**Autonomous Drone**

ECE4012 Senior Design Project

**AutoDrone**

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# **Executive Summary**

AutoDrone is an unmanned aerial vehicle that can perform three specific tasks without a drone operator: GPS waypoint navigation, object tracking, and 3D reconstruction of the explored environment. The final system will include an autonomous drone and a user interface where the user can give basic instructions and view the mapping and information sent back from the quadcopter.

The purpose of this project is to provide a way for first responders to utilize drone technology when searching for survivors or inspecting infrastructure. In the UI, the operator will create a geofence for the drone. As the drone flies within the area autonomously, it will send back flight data for the operator to analyze. There are some companies that provide drone imaging services, but require a drone operator to skillfully fly the drone. With this product, first responders can take advantage of this technology without having the knowledge of flying one.

The expected outcome of the project is a well-designed autonomous drone. The drone will be able to use GPS data provided by the users to fly within a certain area avoiding obstacles and recording flight data, color images, and depth images. This information will be sent through a Wi-Fi link to the ground control computer to convert the flight data into a 3D reconstruction of the area. If the drone is set to tracking mode, it will be able to identify and track objects and provide the GPS coordinate of the found objects.

The team will assemble the drone frame with the autopilot, on-board computer, camera, sensors, motors, speed controllers, and power system. The cost for all of the parts needed for a single drone will be around $900.

**Autonomous Drone with Tracking and Mapping Capabilities**

# **1. Introduction**

The AutoDrone Team will design and build an autonomous quadcopter capable of tracking objects and aerial mapping. The team requests $900 to fund the prototype design.

## **1.1 Objective**

The objective of the project is to design a fully autonomous quadcopter that can fly around a geofenced region and gather data from that area. The data captured during the flight will be used to recreate a model of the area on the user’s computer. The drone will also be capable of finding and tracking various objects during the flight.

The main objective is to provide a system for first responders to use when reacting to a natural disaster. For example, this drone can be used to more efficiently search for survivors in the aftermath of a hurricane. The first responder is able to first send a drone out into a region to fly around and search for people. The drone will mark every GPS location where it believes it identifies a person. This way, the first responder is able to more efficiently search the area than just wandering around. Another use case would be to first send the drone into a region to check for dangers so that when the first responders enter the region, they will be properly prepared.

Although designed for first responders, this product has many useful applications. It can be used for cargo inspection, agriculture inspection, aerial photography, extreme sports filming, and small package delivery. This product will allow everyone to utilize drone technology without having to know how to fly one.

## **1.2** **Motivation**

Most companies and groups that are currently working on developing an autonomous drone are focused on finding the solution for a specific task. David Bird, a biology professor, is developing a drone to be used for monitoring various animal populations that costs $1,300 [1]. Domino’s pizza and Amazon are trying to utilize drones for quick delivery [2][3]. The goal of AutoDrone is to make a multipurpose autonomous quadcopter that can be programed to complete various tasks in an outdoor environment.

## **1.3** **Background**

There are plenty of examples of companies or groups using UAV technology. A team of engineers in California launched the Burrito Bomber, a UAV that uses GPS coordinates to drop burritos by parachute [3]. Domino’s pizza tried to deliver pizza using a drone in Australia [2]. Amazon tried to implement fast drone delivery of small items. Although there are many teams working on utilizing drone technology, it is still in the beginning of the development cycle. There are a lot of FAA regulations and implementation details that need to be considered.

Nowadays, most biology scientists perform tasks such as population counting and recording the wildlife by manned aircraft. However, researches are looking into using drones to more effectively complete this task. For example, David Bird, a wildlife biology professor, used the self-designed drones to count the population of the birds [1]. Using drones is a safer and less invasive way to inspect these wildlife populations. Although these researchers successfully developed the drones, they are not aiming at producing the drones in large quantity.

There are also several companies selling advanced drone technology. For example, DJI sells various types of drones such as Phantom, Mavic, and Inspire for various customer needs such as cargo imagery or aerial photography [4]. DJI sells drones with the ability to move small cargo and take photos of the environment, but advanced functionalities such as feature recognition, object tracing, and aerial mapping, need to be implemented by the customers themselves. There are two companies that provide autonomous systems: Skysence and AiroBitics. Skysence provides drone survey solutions to agriculture, defense and security [5]. AiroBitics provides drone survey, inspection, mapping, and emergency response [6]. These companies, although they provide more advanced drone technology, customize their solutions to their clients therefore making the drones less accessible to the general public.

In 2016, DARPA’s Fast Lightweight Autonomy (FLA) program succeeded in flying a fully loaded autonomous quadcopter through a warehouse at 20 m/h with no GPS or operator controls. The purpose of this program is to demonstrate the ability of small autonomous drones travel at fast speeds in high and low clutter flyby missions. Autodrone will use the DARPA FLA program as an example to begin development. Similar hardware such as the frame, motors, and flight controller will be used.

Two of the key components for the drone are the flight controller and the on-board computer. The flight controller will consist of a GPS and an autopilot for speed and motor control. The on-board computer will be used for implementing the existing algorithm to perform the tasks.

# **2. Project Description and Goals**

The project goal is to build a drone that can autonomously travel between several locations avoiding obstacles. The long term goal is to use a depth and color images from the camera to track objects and map out the environment of the drone. There are two main aspects of the design: hardware and software. The hardware is used to sense the environment and provide feedback to control the drone. The software will provide the necessary guidelines for the drone to fly autonomously. GPS data is integrated into the software and will be used to direct the drone to travel to different GPS coordinates. There will be a wireless link between the drone and a local computer to transfer the flight data to the local computer. The local computer will use the data to create a 3D reconstruction of the drone’s environment. Table 1 shows the hardware and software components as well as the features of the final product.

**Table 1**. List of Features and Components.

|  |  |  |
| --- | --- | --- |
| **Hardware Components** | **Software Components** | **General Features** |
| * Onboard computer * Depth camera * GPS * Infrared sensor * Flight controller * Speed Controller | * Communication link between drone and remote computer * Sensory input configured for microcontroller * Algorithm for the drone to fly based on flight data * Algorithm for drone to recognize and track specific objects * Algorithm for drone to reconstruct the explored environment | * Simple user interface * Autonomously fly from point A to B * Recognize objects and track them * Map of explored environment * Cost less than $2000 |

# **3.** **Technical Specifications**

The four main components of this project are the hardware, on board computer, camera, and other sensors. The specifications for these can be found in Tables 2-5 below.

**Table 2**. Hardware Specifications

|  |  |  |
| --- | --- | --- |
| **Hardware Specifications** | | |
| Description | Updated Value | Measured Value |
| Weight | 0.8 - 1.6 kg | 1.6 kg |
| Dimension | 450mm diagonally (from motor to motor) | 450mm diagonally |
| Payload | 1.4 - 1.6 kg | 1.6 kg |
| Battery Capacity | 2000mAh - 7000mAh, 4S LiPo | 6600 mAh, 4S LiPo |
| Operating Power | 3.3/5V PWM input signal level compatible, Max 17.3V\*20A/rotor | 3.3 PWM input signal level,  16.8V\*15A/rotor |
| Autopilot | Pixhawk | Pixhawk |

**Table 3**. On Board Computer Specification

|  |  |  |
| --- | --- | --- |
| **On Board Specifications** | | |
| Description | Updated Value | Measured Value |
| Frequency | 1.1 - 2 GHz | 2 GHz |
| Memory | 2 GB | 2 GB |
| Cores | 4-8 cores | 8 cores |
| Power | <60 W | 20W |
| Operating System | ROS | ROS on Ubuntu Mate |
| Communication Portal | Wi-Fi | Wi-Fi |

**Table 4**. Depth Camera and Other Sensor Specification

|  |  |  |
| --- | --- | --- |
| **Sensor Specifications** | | |
| Description | Updated Value | Measured Value |
| Frame Rate | 30-60 FPS | 30 FPS for Depth, 30/60 for RGB |
| Resolution | Depth: 320x240, 480x360  Color: 320x240, 640x480, or 1920x1080 | Depth: 320x240, 480x360  Color: 320x240, 640x480, or 1920x1080 |
| Depth Range | Inside range: 0.5-3.5 m  Outside range: up to 10 m | Inside range: 0.5-3.5 m  Outside range: up to 10 m |
| GPS Resolution | <3m | <3m |

**Table 5**. Software Specification

|  |  |  |
| --- | --- | --- |
| **Software Specifications** | | |
| Description | Updated Value | Measured Value |
| On Board Tracking Processing Speed | <100 ms per frame | <100 ms per frame |
| Local Mapping Processing Speed | <300 ms per frame | <300 ms per frame |
| Graphic User Interface | Yes. There will be graphic user interface, so users can give basic instructions to drone, and view the mapping of the area. | Yes |
| Localization Accuracy | <1 m | N/A |
| Communication between On Board Computer and Flight Controller | MavLink | MavROS built on MavLink |
| Communication between On Board Computer and Local Computer | Use distributed ROS system, with nodes running on both local computer and onboard computer | Use distributed ROS system, with nodes running on both local computer and onboard computer |
| Object Tracking | Yes | Yes |
| Used Sensor Information | RGBD images, GPS location, orientation, and distance | RGBD images, GPS location, and orientation |
| Path Planning | Optimize the steps, if destination is given. Do breadth-first search to explore the area. | N/A |

# **4. Design Approach and Details**

## **4.1 Design Approach**

The design approach for AutoDrone can be separated into hardware and software design. The hardware design consists of the physical build and connections between the components of the quadcopter. The software design consists of communications, algorithms, and controlling the autonomous movement of the drone.

### **4.1.1** **Hardware Design Approach**

The compatibility and size of the components must be taken into consideration when deciding what will go on the drone. All the parts must be able to communicate with each other while also being as light as possible to reduce weight. The DJI Flamewheel F450 will be used for the frame of the drone. It has a maximum payload of 1.6kg and landing skids. The drone will be fitted with the DJI e305 motor kit. The motor kit contains 4 motors, 4 propellers, and 4 ESCs. The maximum takeoff weight for all 4 motors put together is 1.6kg. The motor kit and frame kit were modeled off of the DARPA FLA quadcopter build. The most important part of the drone will be the flight controller and on board computer, since those components will run and execute the algorithms to fly autonomously. The flight controller must have features such as self takeoff and landing , waypoint navigation, telemetry, and have an open source firmware [7]. The 3DR Pixhawk Mini flight controller satisfies all these requirements, and also comes with a GPS module. It is one of the best autonomous flight controllers in the market. The Odroid XU4 is chosen for the on board computer, since it is one of the only micro computers that has been verified to be compatible with the Pixhawk [8]. The XU4 has 8 cores which will provide ample processing power for all the computer vision algorithms needed to fly the drone autonomously. The Intel Real Sense R200 will be used as the on board camera. It provides RGB, depth, and IR images. It requires a USB3 connection which the XU4 has. A Sharp infrared sensor can be used with the design to provide a distance reading from the bottom of the drone to the ground to assist with landing and keeping the drone at a stable altitude. A 4S LiPo battery must be used to be compatible with the motors. The Multistar 6600mAh battery was selected since it provides the correct voltage output and current output needed to power the motors. It also has a very high capacity which will help increase the flight time of the drone. Overall, the drone is estimated to have a flight time between 15-20 minutes. A full list of the selected parts can be found in Table 6 shown below.

**Table 6**. Chosen and Unchosen Parts for the Autonomous Quadcopter.

|  |  |
| --- | --- |
| **Hardware** | **Part Name** |
| Flight Controller | Pixhawk Mini |
| Onboard Computer | Odroid XU4 |
| Battery | Multistar 6600mAh 4S 10C Multi-Rotor Lipo Battery |
| Motors | DJI e305 motor kit |
| Frame | DJI Flame Wheel F450 |
| Camera | Intel Realsense R200 |
| Landing Skid | DJI Flame Wheel 450 Landing Gear Set |
| GPS mounting stick | DJI GPS holder |
| RC receiver | Futaba R6303SB |
| Telemetry Unit | 3DR telemetry radio |
| Pixhawk Power board | Holybro APM Power Module 10S |
| 36V-5V Buck converter | CUI DC/DC converter 5V 30W |
| Level Shifter | Sparkfun Bidirectional Voltage Shifter |
| Cables/Connectors | XT-90 connectors |

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### **4.1.2** **Software Design Approach**

The relationship between the different components and sensors can be seen in Figure 1 below. The main scripts are run on the Odroid and Local computer. The two computers will be run on the same ROS system so they can both access all the sensor data from the drone.

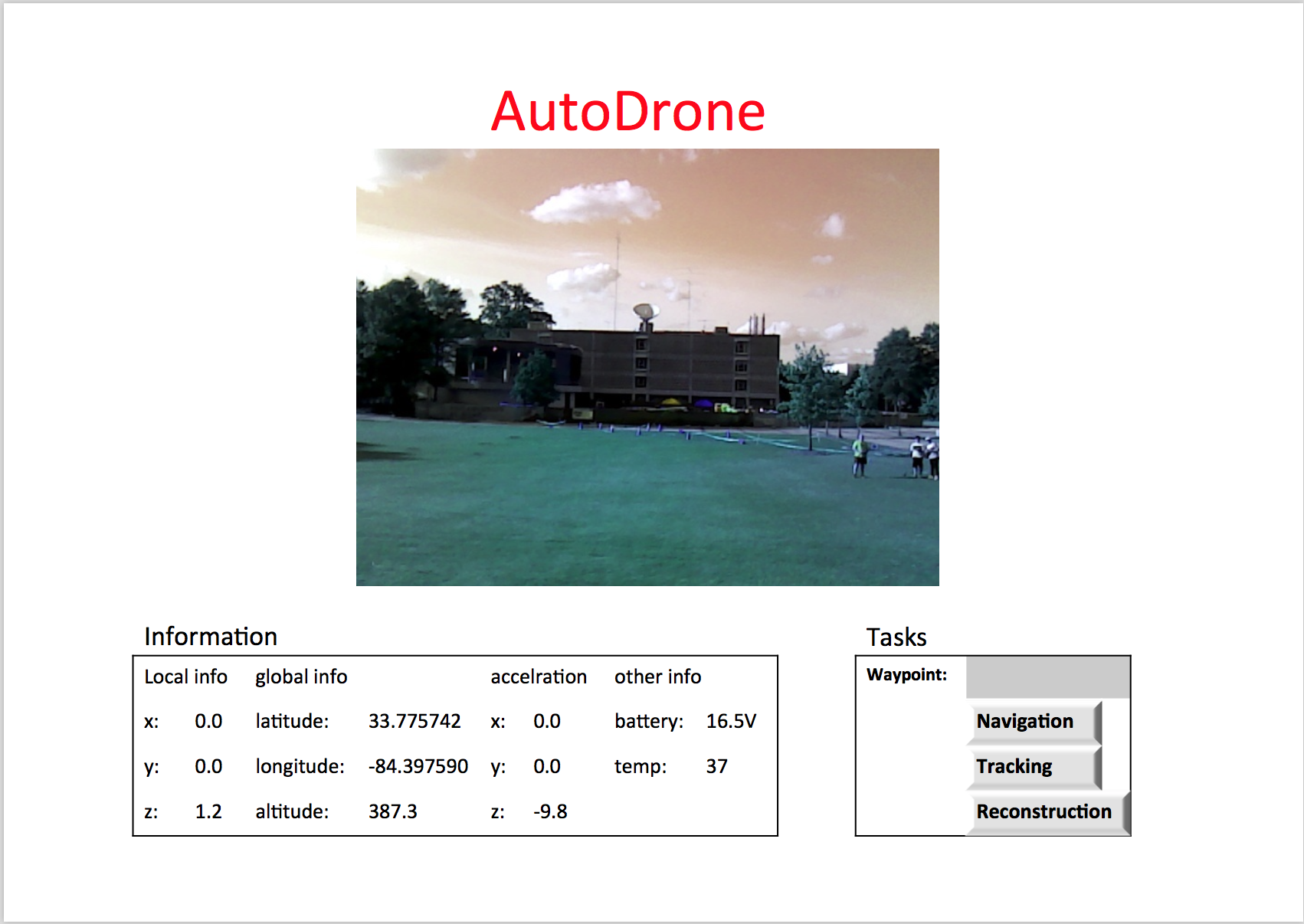


**Figure 1.** Main components for the software system.

There were many steps to enable the Intel camera and the Odroid to communicate with each other. Intel provides a the driver software and development library for the Realsense camera, but it is not natively compatible with the ARM architecture found on the Odroid. To use the camera, the Linux kernel on the Odroid must be upgraded to version 4.9. Also, the configuration file was edited to enable the USB3 ports to work with the camera. After updating, the Odroid is able to grab images taken from the Realsense camera. A Realsense ROS camera node is used to start the camera and publish images and calibration information. 

MavROS, a ROS node that implements the MavLink protocol, is used to communicate between the Pixhawk and the Odroid. Depending on how the two are connected, whether through direct connection or telemetry, the port number and baud rate need to be configured when starting the ROS node. The communication between local computer and Odroid is established by running single ROS system on both machines, and ROS master will coordinate the information exchange. Finally, the local computer and Pixhawk can be connected with a micro USB cable or telemetry. This connection is used to tune the sensors in Pixhawk and create mission files to send to the Pixhawk.

**Figure 2.** Communication between the On-Board Computer and the Local Computer.

The ROS nodes and system setup can be found above in Figure 2. The camera node launches Realsense camera, and publishes RGBD images and calibration parameters. The MavROS node takes in instructions, such as flight mode change and waypoint setup, and publishes sensor information on Pixhawk and GPS location. A depth correction node is used to create a registered depth and color image and adjust the publishing frequency of the image topics. Because the default camera calibration was not accurate, the raw depth and color images did not correspond 

**Figure 3.** User Interface

perfectly with each other. Experiments were conducted to determine that the depth image is shifted by 20 pixels, regardless the distance to objects. Therefore, the depth correction node was used to shift the depth image downward 20 pixels to create the calibrated image. In the future, a proper camera calibration can be done to fix this problem. Another functionality of this node is to adjust image frequency. The ORB-SLAM algorithm can not handle the 30 FPS published by the original camera node, so the registered depth node publishes at a slower rate of 10 Hz. The GPS navigation node is used to send GPS coordinates for the drone to fly to. The Object Tracking node is used to find and track objects. The drone can find the center of a green circle and adjust its speed and orientation to keep the circle centered in its field of view.

Last, the user interface can be seen in Figure 3 above. Central area shows the video feed from camera. Left low corner shows drone related information, such as GPS location and drone orientation. Right low corner gives task options.

## **4.2** **Codes and Standards**

The FAA part 107, the IEEE 802.11, and the NMEA 0183 codes are the three major codes and standards that are applicable to this project.

### **4.2.1 Federal Aviation Administration (FAA) part 107**

Part 107 of the FAA code discusses the rules and regulations of unmanned aircrafts. When designing and flying this drone, none of these rules must be broken. The code discuss where and when the unmanned can be flown. It also discusses drone flight regulations such as not exceeding a maximum ground speed of 100 mph, a maximum altitude of 400 ft above ground or a structure, cannot weigh more than 25 kg, and can only be flown in daylight [11]. When designing this drone, all the limitations and rules in the document must be heeded.

### **4.2.1 IEEE 802.11**

The IEEE 802.11 will be used to transfer images and commands over WIFI from the ground station to the quadcopter. Both the on board computer and ground station computer will need to implement and be aware of the proper protocols when transferring data via wifi to ensure reliable data transfer. This code also tells what frequency bands the drone and ground stations can use to communicate [12].

### **4.2.3 National Marine Electronics Association (NMEA) 0183 and Global Positioning System (GPS)**

The National Marine Electronics Association (NMEA) 0183 provides the specifications required to communicate for GPS units [14]. The on board computer of the quadcopter must be able to parse this data inputted from the GPS module and navigate the quadcopter to the final destination. The data read from the receiver includes the drone’s position, velocity, and time [13]. Since GPS only works when it locks onto satellite signals [15], the GPS function of the drone can only be used outdoors.

## **4.3** **Constraints, Alternatives, and Tradeoffs**

There is a tradeoff between the drone being more aware of its surroundings and the weight. The prototype of the design will not contain any sensors to detect nearby objects. The only sensor input will be provided by the depth camera. With less sensors, there is less weight, but is harder to prevent unwanted collisions to the drone. Less sensors also simplifies the overall design and price of the drone. More sensors can also provide better feedback about the drone’s environment to create a more accurate reconstruction of the area.  
 There are several options for a microprocessor as well as the flight controller components. Only certain microprocessors and flight controllers are readily compatible together, which greatly reduces the number of components available for the prototype. The weight and capacity of the battery also played a large role in the design of the prototype. A larger battery can provide a longer flight time but the increased weight will increase the required power for flying and reduce the payload capacity that the quadcopter has for other hardware components.  
 The type of drone used in the prototype is a multirotor quadcopter. Quadcopter drones are ideal for photography and aerial observation, but the short flight time is not ideal for large scale aerial mapping. For aerial mapping a fixed wing drone is preferred, but they are expensive and difficult to fly [16]. **5. Schedule, Tasks, and Milestones**

The Autodrone team designed and dedicated to the tasks over the past 4 months from January to the end of April. The table in Appendix A lists all of the major milestones, people assigned to the tasks and the degrees of difficulty of the tasks. Appendix B provides the overall project time line in the form of a GANTT chart.

# **6.** **Project Demonstration**

There will be two tasks the drone will have to complete to demonstrate autonomous flight capabilities listed below:

1. Given a GPS coordinate, the drone will take off, fly to that coordinate, and land without hitting any obstacles.
2. Given the GPS coordinates the drone must stay within, the drone will fly around and take data in the area. The data will be sent over WIFI to a computer base station which will reconstruct a map of that area.

To prototype during the design process, there will be small milestones to demonstrate the drone’s capability to do smaller tasks listed below:

1. Tun the flight controller so the drone can take off, hold a constant altitude for 5 seconds and land.
2. Use just the flight controller data, the drone will fly 10 meters in a straight line from the current location.
3. Demonstrate that the drone can read/send out the GPS coordinates from/to the on-board computer
4. Use GPS coordinates to fly 10 meters in a straight line.
5. Demonstrate that the drone can recognize and track an object.
6. Demonstrate that the drone can follow the tracked object from a distance.
7. Demonstrate the connection between the on board computer and ground control computer.
8. Demonstrate the ability of the ground control computer to recreate image and depth data from the drone.

# **7.** **Marketing and Cost Analysis**

## **7.1** **Marketing Analysis**

Mapping with an autonomous drone is a concept that is being adopted by end users since it is simple and cost effective compared to old methods. Surveying land is a task that traditionally requires several days to gather data, with a drone the task can be completed within one day. Surveyors in the field risk injury when surveying sites such as mines, but using a drone removes that risk of injury. Sense Fly has several autonomous aerial vehicles available that allow a user to directly input the area of coverage to be surveyed as well as the desired ground sampling rate [17]. Maps made easy offers users an IOS app to select the area of interest, the user must purchase their own drone and camera to gather the information. Maps made easy also allows users to upload their data to their website to produce a high resolution map [18]. Both of these companies use autonomous aerial vehicles to map land, but both of these companies require the user to be knowledgeable about either mapping software (Sense Fly) or drone hardware (Maps made easy). Sense Fly requires the user to be knowledgeable with the mapping software that they provide, while Maps made easy requires the user to build their own drone and equip it with a camera. The fact that potential users must have prior knowledge to use a certain product can be unattractive to them. Autodrone aims to produce a complete drone surveying kit with a simple user interface that anyone can operate to their desired needs.

## **7.2** **Cost Analysis**

The total cost for the development of a prototype Autodrone is $52,444. Table 7shows a breakdown of the costs of all of the components necessary to build the prototype. The cost for any additional cables and wiring components can be obtained without cost from the senior design lab. We have neglected the cost of an RC transmitter since we will borrow one to use for the project and the final product will not include one. The price of each component was rounded up to the nearest dollar.

**Table 7.** Component Costs for Prototype

|  |  |
| --- | --- |
| **Item** | **Cost** |
| Pixhawk Mini | $199 [19] |
| ODroid XU4 | $123 [20] |
| Multistar 6600mAh, 4S, 10C | $43 [21] |
| DJI e305 motor kit | $149 [22] |
| DJI Flame Wheel F450 | $32 [23] |
| Intel Realsense R200 | $169 [24] |
| Sharp GP2Y0A02YK0F | $15 [25] |
| DJI Flame Wheel 450 Landing Gear Set | $20 [26] |
| GPS mounting stick | $7 [27] |
| RC receiver | $70 [28] |
| Telemetry Unit | $43 [29] |
| Pixhawk Power Board | $21 [30] |
| 36V-5V Buck converter | $35 [31] |
| Level Shifter | $3 [32] |
| Cables/Connectors | $12 [33] |
| **Total** | **$941** |

There will be four engineers working to design and develop a prototype. The total amount of labor hours to develop a prototype per engineer is outlined inTable 8.

**Table 8.** Prototype Development Hours Per Engineer

|  |  |
| --- | --- |
| **Task** | **Hours** |
| Weekly meetings | 16 |
| Research | 16 |
| Assembly | 4 |
| Flight testing/trouble shooting | 8 |
| Code autonomous algorithm | 14 |
| Code tracking algorithm | 12 |
| Code algorithm to integrate GPS data | 8 |
| Code mapping algorithm | 24 |
| Testing debugging | 50 |
| **Total** | **152** |

**Table 9.** Total Development Costs

|  |  |
| --- | --- |
| **Development Component** | **Cost** |
| Parts | $941.00 |
| Labor | $17,396 |
| Fringe Benefits, % of Labor | $5,501 |
| Subtotal ( Parts, Labor, Fringe Benefits) | $23,838 |
| Overhead,% of Material, Labor, & Fringe Benefits | $28,606 |
| **Total Overall Development Costs** | **$52,444** |

The salary per engineer is assumed to $61,420 per year, which is the average starting salary for a BS in electrical engineering [34]. 152 hours per engineer totals $17,396 in labor costs. The analysis for total development cost assumes 30% fringe benefits of labor and 120% overhead on materials, labor, and fringe benefits. The total development cost is outlined in Table 9.

For production over five years it is assumed that 5000 units are sold within a five year span. The cost for the parts was estimated to be 10% less, since all parts will be purchased in bulk. Technicians will be hired at $20 per hour to assemble and test the product. Fringe benefit is assumed to be 30% of total labor and overhead is assumed to be 120% of materials, labor, and fringe benefits. Sales expense, in the form of marketing will be 5% of the final selling price. The final selling price will be $2,500 and the expected profit for each unit will be $183, and the percent profit is 7.32%. There will be an expected profit of $915,000, and the expected revenue will be $12,500,000 over a 5 year period. The selling price and profit per unit over a five year span is shown in Table 10.

**Table 10.** Selling Price and Profit Per Unit (Based on 5000 unit production)

|  |  |
| --- | --- |
| **Expense or Income Component** | **Cost** |
| Parts Cost | $847 |
| Assembly Labor | $40 |
| Testing Labor | $20 |
| Subtotal (Labor) | $60 |
| Fringe Benefits, % of Labor | $18 |
| Subtotal (Parts, Labor, Fringe Benefits) | $985 |
| Overhead, % of material, Labor, & Fringe Benefits | $1182 |
| Subtotal, Input costs | $2167 |
| Sales expense (5% of total cost) | $125 |
| Amortized Development Costs | $25 |
| Subtotal, All Costs | $2,317 |
| Profit | $183 |
| **Selling Price** | **$2,500** |

# **8.** **Current Status**

This project has all necessary hardware components for drone flight and video recording selected and configured. A GUI has been created where a user can monitor the drone’s GPS location, velocity data, and view real time flight video. Pixhawk calibration and flight mode selection are performed by the user in QGroundControl. The drone can then be armed and the user can select different flight modes from the RC transmitter. Some of these flight modes include auto-takeoff, auto-land, and mission. The The drone is currently able to localize outdoors using GPS. A user can use QGroundControl to input GPS waypoints for which the drone to travel, the drone can then be armed and switched into mission mode where it will travel along it’s preset navigation route.

The Intel Realsense R200 depth camera is mounted to the front of the drone and can record video and depth information while in flight. The user can observe in flight video in real time from a remote computer. ORB SLAM can be used to analyze the depth information and localize the drone.

The Pixhawk has a built in feature referred to as “offboard mode” where RC inputs will be pushed to an offboard source that will communicate Pixhawk through MAVlink. The RC inputs can be overridden at any time with the RC transmitter. In offboard mode the pixhawk can control the quadcopter through a script. This has not been fully implemented yet, and would be the next phase of this project. Some other things to consider would be to integrate distance sensors on the drone so that the drone has a lower chance of crashing. Another thing to consider is the payload. Currently the drone is at the maximum payload, to increase the payload more powerful motors or a bigger drone such as an octocopter will be needed.

The hardware on the Autodrone is essentially complete and the product is now currently ready for software development. The software would include a path planning algorithm so that the drone can act on its own when flying. Also a control loop with newly integrated depth sensors will help prevent the drone from hitting obstacles. As well as a reconstruction algorithm that is modified from ORB SLAM. This software to be developed will allow the drone operate in a true autonomous mode.

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# **9.** **References**

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# **Appendix A - Milestones, Task assignments and Risk Levels**

|  |  |  |
| --- | --- | --- |
| **Task Name** | **Task Leader** | **Degree of Difficulty (Risk Level)** |
| **Class Related Tasks** | All | Low |
| Project Proposal Form | All | Low |
| Project Proposal Paper | All | Low |
| Design Review | All | Low |
| Oral Presentation | All | Low |
| Final Project Demo | All | Medium |
| Final Presentation | All | Low |
| **Hardware Tasks** | All | Medium |
| Order Parts | All | Low |
| Assemble parts | All | Medium |
| Calibrating parts | IB | Low |
| Basic Flight Test with manual control | IB | Medium |
| Integrate hardware | QW | Medium |
| Troubleshooting | All | Medium |
| **Software Tasks** | All | High |
| Setup on board computer and communication | All | Medium |
| Software integration | YB, QS | High |
| Camera setup and calibration | YB, QS | Medium |
| Autonomous fly A to B based on flight controller data | All | High |
| tracking a given object | YB | High |
| Autonomous flying A->B based on GPS coordinates | All | High |
| Localization and mapping | YB, QS | Medium |
| Troubleshooting | All | Medium |

# **Appendix B - Project Gantt Chart**

