EGR 4830 – Senior Project

CalPolyPomona

Northrop Grumman Collaboration Project - UAV

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1. How long did it take to complete this executive summary? 4 hours
2. Did you attend or watch the lesson provided by Mr. Paul Hottinger regarding Information Literacy (check the correct box)? ☒YES ☐ NO

Northrop Grumman Collaboration Project - UAV

Section I. Introduction

With the rising trend of Unmanned Aerial Vehicles (UAV) and drones, more and more applications have been thought up to utilize these emerging technologies. One such application has been using UAVs to assist in carrying out Search and Rescue missions. In the United States alone there are estimated to be over 100,000 search and rescues that take place every year (1), making this issue a very prevalent one, especially for those who have not been able to recover lost loved ones and family. Due to the nature surrounding search and rescue missions, it can often be difficult, and even life threatening, for the rescuers involved. Many times, after natural disasters physical conditions can be either too harsh or too dangerous for humans to traverse. This issue, combined with the ever-growing improvements to microcontrollers and the creation of increasingly smaller sensors has enabled the implementation of unmanned vehicles in search and rescue missions. The Northrop Grumman Collaboration Project's (NGCP) mission, therefore, is to provide a set of systems designed to successfully perform a simulated search and rescue mission, with the responsibility of designing each system being divided between Cal Poly Pomona and Cal Poly San Luis Obispo. The team at Cal Poly Pomona aims to provide a solution to search and rescue efforts in the form of a UAV system that will be capable of autonomous flight, detecting and locating a lost hiker via radio signal, drop a relief package, and detect a fire while in flight.

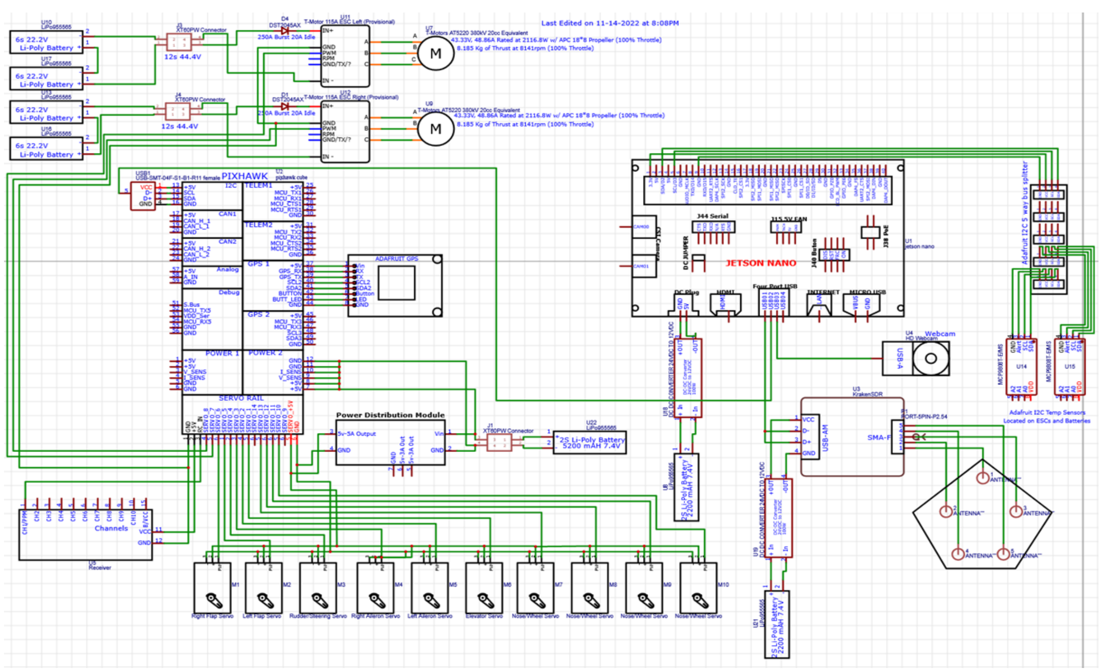
The objective of the project is to design, build and test a group of systems to fulfill a specified Request of Proposal (RFP) assigned by Northrop Grumman to demonstrate the ability to complete a project on a smaller scale of an industry program. This specific mission from Northrop Grumman was the rescue of a stranded hiker and the putting out of a simulated wildfire. The mission involved an unmanned air vehicle tasked in locating the hiker through radio location finding, locating a fire through image detection, and dropping a relief package near the hiker. Once the hiker is located, an unmanned ground vehicle (UGV) picks up the relief package and hiker, then travels to a specified location to await a second UAV. Once the fire is located, the first UAV sends the coordinates of the fire's location to the Ground Control Station (GCS) unit, then relays it to a second UAV, deploying the UAV to put out a simulated fire. From there it will travel to the UGV's location to pick up the hiker and take the hiker to a separate location representing a hospital to drop off the hiker and then return to the vehicle's point of origin. The first air vehicle will return to its point of origin after locating the fire and hiker and dropping off the package, and finally the ground vehicle will return to its point of origin after the hiker was picked up by the second air vehicle. The scale of this mission has been reduced to allow all teams to create feasible builds within the time and budget constraints given.

Section II. Literature Review

Due to the wide range of variation in applications for UAVs to be used in search and rescue missions, there has been a greater push to implement UAVs to perform these missions, removing the risks of losing more human life. Perspectives across the field of engineering and disaster management have all reached a consensus that the utilization of robots over humans would be more ethical, efficient, and effective than sending humans rescuers to retrieve the victims (2). Moreover, human error is inevitable; due to limitations of human perception, vital details can sometimes go by unnoticed, leading to a loss of valuable information and even resulting in greater numbers of fatalities (2). Another widely common perspective among researchers relates to the ethical implications of developing machines that will be tasked with making complex decisions that could lead to the survival or demise of a human life. One of the reasons why humans would still be preferred in search and rescue over solely machine intervention, is the capacity for humans to consider multiple different aspects that extend beyond mere algorithms and calculations. It has become widely accepted that, to reach a point where unmanned vehicles can be confidently relied upon in search and rescue, there must be a set of guidelines that all machines and robot assisted rescue teams must follow. Variation in perspective only differs, not when it comes to whether the resources should be allocated to developing this technology, but in the situational nature of the terrain the vehicles must traverse. In other words, the perspective depends on the conditions in which the search and rescue will take place. The design of the vehicles being developed is almost solely influenced by the sensors and controllers that will be required to perform the mission effectively given the environment (3).

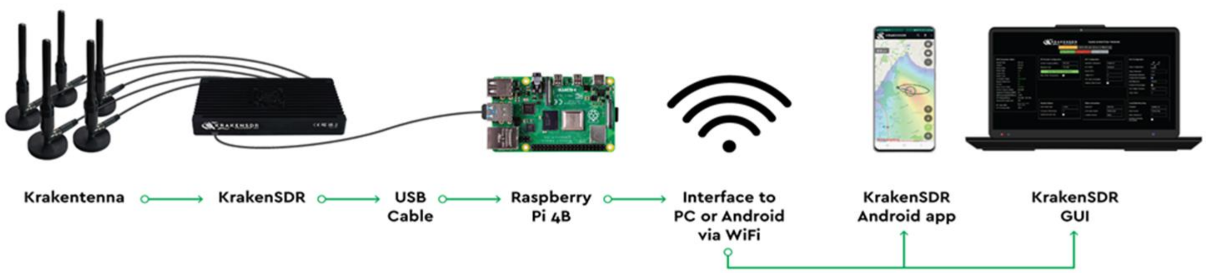
Section III. Results and Discussion

The various electrical systems that have been tested in-flight include the Pixhawk 4 Cube Orange flight computer, an FrSky X8R flight receiver, a 40A electronic speed controller, a 3300mAh four-cell lithium-polymer propulsion battery, a Jetson Nano microcomputer with a 5V buck converter to power it from a 7.4V 2200mAh two cell lithium-polymer battery, a Logitech 1080p webcam, and servos controlling the left aileron, right aileron, elevator and rudder of an E-flite Apprentice STS 1.5m wingspan R/C airplane, which served as a stand-in for the 50% scale model (which had a very restricted total payload capacity) until the 100% scale model can be built by the manufacturing and safety team. In-flight electrical testing on the 100% scale model will consist of an antenna array connected to a KrakenSDR radio-direction finder, and an additional six servos for a total of ten. Below is a wiring schematic of the entire systems and how they will interact with each other.



Results and Discussion Figure a) Electrical Wiring Schematic for Entire UAV

When it came to testing the KrakenSDR, we ran into a few issues early in testing. The first was a problem that we, initially, believed was due to the nature of the hardware itself in that it would take a while for the device to connect to the KrakenSDR server through the web GUI and begin processing data. We carried on while taking this issue into consideration as we moved forward. Then, in later testing, we ran into an issue where one of the antenna's channels stopped working and we believed it to be due to a power surge, which could have happened sometime during testing with a different battery than we had first used in testing. However, after replacing the device for a new one, we found that the new KrakenSDR device connected to the server and began processing data much quicker than the KrakenSDR we had originally received. This fact led us to believe that we initially had a defective device as opposed to a power surge. Our next issue occurred during subsequent testing where all the antenna channels on the KrakenSDR stopped working due to a short in the buck converter, a variable voltage regulator, we had been using. This issue led us to explore other options to replace the buck converter, upon which we decided on a Bel DC/DC Converter.



Results and Discussion Figure b) KrakenSDR Flow Diagram

NON-ISOLATED DC/DC CONVERTERS
4.5 Vdc -14 Vdc Input   0.75 Vdc - 5.0 Vdc/6 A Output

bel

Jan. 25, 2013   ***Bel Power, Inc. , a subsidiary of Bel Fuse, Inc.***

Output Specifications(continued)

Parameter	Min	Typ	Max	Notes
Ripple and Noise (pk-pk)				
Vo=5.0 V	-	100 mV	140 mV	Tested with 0-20 MHz, with 10 uF/10 V tantalum capacitor & 1 uF/10 V ceramic capacitor at the output
Vo=3.3 V	-	80 mV	120 mV	
Vo=0.75 V	-	35 mV	7 0 mV	
Ripple and Noise (rms)				
Vo=5.0 V	-	35 mV	50 mV	
Vo=3.3 V	-	25 mV	40 mV	
Vo=0.75 V	-	10 mV	15 mV	
Turn on Time	-	6 mS	12 mS	
Overshoot at Turn on	-	0%	3%	
Output Capacitance				
ESR ≥ 1mohm	0 uF	-	1000 uF	
ESR ≥ 10mohm	0 uF	-	2200 uF	
Transient Response				
50% ~ 100% Max Load (All outputs)	-	200 mV	350 mV	di/dt=2.5 A/uS; Vin=12 V; and with 10 uF/10 V tantalum capacitor & 1uF/10 V ceramic capacitor at the output.
Settling Time (All outputs)	-	25 uS	50 uS	
100% ~ 50% Max Load (All outputs)	-	200 mV	350 mV	
Settling Time (All outputs)	-	25 uS	50 uS	

Results and Discussion Figure c) Data Sheet of Bel DC/DC Converter to Power Kraken SDR

The onboard computer we have chosen that will handle the majority of the data processing and communications with GCS is the Jetson Nano 4gb. This small yet powerful computer was chosen over other choices given its low power consumption, the high amount of port availability outside of the 40 pin GPIO (general purpose input/output), and a Quad-core ARM A57 CPU that will enable the high levels of data processing involved in performing communications with GCS, radio location finding, and image detection aboard the UAV. Due to the Jetson Nano running Linux as its operating system, we had to choose electronics that would be compatible with Linux. To confirm our sensors and other components would be compatible with the Jetson Nano and the batteries would be sufficient to power all our components, we tested each component individually before testing the entire system together. Through these tests, we were able to confirm that all necessary devices, those being the KrakenSDR, the flight controller, and the camera for fire detection, could effectively communicate with the Jetson Nano.

Section IV. Conclusion

In conclusion, the architecture selected has undergone enough consideration, testing, and review to confirm that the system of systems has the technological capability to carry out the mission specified in Northrop Grumman's RFP. The embedded systems needed for the mission, such as sensors and flight controllers, have been flown during subsystem testing on the UAV to demonstrate their independent functionality. Along with wind tunnel and propulsion testing, we also built a half-scale model to demonstrate the aircraft's aerodynamics and ability to fly for the duration and speed necessary to finish its component of the mission. Both discussed the advantages and disadvantages of the selected aircraft architecture as well as the derived requirements presented. While these criticisms have been mitigated or corrected, the following were their main points: The requirements gave no priority ranking to the finding of the hiker and hotspot, given the named objective of the mission is the rescue of the hiker, an emphasis should be able to be seen by the customer to ensure the decisive hierarchy of action taken in the mission.

Work Cited

[1] National Oceanic and Atmospheric Administration, “Search and Rescue | SARSAT,” *www.sarsat.noaa.gov*. https://www.sarsat.noaa.gov/search-and-rescue/

[2] H. Chitikena, F. Sanfilippo, and S. Ma, “Robotics in Search and Rescue (SAR) Operations: An Ethical and Design Perspective Framework for Response Phase,” *Applied Sciences*, vol. 13, no. 3, p. 1800, Jan. 2023, doi: https://doi.org/10.3390/app13031800.

[3] Y. Naidoo, R. Stopforth and G. Bright, "Development of an UAV for search & rescue applications," IEEE Africon '11, Victoria Falls, Zambia, 2011, pp. 1-6, doi: 10.1109/AFRCON.2011.6072032.