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Embry-Riddle Aeronautical University
Team UAS Tech

Faculty Advisor: Professor Alexander Mirot
Faculty Advisor: Dr. John Robbins

Team:
Jamie Glover, Robert Halley, Laura Serrio, Shane Aldridge
Kirsten Kasper, Mike Goodman, Nicole Bonk

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Abstract

Team UAS Tech presents "Titan IV", an Unmanned Aircraft System (UAS) comprised of various components including the airframe, autopilot, imagery system, data link, ground station and its operators. Titan IV is a lightweight airframe designed to meet the performance objectives outlined in the 2013 AVUSI SUAS Competition Guidelines, as well as additional team set objectives such as stability and endurance factors. As a first year team, Team UAS Tech used a systems engineering approach to develop a low cost solution capable of competing with high end productions from other teams. Based upon reviews of previous competitions and systems utilized in them, UAS Tech has designed a versatile platform for aerial surveillance and reconnaissance missions that have not yet been seen by AUVSI. With limited budget and time constraints, Titan IV was developed using mostly "off the shelf" items. An in depth review of our total system will be divided into multiple categories based on individual function and their relationship to partner components. This review shall also include analysis of flight tests and data collection, with stated objectives in mind.

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1. Introduction

1.1 Requirements Analysis

The Titan system has been designed to meet the requirements set by the Student Unmanned Aerial Systems Competition (SUAS). There are six Key Performance Parameters (KPPs) listed in the rules that stand as the main objectives to meet; Autonomy, Imagery, Target Location, Mission Time, Operational Availability, and In-flight Re-tasking. Each of the categories listed have minimum thresholds that need to be met in order to sufficiently meet the requirements set in the rules. There are also objective requirements for each KPP that are optional goals, that if possible without putting the main threshold requirements in jeopardy will be attempted. For example, determining all five target characteristics have been unreliable with current imagery settings for team UAS Tech, and unless changes can be made with the current camera settings without diminishing the ability to complete the threshold requirements on the KPPs the team will only acquire the required target characteristics. The competition tasks that are not explicitly listed in the KPP, such as autonomous target cueing, actionable intelligence, and communication with the Simulated Remote Intelligence Center (SRIC), were added as additional goals.

Team UAS Tech's goal for the 2013 AUVSI SUAS Competition is to display the ability to safely execute the prescribed mission utilizing a cost effective solution compared to what may be found in today's market. Our goal is to inspire those individuals with interest in the Unmanned Aerial community that may feel the burden of the associated costs in the development of an Unmanned Aerial System (UAS). Utilizing open source hardware and software, Team UAS Tech will display just how well a budget friendly UAS can adapt and compete against major competitors that may be present for a fraction of the cost.

1.2 Team UAS Tech

Team UAS Tech is a student activities group of individuals whose origination stemmed from the development of the Unmanned Aerial Systems Bachelor of Science Major at Embry Riddle Aeronautical University in Daytona Beach, FL. We are a multidisciplinary unit that consists of Systems Engineering, Homeland Security, Aeronautical Science, Mechanical Engineering and Unmanned Aircraft Systems majors. Our team is led by the Club President, Robert Halley and Vice President Laura Serrio. Our auto pilot operator and payload operators are Shane Aldridge, Mike Goodman and Nicole Bonk and our safety pilot is Jamie Glover. Team UAS Tech, currently in its first year of existence, has evolved to become a model academic association within Embry Riddle Aeronautical University. However, because we are a newly established club, we faced many disadvantages. For example, our limited budget was set at $500 for the project development. Our resources have not yet been fully established and our sustainability relied heavily on club member and local business donations. It is because of these acts of generosity that Team UAS Tech declares that this projects disadvantages became advantageous, in that the support we have received shows great credit upon the UAS community as well as the determination demonstrated by our team to rise to a challenge when the situational elements were against us. This gives way to our goal of inspiring individuals with interest in UAS. We have taken great pride in our system and its development and spent countless hours conducting research in acquiring a mission capable system.

1.3 Systems Preview

UAS Tech's System, Titan IV, is comprised of three subsystems that are all interlinked to make up a completely operational unmanned aerial system. These three subsystems are the flight system, payload system and ground control station. Our flight system includes the Skywalker 1900 airframe accompanied by an open source auto pilot, ArduPilot. ArduPilot is responsible for navigation as well as geo rectification of our imagery. ArduPilot communicates to the ground station via a 900 MHz telemetry module on board. It also displays the on screen display (OSD) to our video link providing location vicinity to a target. The imagery is captured via two sources, one being a compact camera and the other, a color CMOS board camera. Other communications between the ground station and aircraft include a 1280 MHz for video and 2.4 GHz for image retrieval. All components have been installed with the ability to be quickly removed for ease of access, trouble shooting and transferability between airframes.

The ground control station (GCS) is made up of two designated laptops; one for auto pilot communication, and one for payload data. A separate 19 inch monitor is used to view a live video feed in which the payload operator determines the presence of a target. Each laptop includes a designated software suite for its particular application. An antenna tracking station has been equipped with directional antennas for each frequency being utilized for communications, so as to increase the standard performance levels of our receivers. Video link is record to a hard drive via a video capture card for post mission retrieval. The ground control station is extremely portable and does not require any fixed external power sources in order to function. Each component houses its own battery source, which last in excess of one hour during full operations.

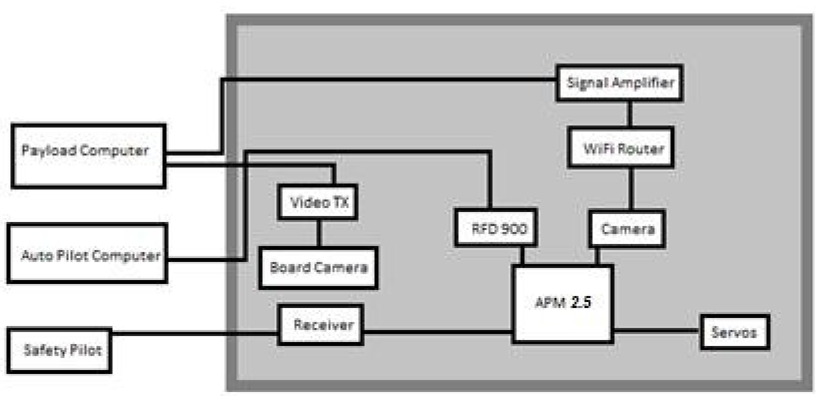


Figure 1: System Diagram

1.4 Procedural Execution

After receiving the mission, the team will develop the best plan of action in which to approach the requirements. Once a plan has been put in place, setup of the GCS will begin. Simultaneously, the airframe and payload will be assembled and cross checked. Each subsystem contains its own checklist which will be verified by its operator. The team lead will verify that all operators have performed their safety and functions checks prior to mission start. The safety pilot will have the final say in the determination of the airframes airworthiness. Once setup is complete, the mission will be uploaded to the autopilot. Once the waypoints have been written, the safety pilot will arm the motor and place the RC controller into Auto mode. Titan IV will then go into autonomous launch mode where it will climb to a designated altitude before beginning the waypoint mission. Upon reaching this altitude, Titan IV will begin following a series of waypoints in search of targets, providing a wireless video link to the GCS where the operator actuates the still imagery in the event that a target is identified. Upon completion of the mission and all targets have been located, the auto pilot will transition into autonomous landing mode. During this time, any imagery obtained during flight will be retrieved from the onboard camera to be geo referenced in Google Earth for verification of the targets locations. After landing, the motor will be disarmed and a post flight check will be performed by the safety pilot. Meanwhile, the payload operators will verify all data entries and save them to a data stick that will be handed over to an evaluator. At this time, the mission will be presumed complete.

2. Flight Overview

2.1 Airframe

Titan IV is a standard Skywalker 1900 high wing airframe constructed of EPO Foam that utilizes a pusher prop design. Its wing spans 6.2 feet and is a total length is 45 inches long**.** Titan IV consist of an electric propulsion system made up of an E-Flite Park 480, a 45 amp speed controller, and one 3300 MAh 3S battery pack. With this setup, Titan is able to maintain a 45+ minute flight time while in standard weather conditions. Titan IV weighs in at approximately 4.8 lbs. and has a gross takeoff weight of approximately 6 lbs. in its current configuration. Titan IV has a cruise velocity of 10 m/s and a stall speed of 2 m/s.

2.1.1 Design Phase

Initially, Team UAS Tech looked at several off the shelf designs for our airframe including a Skywalker 1900, NexStar, Global Hawk and a Telemaster. Our goals for the airframe included portability, flight endurance, stability, maneuverability, payload carrying capacity and the ability to be easily maintained or repaired with little cost. After testing and evaluation of these airframes, Figure 2 displays results that were key to our decision in which airframe to use:

Pugh Selection Matrix Airframe					
		Airframes			
		Global Hawk	NexStar	Skywalker 1900	Senior Telemaster
Criteria	Weight	1	2	3	4
Portability	6	4	5	4	1
Endurance	3	3	3	5	3
Stability	7	5	3	5	3
Maneuverability	4	3	4	5	4
Payload Capacity	5	1	4	3	5
Easily Maintained	1	3	2	4	2
Crash Absorbant	2	3	2	3	1
Score		94	102	119	81

Figure 2: Pugh-Matrix UAS Airframe

2.1.2 Competitive Comparison

As seen in the results in Table 1, we found that the Skywalker 1900 was best suited for our needs. In studying what other teams have utilized in previous competitions, The Skywalker 1900 met or exceeded overall standards in comparison to its competitors. The Skywalker is far more cost effective, provides plenty of payload space and its flight longevity was almost triple that of others. While the UAS market stream lines on composite airframes, the civilian market may look toward airframe designs that are far less expensive. Keeping this in mind, it was the goal of Team UAS Tech to make this possible, yet maintain a competitive edge. A specific characteristic that has proven itself on more than one occasion when it comes to UAV's with the Skywalker is its ability to be repaired in minutes in the event of a catastrophic collision. The same type of collision that a current composite frame would leave the operator picking up pieces and require a month and costly replacement parts to put it back together; whereas the Skywalker 1900 simply requires a hot glue gun and 15 minutes to be airborne; once again saving time and money.

The Skywalker 1900 can be classified in the same category as those such as the Raven and other Mini UAV's (MUAV). Team UAS Tech is currently researching possibilities to increase the Skywalker's longevity to meet that of current gas powered composites that would provide 8+ hours of flight endurance on a single battery. With these types of overall characteristics, the Skywalker creates less of a foot print, providing the same capabilities as its more expensive counterparts.

2.1.3 Design

To date, it is believed that no team has entered the AUVSI SUAS Competition using a Skywalker 1900 Airframe as their platform. Through review of previous competitions journal papers, it is apparent that a lot of new teams have utilized airframes that have previously proven themselves during the flight phase and thus have had some idea of how to setup their systems. Team UAS Tech has taken on the challenge of introducing a new design that has not yet been seen. Our goal was to maximize the Skywalker's capabilities through ground and flight tests within our means. Again, being a new organization, our resources were limited.

As mentioned earlier, the Skywalker's strengths made it a great candidate for our platform. With its characteristics inherently built in such as its high lift to weight ratio and stability, our mission was to incorporate a payload without hindrance to these qualities. This required determining the best placement of the Center of Gravity (C.G.) to achieve the best performance possible. Through initial flight tests without payload, it was determined that the best placement for the C.G. was between 4.1 and 4.5 inches aft of the leading edge of the air foil. Taking this into consideration, placement of the payload was calculated (Weight x Arm = Moment) in order to keep the C.G. within this specified limit. Through team members' prior experience, it was known that the Take Off Weight (TOW) should be kept below 6 lbs. for best performance. Keeping this in mind, all components of the payload were selected based on their size and capability, to reduce the overall weight of the payload and maximize on the Skywalker's interior payload space.

During the design phase, landing gear was an option that was deemed to be non-essential, as it would produce more weight and increase parasitic drag on the airframe. With this decision being made, we had to comprise a solution for mounting the imagery sources. Our solution was a simple cutout in the belly of the plane that allows the camera lens to extend into the void, but not exceed past the outermost portion of the fuselage. This provides protection during flight and landings as well as anti-vibration to the imagery system to prevent blurred photographs. With all components that were to be installed, space was limited and a gimbal was not an option due to its size. A ½" thick sheet of rubber foam was installed along the interior belly and side walls to eliminate vibrations from reaching the camera. The camera is secured into the fuselage utilizing industrial velcro straps.

The selected propulsion system was chosen based on its efficiency and ability. Titan IV utilizes an Eflite Park 480 1100kv brushless motor in conjunction with a 45 amp ElectriFly Speed controller and an EZ Flite Pro 3300 Mah battery pack. As shown in figure 3 below, we see that the average current draw at full payload capacity is 13 amps at 50% throttle. At full throttle, Titan IV only draws 19 amps. Figure 3 depicts current draw on a day in which the winds were in excess of 15mph, indicating a worst-case scenario. In calculating the approximate flight times based on the given data, we can derive flight times of approximately 16 minutes. However, this value has been proven multiple times to be false in that we are seeing triple those times on a single battery pack utilizing only 75-80% of the battery capacity with drawing only 5 amps continuous, requiring approximately 20% throttle. This is explained by the glide ratio, requiring less motor input for the airframe to stay aloft after it has reached its designated altitude and a wind velocity of 3-5 mph.

Figure 3: Battery Current/Throttle Analysis

2.2 Auto Pilot

A key requirement in competing in the AUVSI SUAS competition is the ability of the UAS to autonomously navigate itself through the course. In an era of UAV's birthing worldwide, there were multiple options for selecting an auto pilot that was capable of handling this task. In searching of an auto pilot, Team UAS Tech wanted the most autonomy for the price as well as a user friendly interface that would allow for a fast learning curve. Auto pilots such as the Piccolo Nano, Paparazzi and ArduPilot Mega (APM) were early contenders during our selection process. Piccolo Nano had the functionality that we required, however its cost was not within our means and thus eliminated early on. Paparazzi is well suited and utilized by many teams across the nation, however, through aggressive competition with APM, our final decision rested on ArduPilot Mega. Our deciding factors were the customer service base, locality and its robust plethora of functions compared to Paparazzi. For example, APM has imagery geo-rectification abilities as well as antenna tracking built in without adding major accessories. Its user base is extremely large, very capable and continuously upgraded. APM provides the ability for our safety pilot, auto pilot and payload operator to simultaneously provide inputs utilizing three separate controls, correlating to their respective system. This functionality decreases the integration of multiple control systems, saving space and weight within the airframe.

APM shown in figure 4, is an open source auto pilot whose sensor suite includes a 3-axis gyro, accelerometer, Mediatek MT3329 GPS, magnetometer, MS5611-01BA03 high resolution barometer, Atmel's ATMEGA2560 and ATMEGA32U chips for processing and a 4 MP data flash chip for automatic data logging (Figure 3). These sensors, coupled with a 1 watt RFD 900 MHz transmitter/receiver, provide the means to collect and view telemetry data on the ground control station software, Mission Planner shown in Figure 4; as well as control the systems attitude in flight. APM is also housed in a plastic case, preventing false readings of barometric pressure changes due to airflow within the fuselage.

APM features a rich environment for which to control the UAV in flight. Its precise corrections allow for tight navigation, which is needed to operate within the confines of restricted airspace. Safety features incorporated into the APM include fail-safes for loss of RC signal, loss of data link, loss of video and breach of a geo fence. These safety features allow the APM to determine a designated course of action to follow in each of these events. Loss of link includes a short, 1 second loss of signal, as well as a long, 30 second loss of signal. Each event has a dedicated action to take based upon the rules of the competition.

Figure 4: APM

2.3 Ground Control Station Suite

As mentioned earlier, our ground control station program is Mission Planner shown in Figure 5, which is open source software created by Michael Osborne. Mission Planner runs on a dedicated laptop connected to a RFD 900 MHz telemetry module allowing it to communicate with the UAV. The interface is widely known as one of the simplest, yet most sophisticated programs on the market. Mission Planner utilizes features such as point and click waypoint entries, selection of mission commands from drop down menus, downloading and analysis of mission log files, configuration of APM settings, simulations, and viewing of live telemetry data. A hidden window allows the user to access options such as Geo-rectification of imagery, video overlays into the heads up display and other various programing tools.

Mission Planner stores telemetry files on the computer for later access and review of in-flight data. With the ability to play back missions, users can study behavioral attitudes of the UAV in previous flights for many purposes. In addition, its ability to conduct in-flight changes to missions is a key feature needed for the competition. The overall interoperability between users is rated top among the team and is well liked by each of our members.

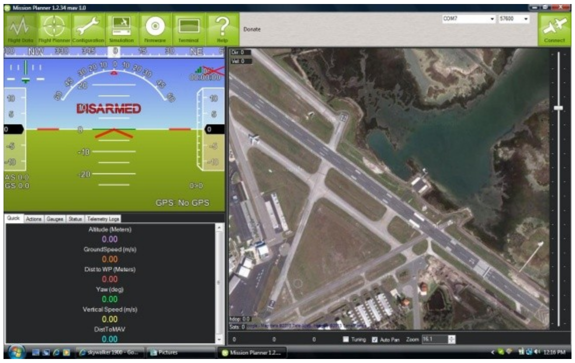


Figure 5: Mission Planner

3. Payload Systems Overview

3.1 Cameras

An integral portion of this competition relies heavily on imagery. With this in mind, our selection process was limited there again due to budgetary constraints. The camera had to be small enough to fit within the fuselage, yet provide the necessary resolution to distinguish a target and its characteristics from an altitude greater than 100 ft. AGL. The camera also had to be capable of relaying its images to the GCS via a wireless link. As shown in figure 6, we assessed the GoPro Hero II, contour and the NIKON COOLPIX S800C. Initially, our design process incorporated a GoPro camera linked to a Minim OSD providing location data that would be fed back to the GCS for viewing. It would then be analyzed and an approximation would be made to manually determine the location of the target based on a freeze frame and the planes attitude during the time of the frame capture. This possibly could have worked, however it was very time consuming and inaccurate. After a review of previous setups at AUVSI's earlier competitions, it was eliminated as an option. Knowing that we did not possess the ability to pursue such a high tech imaging system, or coding a program to calculate blob detection and location, we set out to find an alternative. This led us to the Nikon Coolpix S800c; a compact camera that provides high resolution images coupled with an Android operating system, WiFi and GPS data. This allowed access to the cameras images onboard the plane via a wireless link to the GCS. Originally, this design concept was feasible, however after several flight tests, it was proven to be unreliable in capturing images of interest, as it was based on the camera being triggered by the auto pilot at designated waypoints. This led the team to incorporate a manual override of the camera shutter and install a live video feed from a CMOS board camera oriented in the same view of the compact camera. This was a huge success in that it reduced the number of images taken by the camera from approximately 500-600 images down to approximately 20 images that are guaranteed to contain targets.

Pugh Selection Matrix Payload

		Platforms		
		GoPro Hero II	Contour	NIKON COOLPIX S800C
Criteria	Weight	1	2	3
Cost	3	3	3	3
Weight	4	3	3	3
Still Image Capable	6	4	4	5
Zoom range	1	0	0	5
Resolution	7	3	3	5
GPS	2	0	5	5
WiFi	5	5	5	5
Score		91	101	126

Figure 6: Pugh-Matrix UAS Payload

3.1.1 Nikon Coolpix S800c

Providing still imagery, the Nikon Coolpix S800c (Figure 7), as mentioned above, is a compact camera that is one of two on the market that are operating on an Android 2.3 Operating System (Gingerbread). Full functionality with Android applications; give it a unique advantage compared to most compact and DSLR cameras. The Nikon incorporates a 1/2.3” Back Side Illuminated (BSI) CMOS sensor, a 25-250mm equivalent 3.2-5.8 Focal lens, 2GB of internal memory, WiFi and GPS and is capable of shooting up to 8 frames per second (fps). The footprint is 4.37 x 2.36 x 1.06" and weighs in at 184g. When compared to other cameras with these types of functions and capabilities, the Coolpix S800c is one of the smallest and versatile in its class.

Figure 7: Nikon Coolpix S800c

3.1.2 CMOS Board Camera

Needing a live video feed to improve our design, a small generic camera was incorporated into the payload. The camera is a 420 TVL Color CMOS (complementary metal-oxide semiconductor) board camera with a 3.6mm lens and an audio function shown in Figure 8. The camera operates on the NTSC standards and provides 510x492 pixels of resolution. This CMOS board camera provides automatic backlight compensation and white balance. In addition, it only requires a 0.5 Lux for viewing. The compact size (38x38mm@10g) allows it to be incorporated into our design with ease. Adding this feature, allows the payload operator to see the view of the still image camera and manually trigger the shutter when he/she sees a target in the frame. Coupled with a Minim OSD, location data can be obtained for a general location of the target. This will be further rectified in post processing by the secondary payload operator to pinpoint the actual location of the target.

Figure 8: CMOS Camera/Minim OSD

3.2 Communications

In order to be successful in mission operations, Team UAS Tech needs to communicate with the UAV whilst in flight. Titan IV incorporates four lines of communication for command and control and payload data. These lines of communication include, the RC Control link in which the safety pilot has the overall authority, the autopilot link providing the AP Operator the ability to command the UAV and receive telemetry data, a video link in which the Payload Operator identifies targets, and the payload data link, which is necessary for retrieving images during flight and communicating with the SRIC.

3.2.1 RC Control

Primary authority of the UAV while in flight lies upon the Safety Pilot. His duty to act in the event of a systems malfunction or in the event an unsafe maneuver is performed by the auto pilot. This command authority is achieved via a Spektrum 2.4Ghz DX8 RC Transmitter (Figure 9). Operating on DSM2 wideband technology, this Rx/Tx combination is less prone to interference from outside sources. This is key in that the utilization of an on board router is necessary and could pose a significant threat to the communications between the safety pilot and UAV. The Spektrum DX8 offers a suite of safety options to keep the safety pilot updated on the status of the UAV while in flight. Parameters such as the UAV's battery voltage, signal quality (RSSI), temperature and RPM are displayed on the transmitter, allowing the safety pilot to assess the situation at any given time.

Figure 9: Spektrum DX8 2.4 GHz

3.2.2 Telemetry/Auto Pilot

In order to communicate with the UAV, a link was needed between the auto pilot and GCS. Several options were available, such as the Xbee and 3DRadio, however through research of given reviews, these modules were un-reliable past 300 meters. We needed to have the ability to communicate with the UAV without fear of losing signal out to approximately 1 km. An alternative to the standard modules was the RF Design 900 MHz 1 watt telemetry module. Providing the ability to reach up to 40 km in range without the need for an FCC License, the RFD 900 was our best option which is shown in Figure 10. The RFD frequency band spans from 902 MHz to 928 MHz. Air data transfer rates are user selectable and default to 64 kbit/s providing timely updates to the GCS and reducing lag time between the UAV's actual performance and what is displayed to the AP Operator. This is extremely important due to the fact that data transferred from the UAV to the GCS is used to orient an antenna tracking station which provides the signal link for all lines of communications.

Figure 10: RFD 900 MHz Telemetry Module

3.2.3 Video Link

The Payload Operator utilizes a live video feed that is displayed on the GCS. The main purpose serves to reduce an abundance of images for later processing. Shown in Figure 11, this video link is streamed through a 1.3 GHz 1.5 watt transmitter operated on Ch. 9 (1280 MHz). Accompanied by a cloverleaf style antenna constructed by Marco Cruise greatly reduces the possibility of signal drop due to changes in polarization.

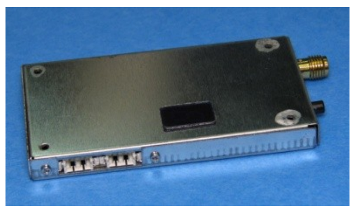


Figure 11: 1.3 GHz Transmitter

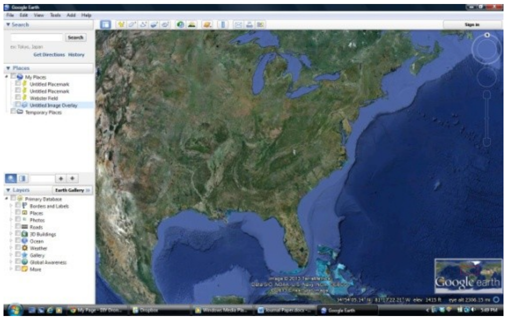
3.2.4 Payload Data Link

Having the ability to retrieve images from the on-board camera while in flight is a necessity in meeting the time allotted for the mission. To achieve this, we have integrated an on-board ASUS 2.4 GHz WL-330N wireless router. Having a footprint smaller than that of a credit card (90 x 38.9 x 12.8 mm), this router could be placed into our existing setup without interfering with the already established C.G. The router is linked to the Coolpix S800c camera through WiFi and is also networked to a separate router located within the GCS. An app installed on the camera, WiFi File Transfer, allows the payload operator to access the images that are stored in the cameras memory as thumbnails through an IP address. When the payload operator sees an image of interest, he/she can then download the actual full resolution image to place into an overlay on Google Earth. A modification was made to support the range needed to communicate with the router by adding a 1 watt signal amplifier and a cloverleaf antenna to avoid loss of signal due to distance and orientation of the UAV from the GCS.

Figure 12: On-board Router, Amp and antenna

3.3 Image Processing

In order to determine the location of a target within a given picture, the image needs to be geo-rectified, sized and orientated to the correct dimensions and heading. Team UAS Tech has developed a process in which the images can be processed, utilizing all open source software; these programs are Mission Planner and Google Earth (Figure 13).



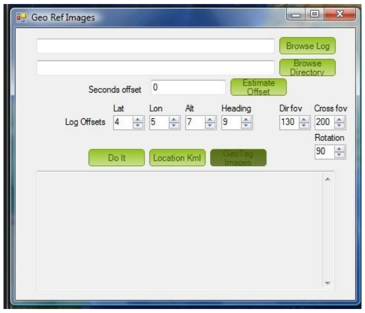


Figure 13: (from left to right) **Google Earth, Mission Planner Geo Reference**

The process begins by the Payload Operator (PO) viewing a live video stream through a ground station monitor. When he/she sees a target within the view of the camera, he actuates the still image camera via a joystick interface to the auto pilot to capture a high resolution image. He will read out the lat/long and altitude displayed at the time of capture. An Assistant Payload Operator (APO) will then note the location and altitude, and access the image from the on-board camera via a WiFi linked router on board the UAV. The image will initially appear as a thumbnail. This thumbnail will then be opened as a photographed layer in Google Earth. Here, two options will be available for the APO to determine the location of the target. While one of the two options is being performed, the high-resolution image will be downloading in the background. Once the image download has completed, the thumbnail image can be replaced with the high resolution image.

3.3.1 Option 1

Option 1 shown in Figure 14, provides the most accurate location determination. The image will be sized based on a calculation from the height of the UAV at the time of capture. It will then be oriented to known features present in Google Earth that appear within the image such as buildings, runways, etc. The APO will then determine the location and orientation of the target and all of its distinguishing characteristics. Utilizing this method, we have been able to determine the location of a target to within 5 feet of accuracy.

Figure 14: Example of Option 1 displayed in Google Earth

3.3.2 Option 2

Option 2 will be utilized in the event that no distinguishable landmarks are visible within the captured image. This requires a post flight processing procedure in which the images that have already been received by the GCS are put into a geo-rectification suite offered by Mission Planner. This program utilizes the UAV's telemetry data to tag an image with GPX data. The images are then viewed in Google Earth, where the location and target characteristics can be obtained. This is the least desirable option in that the required telemetry logs for the geo-rectification suite cannot be obtained until telemetry data links have been terminated with the UAV. This requires the UAV to have completed its mission and landed safely before the APO can obtain the needed logs, thus adding to the overall mission time.

Once the photographs have been processed and target locations and characteristics have been identified, all data will have been recorded into a Microsoft Excel spreadsheet. This data will then be stored onto a thumb drive as well as the Payload Operations Computer. At the completion of the mission, the judges will be presented with the thumb drive at which point Team UAS Tech's mission time will stop.

4. Ground Control Station Overview

4.1 Overview

Titan IV is not complete without the Ground Control Station (GCS). The purpose of the GCS is to serve as a hub for communications between the UAV and all on-board systems; as well as decipher payload data, turning un-ordinary data into usable information. The GCS is made up of various components that are vital in the successful operation and completion of a mission. Without these components, Titan IV would be an ordinary RC plane.

The Ground Control Station is separated into two individual control sections: Auto Pilot and Payload, which are manned by three personnel. Each section is fully equipped to perform their designated duties throughout the duration of the mission. Designed to maximize resources that allow for ease of operation, provides better situational awareness for its operators, thus creating a smoother flow for mission essential tasks.

4.2 Auto Pilot Operations Control Section

The auto pilot operations control section consists of one laptop that is linked to Titan IV via a 1 watt RFD 900MHz telemetry module. The Auto Pilot Operator utilizes Mission Planner, an open source GCS software suite, to communicate with the UAV. Here, missions can be planned, tuning can be performed, in-flight re-tasking can be commanded and all in-flight telemetry data can be viewed. To ensure communication is maintained with Titan IV during flight, a directional antenna has been applied to the telemetry module, which is oriented toward the UAV via an antenna tracker that utilizes telemetry data to determine its location.

4.3 Payload Operations Control Section

The payload operations control section is made up of one laptop equipped with Google Earth and Mission Planner. These two software suites are used in conjunction for the processing of photographs taken by Titan IV. As mentioned earlier, a video link has been established to provide real time imagery. This is viewed on a 19” Insigna T.V. monitor and is received by a 1.3 GHz video receiver. This receiver is equipped with a directional antenna to provide stronger signal quality at a distance. The Payload Operator actuates the onboard camera through a joystick interface that is linked to the auto pilot sections laptop. Still images are viewed on the payload sections laptop that is connected to the on-board payload via a 2.4GHz WiFi router. Both directional antennas are mounted on the GCS’s antenna tracking station. Here, targets can be detected, images are captured, and location and characteristics can be identified.

5. Testing and Evaluations

5.1 Individual Components

5.1.1 Airframe

The Skywalker 1900 airframe is known for its stability and control. After completion of each build, each airframe is tested for airworthiness before and after major payload components are added. Tests included flight characteristics, critical incident recovery and Center of Gravity determination/verification. Currently operating on our fourth airframe, as the previous three were lost due to catastrophic failures involving brown outs, auto pilot malfunctions, and an auto pilot initiated fly away.

5.1.2 Auto Pilot

Team UAS Tech initially started testing of the auto pilot in January 2013. Initial tests were conducted “on the bench” to ensure all functions were working properly. After selecting an airframe, the auto pilots’ primary method of testing relied on flight tests that were conducted on a weekly or sometimes bi-weekly basis. To date, Team UAS tech has performed over 160 flights ranging from airworthiness, safety features integration, and fully autonomous missions. While there have been some setbacks due to firmware upgrades causing malfunctions and bugs within the auto pilot, we currently consider our system fully capable of accomplishing the AUVSI competition to a satisfactory standard.

5.1.3 Imagery Systems

Testing of the imagery system started as ground tests to determine the distance at which a target could be visibly distinguished. Team UAS Tech took into consideration that the smallest target at competition would be 2ft with letters as small as 50% of the overall size of the target. With this in mind, 6 targets of various shapes and colors were constructed to imitate the smallest targets that could potentially be used during the competition. This provided strenuous grounds for testing of the imagery system. If we were able to distinguish the smallest target, then the bigger ones would stand out. Distances from the ground tests were used to set an approximation of the operational altitude at which Titan IV could perform at its best. Initial ground test provided imagery that was suitable at 300 feet without utilizing the zoom function on board the camera. After performing flight test verification, this altitude was lowered to 150-200 ft. AGL due to image quality and a slight blur. Further steps were taken to reduce the blur by taking out the original cell foam padding and replacing it with rubberized foam padding. To date, we have found that all target characteristics of a 24 inch target can be distinguished from 150-200 ft, and only the target shape and color can be identified from 400 ft.

5.1.4 Communications

As outlined earlier, there are four lines of communication established from the UAV to the GCS. The first is the 2.4 GHz RC control utilized by the safety pilot. Before initial flight tests began, range checks were performed to ensure the distance across an open field exceeded expectations of the safety pilot. Tests confirmed that the RC link was valid beyond 700 meters. The second line of communication is the telemetry module, which utilizes 900 MHz at 1 watt. Ground tests were again performed utilizing stock antennas, which exceeded 1000 meters. The third line of communication is the video link. It utilizes 1.3 GHz transmitter with an output of 1.5 watts. Ground tests were conducted with cloverleaf antennas, providing over 1km of uninterrupted signal and 1.5 km before losing signal completely. Lastly, the on-board 2.4GHz WiFi router with output strength of 1 watt provided the data link to the on-board camera. Ground tests have been performed utilizing a combination of a cloverleaf antenna and directional antenna. Results have produced distances of communication of over 800 meters. Having incorporated all four sources of communication into the airframe, range checks were again performed, achieving similar results and verifying that no interference was present between components.

5.2 Systems Integration

Team UAS Tech began conducting full scale flight tests incorporating all systems components early on in the flight testing schedule. Confidence needed to be established within the operational abilities of the system to affirm the results received during the ground test phase. After many successful flights and evaluations of each flights data, it was determined that Titan IV is a solid performing Unmanned Aerial System. Team UAS Tech will continue to perform weekly flight tests to ensure that Titan IV and our team are ready to face the challenges of the AUVSI competition head on.

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- Dr. John Robbins; Faculty Advisor
- Professor Tom Haritos; Faculty Advisor

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