# Senior Design Proposal

# Notre Dame Rocketry: UAV Design

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## 1 Introduction

Our team shall be designing the UAV payload electrical systems for Notre Dame's NASA Student Launch team. Included responsibilities are management of power, flight controller, onboard microcomputer, 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 - April, with Launch Day scheduled on April 6. During these 8 months, we will complete a series of design reviews that resemble the NASA engineering design lifecycle.

## 2 Problem Description

Below are NASA's explicit requirements for the Student Launch UAV Payload subsystem:

> Payload Experiment: College/University Division – Each team will choose one experiment option. This year NDRT chose Option 2: Deployable UAV/Beacon Delivery.
>
> Key NASA Student Launch Competition 2018-2019 Requirements:
>
> > 4.4.1 Teams will design a custom UAV that will deploy from the internal structure of the launch vehicle

4.4.2. The UAV will be powered off until the rocket has safely landed on the ground and is capable of being powered on remotely after landing.

4.4.5. After deployment and from a position on the ground, the UAV will take off and fly to a NASA specified location, called the Future Excursion Area (FEA). Both autonomous and piloted flight are permissible but all reorientation or unpacking maneuvers must be autonomous.

4.4.8. Once the UAV has reached the FEA, it will place or drop a simulated navigational beacon on the target area.

4.4.10. Teams will ensure the UAV's batteries are sufficiently protected from impact with the ground.

4.4.11. The batteries powering the UAV will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other UAV parts.

Implicit requirements are that the UAV must be able to sustain flight for long enough to detect and navigate to the designated target to deploy a beacon. Furthermore, an onboard system must be established for communication with a ground station, and the aforementioned targeting system must be established. System weight must be minimized because the allocated mass for the UAV and deployment system is small.

## 3 Proposed Solution

The UAV will be a quadcopter with four brushless motors. The arms of the quadcopter will be spring-loaded and will be folded during rocket flight. Once the rocket has landed and the UAV is deployed from the payload housing, the spring loaded arms will unfold. To limit weight while retaining durability, a carbon fiber body will be fabricated.

A camera and onboard computer will be mounted to the UAV for video and image processing necessary to detect the beacon deployment target. Once detected, the coordinates will be communicated to the flight controller directly from the onboard computer. Telemetry on the computer and the flight controller will be established to transmit GPS coordinates and a video stream to the ground station.

The beacon will be deployed with a servo motor once the target has been reached.

## 4 Demonstrated Features

Once the UAV system is completed, there will be five main features that it shall demonstrate.

To preserve power and meet NASA requirements, the UAV shall remain powered off until deployment.

Upon landing, the remote deployment officer, a NASA representative, will verify that the drone is safe to fly. Following a go-ahead signal from the remote deployment officer, the deployment mechanism (designed by other members of the Notre Dame Rocketry team) will deploy the UAV from the rocket body.

The UAV shall then takeoff into the air and establish its GPS location. It shall conduct a search for the beacon deployment target by following a dynamic search path.

Once the target has been detected, the onboard computer shall update the flight controller GPS coordinates and approach the target.

While hovering above the target, the UAV shall deploy the beacon onto the target. Finally, the UAV shall return home and land.

## 5 Available Technologies

We have selected the following components:

1. Motors

The three motors considered were all products from T-Motor, a trusted and reputable RC motor company. These were the MN1806, MN2212, and Antigravity 4004. FPV motors were also looked at because they offer a very high thrust to weight ratio, however the current draw is too high for our system and would require a battery that would have put us outside of weight allowance. The Antigravity motor was considered because it provides the most thrust per Watt, however we did not choose it because the total thrust provided was more than we needed, even on the lowest end. Comparing the MN1806 to the MN2212, the MN1806 fit our 30-40 oz thrust range, and it also outperformed the MN2212 in thrust per watt while weighing 45g less per motor. For this reason, we moved forward with the MN1806 KV1400 motor from T-Motor.

2. Props

The options for props was narrowed down greatly by the specifications for the selected motor. The motor we chose provides data for props between 5 and 9 inches. The prop ultimately selected was the Multirotor Carbon Fiber T-style Propeller 7x2.4. This was chosen because of its length, thrust capability, and required battery size. It is a two-blade prop that is short enough to fit into the payload bay when implemented into the body that we have designed. Also considered were longer props and four-blade props. Their advantage was greater thrust at a given voltage. However, they were too large to fit in the payload bay and had to be discounted. When comparing the 7 inch option to the other size options, the 7 inch prop was the only prop size that provided enough thrust.

3. Electronic Speed Controllers (ESC)

The ESC ultimately selected was the Lumenier 18A 32bit Silk ESC OPTO (2-4s). This was selected primarily based on its amperage rating, corresponding to the required amperage rating of the selected motor.

4. Battery

The battery ultimately selected was the Turnigy nano-tech 4500mAh 3S. This provided enough power for the selected ESC's and motors for the desired flight time (around 9-14 minutes). This was an upgrade in terms of capacity from a 3000mAh battery once it became clear we needed more flight time.

5. Raspberry Pi 3B

Onboard Pi 3B performs all target detection processing and sends coordinates to the flight controller. This solution protects from communication loss with the ground station. Our team selected this CPU for our UAV due to the reduced complexity in wireless communication.

6. Pixhawk 4

Compared to the Pickawk Falcon, the Pixhawk 4 is faster, has onboard heating for cold weather testing, has more connection ports including a servo rail that is useful for power splitting. Despite having several more features, this option is not significantly larger or heavier than the Pixhawk Falcon. Thus, our team selected this model to use for our UAV.

7. Ground station

For the ground station, our team will be utilizing two separate laptops for increased viewing screen real estate. One will be receiving video stream from telemetry with the Raspberry Pi 3B, and the other will be utilized to observe real time UAV coordinates.

8. Handheld transmitter

The main metrics for the transmitter were compatibility with the Pixhawk and the cost. In the end, the Spektrum Dx6e was chosen because it is more economical compared to other Spektrum transmitters. Also considered was the Taranis Qx7, because of its price point, however the transmitter does not transmit using the DSM/DSMX communication protocol and would require additional adapters and converters that add cost and weight to the UAV.

9. Pi Camera Module V2

This model is standard camera module that integrated with Raspberry Pi CPUs. It provides 8 megapixels of resolution, and can take high resolution videos as well as still photographs. We would use this device to stream constant video to our Raspberry Pi 3B, which can then be used either for target detection or manual flight. Thus, our team selected this model.

## 6 Engineering Content

The UAV system will be designed such that it will be able to fulfill its mission with complete autonomy. However, the system will also have a redundancy such that a switchover to manual flight control is possible. The UAV will fly a preprogrammed flight plan upon deployment from the drone. During flight, the onboard CPU, a Raspberry Pi 3 Model B, will process data from the onboard camera using a search algorithm to detect the target. Once the target has been detected, the onboard CPU will upload a new flight plan to the flight controller (a Pixhawk 4).

In the interests of redundancy, the onboard CPU will stream the visual data via telemetry from the onboard camera to a CPU on the ground (also a Raspberry Pi 3 Model B) which will display the data for first person view. There will also be a telemetry link between the flight controller and the ground station (laptop). This will provide real time spatial coordinates of the UAV visible on Google Maps. Lastly, there will be a handheld controller for use in the case where manual takeover is deemed necessary. An overview of the Communication System architecture is visible in Figure 1.

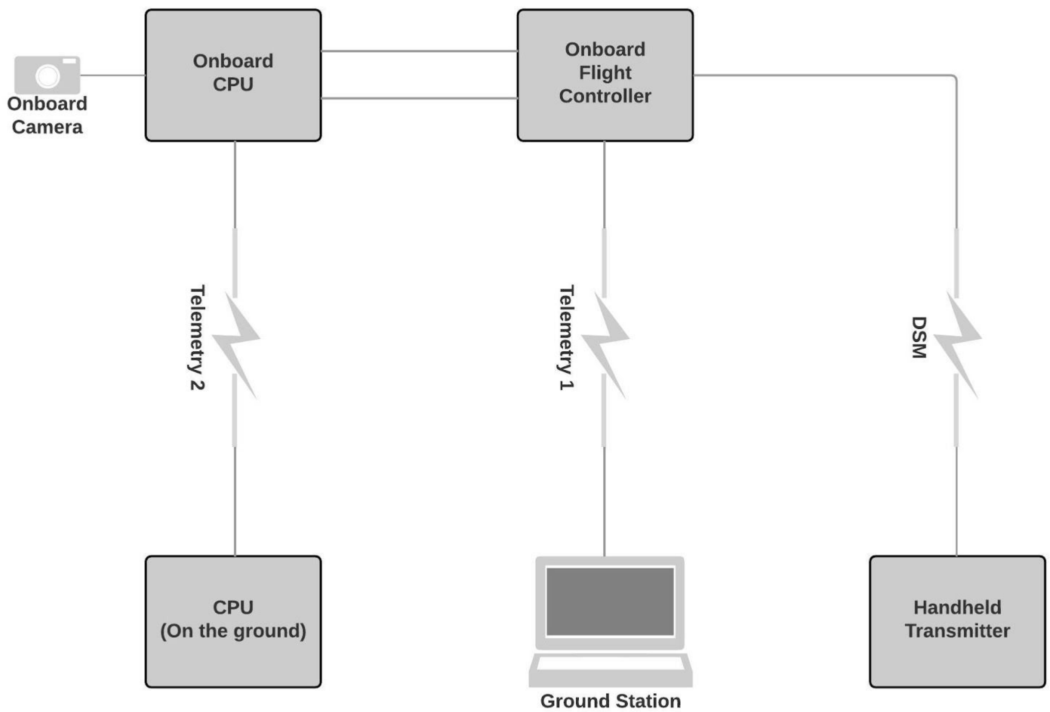


FIGURE 1: Communication System Architecture

We will use a Button-on-Arm power-on system includes two mechanical buttons and two contacts, one per arm. The first button will be inserted between the power distribution board and the flight controller, and it will be placed on the side of the UAV body. The second button will be placed between the power distribution board and the onboard CPU, and it, too, will be placed on the side of the UAV body. The contact will be a small plastic rod placed on the inside of one of the UAV arms. While the UAV is folded and inside the rocket, the contact will push the button and prevent the power distribution board from powering the flight controller and CPU. During the deployment sequence, a torsion spring will unfold each of the four arms. Once the arm with the button-contact interface unfolds, the contact will no longer press the button and the power distribution board will power on the electrical system. This design consumes no electrical power and removes the potential for the system to turn on due to battery depletion, as might be the case for an electromagnetic relay. An overview of the systems architecture is visible in Figure 2.

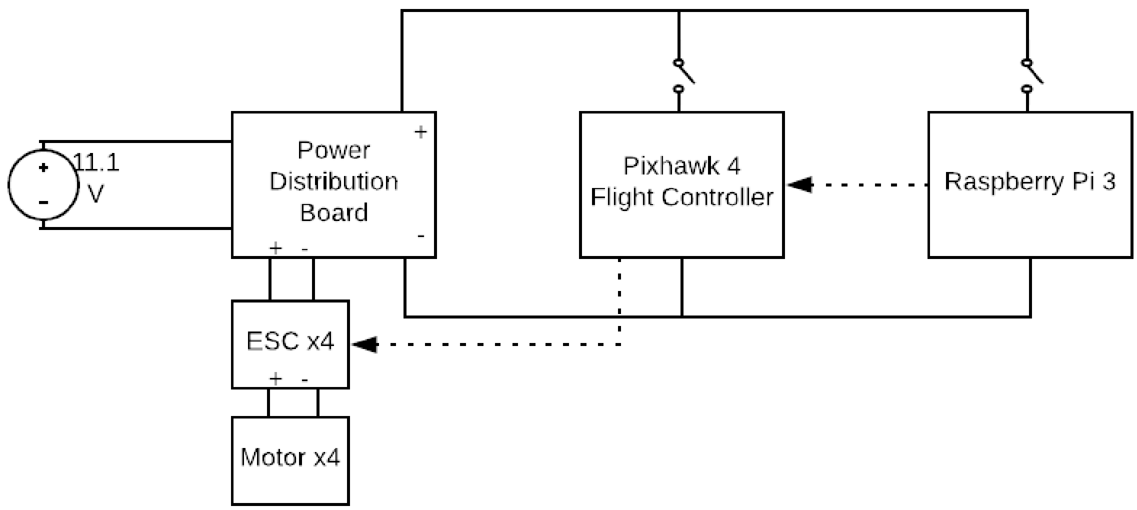


FIGURE 2: Systems Architecture

## 7 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 leading the decisions. It is imperative that the system does not fail during performance, and we have designed in redundancies to keep the UAV operating. The UAV will be able to update its destination autonomously without ground station intervention, but the ground station has the ability to override in the event of failure. In the event the UAV cannot autonomously move to the GPS destination, the ground station team will have the ability for manual flight takeover.

We will be operating on an accelerated schedule compared to the rest of the EESD class. As such, we plan to demonstrate the majority of our capabilities by the end of the fall semester. We've identified the most difficult capabilities to be target detection, communication and GPS update 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.