Stephen Bolster
Len Pieroni
Diego Calvillo
EE 41430 Senior Design
NDRT Payload Project Proposal

Introduction

Every year, the Notre Dame Rocketry Team (NDRT) competes in NASA's Student Launch Initiative and a team of electrical engineering seniors design their payload for the competition. Previous teams have built Unmanned Aerial Vehicles, an Unmanned Ground Vehicle, and a panoramic camera lander. This year, the senior design team will collaborate with members of NDRT to build a flight tracker that records data from an array of sensors during flight. After landing, that data will be used to calculate the rocket's final position relative to its launch site and both the launch site and the landing site will be mapped onto a satellite image of the landing zone with an overlaid grid.

Problem Description

The requirements provided by NASA which are relevant to this senior design project are listed below. For the full list of payload mission requirements, see pages 13-14 of the 2022 NASA Student Launch Handbook.

NASA Student Launch Handbook:
https://www.nasa.gov/sites/default/files/atoms/files/2022_nasa_students_launch_handbook.pdf

4.1. College/University Division – Teams shall design a payload capable of autonomously locating the launch vehicle upon landing by identifying the launch vehicle's grid position on an aerial image of the launch site without the use of a global positioning system (GPS). The method(s)/design(s) utilized to complete the payload mission will be at the teams' discretion and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge.

4.2.1. The dimensions of the gridded launch field shall not extend beyond 2,500 feet in any direction; i.e., the dimensions of your gridded launch field shall not exceed 5,000 feet by 5,000 feet.

4.2.2.1. The dimensions of each grid box shall not exceed 250 feet by 250 feet.

4.2.2.2. The entire launch field, not to exceed 5,000 feet by 5,000 feet, shall be gridded.

4.2.2.6. The identified launch vehicle's grid box, upon landing, will be transmitted to your team's ground station.

4.2.3. GPS shall not be used to aid in any part of the payload mission.

4.2.3.1. GPS coordinates of the launch vehicle's landing location shall be known and used solely for the purpose of verification of payload functionality and mission success.
4.2.4. The gridded image shall be of high quality, as deemed by the NASA management team, that comes from an aerial photograph or satellite image of your launch day launch field.

4.2.4.1. The location of your launch pad shall be depicted on your image and confirmed by either the NASA management panel for those flying in Huntsville or your local club's RSO. (GPS coordinates are allowed for determining your launch pad location).

Proposed Solution

The first solution the team considered was a UAS imaging system. It would consist of a quadcopter that would eject from the payload tube either during descent or after landing. The UAS would then take off and ascend to a sufficient height to capture an image of the entire launch field. It would use on board image processing to identify the launch rail and the landed rocket, overlay a grid onto the image, and transmit the image and rocket's grid location to the ground station. This solution was determined to have likely reliability issues and was discarded.

The current design trajectory is an inertial navigation system (INS) which will use a sensor array to track the rocket's relative position throughout the flight. The predetermined grid will be centered on the launch rail and the INS will calculate the rocket's grid square upon landing. The INS will send the grid number to the wireless transmission system, which will transmit it to the ground station for submission to NASA. This proposed solution will consist of the following subsystems:

1. <u>Inertial Navigation System</u> - senses the payload's motion and calculates it's landing location; outputs the number corresponding to the grid square that the rocket landed in.
    a. Programming the INS algorithm will be the responsibility of several members of the payload team outside this senior design group.

2. <u>Payload Transmission System</u> - transmits the grid number from the INS upon landing.

3. <u>Ground Station</u> - receives the grid number from the Payload Transmission System upon landing.

4. <u>Power Delivery System</u> - regulates and distributes power to each of the payload's subsystems.

Demonstrated Features

Demonstration of the following features at the conclusion of this project will constitute success.

1. The transmission system will receive a message from the INS microcontroller over a serial interface.
2. The transmission system will transmit the serial message wirelessly to the ground station.

3. The ground station will receive the message from the transmission system and display it to the user.
4. The transmission system and ground station will send/receive a message at the maximum required range of 2500ft.
5. Entire payload will operate on a single battery.
6. The power delivery board will supply the correct voltage and sufficient current to each of the payload's electronic modules.
7. The INS, transmission system, and power delivery system will meet the mass and volume requirements provided by the NDRT systems lead.

Available Technologies

Technologies that could possibly be implemented are listed below with their respective sub-systems:

1. Inertial navigation system:
    a. Sensors:
        i. There are several available multi-function sensor modules that integrate accelerometer, magnetometer, and gyroscope into a compact board with an I2C interface.
    b. Processor / microcontroller:
        i. A small form-factor computer like the Raspberry Pi Zero or PocketBeagle would be able to interface with all the sensors and has enough processing power to run the INS algorithm.
2. Payload transmission system / Ground Station:
    a. Transceiver:
        i. Long range 2.4GHz transceiver module (ex. NRF24L01)
        ii. LoRa transceiver (ex. STM32WLE5JC)
        iii. RFD900 series 915MHz long range telemetry transceiver
3. Power Delivery System:
    a. Battery:
        i. 2s LiPo or Li-ion battery pack
    b. Power regulation:
        i. 5V Buck converter module
        ii. Custom board with buck converter and LDO to provide separate power rails to the sensors and processors

Engineering Content

This project will require selection of the modules that will be used for position sensing, processing, transmission, and power delivery. Each of these components must be researched to ensure that they can fulfill the mission requirements. Next, the payload and ground station systems must be assembled, wired, and programmed, with the exception of the INS algorithm being written by other members of the payload team. There may be multiple assembly iterations required in the case that the payload is lost due to rocket failure. Additionally, the team is considering building a custom power distribution board to conserve space and weight. It would connect to a 2 cell battery and output at least two power rails - one low noise 5V rail for the sensors and another high current 5V rail for the processors and transceiver. Along with the documentation required for the Senior Design course, this team must also write and present detailed technical documentation for each of the reports provided to NASA.

Conclusions

The proposal is to build a flight recorder that will compute the rocket's trajectory using data measured during flight. The recorder must be accurate enough to locate the takeoff and landing positions within the correct 250ft x 250ft grid square consistently and the INS must be able to transmit the calculated positions to a ground station located up to 2500 feet away.