Senior Design Proposal: DroneHook

1 Introduction

Package delivery through the use of drones has rapidly become an area of great interest, spending and progress. Numerous companies are diving headlong into the race to develop the first fully functioning system that can be certified by the FAA and rolled out into use by the general public. Wing, Prime Air, and Flight Forward are a few examples of forays into this expanding field backed respectively by billion dollar competitors Google, Amazon, and UPS. That being said, the package retrieval side of the equation has not received nearly as much attention from these companies. Drones have mainly been viewed as a last link in the supply chain (e.g. Prime Air's vision of delivery trucks functioning as moving distribution centers from which drones can be deployed to handle the doorstep delivery). Their potential as the first link has not been considered as seriously. However, there do exist time-critical retrieval scenarios that would benefit from the introduction of drones. Examples that demonstrate this need include the retrieval of test samples from patients unable to make the trek to regional testing centers or the retrieval of medication from one field hospital in an area of poor infrastructure for the delivery to another that has a patient requiring that medication.

2 Problem Description

In recent times, potential package delivery and retrieval unmanned aerial vehicles (UAVs) have mainly consisted of multi-copter (i.e. vertical lift) topologies. Although there are many good reasons for this bias towards multi-copters, there are numerous situations in which a fixed-wing topology would be not only advantageous, but of necessity. For instance, a relatively long distance and/or high-speed delivery flight would substantially favor a fixed-wing vehicle over a multi-copter. That said, conventional fixed-wing airframes lack the functionality to allow a user safely and efficiently on the ground to transfer a package for delivery. The only realistic option with a traditional airframe is to abort powered flight and conduct a full landing at the user's location. In many situations, such a maneuver is difficult if not impossible. Once on the ground the UAV is directly accessible to the user. Such a situation is prime for intentional and unintentional tampering with the system. In short, the current technological landscape does not possess a viable approach to package retrieval situations that favor fixed wings. Zipline, one of the few companies in this sector utilizing fixed-wings for delivery, requires a large and complex catapult-like mechanism to launch their UAVs back into the air once they have landed. As such, this is a solution only viable in areas of developed infrastructure.

3 Proposed Solution

DroneHook mitigates the aforementioned issues such that we can make use of a fixed-wing's superior efficiency and cruise speeds. We propose developing a system capable of retrieving a package "in-stride" and continuing onto its destination with little to no delay or change in altitude. Our system draws significant inspiration from the Fulton surface-to-air recovery system. We hypothesize that a fixed-wing with our system is capable of outperforming a variable takeoff and landing (VTOL) air frame. A package with a balloon attached to it will be deployed. Through the utilization of transmitted GPS coordinates, a

fixed-wing will fly into visual sight of the balloon and then use its on-board computer vision system to snag the line and reel in the package. The senior design team will take on the embedded device components of the proposed system. Firstly, we will be concerned with creating a balloon mechanism with associated sensors capable of positioning the system and quantifying the volatility of the environment. This data must be broadcast by an appropriately sized radio module such that it can be received by an out-of-sight fixed-wing. Secondly, we will develop a system that will be onboard the vehicle that will receive the broadcast sensor data and utilize it to generate an appropriate path to the balloon and attached package.

4 Demonstrated Features

1. **On-vehicle system**
    a. RF transceiver to interface with microcontroller and receive the GPS and auxiliary data broadcast by the balloon system
    b. Barometer to interface with the microcontroller and provide the control sequence with an accurate reading for the vehicles current altitude
    c. Microcontroller to interface with the above sensors and the Raspberry Pi 4 or other single board computer (SBC) which serves as the companion computer to the flight controller (the flight controller handles the granular flight function like rolling and pitching while the companion computer handles the higher level control) → microcontroller prepares the data received from the balloon such that it can be usefully read into the control algorithm running on the Raspberry Pi
2. **On-balloon system**
    a. RF transceiver to broadcast the GPS and auxiliary data to the complementing unit onboard the vehicle possessing the snatching mechanism
    b. Barometer to interface with the microcontroller and provide the vehicle's control sequence with accurate altitude data assisting in reliable line snagging
    c. GPS module to interface with the microcontroller and provide the vehicle's control sequence with general positioning data to guide the vehicle from beyond visual line of sight (BVLOS) to visual line of sight (VLOS)
    d. Inertial measuring unit (IMU) to interface with the microcontroller and provide the vehicle's control sequences with data regarding the volatility of the snag objective
    e. Microcontroller which will aggregate the data from the various sensors mentioned above and formulate it into a message format that is sent via the RF transceiver
    f. Power circuitry capable of sustaining the aforementioned components for a period of at least 10 minutes with a source consisting of an appropriately sized battery

Points **a**, **b**, **c**, **d & e** for the on-balloon mechanism and points will utilize basic serial protocols to communicate (i.e. SPI, I2C, or UART). If time allows, we will look into simplifying or increasing the robustness of various components (e.g. the use of SENT -- single edge nibble transmission -- sensors). Additionally, if the number of components grows extensive we could investigate the use of CAN bus.

The senior design team's component will be successfully demonstrated through the flying of the plane possessing the above embedded system within 10 ft of the balloon system and taking a

picture of the balloon. The demonstration will begin with the balloon mechanism not deployed and the plane in the air. The balloon system will be deployed such that the plane's visual control system is not within operating range and the radio broadcast of the sensor data must be relied upon.

5 Available Technologies

We have previous funding from NASA for this project so we will be using that money to purchase equipment and drive development.

RF Transmitter/Receiver - RF transmitter will be used to send position data from the balloon to the UAV for locating the balloon.

Link:

https://www.sparkfun.com/products/10535

TDK InvenSense ICM-20798 - This sensor package will be used on both the balloon and UAV to get position measurements to accurately guide the UAV to the balloon. It includes an accelerometer, gyroscope, and barometer.

Link:
https://www.cdiweb.com/products/detail/icm20789-tdk-invensense/605146/?pid=568&utm_campaign=12602562379&adgroupid=123539444847&utm_content=508725275177&utm_term=&gclid=Cj0KCQjw2tCGBhCLARIsABJGmZ6Nlig0ipCDyDh1APdIW-YwQtAldp1oa0MmdjdcykVSTAAtGYnXFT8aAjzzEALw_wcB

PIC24 Microcontroller - Used to interface with sensors and compile data to send to UAV through the transmitter.

Molex 206640 GPS - A RF GPS will be used to pass on position data to the UAV once in the range of the RF transmitter.

Link:
https://www.digikey.com/en/products/detail/molex,-llc/2066400001/9094611?utm_adgroup=RF%20Antennas&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Product_RF%2FIF%20and%20RFID_NEW&utm_term=&utm_content=RF%20Antennas&gclid=Cj0KCQjw2tCGBhCLARIsABJGmZ4uOfwGRjcLGvsgAYjZKwnygDDTzk9B9hA7Fk1gyI-RBv2a0Zu29XAaAkijEALw_wcB

Lithium ion cell battery (AA battery) - A lightweight battery will be used to power the board and electronics associated with the balloon.

6 Engineering Content

In order to design, build, and test the system, we will be allocating different portions of work to different team members. The two main components, the on-vehicle system, and the on-balloon

mechanism, will be designed separately in groups of three. Initially we would like to get the communications protocol working between our various subsystems, and powering all of those units. Once the communication protocols are working we would like to simulate a flight path of the fixed wing drone from reasonable variable values. Next we would release the balloon with the on board sensors, communication module, and power supply and receive actual variable values to simulate the flight path. The final step in the iterative design and testing process would be to incorporate the UAV communication module and power supply with the ability to physically alter the flight path based on the data incoming from the balloon. Our final deliverable would be to fly the fixed-wing drone from a location out of sight of the balloon and have it use the GPS and altitude data to find the drone and fly within 10 feet of it and take a picture of it.

The bulk of the engineering content comes in designing our boards and associated power supplies, appropriately interfacing the various sensors with the microcontrollers on-board the vehicle and balloon with both software and hardware, and implementing the control sequences responsible for the control of the plane.

7 Conclusions

DroneHook allows for companies to conduct speedy and efficient package retrieval. As drone delivery has become very popular in recent years, the need for a package retrieval system cannot be overstated. If a customer needs to return a lightweight item, that can now be done with the push of a button. It allows UAVs to remain safe during their flights and prevents the unwanted tampering of items within the system.