AUVSI sUAS Competition Drone

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***Abstract* – This paper details the design and testing of the electronics for the Robotics Club at UCF's entry into the AUVSI (Autonomous Unmanned Systems International) sUAS (Student Unmanned Aerial Systems) competition. A competitive entry requires a UAV that can fly 4 miles with a 3-lb UGV payload, lower the payload safely to the ground without landing the UAV, and then flying another 3 miles while using cameras to search an area for ground targets.**

***Index Terms* – Aircraft Propulsion, Autonomous Vehicles, Batteries, Robot Vision Systems, Unmanned Aerial Vehicles**

I. INTRODUCTION

The Robotics Club at UCF constructs autonomous robots for entry into various competitions or for use in outreach events. Many of these competitions are offered by AUVSI and center around autonomous vehicles in land, air, and water settings. This year the Robotics Club is constructing entries into the sUAS competition and the IGVC competition. The sUAS competition requirements mean that a suitable vehicle needs complex and high-performance electronic systems to permit the vehicle to fly and complete mission objectives. Building this vehicle required construction of parts not easily made from off-the-shelf components and complex integration of electronics and software to produce a suitable platform for the competition. The electronics must be developed in collaboration with a MAE senior design team and programmers from the club. The project is funded by the Robotics Club and constructed using their facilities.

II. COMPETITION DESCRIPTION

The SUAS competition consists of three main stages: waypoints, payload drop, and search [1]. The waypoints stage has the sUAS fly through a series of waypoints with the payload, for approximately 4 miles. The payload drop stage requires the sUAS to drop a UGV (Unmanned Ground Vehicle) onto a GPS waypoint. The UGV must carry an 8-ounce water bottle to another GPS waypoint after landing and must weigh less than 48 ounces with payload and landing system. The search stage requires the sUAS to fly over a 0.125 square mile area, where it must locate a series of ground targets that consist of a colored alphanumeric character on top of a colored shape.

During all 3 phases, the sUAS must contend with a random set of no-fly zones that are uploaded to it from the ground station. The no-fly zones are virtual volumes that the sUAS must navigate around to avoid point losses. The challenges in the competition closely mirror real world UAS tasks, such as delivering packages to a consumer or finding a lost person in the wilderness. The competition allows for a large-scale test of these systems that would be difficult to achieve otherwise, and provides clear goals and restrictions based on AUVSI expertise.

A. Autonomous Flight & Waypoints Stage

The autonomous flight & waypoints stage require power and control systems that allow the drone to maintain controlled flight between GPS-based waypoints, stay powered throughout the entire mission, and communicate with the ground station. To complete the mission with the given requirements and necessary components, the drone must be relatively large (roughly 40 to 50 pounds) with strong motors. The Robotics Club at UCF determined that an octocopter in X configuration is most desirable given the available components and desired capabilities. Such a system consumes approximately 2900 watts while hovering and 6000 watts while at full power. In addition to the motors, power must be supplied to onboard cameras, a flight controller, onboard computer, speed controllers, a GPS module, RF microcontrollers and more. To meet this demand, the power system must supply enough power to the motors (which can be unregulated) and have voltage regulators with enough power capacity for the other systems.

The mission also requires that the drone be able to communicate with a ground station. Communication with the ground station will involve the drone sending back telemetry data on its position, speed, and status, while also sending back images taken from the cameras and taking commands from controllers.

B. Payload Delivery Stage

The payload delivery stage requires communication with the UGV and electrical systems for deploying the UGV from the sUAS. To ensure the ground vehicle completes its mission and to aid development, the ground vehicle must be able to relay important telemetry back to the ground station. The vehicle should be able to maintain communication even if it lands in an area preventing line of sight. Low-power communication systems independent from the main ground control to sUAS communication link are required.

C. Area Search Stage

The area search stage requires high-performance image acquisition and processing systems to search an area efficiently and quickly. An integrated gimbal system is crucial to maintain appropriate orientation during airborne image capture. Computer hardware that can process the image data in real time and detect features of interest (i.e. alphanumeric characters on geometric shapes) is required. The computer hardware must be selected and integrated well enough to provide a good platform for the Robotics Club CS students to run computer vision algorithms.

III. FLIGHT CONTROL

Our flight controller of choice is the BeagleBone Blue from Texas Instruments. Aside from being donated to us, the BeagleBone Blue satisfies our need for a flight controller by having 8 servo outputs and a processor which supports run a real-time kernel, which is critical as UAV control is inherently a real time problem, and missing control updates can be catastrophic due to the lack of aerodynamic stability. The BeagleBone Blue can also be used as the controller for the UGV with a few software modifications, reducing the number of hardware platforms we need to support.

A. Specifications

The BeagleBone Blue is a Debian Linux-based robotics computer that functions by using and Octavo OSD3358 SiP (System-in-Package). The processor on this chip is a TI AM335x ARM® Cortex-A8 with a clock speed of 1GHZ. For improved best-case runtimes, the chip has a 64KB L1 cache (evenly divided between instructions and data), a 256KB L2 cache, and 64KB of on-processor L3 RAM. For memory, the SiP contains 512MB of DDR3. To introduce an environment of hard real-time this System-in-Package includes two 32-bit Programmable Real-time Units (PRU), that improves systems ability to adhere to strict deadlines.

B. Autopilot Software

To fit the scope of this project, our UAV must be able to navigate a course autonomously. To achieve autonomous navigation, our flight controller must communicate with an NVIDIA Jetson that processes data received from our camera system. This processed data takes the form of waypoints that get sent to the autopilot software.

C. ArduPilot

For the BeagleBone Blue, the recommended software package is ArduPilot. ArduPilot is a software suite that consists of multiple autopilot software, including: ArduRover, ArduPlane, and ArduCopter. Along with the autopilot software, ArduPilot is packaged with utilities to aid the autopilot, such as: Mission Planner, QGroundControl, MAVProxy, and AntennaTracker to name a few. As our UAV is an octocopter, ArduCopter is the obvious choice, and ArduRover can be used to pilot the UGV.

D. Ground Control Software

For our Ground Control Software Mission Planner was chosen as it tends to be the most compatible with Flight Controllers running ArduPilot software. Mission Planner is a part of the ArduPilot software suite and is recommended for use with ArduCopter. Included in the Mission Planner software are several features that we use to calibrate our UAV, simulate flight, create a flight plan, and record flight data.

E. Configuration and Calibration

With the autopilot software installed on the UAV, it must be configured and calibrated before it is ready to fly. Through the Mission Planner interface the frame type is configured, and the accelerometer, radio control, and compass are all calibrated. Aside from calibration, this interface is used to adjust the flight modes and fail safes for the UAV.

F. Flight Plan

The flight plan feature in Mission Planner grants the ability to setup waypoints and events for an unmanned mission but requires a human operator to set the waypoints. The competition has the data for waypoints and tasks stored on a server connected to a local network, so our UAV will get waypoints from the MAVLink connection to the Nvidia Jetson TX2. The full autonomy stack is being developed by the Robotics Club using MAVROS to send waypoints based on data from the competition server about task locations and virtual obstacles. The MAVROS connection will dynamically create a mission with commands for takeoff, landing, and waypoints, and can change the mission in flight to account for battery condition or moving obstacles.

G. Flight Data

During the flight, the flight controller stores flight logs on the flight controller’s onboard memory. In ArduCopter these data flash logs start when the UAV is armed and can be downloaded via the MAVLink post-flight. These logs contain all information relevant to the UAV’s flight, such as yaw, roll, pitch, compass information, GPS information, along with event and error messages. More stored data includes accelerometer and gyro information, flight mode data, and performance monitoring. The values stored in these data logs can be viewed graphically through Mission Planner’s user interface when downloaded onto a computer running the program and have been vital to diagnosing issues with the frame of the UAV.

IV. IMAGE PROCESSING

To complete the area search mission objectives, the UAV needs to be capable of capturing and processing a large amount of image data without missing targets due to high-speed communications dropout.

A. Image Capture System

The area which needs to be searched for targets is approximately 1/8th of a square mile, and the targets have features approximately 1 inch wide. To search this area at this resolution, the UAV must make multiple passes. Since the energy requirements of the UAV are overwhelmingly driven by the distance it must fly, minimizing the number of passes over the search area is paramount, so the resolution and field of view of the imaging system is the first design priority. Given the target of identifying 1-inch wide features, the imaging system should be chosen to provide maximum coverage of the target area at this resolution or better. The imaging system can also be chosen to take advantage of the fact that the UAV flies forward relatively slowly compared to the capture rate, so the size of the captured image in the direction of flight can be relatively small to reduce the amount of data for a given image width.

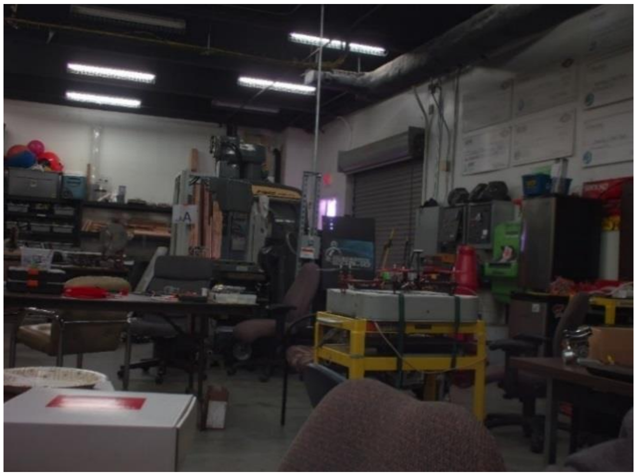

Fig. 1. Overall frame from one camera. Test target is a series of capital letter A 30 feet away

The second design priority for the imaging system is the method by which it interfaces with the image processing system. The simplest method is to use an all in one camera that simply saves images to an SD card which is removed and processed on the ground, but this loses substantial points compared to having live, in-flight processing. Easily available options for in flight processing are USB2, USB3, and Camera Serial Interface. USB2 provides only a very limited bandwidth, and even USB3 is completely utilized by some cameras. Selecting a computer and camera that support CSI allows for very high bandwidth image data. An e-CAM130_TRICUTX2 was selected since it can connect 3 13MP cameras to an NVIDIA TX2 dev board using 4 CSI-2 lanes each. One hurdle encountered during testing is that due to the very high resolution of the camera sensors coupled with the 1/3.2-inch sensor size, very high-quality optics are needed to utilize all the available resolution. The provided optics had reasonable resolving performance but a wide field of view that would not be appropriate for the altitudes involved. A new set of lenses was purchased with a longer focal length that reduced distortion and allowed higher flight altitude during the area search but had to be carefully sourced to ensure the lens quality was enough to resolve the ground targets from far away. Because of the small sensor, the full resolution is unusable because the diameter of the Airy disk for a f/2 aperture lens (the smallest aperture reasonable) is 2.7 micrometers, while the sensor pixels are 1.1 micrometers.

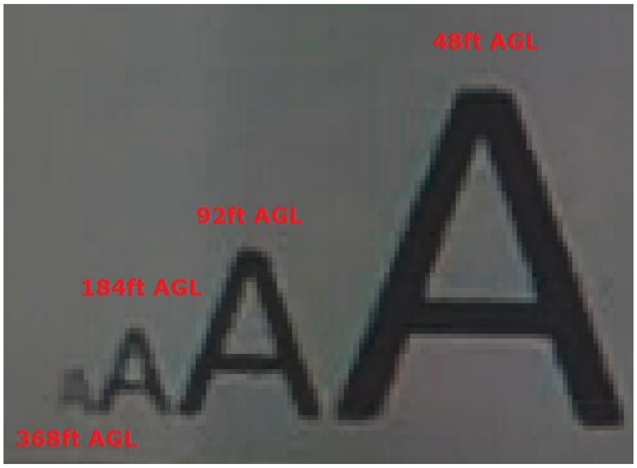

Fig. 2. Detail of camera frame showing test target annotated with equivalent viewing altitude

The final image capture system uses the TRICUTX2 cameras each with an Edmund Optics 5.6mm focal length high resolution S-Mount lens, with an IR cut filter epoxied onto the back to preserve color quality while outside. **Fig. 1** shows the full field of view of one of the cameras while **Fig. 2** shows a detail of a test target in the frame, located in the middle vertically and one third to the left of frame. The test target is a series of capital letter A's at varying sizes, which simulates a view of a target at varying altitudes (assuming the focus is appropriately set for each altitude). The altitude Above Ground Level (AGL) that would give the target the same size in the image as it has in the fixed distance lab test is annotated in **Fig. 2**.

The image capture system also includes a camera gimbal so that the cameras can maintain a roughly fixed orientation despite the rapid orientation changes of the UAV inherent to multirotor flight. The gimbal is a 2-axis gimbal that stabilizes the cameras in the roll and pitch axes, which is sufficient to keep the cameras pointed downwards along whatever heading the vehicle is following. The gimbal uses a pair of brushless motors with a dedicated gimbal controller re-flashed with the SimpleBGC software to allow us to tune PID parameters, motor strength, calibrate sensors, and send commands over a serial port if need be.

B. Image Processing System

The immediate choice for processing the image data was the NVIDIA Jetson TX2. The TX2 allows image processing with CUDA, giving much greater performance than other solutions such as a mobile i7 for much less weight and power. Other embedded computers like the Raspberry Pi 3 or the ODroid XU4 were considered, but they generally struggle on complex image processing tasks even with much lower resolution cameras, and either have very few CSI lanes or have just one USB3 port. The main limitation of the Jetson is that the best available camera solution requires using the dev board supplied, which is much larger than necessary, but the UAV is large enough to work around this.

The actual image processing software is being written by the Robotics Club, but generally consists of an initial point of interest finding step that quickly finds regions which may contain an object, followed by convolutional neural network classifiers to determine things like the shape of the object, color of the object, and the letter on the object. Since the software is written with TensorFlow, the CUDA cores on the TX2 can be well utilized.

V. POWER SYSTEMS

The two classes of devices needing power on the UAV are the flight motors and the computers/payload systems. The flight motors draw an overwhelming majority of the power, but don't require any sort of voltage regulation after the batteries. The rest of the systems require a stable 12V or 5V, but only draw 1% of the peak flight motor power.

A. Flight Motor Power

The flight motors can each consume ~36A at the 22.2V nominal voltage, giving a total of 288A for the full set of 8 motors. Normal operation will use less, but the power system should be able to handle this high load continuously to ensure the motors always have the full thrust available so that the UAV can stabilize itself even when operating at cruise speed.

Most UAVs use pouch Lithium-Polymer cells for their excellent specific energy (Wh/kg) and specific power (W/kg), but to achieve the long ranges required for this competition we chose Sanyo/Panasonic NCR20700B cells because they offer the highest commercially available specific energy without sacrificing too much specific power. Pouch Lithium-Polymer cells typically offer specific energies in the range of 120-200Wh/kg [2], while the NCR20700B offers a specific energy of 224Wh/kg [3]. This 10% improvement over even the best pouch cells is what led us to use these cells. The drawback of high specific energy cells is that they tend to have lower maximum power output. Battery power output is commonly rated as a multiple of the capacity (C-rating) where a 10C battery can deliver all its charge in 1/10th of an hour or current at 10 times the amp-hour number. Pouch Lithium-Ion cells are commonly available with 25C ratings, with 100C being at the upper end of what is on the market. The NCR20700 is rated for only 4C continuous with temperature-limited operation at 6C for short times. This means that the UAV cannot operate without at least 72Ah of cells on board to meet the maximum motor power draw, but this is acceptable because the UAV needs 80Ah worth to maximize range. The required number of cells was calculated by first selecting the number of cells to be put in series, which for multirotor UAVs of this size is commonly 6, then collaborating with the MAE team who had modelled the energy required to fly some distance, and checking against available hobby UAV calculators such as xCopterCalc and XOAR's manufacturer data to settle on the 80Ah figure as the capacity beyond which range would decrease due to the energy cost of carrying discharged battery material. Another benefit of the cylindrical lithium cells is that they feature built in thermal cutouts which disconnect the cell in the event of excess current or heat buildup. Combined with the chemistry and low discharge rating this makes these cells somewhat safer than pouch LiPos in the event of an electrical fault or catastrophic crash.

To make the construction of the flight power system more practical, the batteries and associated power wiring were split into 4 sections, with each battery powering 2 motors and contributing to the payload power. The cells are connected in 6 series groups of 5 parallel batteries by 0.01-inch thick copper strips welded onto the cells using the Innovation Lab's micro-TIG welder. Cylindrical Lithium cells are typically connected using nickel strips welded with a resistive welder, but the copper strips offer better conductivity per weight at the expense of requiring the micro-TIG machine. This gives each battery a 20Ah capacity with a 22.2V nominal output. The output of the batteries is routed through two copper strips each on the topmost positive and bottommost negative terminals into the battery monitoring board.

The batteries each have a battery monitoring board which can communicate over I2C with the onboard computer. While not directly compatible with the flight control software which expects either analog inputs or proprietary monitor chips, the measurements can be utilized by another piece of software to instruct the flight controller to return to launch or land on the spot if the batteries are low. The battery monitoring is accomplished using a TI BQ34Z100 battery gas gauge IC, which uses an external voltage divider to measure battery voltage, and a shunt resistor on the low side of the battery to measure battery current. The gas gauge is also connected to a shift register that works with a set of LEDs to indicate the battery charge state, and to a magnetic I2C isolation IC to protect the control computer in the event of a fault. The BQ34Z100 can report current, voltage, and temperature directly, but also can use a proprietary set of monitoring algorithms to give a percent charge remaining. Calibrating the charge remaining algorithm requires running multiple charge and discharge cycles which takes 12 or more hours per battery along with an expensive single purpose programming module from TI, so it is not currently utilized. The UAV can do without the charge remaining calibration by sensing battery voltages, which can provide adequate warning of battery depletion, even if they are not accurate for determining the exact charge remining.

Charging the batteries is accomplished with a commercially available computerized charger configured for these specific batteries. The charger also ensures that each series set is kept at the same voltage so that one set does not get overcharged, without preventing the whole battery from being fully charged. The batteries have been tested for both measurement accuracy and power output using banks of power resistors as well as the motors on the UAV itself. Testing with power resistors showed that the measurements from the gas gauge were accurate to within the 2% of the available current clamp.

B. Computer and Communications

Voltage Regulation System

The logic systems on the UAV require power that is of a regulated voltage and is protected from spikes and excess noise created by the motors. The requirements for this project call for 5 watts of continuous 5V power and approximately 40 watts of continuous power at 12 volts. The vehicle batteries are the only energy supply on board, so the voltage regulation system will need to accept the 22.2V nominal power from the batteries and convert it to something usable by the other systems. However, the batteries can exceed 24V when fully charged or if the motors slow down quickly and can go lower than 22.2V under heavy load or when somewhat discharged, which complicates the operation of all regulators, especially the 24V regulator.

Regulation Components

For our voltage regulation system, the regulator we chose was the LMR33630 from Texas Instruments. Using recommended switching regulator designs as a baseline, we chose this regulator due to its efficiency, which is above 95% in an ideal case. The LMR33630 is a buck converter and can accept as low as 3.8 volts and a maximum voltage of 36V, which falls within our 24-volt battery range. We originally designed the output of the regulator to be set at 12 volts with a designated current of 3 amps for a total power output of 36 Watts. After completing the original design of our regulator board, we discovered that our expected power consumption would be roughly 9 watts higher than our PCB was designed for, meaning the switching regulator would need to drive more amperage than expected. Thankfully, the LMR33630 has the capacity to supply more than the 3 amps of current if need be. The maximum output current of the LMR33630 is a function of it's high-side (I_{LIMIT}), and low-side (I_{SC}) current limits. The maximum output current of this switching regulator is the average of the two current limits, which in this case are 5.05 amps on the high side and 4.1 amps for the low side, giving our board a maximum output current of roughly 4.6 amps. With an output voltage of 12 volts at the maximum output current, our potential power output is approximately 55 watts, which fits within the scope of our design.

To forgo the need to add extra power sources to our UAV, increasing the weight and complexity of the system, the computers and communication are powered by the same batteries that power the drone's motors. As all four batteries are connected to the voltage regulation board at once, some switching mechanism is needed to determine which battery to draw power from. For this purpose, we chose the SM74611 Smart Bypass Diodes from Texas Instruments. These bypass diodes were chosen for their extremely low dropout voltage, only dropping 26mV with a forward current of 8 amps. For the switching setup, each battery input is connected in series to a bypass diode. These input/diode combinations are connected parallel to each other, allowing our regulator to draw power from the battery with the most charge, balancing the UAV’s total power consumption to a degree.

VI. WIRELESS COMMUNICATIONS

Per the competition requirements the UAV must transmit back telemetry data at an average rate of 1 Hz and image data can be streamed for additional performance points. Since the telemetry data requires a low data rate, but very high reliability and the image data requires a high data rate but low reliability, it was decided that two separate wireless communication mediums would be used for each type of data.

A. Telemetry Data

There are several telemetry system requirements and environmental conditions outlined by the AUVSI SUAS competition rules that call for a long-range, efficient, lightweight, and robust telemetry system [1]. Maintaining a reliable and consistent telemetry connection at distance is critical to meeting performance criterion and fulfilling the objectives necessary to acquire competition points. Communication between a ground station and UAV clearly implies the requirement of wireless communication. Multiple platforms were considered to fulfill this requirement as included in **Table 1**.

TI CC1350s were donated and readily available for testing. Field testing at 900 MHz showed that the RSSI dropped off significantly after 200m. This was expected due to the low transmit power provided by the CC1350s. The RFD900 was then selected due to its excellent transmit power, long advertised range and tested compatibility with the ArduCopter software. A 600m range test between parking garages Libra to C showed an average RSSI between 130 and 170 which was well above 60, the value needed for data transmission.

Table 1. Comparison of telemetry data transmission systems

	TI CC13x0	**Digi Xbee-PRO900HP**	**Microchip RN2483**	**RFD900**
Frequency Bands (MHz)	433, 902-928	900	433, 868	902-928
Transmit Power (dBm)	15	24	14	30
Receive Sensitivity (dBm)	-110	-110*	-148	-121
Advertised LoS Range (miles)	0.125	9*	None	25

B. Image Data

The requirement for image data is to transmit 640x480 frames at 30 frames per second from 700m away (the maximum distance during competition). Using H.264 video compression this requires about 2-3 Mbps of bandwidth [4]. With a significant margin for variability the desired bandwidth is about 6 Mbps to ensure consistent video. A radio system with a high frequency, high power and low receiver sensitivity is necessary to do this.

Table 2. Comparison of image data transmission systems

	Rocket M5	**Rocket 5AC Lite**	**Bullet IP67**
Weight (g)	272	250	213
Max Power Consumption (W)	8	8.5	7
Max Receive Sensitivity (dBm)	-96	-96	-93
Max Output Power (dBm)	27	27	21
Max Band-width	40MHz	60MHz	40MHz
MIMO	Yes	Yes	No
Cost ($)	Donated	135	129

Ubiquiti is the leading company is long distance high bandwidth radio modules, so their products are a natural starting point. The Robotics club already had access to two Ubiquiti Rocket M5's which have the necessary parameters for long-distance high-speed transmission. The Rocket 5AC Lite and Bullet IP67 are Ubiquityi's newer products for 5.8 GHz transmission. A comparison of the products is included in **Table 2**. Since the new Ubiquiti devices don't offer significantly better characteristics the M5 was selected for cost savings. After selecting the Rocket M5, several antenna combinations were tested between parking garages Libra and C (about **600m**) as included in **Table 3**.

Table 3. Comparison Rocket M5 antenna configurations

	UAV Antenna	**UAV to Ground (Mbps)**	**Ground to UAV (Mbps)**
AMO-5G13	AMO-5G13	20	20
AMO-5G10	Rubber Duck	19	12
Dual Yagi	Rubber Duck	6	8
Patch	Rubber Duck	15	15

From the results the AMO omni directional antennas from Ubiquiti provide superior performance. However, due to weight requirements from the MAE team the AMO antennas were not suitable for the UAV side. In addition to this, the radiation pattern for the AMO antenna is an omni directional disk with a small beam-width making them difficult to position on the ground side. After guidance from Dr. Gong, dual Yagi antennas were selected for the ground side due to their conical radiation pattern, and mono-pole (rubber duck) antennas were selected for the UAV side due to their wide, omnidirectional pattern and light weight. However, during testing the Yagi antennas didn't provide the desired directionality or bandwidth. Custom patch antennas were then designed and fabricated for the ground station as seen in **Fig. 3**. During testing these antennas provided sufficient bandwidth and good directionality.

Fig. 3. Custom patch antennas connected to the Rocket M5 for range testing on the libra parking garage

VII. I2C COMMUNICATION PCB

The TI BQ34Z100 modules communicate over I2C and all have the same I2C address, so some conflict resolution is necessary. The Linear LTC 4316-18 and TI TCA9544APWR were considered as possible chips to use for address resolution. The LTC 4316-18 uses an address conversion method and the TI TCA9544APWR uses address multiplexing. Since the data rate coming off the gas gauges modules is low frequency, address multiplexing can be used as time used to switch between buses is insignificant for the data rate necessary. As such, the TCA9544APWR was chosen since it only required one component versus the four needed with the LTC 4316-18.

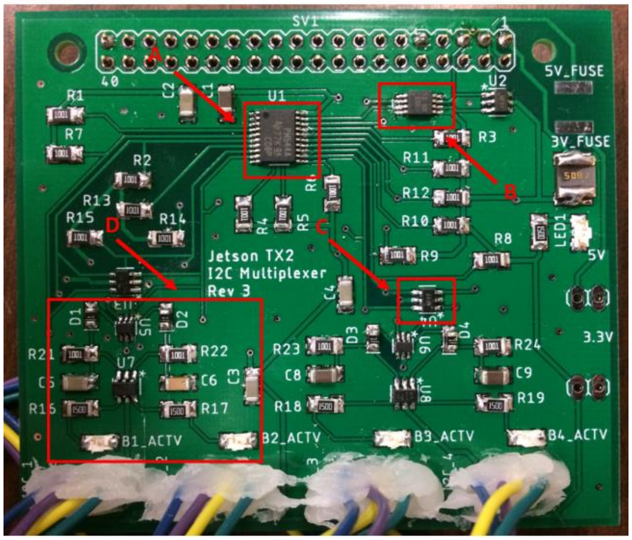

Fig. 4. A. I2C multiplexer, B. Voltage translation and buffer, C. ESD protection diodes, D. Hardware for LED indication

Aside from address multiplexing the board also needs to provide voltage translation and buffering. The battery monitor board uses an Analog Devices ADuM1250 to provide magnetic isolation between the battery monitor board the and I2C board. The output of this chip is I2C compatible but not I2C compliant, so voltage translation is necessary to communicate with the Jetson TX2. This is resolved using a TI 9803DGKR which provides buffering and level translation. In addition to this the board provides indictors for bus use based off the clock signal using and inverter, buffer and RC circuit. The components are labeled in **Fig. 4**.

VIII. FLIGHT TESTING

In addition to the ECE project requirements, there are requirements from the MAE team for the flight performance of the vehicle. Completing these requirements and our own requires multiple flight tests of the vehicle. Through flight testing we confirmed that the power system would handle the full motor power requirements by running the UAV at full throttle and verifying that the control systems don't lose power while the batteries are under high load.

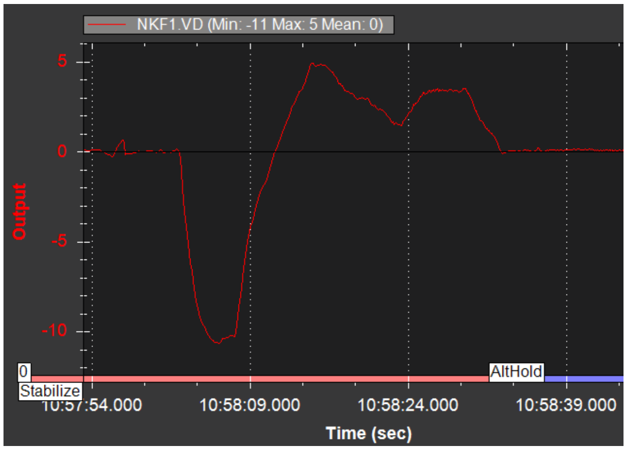

Fig. 5. Vehicle vertical velocity during climb rate test in meters per second (velocity is relative to the down direction, so a negative velocity indicates a climb)

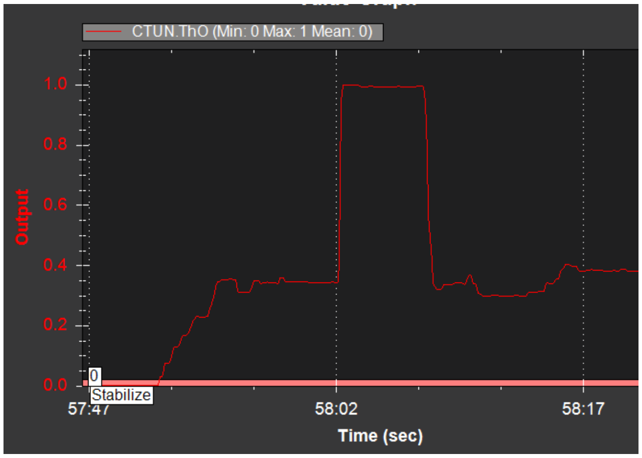

Fig. 6. Vehicle throttle setting during climb test (Unit is fraction of full throttle)

Flight testing of the maximum climb gave a maximum climb rate of 10.5m/s as indicated by the most negative peak in **Fig. 5**. Throttle setting during the climb test is shown in **Fig. 6**, which shows 5 seconds of maximum throttle application. The ground speed was also tested, with the speed shown in **Fig. 7**, with a maximum speed of 7.5m/s, although higher speeds are likely obtainable since the vehicle was only running at 45% throttle.

We also verified that the flight controller was capable of following waypoints by setting the UAV to run a circular course of 20 meters in radius at 2.5m/s, which it successfully completed fully autonomously. The vehicle's GPS track for that test is shown in **Fig. 8**, starting in the lower right corner and going clockwise around the circle starting at the south. Flight testing also showed that our telemetry system worked reliably to connect Mission Planner to the UAV controller.

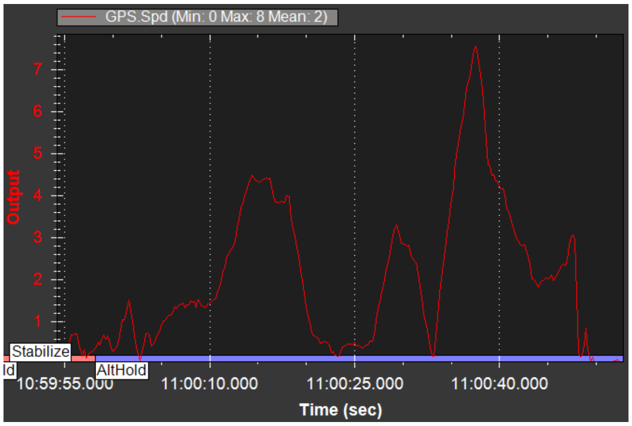

Fig. 7. Vehicle ground speed during ground speed test (Units are meters per second)

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Fig. 8. Vehicle GPS track during waypoint test. Waypoints are in light blue and the vehicle track is in yellow.

IX. CONCLUSION

The electronic systems for a UAV to compete in the AUVSI sUAS competition were developed and flight tested to produce a high-quality vehicle that provides an excellent platform for current and future autonomous UAV projects.

X. TEAM MEMBERS

Brandon Cuevas is a current senior at the University of Central Florida and will graduate with a B.S. in E.E. & Cp.E. Brandon has three years of experience as a manufacturing R&D CWEP for UCF/Lockheed Martin and plans to begin working full time in the summer at Texas Instruments as a Product/Test Rotation Engineer.

Garett Goodale is an EECS at UCF. He has a year and a half of experience working at as a manufacturing R&D CWEP for UCF/Lockheed Martin and plans to intern at Sandia National Labs before pursuing an M.S. degree.

Nicholas Omusi is a current senior at the University of Central Florida and will graduate with a B.S. in E.E. & Cp.E. Nicholas has extensive research experience in the field of bioelectronics and plans to pursue a Ph.D.

Nicholas Peters is a current senior at the University of Central Florida and will graduate with a B.S.E.E. in May of 2019. Nicholas has worked for Harris Corporation and IAM Robotics developing software for robots and plans to begin working full time in the fall at Aeronix.

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