UAV Team High Level Design

Rachel Bonek, Kevin Conway, Stephen Jackson, Tom Pollei, Michael O’Brien
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1 Introduction

Our team shall be designing the unmanned aerial vehicle (UAV) payload electrical systems for Notre Dame's NASA Student Launch team. Included responsibilities are management of power, flight controller, onboard microcomputer and camera, and electronic speed controllers. Our UAV shall have the capability to automatically detect and navigate to a target where a navigational beacon shall be deployed.

The official competition description per NASA's website is as follows:

> "The NASA Student Launch (SL) is a research-based, competitive, and experiential learning project that provides relevant and cost-effective research and development."
>
> "Student Launch reaches a broad audience of colleges, universities, and secondary institutions across the nation in an 8-month commitment to design, build, launch, and fly a payload(s) and vehicle components that support NASA research on high-power rockets. The College/University Division challenge is based on team selection of one of the following experiment options: 1) deployable rover and soil sample collection or 2) deployable unmanned aerial vehicle and delivery of a navigational beacon."

This year Notre Dame Rocketry Team selected experiment option 2, a deployable UAV. NASA's Student Launch competition runs from August to April, with Launch Day scheduled for April 6, 2019. During these 8 months, the team will complete a series of design reviews that resemble the NASA engineering design lifecycle.

This document includes the high level design details not already included in our Preliminary Design Review (PDR), which was written with the Notre Dame Rocketry Team for NASA's student launch competition. Our Preliminary Design Review includes our project requirements, system diagrams, and high level design decisions. This High Level Design report includes future enhancement requirements, open questions, major component costs, and general conclusions.

2 Future Enhancement Requirements

The UAV will have a large variety of capabilities, but the constrained time schedule, limited budget, and overall design constraints have provided limits on the UAV's total capability. If time, budget, and weight restrictions allowed, the following capabilities would be assessed.

I. Two fixed cameras or one camera on a gimbal

The current camera system design utilizes one camera at a fixed angle. Consequently, the field of view is limited and may only be adjusted by repositioning the entire UAV. An enhanced camera system with two cameras could be arranged with one camera at an angle and one camera facing directly downwards. This configuration would allow the UAV to detect a target off in the distance and provide first-person view, while also providing a visual of the ground for positioning, beacon deployment, and landing. A one-camera, gimballed system would provide the same features in a different way by simply actuating the gimbal to face downwards.

II. Robotic folding arms

The current loading sequence requires the arms of the UAV to be manually folded and then placed inside the rocket body. Each arm is under constant force from a spring during takeoff, flight, and landing, and this force is not removed until the UAV is completely deployed. The deployment sequence starts with a lead screw that will gradually extend the UAV payload platform out of the rocket body. As the UAV arms clear the walls of the rocket, they are free to open under the force of the springs. The spring design poses two issues. First, the constant force on the arms increases the wear and tear of the arms and decreases their lifetime. Second, as the UAV begins to clear the wall of the rocket, there is a possibility that the arms, under force from the springs, will push off the rocket and destabilize the UAV on the payload platform. Arms equipped with actuators and controlled by the onboard system would provide increased control over the entire UAV and would mitigate the negative effects of an all-mechanical system. There are potential downsides such as battery life and loss of control, but quality design could avoid these issues.

III. LTE Video Stream

Most telemetry setups for video streaming use an antenna and broadcast over 915 MHz, however 4G and 4G LTE video streaming options are becoming increasingly common. These options provide longer range and faster speeds, overall providing a better first person view experience with less latency and less data loss. The packages available are not light or cheap enough for the current design. In the future when more money becomes available, a slight redesign to reduce weight will be necessary to add video streaming capabilities over 4G, 4G LTE, or maybe even 5G.

3 Open Questions

Our team has yet to establish communication between the onboard CPU — the Raspberry Pi 3B, and the flight controller — the Pixhawk 4. This data stream is critical to autonomous flight, as the Raspberry Pi would send coordinates to the flight controller once the beacon deployment target is detected. Further research will be necessary to determine which protocols can be used to successfully achieve this goal. If this issue is not able to be resolved, the live stream video feed can be utilized to manually pilot the UAV.

Another system that our team must integrate into the design is the beacon deployment servo motor. Although we believe that the flight controller can send a signal to control the motor, we are unsure of how this will be achieved. Furthermore, we currently do not know how to command the Pixhawk 4 to send this signal to the servo motor.

Although some of our team members have previous experience building and testing drones, our drone has not yet flown. Thus, we must ensure that our intended software, telemetry, and flight controller all communicate properly. Additionally our electrical systems have not been tested, so there is a possibility that components could be wired incorrectly. The effects of physical complications such as balance are also currently unknown. Our team plans on flying the drone prior to the end of the semester, so some of these uncertainties should be answered soon.

Currently, our team intends on using a push button fixed to one of the drone's arms to power it on. The switch will be normally closed and will be pressed open while the drone is in the rocket, preventing power from flowing. Once the drone is deployed the arms will unfold, releasing the button and powering it on. We have not selected a button yet, so we must find one that fulfills our requirements. Our team is also concerned with how this button will react to the rocket's flight and if it will falsely power on the drone before deployment. A toggle switch is a potential alternative, and this would likely reduce the possibility of falsely triggering the power-on sequence. Another alternate power-on mechanism may be required if one of these two options does not solve these issues.

4 Major Component Costs

Below is a table detailing the main component costs.

Part Description	Part Name	Quantity	Cost (Each)	Total Cost
Motor	T-Motor MN1806 KV1400	6	25.9	$155.40
ESC	Lumenier 18A 32bit Silk ESC OPTO (2-4s)	6	9.99	$68.41
Plastic Prop		5	2.55	$12.75
Pixhawk 4		1	220	$220.00
Battery	Turnigy nano-tech LiPo	2	40.25	$80.50
Charger	Keenstone Battery Charger 10A Lipo	1	49.99	$49.99
Adapter Rings		1	2.49	$2.49
Zip Ties		1	13.98	$13.98
Velcro straps		1	8.99	$8.99
Metric Screws		1	11.99	$11.99
MT60 Connectors		1	14	$14.00
XT60 Connectors		1	7.45	$7.45
XT90		1	9.99	$9.99

Connectors				
RPi3 B		2	35	$70.00
Transmitter	Spektrum Dx6e *(on loan from CSE Dep't)*	0	170	$0.00
Telemetry Set	Transceiver Telemetry Radio Set V3	2	45	$90.00
Camera	RPi Cam v2	1	30	$30.00

5 Conclusions

Designing the UAV system components and system architecture is not a trivial task. Each component was selected through an engineering design iteration with flight time and power consumption driving the decisions. It is imperative that the system does not fail during performance, and the design includes redundancies to ensure smooth UAV operation. The UAV will be able to update its destination autonomously without ground station intervention, but the ground station has the ability to intervene in the event of autonomous system failure. In the event that the UAV cannot autonomously move to the GPS destination, the ground station team will have the ability for manual flight takeover.

The most difficult capabilities have been identified as follows: basic flight, target detection, interfacing between onboard computer and flight controller, live video streaming, and system power on. Target detection is not our responsibility, but we are responsible for the other three requirements.

Relevant PDR pages:

68 - Mission Success Criteria
69 - 70: UAV Electrical Design Trade Study
79 - 87 : UAV Electrical Design