UAV Outback Challenge 2016

Deliverable #1

Matt De Bono, Alex Daraio, Wesley Lim, Shanon Loveridge

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1 Aircraft Design

1.1 Flight

In order to achieve the required flight range (up to 60km) and endurance (60 minutes), the UAV will be a hybrid aircraft, fusing both a traditional fixed-wing aircraft and a Vertical TakeOff and Landing (VTOL) multi-rotor aircraft. A Skywalker X8 frame is being used, with 3 motors in Y3 configuration, as shown by the prototype in Figure 1.

These motors will act as a tri-copter when in VTOL mode, with a servo mounted in the back stabilising the aircraft's yaw by controlling the back motor, offsetting the rotation caused by the 3 motors. A servo system in the front of the aircraft allows the front motors to rotate forwards, transitioning the aircraft to fixed wing flight mode. The back motor is then disengaged, and the servos controlling the ailerons are engaged.

Figure 1: Outback Challenge aircraft - Prototype #1

1.2 Sensing and Control

Figure 2 outlines the on-board sensing capabilities that will be available to the aircraft. Each sensor is detailed below, as well as the control devices that will facilitate the autonomous behaviour of the aircraft.

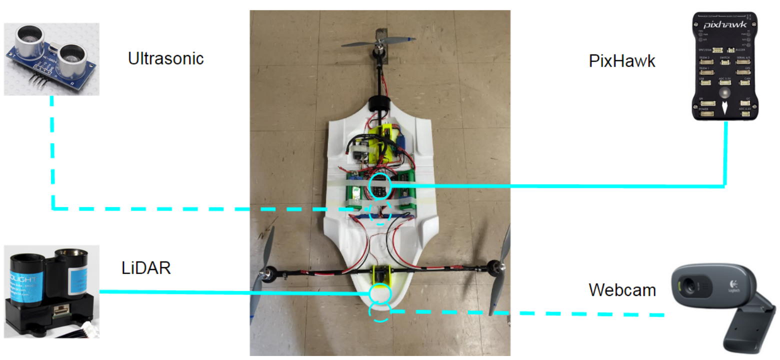

Figure 2: Onboard sensing capabilities for Prototype #1

Raspberry Pi

The Raspberry Pi will act as the aircraft's on-board computing platform, providing autonomy by giving flight commands to the flight controller, as well as the processing and intelligence for path planning, and object detection. It will also pull flight data from the PixHawk and other sensors, and generate detailed flight logs for later review.

PixHawk Flight Controller

The PixHawk will control the aircraft's flight functionality, such as controlling motors and ailerons, and executing flight paths and commands from the Raspberry Pi. It also has several in-built or plug-and-play sensors, including a 3-axis accelerometer, altimeter, compass, and GPS. The PixHawk will provide the aircraft's telemetry to the Raspberry Pi and the base station, which will be augmented by the additional sensors below.

Ultrasonic Module

The ultrasonic module will be mounted underneath the aircraft. The GPS and altimeter will provide altitude measurements during fixed-wing flight; the ultrasonic will augment these by providing a more reliable and controllable height measurement during rotor-based flight, assisting with search and landing.

Webcam

The webcam will be mounted beneath the nose of the aircraft. It will provide vision for the aircraft's obstacle avoidance manoeuvers, and will form the basis for identifying Joe using his hat and blue jeans.

LiDAR

The LiDAR will be mounted in the nose of the aircraft. The LiDAR can only measure the range of objects directly in front of it, so it will be mounted on a dual servo system that allows it to sweep a hemisphere in front of the aircraft (see Figure 3). It will provide a 3D map of the environment in front of the aircraft, and will assist in path planning and obstacle avoidance.

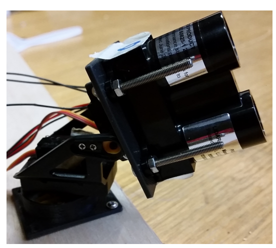

Figure 3: LiDAR mounting

1.3 Geofence System

A monitoring system will be implemented on the aircraft to detect proximity to, and crossing of, Geofence boundaries, as per 3.1.3. Although the PixHawk has inbuilt Geofence capabilities, the UAV will instead use the Raspberry Pi, as it will be at the highest level of control.

The PixHawk will provide the Raspberry Pi with the GPS, altimeter and accelerometer measurements, which will be used to estimate and monitor the position of the aircraft. As the Raspberry Pi is the highest level of control and autonomy onboard the aircraft, a breach of the Geofence boundary will result in the immediate disengagement of control to all subsystems, and activation of the flight termination system, detailed below.

1.4 Flight Termination System

As per 3.1.4, there will be two options for flight termination on the completed craft. The higher level Raspberry Pi will be able to send termination signals to the Pixhawk directly if termination is required, such as Geofence crossing or loss of radio contact. On a lower level, the PixHawk firmware will be modified to comply with termination requirements from the Raspberry Pi, or to automatically engage termination if communication with the Pi is lost.

In the event that the aircraft must terminate its flight, either by the PixHawk or Raspberry Pi, control will be overridden and commands will be given to each control surface as per 3.1.5, depending on the flight mode of the aircraft. If the aircraft loses communication with the PixHawk, then control of the motors and control surfaces is no longer possible; the Raspberry Pi will then disengage power to the aircraft, causing vertical descent (rotor mode) or glide (fixed-wing mode).

As per 3.1.6, the flight termination protocols stated above will be automatically activated if the aircraft crosses a Geofence boundary, if the Geofence detection system fails, or if the autopilot has failed or “locked up”. Flight termination can also be activated manually by sending a signal to the Raspberry Pi at the request of judges or range safety personnel, for example, if the aircraft is deemed to be out of control.

1.5 Miscellaneous

Power Systems

In order to maximise safety and reliability, the aircraft will be equipped with several independent power supplies. The sensors, servos and Raspberry Pi will be powered by the main LiPo battery system. The PixHawk and motors will be powered by a separate LiPo system, with a backup power system, so that in the event flight termination is required there will be several redundancies to ensure successful activation. This will also increase the likelihood of manual override if failures occur.

Communications

The aircraft will make use of Rocket M M5 5GHz transmitters to maintain telemetry radio communications during flight, as per item 6 of the *General Requirements.* This system is preliminary, and subject to investigation of the ACMA spectrum licences.

Safety Systems

The aircraft will be equipped with an external emergency stop button, red in colour with yellow surrounding disk, to disengage power, as per item 7 of the *General Requirements.* It will also be equipped with an external arming switch, and a visual state indicator to indicate armed (red) and disarmed (green) states, as per item 8 of the *General Requirements.*

Storage Compartment

The aircraft will be fitted with a storage compartment of appropriate dimensions in it’s center, allowing for Joe to deposit the sample described in 1.4.1.

Mission Display

The ground station will make use of Ardupilot Mission Planner to provide a graphical display and data feed of the aircraft’s mission, per 3.2.2. In addition, bespoke software will be developed to visualise the data sent back by the aircraft.

2 Use of UAVs

Execution of the mission will begin once the arming switch is pressed, and the aircraft becomes armed, at which point the aircraft will immediately begin autonomous operations; there will be no commands given by the UAV controller to initiate the mission.

Upon arming, the aircraft will perform vertical takeoff from the Base using its VTOL mode, and will ensure it remains within the base Geofence. Once it has reached an appropriate altitude (yet to be tested, no more than 1500ft AGL), the aircraft will transition to its fixed-wing flight mode by rotating its front motors 90° using the inbuilt servo system, and disengaging the back motor.

Once fixed-wing mode is engaged, the aircraft will begin its transit to the remote landing site, through the transit corridor(s), whilst continuing to monitor its position relative to the Geofence boundaries.

Upon reaching the remote landing site, the aircraft will begin performing sweeps within the landing site Geofence, attempting to get an approximate position for Joe's location using the webcam, while remaining in the air.

Once Joe has been located, the aircraft will transition back to VTOL mode. It will then use the webcam and LiDAR to maintain vision of Joe, while avoiding obstacles in the environment, in order to land in the safe zone (30m-80m) around Joe.

After landing, the Raspberry Pi will disengage all power to the motors, and will display the "disarmed" signal to Joe. He may then approach the aircraft to place the Sample in the Storage Compartment, and engage the arming switch.

Having been rearmed, the aircraft will wait one minute before initiating vertical takeoff, and reversing the manoeuvres to return to base; transitioning to fixed-wing flight, traveling through the transit corridor(s), and returning to VTOL mode to land at the Base. The aircraft will then disarm itself once more, and the mission will be completed.

This behaviour is consistent with the rules outlined in section 3. If at any time during the mission the Raspberry Pi determines that a Geofence is breached, the flight termination system will be immediately activated, per sections 3.1.4-3.1.6.

3 Risk Assessment

See attached "Risk Assessment" document.

4 Risk Management

See attached "Risk Assessment" document.