wireless telemetry and receive commands from the ground station. The ground station runs Mission Planner 2016, a program with many capabilities including real time status displays, real time command, and can update Apex's mission mid flight In case manual control is needed, the team will use a 433 Mhz Rangelink control radio with up to a 30 kilometer range. Through many tests, ground and flight, UAV Gilman has determined Apex is ready and capable of completing AUVSI SEAFARER's objectives safely.

1. Introduction

1.1 Overview

UAV Gilman is a team consisting of high school students from Gilman School, located in the Roland Park region of Baltimore, Maryland. Team members are listed below:

Team Captain : Casey Nelan
Imaging Systems Engineer / Safety Officer : Christopher Song
Computer Systems Engineer : Wolfgang Drake
Faculty Advisor : Dr. Alvaro Salcedo

General Team support has also been provided by Sean Nelan, former Calvert Hall Team Captain, now University of Delaware, Electrical Engineering, Dr . Caren Euster MD,MPH, ER / Flight Surgeon, and Dr. Edmund Nelan, MS., M.S,. PhD. Space Telescope Science Institute.

1.2 Competition Goals

UAV Gilman plans to attempt both primary objectives and seven secondary objectives. The first primary objective, Autonomous Flight Task (7.1), consists of four components: Takeoff (7.1.1), Flight (7.1.2), Waypoint Navigation (7.1.3), and Landing (7.1.4). Apex will complete the Takeoff task while in autopilot mode (7.1.1.3). Flight and Waypoint Navigation will be accomplished autonomously using open-source software. Landing will remain under autopilot control until the plane comes to a complete stop. We will achieve the second primary objective, Search Area Task (7.2), during flight using an onboard camera that streams analog video to the ground station. The secondary objectives we will be attempting to accomplish include ADLC task (7.3), Actionable Intelligence Task (7.4), Off Axis Target Task (7.5), Emergent Target Task (7.6), Simulated Remote Information Center (SRIC) task (7.7), Air-Drop Task (7.9), and the

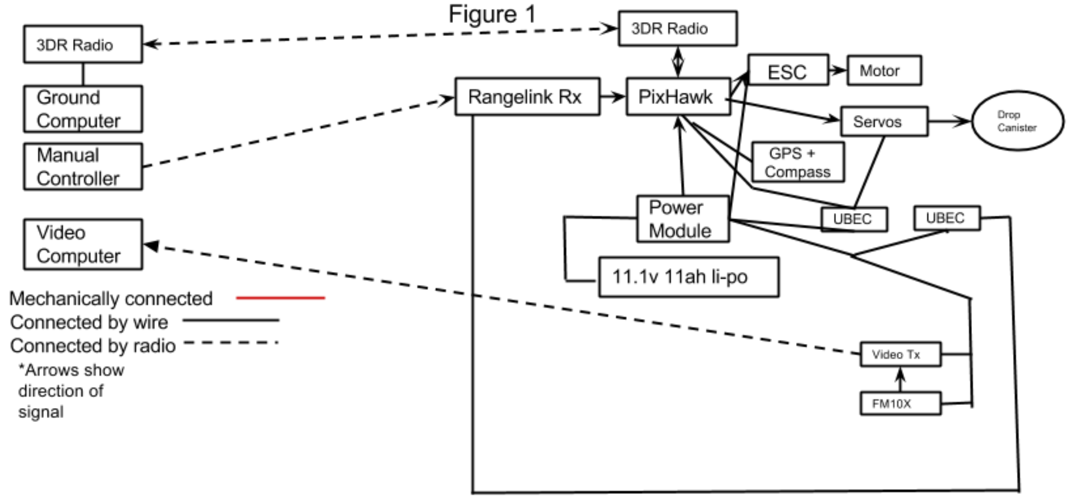
Interoperability Task (7.10). We will achieve Actionable Intelligence, Off Axis Target and the Emergent Target Tasks using the UAV's onboard camera and radio communication system. We will control a team-designed air-drop apparatus using open source software in order to accomplish the Air-Drop task. The mission will be safely completed within 30 minutes without entering restricted airspace.

1.3 System Overview

Apex's main control and navigation systems are controlled using two different methods: autonomously by its autopilot computer, which is controlled via open source ground control software Mission Planner; and manually by a rangelink control system which overrides the autopilot when necessary.The ground station, a Windows PC, connects to the autopilot using a 3DR 915 MHz USB radio transmitter. the Apex uses its various sensors to sense the aircraft's surrounding conditions and makes the necessary adjustments according to this data to maintain stability. The autopilot system uses a GPS and compass to sense the plane's speed, heading, and position, and averages data from a barometric pressure sensor and its GPS to measure its altitude. The plane uses eight accelerometers to level the plane and the altitude reading to control minimum speed and maximum and minimum pitch to efficiently maintain flight. The 3DR radio sends 102 raw values to the ground station at a baud rate of 57600 bites per second (bps.) Once the ground station receives the raw values, Mission Planner organizes this raw data into easily readable data. The ground station's 3DR radio can send any command the autopilot can control back up including redefining the mission midflight. For imaging, Apex uses a FM10X servo controlled optical zoom camera. The camera is controlled by a 2.u Ghz receiver functioning independently from the system's control radio. Apex's systems are powered by upgrade to Maxamps for greater energy density and back up by 2, 2.2 Ah (LiPo) batteries. The 3 batteries are connected in parallel, each capable of powering the entire system for redundancy. This circuit is displayed in figure 1.

Figure 1 - System Overview

Figure 1



1.4 Expected Performance

Apex will attempt to complete two primary and four secondary objectives. The Pixhawk will autonomously control the plane through takeoff, navigation through waypoints, and then landing. The system will use its FM10X downlinked through a 800mw 1258 MHz video transmitter to complete the Search Area Task. Secondary tasks that UAV Gilman plans to attempt include the ADLC, Actionable Intelligence, Off Axis Target, Emergent Target, and Air-Drop tasks. UAV Gilman will achieve Actionable Intelligence using both the live video stream and a video analysis program. After seeing targets in real-time using the video stream, the program will analyze them and pair them with the telemetry for their respective heading and GPS coordinates. Additionally, the on board camera's pan tilt system will be stabilized by the pilot controller in order to assist the team in receiving the most usable video stream. The airdrop task will be achieved with a drop pod commanded manually through the ground station. The aircraft will autonomously fly to the drop point, at which the team will inspect the area using the video link, and then manually drop the load.

1.5 Programmatic Risks and Mitigation Methods

We have identified and attempted to prevent various potential problems in order to account for any possible flight complications. Such risks include both physical (hardware) malfunctions and software errors. In order to prevent physical failures, we reinforced the airframe of the plane, providing it with strength and durability. We upgraded the two batteries from 2015 to one 11,000 Mah Maxamps with greater energy density inn order to get more power for weight also in order to mitigate battery depletion and failure. The older batteries are now for back up. We installed a UBEC

(Universal Battery Elimination Circuit) to distribute power to servos, the receiver, and APM, so battery failures will prove much less destructive, as a fourth battery can provide backup resources to land the Apex system. In order to address most autopilot software malfunctions, most notably, failure and radio range breach, we implemented manual controls, which can override the autopilot when necessary, with a range (30 km) further than that of the autopilot range. As a penultimate resort, we implemented a return-to-launch function, with which the Apex flies to its point of takeoff. Combining all of these disaster mitigation systems, we equip the plane with a formidable defense against almost any flight failure or problem. Lastly, if both the command link from the ground station and the manual control link fail, we programmed the plane to spiral to ground, making it land at the point at which contact was lost.

2. Description of UAV

2.1 Overview

UAV Gilman carefully selected and built Apex's various parts. We contructed a hybrid 2013/2016 Skywalker 1880 airframe for the Apex system because of its very large cargo capacity, regarding space and weight, its ability to be modified for various uses, its durability, and its outstanding reputation. It uses one 11,000 mah Maxamps lithium battery for main power and a one-thousand milliamp-hour lithium polymer battery for secondary power. A 3DR Pixhawk controls the plane in autopilot and has a passthrough function for manual control. The plane receives controller input using a Rangelink UHF system to ensure control at long distances. All servos are 13 gram metal gear servos and a 1400 KV brushless motor is used with a 9x6 pusher prop for thrust.

2.2 Power Systems

2.2.1 Capacity and Reserve

The mission requirements call for a medium length mission with possible obstacles such as wind or additional waypoints as needed. Because of this, the Apex system will need sufficient power reserves to ensure both mission completion with possible added requirements. To meet this need, UAV Gilman loaded Apex with one 11,000 mah Maxamp Lithium battery devoted to only powering its motor. This battery can also power the autopilot board. Under minimum power usage, this provides Apex with enough power to stay airborne for up to 1 hour and 30 minutes. More realistically, with heavy winds and turbulence, Apex will need to use more power to accomplish its mission.

Testing has shown Apex to be able to run up between thirty and forty minute missions with wind conditions between fifteen to twenty miles per hour. The same battery is used to power servos, the autopilot system, and the video link transmitter. This is an upgrade from the power system used in previous years.

2.2.2 Distribution

Apex's main power is transmitted through a 3DR power module which both measures the voltage and amperage flow. Through this module and preset battery values, the power module can provide data on percentage of remaining battery capacity. The 3DR power module then connects to a sixty amp electronic speed controler (ESC), commanded by the autopilot board to control the motor. The secondary power goes through a toggle switch for ease of access as the battery. When turned on, the power flows to the video system and two Universal Battery Elimination Circuits (UBECs). One UBEC then provides power to the receiver, camera receiver, and pan tilt servos. The other provides power to the Pixhawk and main flight servos. Meanwhile, the camera is powered by a direct connection to Apex's the Maxamps battery.

2.3 Autopilot and Control Systems

2.3.1 Overview

The Apex system is controlled by a 3DR Pixhawk board with capabilities including autonomous flight, autonomous takeoff and landing, return to launch, loiter (circle), and many other functions. These functions will allow Apex to complete the autonomous flight objective with the autonomous takeoff and landing threshold. The Pixhawk sends telemetry and receives commands using a 915Mhz 3DR radio. With its function to receive commands, the Apex system can make any modification to its mission mid flight. This would help in the case of additional waypoints being needed without landing. For manual control, Apex has a 433mhz Rangelink UHF system with a maximum range of thirty kilometers to ensure that manual control is always available in the event of an autopilot malfunction.

2.3.2 Pixhawk Board

The Pixhawk board made by 3D Robotics (3DR) commands the entire aircraft. It has two inputs, its 3DR radio transceiver and a Rangevideo Rangelink. The 3DR radio transceiver sends telemetry down to the ground station for analysis by the flight crew. It then can receive commands in the event of a mission change or a non planned action being required. The Pixhawk board uses a ST Micro L3GD20H 16 bit gyroscope paired with a ST Micro LSM303D 14 bit accelerometer / magnetometer and an Invensense MPU 6000 3-axis accelerometer/gyroscope to sense the aircraft's movement and adjust as needed.

Figure 2 - 3DRobotics Pixhawk Board (image credit: pixhawk.org)

2.3.3 Servos, Receiver, ESC, and Batteries

We discriminately chose Apex's with the goal of prolonging flight and ensuring reliability. The system uses Turnigy TGY-R5180MG full metal gear servos to ensure all control surfaces work reliably. What sets this servo apart from other servos is its full metal gear train and two kilograms of torque at one centimeter. This means the servo has enough power to force a control surface to move in the event of it getting stuck and the servo will not break from outside forces. The Apex system needs a reliable radio link for medium to long range missions. For this, UAV Gilman has chosen to use a Rangelink UHF system. The Rangelink UHF system consists of two parts, a transmitter on the ground and a receiver on the aircraft. The transmitter uses a 200mW 433Mhz frequency hopping spread spectrum signal to command the receiver in the air. The transmitter has two settings. For primary use, the transmitter has a 200mW setting. Under this setting and optimal conditions, the range of the system is 30 kilometers. The transmitter then has an emergency setting of 500mW to be used in case of a control loss so that the aircraft can safely be flown back into range. The receiver uses a SAW bandpass filter to decrease interference and thus increase range further. The Apex system's main power has two parts carefully chosen for weight and reliability. Two Zippy Compact 4000mAH batteries are used to power a 60 amp Turnigy Plush series ESC. The Zippy Compact batteries were chosen both for their very high power storage to weight ratio and their reliability shown in testing. The Turnigy Plush ESC was chosen for an outstanding record and reputation for reliability. The ESC then powers a 1400KV motor with a 9x6e prop chosen from testing showing it to be most efficient at a minimum throttle cruise.

2.4 Imaging Systems

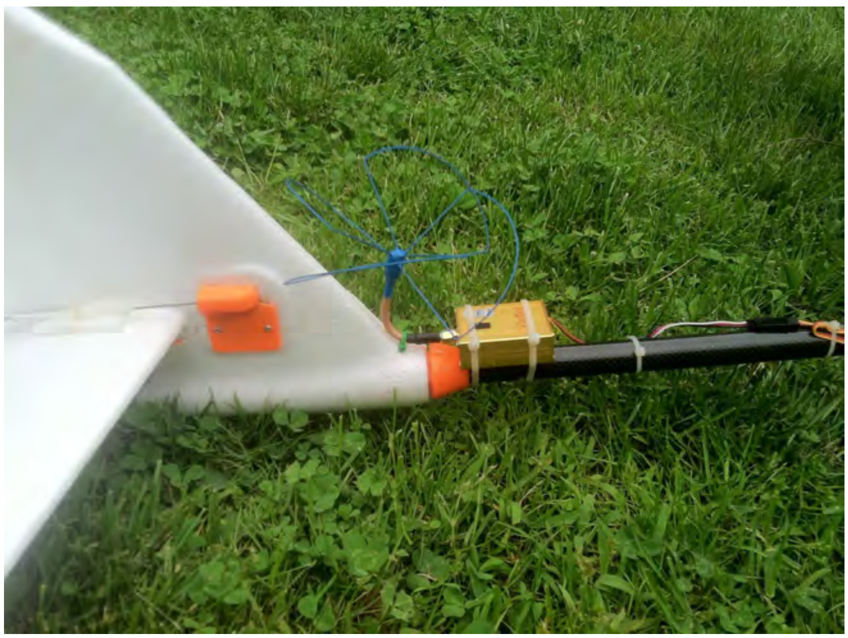
Apex uses a Flytron FM10X camera in order to accomplish all image-related tasks. The FM10X is an analog NTSC camera with a resolution of 700TVL and a servo-operated 10x magnification zoom lens. It transmits a real-time video feed through an 800mW video transmitter capable of operating in either the 1258 MHz or 1280 MHz frequencies. The ground station receives and archives onto the hard drive this video feed at a framerate of 14 fps and a resolution of 640x480 via an analog video receiver connected to an A/V frame grabber. We run this digitized video through a MATLAB image processing program, which splits the video into its red, green, and blue color channels. This program will facilitate target detection, which the team completes manually. The FM10X is mounted inside the plane with Servo controlled zoom.

2.5 Antennas

The Apex system uses three separate radio systems. They are: video at 1258 & 1280 Mhz selectable, a 3DR transceiver unit at 915 Mhz, and its control radio at 433Mhz. Because our video system’s frequency is close to the third harmonic of the control, we have used skew planar antennas to circularly polarize one signal while the other remains linear. This increases range and decreases interference. To increase telemetry range, Apex’s GCS will be using a 50º directional biquad antenna instead of the stock 2Dbi omnidirectional antenna.

Figure 3 - Antennas



2.6 Airframe

Holding all of our systems is a 2013/ 2016 Composite Revolution SkyWalker 1720/ 1880. The SkyWalker airframe is a large, pusher-prop cargo plane. The bare airframe is extremely tail heavy to allow for a large amount of cargo to be held in the aircraft's nose. The airframe is constructed out of high density Expanded PolyOlefin (EPO) foam and carbon fiber. A 1 inch thick carbon fiber tube makes up the middle section of the plane, connecting a thick EPO front pod-like section to the tail. The wings are structurally detachable but remain connected by antenna and servo wires. This allows for the wings to be partially detached and rotated to be lengthwise relative to the fuselage. This allows for easier transport. The wings are made primarily of EPO, but have multiple carbon fiber inserts to increase their rigidity. A front lid is attached by a hinge and connecting removable bolt allowing for easy access while hold a solid attachment.

2.7 Drop Pod

The Apex System uses a simple and light drop system consisting of a servo, a pin, a elastic band, and a wire tie loop. To secure the canister an elastic band holds the bottom of the canister to the plane. One end of the band has a small tube glued to it and the other is secured to the plane. A servo attached to the bottom of the plane holds a pin which runs through a wire tie loop. The servo can either hold it in place so that the pin can not move,or pull it out so that anything on the pin will be released. The pin is then put through the loop on the non connected end of the rubber band. With this, the aircraft can hold the canister in place until a command is
sent for the servo to pull the pin out for the canister to be released.

Figure 4 - Drop Pod

2.8 Ground Station

Compared to previous iterations of the Ground System, our setup will be standard and focused around the primary control computer. This laptop will run the Mission Planner software in addition to the image processing scripts prepared. We will be using a separate laptop for the Interoperability task, depending on the hardware available; any of our personal computers will be able to handle the ethernet connection and web tasks outlined in the IO task outline. The ground station has three main parts : a ground command station (GCS), a receiving video station, a data management laptop, and a router connecting all three. The GCS has a 3DR radio transceiver connected via USB to a Dell laptop to communicate with Apex in the air. The GCS is capable of both sending commands and receiving live telemetry. The GCS is also capable of redefining autopilot parameters or mission parameters mid flight. The receiving video station consists of a 1.3Ghz A/V receiver connected via RCA cable to a DC60 which plugs via USB into a 13” MacBook Air. The receiver is powered by an 11.1V Li-Po battery or any available 12V DC connection. The 3DR radio will be connected to a 50º biquad antenna for increased range. The antenna will be pointed automatically through an antenna tracking system or by hand in the case of an antenna tracker failure.

2.9 Mission Tasks Being Attempted

With these systems, Apex will attempt to complete the following tasks : Autonomous Flight Task (7.1), Search Area Task (7.2), Off Axis Target Task (7.5), SRIC Task (7.7), Air-Drop Task (7.9), and Interoperability Task (7.10). Apex will complete the autonomous flight task’s full threshold including Autonomous takeoff (7.1.1.3), Landing (7.1.4), and Waypoint Navigation (7.1.3). The Search area task will be done using cameras and manual recognition. The off axis target task will be completed using wide angle lenses and the ability to command the plane to circle, rotating the cameras to view outside of the search grid. The Airdrop task will be accomplished using speed information, altitude data, and geographic coordinates to calculate the proper drop time with the RPI. Additionally we will be attempting the SRIC connection task, and Interoperability task.

3. Test and Evaluation Results

Full mission testing has shown the Apex system to be reliable, effective, and safe in many different conditions. The basic airframe with autopilot was built in early January,

2016 and tested without any additional systems. It did not perform well due to the pitch pins. This was updated then once the SkyWalker airframe proved to be reliable, it was tested fully loaded. The SkyWalker airframe consistently showed it could take additional weight while maintaining satisfactory flight performance but used considerable power. To remedy this the Maxamps, a higher energy density, battery replaced the heavier two battery system used previously . A larger propeller and lighter wheels were installed as well These worked well, with the take off straighter and shorter than before.
This worked well however in the last test a wire failed and the plane crashed.The plane was repaired by moving the operating systems into an identical main airframe body with original wings.Skeleton operational systems were nstalled on a Skysurfer as an additional back up in case of additional testing issues.

After this repair, its imagery systems were reinstalled. Two test types were carried out, imaging and flight performance. Preliminary testing of the Imagery System was satisfactory, but not excellent. Because the camera could be tested while other systems were built, the camera was tuned through future test flights, resulting in excellent performance. Flight performance remained excellent. In the reconstruction one camera was placed in the nose straight forward, the other fuselage under the plane protected by polycarbonate: this allowed the removal of the wheels entirely with great savings on vehicle weight resulting in observably improved aerodynamics.The camera view can be rapidly alternated.

A custom-built drop pod was then installed on the aircraft. All of these systems were tested using a full autopilot mission simulating that of AUVSI SEAFARER's waypoints and search grid.

Test Log

Date	System Tested	Results	Fix
9/15/2015	Autopilot Pitch control settings update	Aircraft now is able to maintain altitude in autopilot mode	Continue to tune in autopilot Multiple tune trials
3/20/2106	Autopilot & General flight	Aircraft flies well in manual, although drawing a lot of power. Autopilot	Re-adjust autopilot accelerometers, change out propeller for more

		control surfaces reversed and retested	efficient flight.Retested.
4/15/2016	Camera control range	Good, camera control is solid	No fix needed
4/30/2016	Propellor efficiency test	Aircraft significantly more efficient (25A to 15A), but still needs further streamlining	Tune autopilot for more efficient flight (slower, but more balanced to require less control surface movement)
5/7/2016	Backup airframe tested	Fully auto flight (takeoff to land) Camera control issues	Camera's will be mounted in the body of the plane Retest switch: replace faulty switch
5/16/16	Flight test repaired Aircraft	Shut off after takeoff due to new 5th metal servo drawing too much power from control module through which power goes to the servos	Changed to plastic
5/17/17	Retest with 4 servos	Sudden plane land	Loose battery: velcroed in
5/17/17	Retest	Successful flight, 7 waypoints Steep wobble on turnx2	Further check flights planned Continue to refine turning parameters
Total Flight time	16 hours		

Team Gilman 2016

3.1 Guidance System Performance

The Apex System's Pixhawk has successfully flown the system through waypoints and search grids to simulate those at AUVSI SEAFARER. The Pixhawk board runs identical software and parameters as Apex's previous APM 2.5+ board. Initially in the software's testing, the autopilot would cause the aircraft to dive at roughly 20º despite mission parameters. After investigation, the problem was identified to be the previous board's APM's Total Energy Control System (TECS). The TECS uses pitch and throttle to control speed and keep it inside the predefined parameters, and is intended to prevent a stall. The team found the TECS minimum speed parameter to be set at 25 m/sec. Testing showed the SkyWalker's maximum speed to be 65mph, equal to 29 m/sec. Because the SkyWalker could only achieve this in windless straight forward flight, it was not able to meet its TECS minimum speed using only its motor, causing the APM to pitch down to increase speed. Once this problem was diagnosed, the team adjusted the minimum speed to 9 m/sec, or twenty mph, and tested the autopilot again. The system then maintained excellent altitude control. The next navigation problem encountered was the aircraft circling it's waypoints without hitting them. After research, the team found a solution to change a parameter NAVL1_PERIOD. This parameter controls the time which the aircraft takes to complete a 360º turn. The value had been set at 25 seconds, which the team adjusted to 15 seconds. With this new parameter, the aircraft was able to hit all of its waypoints on the first attempt.

Figure 5 - Example Test Mission

3.2 Payload Performance

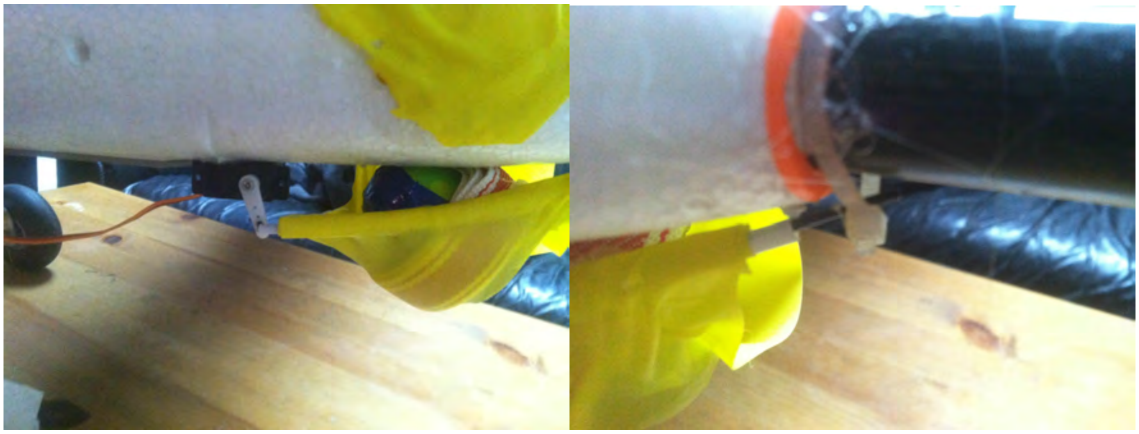
The Apex's system's airframe first and most important requirement was a large cargo capacity, which the SkyWalker 1880 airframe has excelled in. The airframe has been tested when loaded up to 7.8 pounds. At this weight, the aircraft performs just as it does with a weight of 3.5 pounds, the only difference being the angle at which it is able to climb; it can sustain a climb angle of 50-60º under a 3.5 pound payload and 30º under its maximum test of 7.8 pounds. With all of the modifications however the final flight weight is 4.1 pounds, which allows the plane to climb at a 45-70 degree angle. It was noted that at this juncture the plane was in fact, light. In windy conditions it may benefit from weight added back. To be tested in future iterations.

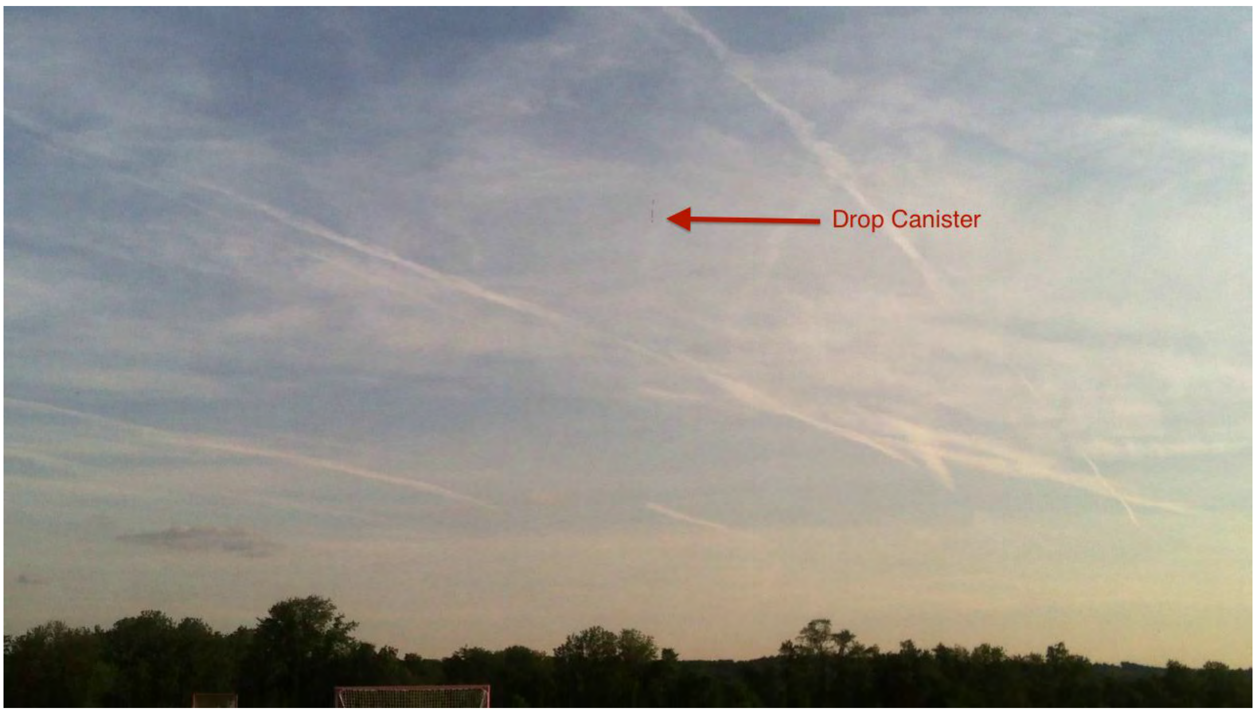
3.3 Drop Pod and Landing Gear

UAV Gilman has tested different landing gear designs two custom built drop pods. In order to allow landings on all types of surfaces, UAV Gilman experimented with Polycarbonate skis. These proved heavy and their connections to the aircraft were fragile, causing UAV Gilman to quickly abandon the design. The team then went with a more conventional design using wheels. The wheels worked well until one landing where the plywood bottom skid plate they were bolted to cracked in half on landing. A polycarbonate bottom skid plate was then installed and the landing gear bolted on. This proved to be extremely durable shown through hard landings with no damage. With this complete, the team designed a plywood drop pod box. This drop pod itself proved to be very durable but too large, on test landings the drop pod would strike the ground and be ripped off of the plane's belly. The drop pod box would also cause a aerodynamic force to push the nose of the plane down due to its large frontal plate. Due to these design flaws, the team redesigned the drop pod. The new drop pod uses a servo connected to a pin, which can then be put through a loop. When through the loop, the pin would stay in place, securing a wide elastic band in place. This elastic band holds the drop canister to the bottom of the airframe. When pulled back by the servo, the pin is retracted from the loop which releases the elastic band, which in turn releases the canister. While this solution is somewhat unorthodox, it is very effective and reliable.

With the elimination of the landing gear in the final hybrid reconstruction the Drop pod has been installed underneath the rear fuselage.

Figure 6 - Drop Pod Test





3.4 Mission Task Performance and Evaluation

UAV Gilman has tested the entire system to simulate AUVSI SEAFARER's mission. The Autopilot has shown its reliability and precision in calm to 17 mph wind with no problems. The FM10X camera tests have shown it to be extremely reliable and high quality. The Flytron FM10X has provided excellent images, showing it is ready for AUVSI SEAFARER's search grid. Apex's drop pod has shown to be safe and reliable through testing. A test plane has flown Apex's manual control and video radios up to 5.5 kilometers away with perfect results of zero interference or loss of signal. While there was a recent crash with damage to the original fuselage, the aircraft was rebuilt using the same body as it had proved itself so well over multple hard landings until the most recent, over the last three years. With all new unstressed body, more energy efficiant battery, decreased weight, fixed cameras to reduse moving parts, and positive test results, the Apex system is very likely to successfully accomplish its mission during the flight stage of AUVSI SEAFARER.

Figure 7 - Sample Images From Apex's FM10X Camera

4. Safety Considerations

With its many safety precautions established, UAV Gilman expects The Apex system to perform its mission safely. That being said, the team has created a problem - solution chart with the "go" or "no go" option. The team also designed Apex to be a safe system through the material used, location of the prop, and power source. While EPO foam allowed for a strong and lightweight airframe, it also is much safer in a crash than metal, wood, or composite plastic. This is because EPO is relatively soft and flexible, it can not cut things as wood, metal, or composite plastic can. The location of the prop makes Apex safer in the case of hitting something or someone head on. This is because the prop is located in the middle of the airframe, and thus in a crash, will not strike the person or thing which it collides with. This is opposed to a front prop aircraft which will cut or slice something or someone with its prop on impact. Next is the power source, which is electric. Aircraft powered by chemical fuel may explode or catch on fire in a severe crash, whereas electric powered aircraft will not. The crew adds the next level of safety. For operation, a minimum of two people need to be present. One to act as a safety pilot, and another to monitor the aircraft's telemetry and mission status. Optimally, four crew members should be present. One to act as a safety pilot, another to monitor telemetry, a third to monitor the aircraft's video link, and a fourth to combine data from the telemetry laptop with the video downlink in order to properly enter target position data.

Preflight Checklist	If not
Telemetry link established	no go
Servos and control surfaces respond	no go
Ground station shows Apex has correct flight data	no go
Video link established	go - but fix if possible
FM10x booted	no go
Samsung HMX-U20 booted	go - but fix if possible
Motor Control	no go
Wings Secured to Aircraft	no go
Drop Pod has canister	go - but fix if possible
All hatches secured shut	no go
Antennas Secure	no go

Flight Failure	Solution	Abort or Continue Mission if problem can't be solved

Loss of telemetry Signal	Try to reconnect - if link can not be reestablished, land using manual control radio	Mission Abort
Loss of Control Signal	Send “Return To Launch” command - if signal is not reestablished, switch to an emergency autopilot land command.	Abort Mission weather resolved or not.
Loss of video Signal	Check ground antennas and connections	Mission Continue
Aircraft is unable to maintain altitude	Check TECS, current speed, and wind. If found to be a high TECS setting, lower TECS and send an “increase altitude” command	If aircraft stays above 100 feet AGL - Mission Continue If aircraft dips below 100 feet AGL - Mission Abort
Servo Failure	Attempt to free servo using manual servo overrides in the ground control station	If servo controls a vital control surface - land if possible. - Mission Abort If servo controls a non vital surface or part - Mission Continue
Main Power Failure (motor)	Land and investigate, Re-launch if possible considering time and problem fix	Manual glide to landing - Mission Abort
APM board error or Secondary Power Failure	Reboot APM, land if possible using manual control	Mission Abort
Loss of Control and Telemetry Signal	Plane will automatically failsafe to circle a predefined coordinate which will be set over an empty field - attempt to reestablish a link	Mission Abort

Medical:
Additional Safety precautions for personnel:
First Aid Kit
Safety glasses
Sunscreen
Hats
Water for hydration
On Site Medical Support

5. Conclusion

The Apex system, designed by UAV Gilman for the AUVSI has been carefully designed, and rigorously tested at each step in order to safely and effectively complete AUVSI SEAFARER's mission tasks. UAV Gilman is confident it will succeed in doing this and will be very competitive against other teams' systems.

Acknowledgements

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