2015 AUVSI SUAS COMPETITION

Illinois Institute of Technology: UAV Team

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AIAA

IIT: UAS Team

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Engineering Approach:

Mission Objectives:

Our team is renewing the IIT UAS tradition by developing a unique system that is expandable and adaptable. The preliminary focus has been meeting primary tasks including: Autonomous Takeoff, Flight, Navigation and Landing; Autonomous Searching, Target Identification, and Analysis. In addition to achieving these primary tasks, our team is seeking to push toward secondary tasks including: Identifying an off-axis target; communicating with the Simulated Remote Information Center (SRIC); and seeking out an emergent target. By creating an open design the IIT team will pursue additional tasks currently incorporated in the AUVSI rules such as the interoperability task, infrared camera tasks, and air-dropping a canister at future AUVSI SUAS competitions.

Design Rationale:

Airframe:

The IIT: UAS team has developed a new airframe for use in the 2015 AUVSI SUAS competition. This airframe was designed by the team to meet the mission requirements of the current AUVSI rules while also allowing for future expansion and adaptation. These two features will allow future IIT teams to pursue additional tasks and contributed significantly to the overall design philosophy.

Payload:

The current payload of the aircraft has been chosen to achieve the wide range of tasks presented by the AUVSI SUAS competition. The adaptability of the current airframe design allows the team to easily fit the systems required for the current set of chosen tasks with room available for necessary equipment in the future. The payload has been subdivided into two primary categories: Electronic Systems and Flight Systems. The design and selection of these systems is discussed in detail below.

Autopilot:

The plane's motion will be controlled by the Pixhawk® autopilot sold by 3DRobotics. This autopilot will allow the team to complete the chosen tasks for this year's competition as well as providing the potential to achieve additional tasks in the future.

Ground Control Station (GCS):

The current GCS is a laptop running Windows 7 connected to an additional screen to provide flight information. Due to the use of an onboard computer, this laptop does not need to analyze imagery and is focused solely on maintaining air/ground communication.

Image Acquisition:

The electro-optical (EO) camera is the primary component of the aircraft for the SUAS competition. As such, many design decisions have been made around this single piece of equipment. Important considerations are how the camera is mounted to the airframe, controlled during flight, and how its data is processed and relayed back to the GCS. In addition to these requirements the camera must also provide suitable resolution, high sharpness, and low distortion for accurate analysis of the images.

Data Processing:

Our team has chosen to install an onboard computer to process images on our aircraft during flight instead of at the GCS. This will help to alleviate communication errors and also increase the reliability of the overall system.

Expected Task Performance:

As seen below in Table 1, the IIT: UAS team plans to meet all of the primary tasks and will also be pursuing some of the secondary tasks as listed below. The cells with a green background are tasks that our team expects to achieve and the cells with a gold background are tasks that our team hopes to complete at the 2015 competition.

TABLE 1: SUMMARY OF EXPECTED PERFORMANCE

Task	Parameter	Threshold	Objective
7.1 Autonomous Flight	*Takeoff*	Controlled manual takeoff	Autonomous takeoff
	Flight	Manual flight	Autonomous flight
	Waypoint Navigation	Manual navigation within tolerance	Autopilot controlled navigation within tolerances
	GCS Display Items	Display required items	Additionally display waypoints W.R.T. boundaries
	Landing	Controlled manual landing	Autonomous Landing
7.2 Search Area	*Localization*	Determine location within 150 ft.	Determine location within 75 ft.
	Classification	Identify any two target characteristics	Identify all five target characteristics
	QR Code Classification	Detection	Decode message
	Autonomous Search	---N/A---	Autopilot controlled search
	Secret Message	---N/A---	Decipher message
7.3 Automatic Detection, Localization, and Classification	*Automatic Localization*	---N/A---	Identify targets within 150 ft.
	Automatic Classification	---N/A---	Identify 3 of 5 characteristics
	False Alarm Rate (FAR)	---N/A---	< 50% FAR
7.4 Actionable Intelligence	*Actionable Intelligence*	Identify target location within 150 ft. and 3 of 5 characteristics in flight	Identify target location within 75 ft. and all 5 characteristics in flight
7.5 Off-Axis Target	*Classification*	Identify any two target characteristics	Identify all five target characteristics
	Payload Autonomy	---N/A---	Automatic tracking of target during search
7.6 Emergent Target Task	*In-flight re-tasking*	---N/A---	Add emergent target as new waypoint
	Autonomous Search	---N/A---	Autopilot controlled search
	Target Identification	Provide image of emergent target	Provide image of emergent target, location within 75 ft., and description of activity
7.7 Simulated Remote Information Center (SRIC)	*SRIC Download*	---N/A---	Download SRIC message
	SRIC Upload	Upload pre-canned image or text to folder	Upload current target picture to the folder
	Autonomous SRIC	---N/A---	Perform Download and Upload under autonomous flight

Flight Risks and Mitigation Methods:

For aerial missions, safety is the most important parameter to take consider for the system. In order to mitigate flight risk, our team has incorporated redundant power supplies and communications into the vehicle. These two accommodations alleviate the two largest safety issues, power loss and loss of communication. Hawkeye is protected against power loss by using batteries connected in parallel such that if one pack has a catastrophic failure the other can be used to safely navigate and land the plane. Finally, telemetry and data communication can occur over both the 915 MHz 3DRobotics radios and 2.4 GHz Ubiquiti Picostation allow for a steady stream from the vehicle to the ground control station.

UAS Design:

Airframe:

The current IIT airframe, Hawkeye, is designed to be an adaptable and expandable component of our system. The airframe features a 10 foot wingspan in a twin-boom pusher configuration. This configuration was chosen for its large, accessible payload bay clear of any obstructions. The large payload area allows our team to control the CG position while adding or removing payload systems as needed. Finally, our team emphasized transportability of the vehicle in our design. This emphasis resulted in a highly modular design that allows the vehicle to be stored in a manageable case and gives future teams the option of further optimizing components based on their choice of payload systems.

The aircraft is primarily made out of fiberglass-reinforced epoxy with foam providing additional stiffness in the lifting surfaces and carbon fiber tubes connecting the tail to the plane. These materials allow for a large payload to be carried in a lightweight vehicle.

Fuselage:

Hawkeye's fuselage is composed of a structural beam to which the structural members are attached covered in a fiberglass shell for aerodynamics. This central beam has hard points to attach the wing and landing gear as well as large area for mounting the payload systems. The size of the payload allows for adjustment and control of the CG location based on incorporated payload systems. The fiberglass shell that will cover these components is visible below.

FIGURE 1: FIBERGLASS FUSELAGE DURING CONSTRUCTION

Lifting Surfaces:

The wings for our aircraft are made of a central foam core with a fiberglass covering. The lifting surfaces are connected by carbon tubes as seen in Figure 2 below.

FIGURE 2: AIRCRAFT LIFTING SURFACES

An optimization analysis was completed using XFLR5 in order to determine the final airfoil and planform shape. The planform dimensions and chosen airfoil are in Figure 3.

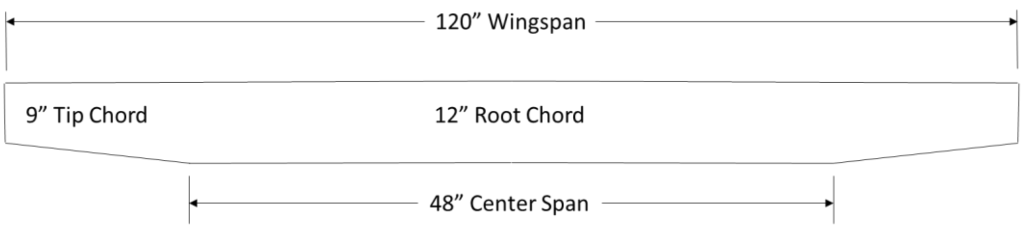

FIGURE 3: PLANFORM DIMENSIONS

Finally, a study was conducted to determine the carbon tube necessary for supporting the tail surfaces. The bending deflection, unit weight, and cost were compared with equal weighting to select our final carbon tube. Based on this analysis, our team chose a carbon tube that has an inner diameter of 0.934” and an outer diameter of 0.988”.

TABLE 2: BOOM TUBE SELECTION

	0.331	**0.505**	**0.628**	**0.76**	**0.91***	**0.96***	**0.988**	**0.99**
0.331	X	0.41	0.42	0.28	0.48	0.70	0.20	0.25
0.505	2.46	X	1.03	0.70	1.19	1.72	0.48	0.62
0.628	12.92	0.97	X	0.68	1.15	1.67	0.47	0.60
0.76	26.45	1.43	1.47	X	1.70	2.47	0.69	0.88
0.91*	53.67	0.84	0.87	0.59	X	1.45	0.41	0.52
0.96*	101.94	0.58	0.60	0.41	0.69	X	0.28	0.36
0.988	27.88	2.07	2.13	1.44	2.46	3.55	X	1.27
0.99	43.39	1.62	1.67	1.13	1.93	2.79	0.79	X

Note: Tubes are listed by outer diameter in inches
*Ultra High Elastic Modulus Carbon Fiber Tubes

Propulsion:

Two motors were compared in order to determine the optimal propulsion system for our aircraft. Initial optimization was conducted by comparing manufacturer propeller data provided by Innov8tive Designs. This data was then verified against the common RC airplane calculator, Drive Calculator.

TABLE 3: MOTOR/PROPELLER COMPARISON

	C3525-18		C4120-22	
Maximum Current	38 Amps		45 Amps	
APC Propeller	16x8	18x8	16x8	18x8
Maximum Power (W)	334	392	383	448
Thrust (lbs)	4.95	6.05	5.45	6.76
Power Consumption (W/lb)	67.5	64.8	70.3	66.3

The C4120-22 motor with an APC 18x8E propeller was chosen because of the extra thrust provided without a significant increase in wattage.

Payload:

Camera:

The Blackfly 3.0 camera from Point Grey Cameras was chosen as our EO camera. This camera provides 1288x964 resolution in a compact frame (30 mm long, 29 mm wide, and 29 mm tall) at 15 frames per second. This camera is also equipped with a global shutter which will reduce distortion due to aircraft vibration and motion, improving image quality. Another feature of the camera is its USB 3.0 connection which allows faster data transfer of images to our onboard computer for processing.

FIGURE 4: BLACKFLY 3.0 CAMERA

Gimbal:

The EO camera is connected to a one degree of freedom gimbal. This gimbal controls camera roll and ensures that the camera can be continuously pointed at the ground during the search tasks or pointed in a controlled direction during the off-axis task. The gimbal is constructed out of aluminum for precise control via a servo connected to the autopilot but is attached to a vibration-insulating frame to prevent the blurring of images.

FIGURE 5: CAMERA GIMBAL

Onboard Computer:

An ODROID XU3 is used as our onboard computer. The XU3 has 2GB of RAM and a 2.0 GHz quad-core processor enabling onboard image processing and analysis. This onboard analysis significantly reduces the pressure on our communications and data link due to low bandwidth or total loss of connection. The ODROID also has 64GB of solid state memory allowing for storage and copying of all flight data. This could prove particularly important in the event of a failure, providing our team with the means to diagnose what occurred. As a solid state device this memory is more durable and therefore likely to survive a crash. In addition to its role as an onboard processor, the ODROID controls communication between the aircraft and the GCS. This setup allows the ODROID to directly control the camera vision, via USB3 vision, while forwarding MAVlink commands onto the Pixhawk for flight control.

FIGURE 6: ONBOARD COMPUTER (ODROID XU3)

Communications:

2.4 GHz

As a high bandwidth data link between the onboard computer and GCS, our team is using the Ubiquiti Picostation. Hawkeye is also carrying a Wi-Fi adapter connected to the onboard computer in order to complete the Simulated Remote Information Center (SRIC) task.

915 MHz

For telemetry data and backup data transfer, Hawkeye utilizes the standard 3DRobotics telemetry radios. These radios provide our aircraft with adequate range for the competition and provide reliable information transfer between our vehicle and GCS.

72 MHz

A 72 MHz Futaba radio is being used for manual flight control due to available parts of the shelf at IIT and to reduce potential interference with the Picostation and Wi-Fi communications.

Autopilot:

The 3DRobotics Pixhawk® is a wildly utilized device that has been thoroughly tested in different conditions and platforms by a variety of users worldwide. This device also has a large, active development community that is extremely open to helping fine-tune the autopilot.

Our vehicle configuration has been with this autopilot in a smaller, replaceable test bed vehicle. This testing has allowed our team to make the necessary adjustments in the Pixhawk® software so that it has control over the V-tail, twin-boom configuration. A wiring diagram has been included below to show how the autopilot system will be incorporated into the overall electrical setup.

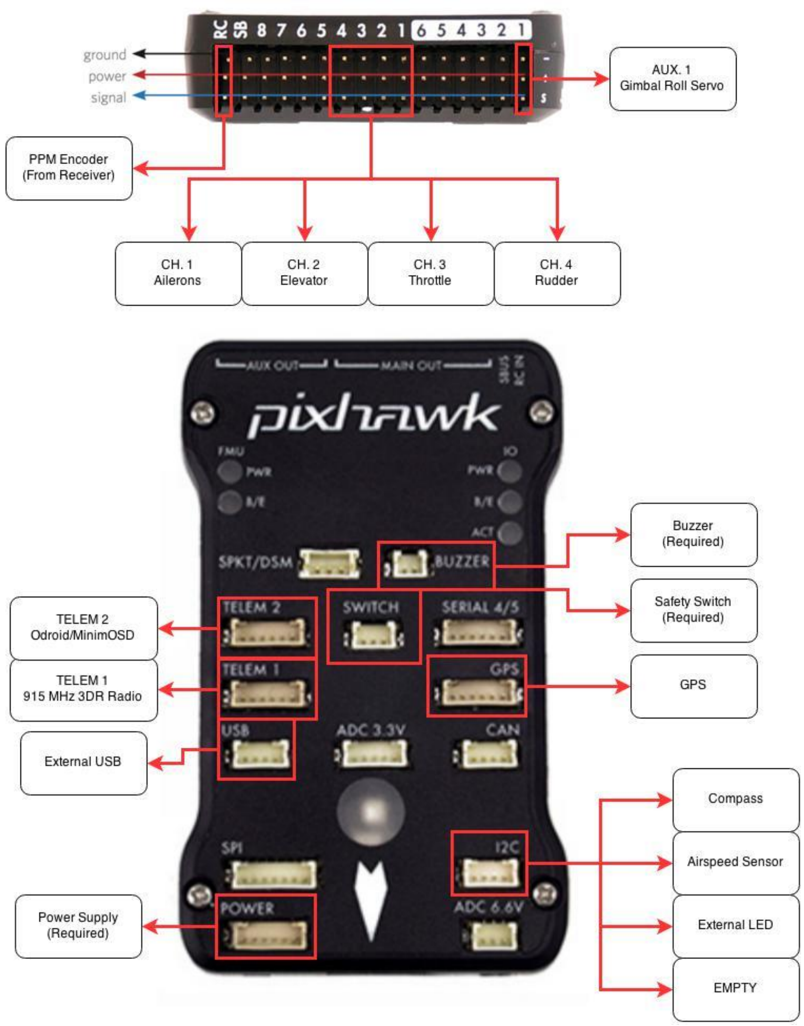

FIGURE 7: PIXHAWK® WIRING DIAGRAM

Wiring Schematics:

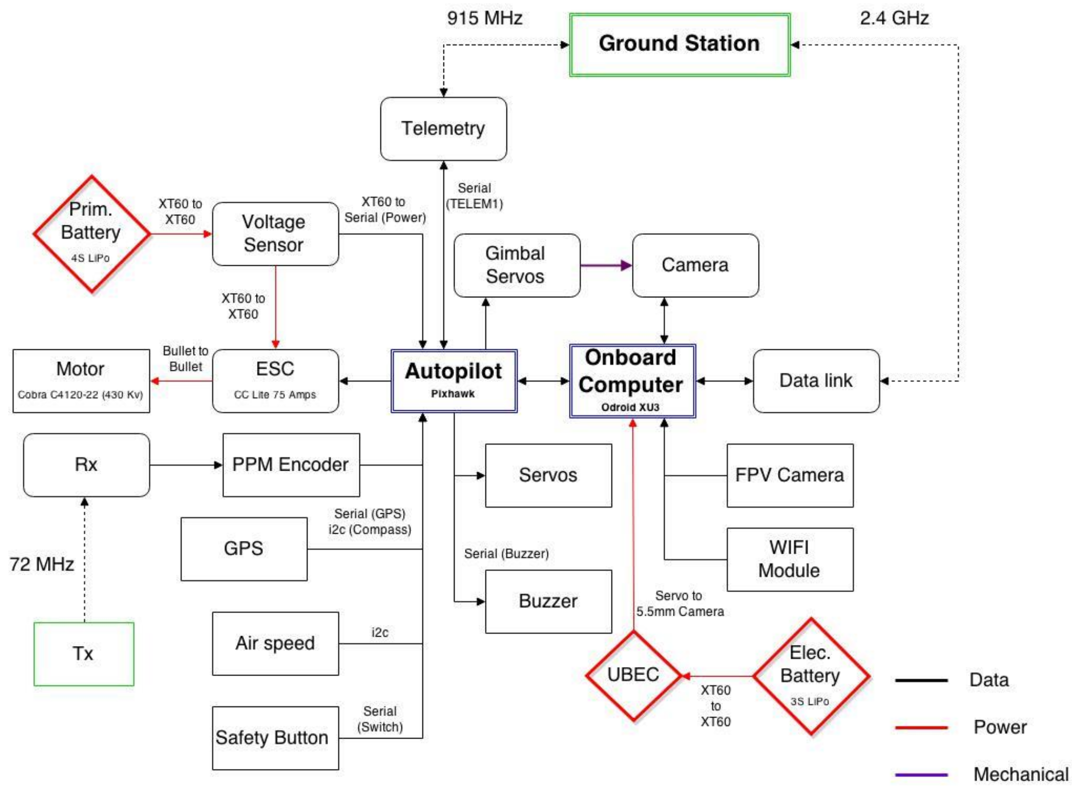

FIGURE 8: ELECTRONIC SYSTEMS WIRING

Ground Control Station:

The 2015 ground control station is a Lenovo laptop running Windows 7. This computer is used to send commands via MAVlink to the autopilot as well as receive imagery from the onboard computer.

Data Processing:

The onboard ODROID XU3 is used for image processing. The XU3 runs the XUbuntu 14.4 Linux distribution. Our team has added the capabilities necessary for completing mission tasks to this environment including: APM Planner 2.0, CUAV, and OpenCV.

APM Planner 2.0:

APM Planner 2.0 is an open source ground control software developed for Linux. It was chosen because it compatible with our onboard computer, ODROID XU3, and autopilot, 3DRobotics Pixhawk®.

CUAV:

The CUAV software is developed and distributed under the Creative Commons license by the Canberra UAV team from Australia. This software was adapted by our members to complete the SUAS tasks, in particular the emergent target task and target localization.

OpenCV:

OpenCV provides the necessary functions for real-time analysis of the images gathered during flight. This software has been configured by our team to parse images in order to determine their identifying characteristics such as target shape and alphanumeric character.

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