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Notre Dame Rocketry Team
Planetary Landing System

EE Senior Design 2021
Final Report

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I. Summary

The Planetary Landing System (PLS) is this year's experimental payload, capable of jettisoning from the launch vehicle, landing, reorienting, and capturing and transmitting a 360 degree photo autonomously. The PLS will be retained within the payload bay during flight, and deployed at an altitude of 525 ft. Following deployment, it will descend under a parachute, land, and use three actively-controlled legs to orient within 5 degrees of the vertical (NASA Req. 4.3.3).

II. Imaging

This payload will need to take a 360-degree image of the landscape after landing (NASA Req 4.3.4). To achieve this, the team will be utilizing four Raspberry Pi cameras with wide-angle lenses. The cameras will be offset 90 degrees from one another. With a horizontal field of view of approximately 120 degrees, the cameras will be able to capture a 360 degree image fracture into four pictures that will be stitched together after they are transmitted to the team. The camera is shown in Figure 1, while the lens is shown in Figure 76. This setup will provide enough image data to construct the required panoramic image.

Figure 1. Raspberry Pi Camera (left) & Wide Angle Lens (right)

The Raspberry Pi only has one input port for a camera, so the team will need to utilize an additional device in order to connect 4 cameras. These cameras will be connected utilizing a

ArduCam Multi Camera Module. This module is shown in Figure 2. This will allow the team to take a picture on each individual camera. The images taken are stored in a .jpg file format, which will allow for easy manipulation and processing later on.

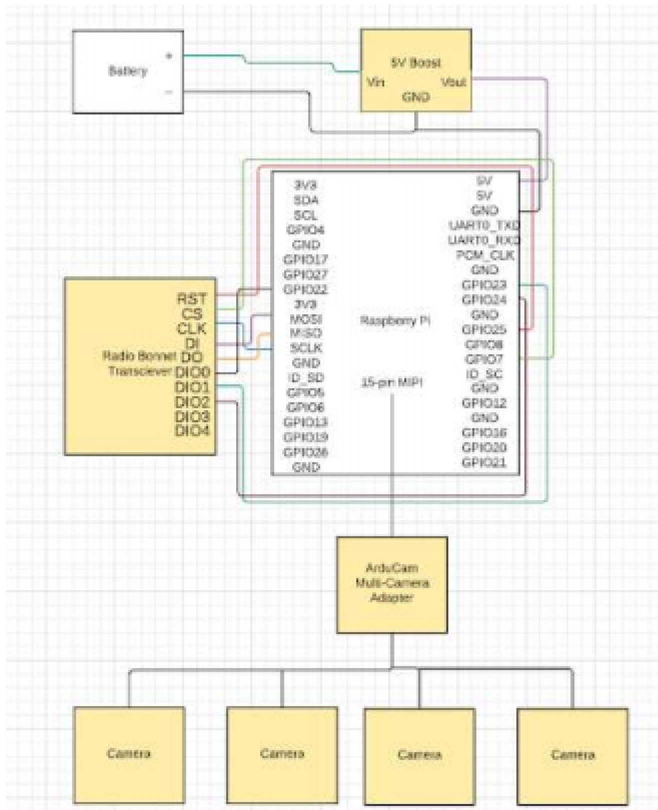
Figure 2. ArduCam Multi Camera Module

After the images are taken, they will be stitched together utilizing a Python OpenCV algorithm. This will generate the desired 360-degree image file, which will be sent through the data transmission subsystem. Because the Raspberry Pi utilizes the Linux kernel and has a file system, the four initial images and the final panoramic image will be able to be stored in flash memory for easy accessibility. This system will be powered by a 3.7 V battery connected to a 5 V boost converter, which will permit this payload subsystem to be powered for at least 2 hours on the launch pad (NASA Req 2.7, NDRT Req RF.7, NDRT Req RE.3).

III. Wireless Transmission

The last subsystem of the PLS is the wireless data transmission of the image data to a host computer at the landing site (NASA Req 4.3.4). In order to complete this task, the team will be utilizing two Raspberry Pis and a radio bonnet. One Raspberry Pi will reside in the PLS, while another Raspberry Pi will be located at the launch site. The Raspberry Pi in the PLS will act as a transmitter, while the Raspberry Pi at the launch site will act as a receiver. A schematic of the subsystem is shown in Figure 3 below.

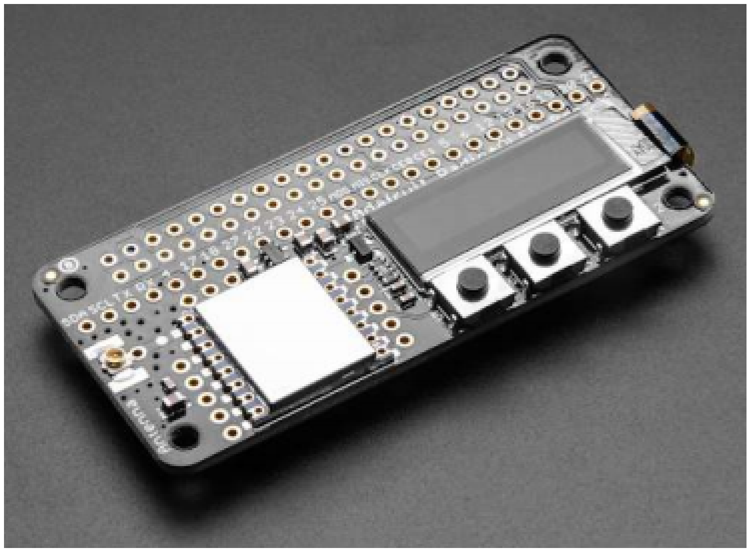
Figure 3. Schematic of Data Transmission and Imaging Subsystems



This system will be powered by a 3.7 V battery connected to a 5 V boost converter, allowing this payload subsystem to be powered for at least 2 hours on the launch pad (NASA Req 2.7, NDRT Req RF.7, NDRT Req RE.3). The transmission itself will be handled by a pre-packaged radio transceiver developed by Adafruit and the LoRa Radio Bonnet RFM96W. This device will allow the team to very easily transmit and receive data using a pre-packaged Adafruit API. The data will be transmitted using the LoRa scheme over a 433 MHz carrier wave, which can carry a signal over 2 km. This distance varies with antenna schemes, so the team will need to test to determine the distance at which the transceivers lose sight of one another. The distance of 2 km was measured by Adafruit using an omnidirectional antenna, so the switch to a dipole antenna should increase the range of transmission. This device also allows for handshaking and confirmation signals, to ensure that the data packets were received properly and mitigate data loss.

The image will need to be split into smaller packets in order to be transmitted over the system, which will be done using OpenCV. Furthermore, this device will allow for easy debugging on an LCD, and includes push-buttons. Each of these devices will be connected to a dipole antenna, which was chosen due to the consistent orientation of the subsystem.

Figure 4. Adafruit LoRa Radio Bonnet RFM96W



This system will be compact enough to fit directly on top of the Raspberry Pi, and the antenna will be oriented directly upward in the payload.

IV. Bill of Materials

	Quantity	Per-Unit Cost	Total Cost
Power Boost 1000 Basic- 5V USB Boost @ 1000mA from 1.8V+	2	$14.95	$29.90
Raspberry Pi 3- Model B	2	$35.00	$70.00
SMA to uFL Adapter Cable	2	$3.95	$7.90
Li-ion Battery Pack- 3.7V 4400mAh	2	$19.95	$39.90
Micro B USB to USB C Adapter	2	$1.25	$2.50
Simple Spring Antenna 915MHz	2	$0.95	$1.90
16GB SD Card w/ NOOBS 3.1 for Raspberry Pi	2	$14.95	$29.90
Adafruit LoRa Radio Bonnet w/ OLED- RFM95W @ 915MHz	2	$32.50	$65.00
Raspberry Pi Camera Board v2- 8 Megapixels	4	$29.95	$119.80
Raspberry Pi Camera V2 [1]	8	$12.50	$100.00
Wide Angle Lenses [2]	6	$30.00	$180.00
Adafruit LoRa Radio Bonnet w/ OLED- RFM96W @ 433MHz	2	$32.50	$65.00

Extra-long breakaway 0.1" 16-pin male header strip (5 pieces)	2	$3.00	$6.00
Servos	4	$31.99	$127.96
Arduino Nano	1	$20.70	$20.70
ADXL345 Triple-Axis Accelerometer	1	$17.50	$17.50
2000 Series Dual Mode Servo	6	$31.99	$191.94
Quarter-Wave Whip Antenna @ 433 MHz [3]	1	$0.00	$0.00
Dipole Antenna @ 433 MHz ANT-433-CW-HWR-SMA [3]	1	$0.00	$0.00
			0
			0
Taxes		$17.29	$17.29
Taxes		$16.03	$16.03
Shipping		$27.56	$27.56
Totals	52	$394.51	$1,136.78
NDRT Total		$251.73	$752.49
Class Total		$142.78	$384.29

Key:

Fully funded by NDRT
Partly funded by NDRT

Notes:

[1] We ordered an additional four cameras, then received a refund on the original set. We had eight total cameras for a functional per unit price of $12.50.

[2] Senior design funded four units, while NDRT funded two units.

[3] These components were not purchased. They were taken from the Telemetry Senior Design SP20 project.

V. Finalized Pin-Out Diagram