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Senior Design

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20 October 2020

Rocketry Team Payload Proposal

1. Introduction

Our Rocketry Payload design will be a planetary landing system (PLS) that fits the configuration constraints given to us by the National Aeronautics and Space Agency (NASA) for the NASA Student Launch competition, in which the Notre Dame Rocketry Team (NDRT) participates annually. This landing system will be launched inside of a rocket, deployed at a defined height, and land in an upright configuration. After the landing system reaches the ground, it will proceed to perform two pre-assigned tasks outlined in the requirements set forth by NASA in the NASA Student Launch Handbook (NSLH). The mission the PLS will perform is twofold. First, the system will deploy a camera apparatus that will take a 360-degree panoramic photo of the surrounding landscape. For the second task, the system will then transmit this photo wirelessly to a host computer.

2. Problem Description

The senior design team is tasked with building a PLS that will ascend with the rocket to an apogee set by the rocket team. Before launching the rocket, both the rocket and the PLS must be able to remain launch-ready on the launching pad for a minimum of two hours, as stated in requirement 2.7. The PLS is then jettisoned from the rocket between 500 and 1000 feet above ground level (AGL). It must land either in an upright position or upright itself completely autonomously within a five-degree tolerance from vertical, and the team must record both the initial and final angles relative to the vertical position. After righting itself, the PLS will take a panoramic 360-degree picture and transmit it to the team for inclusion in a report at a later date. These requirements are all set forth in section 4.3 of the NSLH.

3. Proposed Solution

The system can be broken down into the following subsystems: Orientation Correction, Imaging, and Wireless Transmission. The first of these subsystems reorients the PLS so that it is upright, within a 5-degree margin from the vertical. The imaging subsystem is composed of the camera or cameras that will take the panoramic picture. Finally, the wireless transmission subsystem includes the wireless interface that will transmit this picture to the team.

4. Demonstrated Features

Each of the system's demonstrated features directly contribute to the solution of the original problem. The first demonstrated feature is the launch of the PLS at competition, during which the system must be able to remain powered for at least two hours, and ascend safely in the rocket to then be deployed between 500 and 1000 feet AGL. The next demonstrated feature is the successful upright landing and reorientation of the PLS within a 5-degree tolerance with respect to vertical. By properly designing the orientation system, multiple safeguards and mechanisms strongly aid in the ability for the system to land in an upright position. This is necessary for the camera to be able to adequately take a panoramic photo. The third demonstrated feature is the taking of said photo, where the landing system actuates a grid of cameras and takes a panoramic photo. Our design has four cameras, each taking a photo which will be combined to form the continuous image, as opposed to using a rotating camera to capture a single panoramic picture. The next demonstrated feature is the transmission of the panoramic photo to the team for observation. The digital transmission will require radio frequency (RF) transmission. The final feature is the overall success of the system. The launch will be overlooked by NASA and a successful demonstration is the combined function of the upright landing, capture of the photo and the transmission of the photo.

5. Available Technologies

The senior design team, in conjunction with members of the NDRT, realized a series of trade studies to determine the components and high-level system designs that will be used in the PLS. Table 1 below describes the three particular technologies that were determined as best fit to complete the tasks. If the budget given by the course is insufficient for our needs, we are fortunately able to use funds from the NDRT.

Table 1. Required Technologies

Item	Quantity	Cost per unit
Raspberry Pi Zero	2	$5.00
Raspberry Pi Camera Module	4	$28.99
Multicam Adapter Module	1	$50.00
RF Transceiver Pair	1	$1.90
Antenna	1	$0
9-DOF Absolute Orientation Sensor	1	$34.95

3.7 V Lithium-Poly Battery	1	$12.50
Boost Converter	1	$10.00
Total	**11**	**$225.31**

We determined that a Raspberry Pi Zero microcontroller would be the best fit for the tasks that we intend to complete in our project. Its small size, and consequently its low weight, were major factors when considering this particular component. Furthermore, it is also extremely easy to interface between the Pi Zero and the other components of the system.

Cameras will be necessary to capture the panoramic picture needed to complete the main mission of the PLS. The photograph will be captured utilizing four cameras, each at a 90-degree angle with respect to each other. This system, though larger and more electronically complex, will reliably capture an image of sufficient quality that can be easily 'stitched together'. This system is also mechanically simpler than the considered alternatives (one camera with either a motor or a mirror), which translates into a more compact design. The chosen camera for this mission is the Raspberry Pi camera module with a wide-angle lens, which can easily connect to the Pi Zero. There are devices available that will allow us to split the singular camera port in the Pi Zero into four separate camera ports, which is ideal for our system.

We will require a wireless interface between the team and our landing system so that the system has the ability to transmit those photograph captures it has performed. The team has chosen an RF transceiver pair that can transmit well over 500m. An antenna is also needed to accomplish this. We will need to learn about different types of antennas in order to design an optimal communication system. A preliminary analysis has shown that a dipole antenna might work well, due to the fact that our lander will be righting itself in a consistent manner. We will need to explore other options such as horn, clover, circle, and monopole antennas to make a final decision.

Finally, NASA requires that the angle before and after orientation is recorded. The team has chosen to use a simple inertial measurement unit for this purpose.

6. Engineering Content

Use of the Pi Zero for the imaging and transmission subsystems requires knowledge of coding, specifically with embedded systems and image processing. This code will require extensive testing and debugging. Use of transceivers requires knowledge of communication systems. The system overall needs to be designed to be as space-efficient as possible and needs to have a very low risk for component damage due to the physical constraints it will encounter throughout flight and landing. This will require a knowledge of physics and testing of the physical restraints of our design, as well as good communication with other members and subsquads of the NDRT.

7. Conclusions

We are very fortunate to have the opportunity to collaborate with the NDRT on a multi-part project that requires a lot of coordination and cooperation. There are some limitations that we will have to work around, such as our budget and the ability to work in a physical space due to COVID-19, but these will push us to be more adaptable and regardless still lead to a highly technical experience throughout the whole process. Our three goals of landing, photographing, and transmitting are our technical goals, but our overall goals are to grow as a team and be able to learn skills that we can apply to whatever projects we work on in the future. Although we will face challenges during the implementation of this design, our teamwork and communication will allow us to persevere in these exciting electrical engineering applications.

Parts:

RF Transceiver:

https://www.electrodragon.com/product/433m-rf-wireless-module-a-pair-of-receiver-and-transmitter/

Raspberry Pi Zero:

https://www.pishop.us/product/raspberry-pi-zero/?src=raspberrypi

9-DOF Sensor:

https://www.adafruit.com/product/2472

Wide Angle Camera Module:

MultiCamera Adapter Module