EGR 4830 – Senior Project

CalPolyPomona

BANSHEE UAV (Ground Control Station)

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1. How long did it take to complete this executive summary? 1 Week
2. Did you attend or watch the lesson provided by Mr. Paul Hottinger regarding Information Literacy (check the correct box)? ☐YES ☒ NO

BANSHEE UAV (Ground Control Station)

Introduction

BANSHEE UAV's main objective is to create a high-endurance solution for drone flight travel time. Many unmanned aerial vehicles (UAVs) use lithium-polymer (LiPo) batteries and one of the main drawbacks of this component is the lengthy charge time. In response to this issue, the Robotic Ground System (RGS) has a network of ground stations for the UAV's battery swap. The UAV lands on a platform designed to prepare for battery replacement as a part of the Ground Control Station (GCS). The GCS provides both service to the drone in autonomous battery swap and data transfer as well as user-end remote monitoring of the drone's power sources for every RGS that exists. One problem that occurred with the previous RGS design was the fragility that came with the material of the 3 subsystems. PLA is brittle and easy to melt under extreme conditions. Much focus throughout this year went into redesigning these aspects of the project, including ensuring power throughout the entire system as well as PCB work on the GCS system.

Part of the first half of the year included a personal project in research of web development and deployment types, leading to the launch of a personal website. While having a functional website is important for BANSHEE via the RGS tracking system, web development can also be an important tool in public relations and record keeping.

Literature Review

Previously, BANSHEE's Robotics Ground Station was made of cost-effective PLA [1]. Because of the goal to support remote-access drone flight, the system was at risk of breaking or melting from extreme conditions (**Figure 1**). The design was reconsidered to include material at lower risk of malfunctioning; aluminum structures for both the Battery Vending Machine and Battery Transfer Pod ensure the durability of the RGS system as well as eliminate redundancy in design (**Figure 2**).

The earlier design of the Linear Actuator PCB for the GCS was controlled by a Raspberry Pi which sent a signal to an ATMEGA328P. By switching over communication systems and controls to an ESP32 microcontroller, the system is cheaper ($10 as opposed to $25 according to Amazon) while fulfilling the required tasks for the battery swap process to the same degree of success.

The need for an independent power source for the RGS system [1] is fulfilled by a 48V, 100A battery for a wattage of 48kV. Because of unpredictable extreme conditions in remote locations, it is difficult to manage a sustainable goal of a solar-powered RGS [2]. The consistency that a battery offers outweighs the green footprint of a solar-powered system.

Results and Discussion

<u>Personal Website</u>

In Fall of 2024, one task was a 'skill builder' personal project with the goal of building up experience to become more well-rounded as both a BANSHEE Team Member and an industry professional. Building a website involves working with a markup language and programming language. For this particular project, different pages were made highlighting a 'Home' page, where a brief biography and profile is laid out, a 'CV' page, a link directing to a resume and relevant coursework, a 'Projects' page highlighting past work, a 'Repertoire' page showcasing past performance, and a 'Contact' page for an email directory (**Figure 6**). The website was deployed through Github. This is a straightforward approach to web deployment, with limited tools for complete creative and secure control, but due to shifting priorities to the GCS, Github offered a solution to publishing. Independent deployment involves creating an infrastructure of a server, server operating system, and a web server (i.e Caddy or Nginx). This method gives the creator much more flexibility in terms of environment customization.

GCS PCB

The switch over to the ESP32 centralizes many parameters of the system, so that in addition to the removal of the Raspberry Pi and ATMEGA328P chip, components such as NRF24L01, a 16MHz crystal oscillator, and the reset switch were no longer necessary; the ESP32 has these features already integrated, and thus, trims down much of the fat in the PCB design stage of the GCS circuit. The ESP32 is responsible for the Linear Actuator Control, where four relays that supply power to the linear actuators either lock the drone in place or release it when it is ready for take-off. This locking mechanism, **Figure 3**, is powered by a 12V input, stepped down to 5V using the L78S05CV voltage regulators. One regulator powers the ESP32, while the other powers the PC817 optocoupler and relay switching processes. The optocoupler devices allow for two different circuits to be analyzed. One side includes connection between pins 1-2 of the optocoupler and an LED, which leads to the ESP32 digital pins (there are four separate instances of this connection). This is in series with a 1kΩ resistor and the 5V from the L78S05CV voltage regulator. The other side of the optocoupler is powered by another 5V input, connected to a relay and the PC817's pin 4. This pin 4 is also powering the base terminal of an S8050 NPN BJT. The transistor's collector is connected to the relay and the emitter is connected to ground. This makes it so that the locking mechanism circuit is entirely dependent on the activation of the optocoupler; an active optocoupler switches on the S8050, completing the circuit and allowing the 12V needed for the linear actuators. Two relays are responsible for the side linear actuators and the other two relays are responsible for the back linear actuators. To extend the relays, pins 12, 27 of the ESP32 are set to LOW while pins 14, 26 are set to HIGH. To retract the relays, pins 12, 27 of the ESP32 are set to HIGH while pins 14, 26 are set to LOW. This will determine the configuration of the specific relay used to power the actuator. During testing, the ESP32 showed to function improperly due to the voltage fluctuation in the 12V input connection. One short-term solution was to attach a 10Ω resistor to the output of each relay so that the linear actuators would respond slower from the voltage drop/current loss. A better response to consider investing resources into would be to integrate a time delay circuit so that this issue is trivial.

GCS Power Distribution

For the powering of the RGS system, a 48V, 100A battery is stepped down to the necessary parameters of each subsystem using a total of eleven buck converters, shown in **Figure 4**. Anderson connectors for the 48V battery-to-system were recommended to ensure safe testing for higher-end low voltage applications (i.e automotive or mid-scale robotics). One buck converter powers the BTP stepper motor, stepping down to 24V, 20A. Eight other converters (17V, 5A) are responsible for the charging circuits for charging the inactive LiPo batteries. Keeping this step-down divided into eight separate buck converters prevents parallel charging or keeps the LiPo battery cells balanced. A 12V, 20A converter powers the locking solenoids of the BVM battery chamber, the robotic arm of the BTP, and the entirety of the GCS. The final buck converter supplies 19V, 5A to the RGS computer. The power consumption of the RGS (**Figure 5**) shows that all loads together draw 716.4W, a lean 14.93% of the total power of the battery potential. Being within the power budget to a significant degree indicates the stability of the system, resistant to higher load requirements from expansion or sudden spikes in power.

Conclusion

Overall, the BANSHEE RGS has been optimized with a more durable and reliable approach. The new design of the BVM and BTP allows the RGS to withstand harsher conditions due to the aluminum structures, as opposed to the previous PLA chambers. A focused design in the GCS locking mechanism circuit favoring the ESP32 over the Raspberry Pi and ATMEGA chips streamlines the microcontroller communication process, fulfilling the same needs and tasks of the GCS while reducing the costs. Each buck converter is designed for a specific subsystem that derives power from a singular 48V, 100A battery. The power consumption of the entire RGS system shows the efficiency of the battery utilization; there is enough left ‘in the tank’ for additional load or for handling unexpected power spikes.

Figures

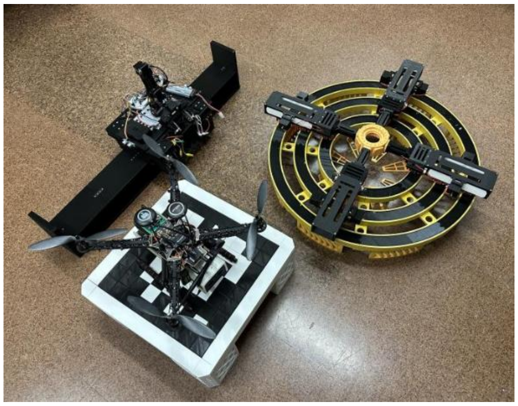

Figure 1, Previous Robotic Ground System

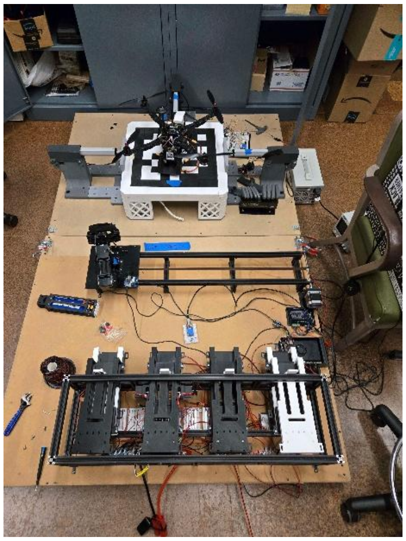

Figure 2: Fully Assembled Robotic Ground System (RGS)

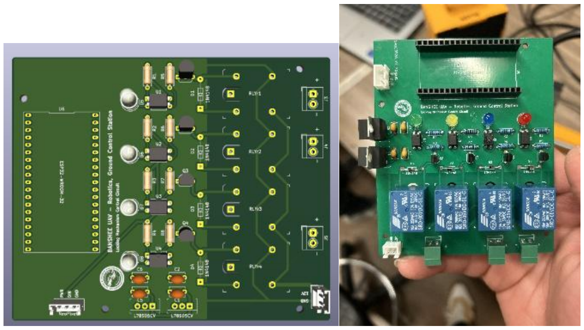

Figure 3: GCS PCB

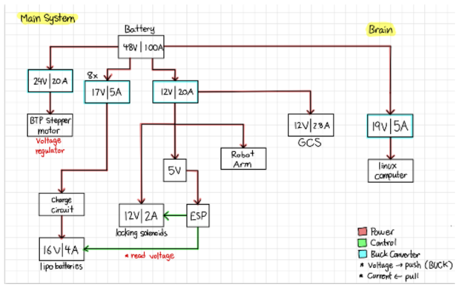

Figure 4: Total Power System

SOURCE	VOLTAGE (V)	CURRENT (A)	AMOUNT	Σ VOLTAGE (V)	Σ CURRENT (A)	POWER SUPPLIED (W)	
Battery	48	100	1	48	100	4800	
LOADS	**VOLTAGE (V)**	**CURRENT (A)**	**AMOUNT**	**Σ VOLTAGE (V)**	**Σ CURRENT (A)**	**POWER CONSUMPTION (W)**	
Robot Arm	12	5	1	12	5	60	
BTP Stepper Motor	24	2.8	1	24	2.8	67.2	
Charge Circuit	17	2.2	3	51	6.6	336.6	
GCS	12	2.8	1	12	2.8	33.6	
Locking Solenoids	12	2	1	12	2	24	
ESP	5	0.2	10	50	2	100	
Linux Computer	19	5	1	19	5	95	
					Σ CURRENT (A)	**Σ LOAD POWER CONSUMPTION (W)**	**% LOAD / SOURCE**
					26.2	716.4	14.93%

Figure 5: Power Calculations

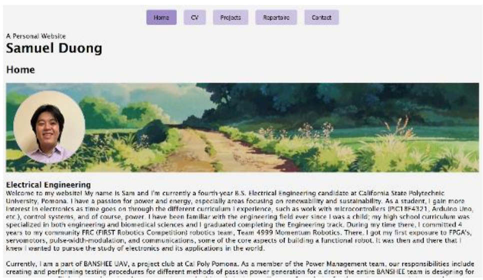

Figure 6: Website Deployment

Work Cited

[1] M. Hoang et al., "Design of Autonomous Battery Swapping for UAVs," *2024 IEEE International Conference on Advanced Intelligent Mechatronics (AIM)*, Boston, MA, USA, 2024, pp. 353-358, doi: 10.1109/AIM55361.2024.10637119.

[2] M. Hoang *et al*., "Designing Regenerative and Sustainable High Endurance Unmanned Aerial Vehicles," *2024 IEEE Conference on Technologies for Sustainability (SusTech)*, Portland, OR, USA, 2024, pp. 212-219, doi: 10.1109/SusTech60925.2024.10553430.