Department of Computer Science & Engineering
The University of Texas at Arlington

Architectural Design Specification
CSE 4316: Senior Design I
Fall 2023

DRO
Raytheon DRO Project

Nick Parker
Jamie Wilson
Roberto Azahar
David Qian
Alec Babaa

Revision History

Revision	Date	Author(s)	Description
0.1	11.5.23	NP,JW,RA,DQ,AB	document creation

Contents

List of Figures

List of Tables

1 INTRODUCTION

The systems defined in the following document sections collectively describe our product: an autonomous aerial vehicle capable of seeking ground vehicles with identifying markers and delivering a payload of water.

2 System Overview

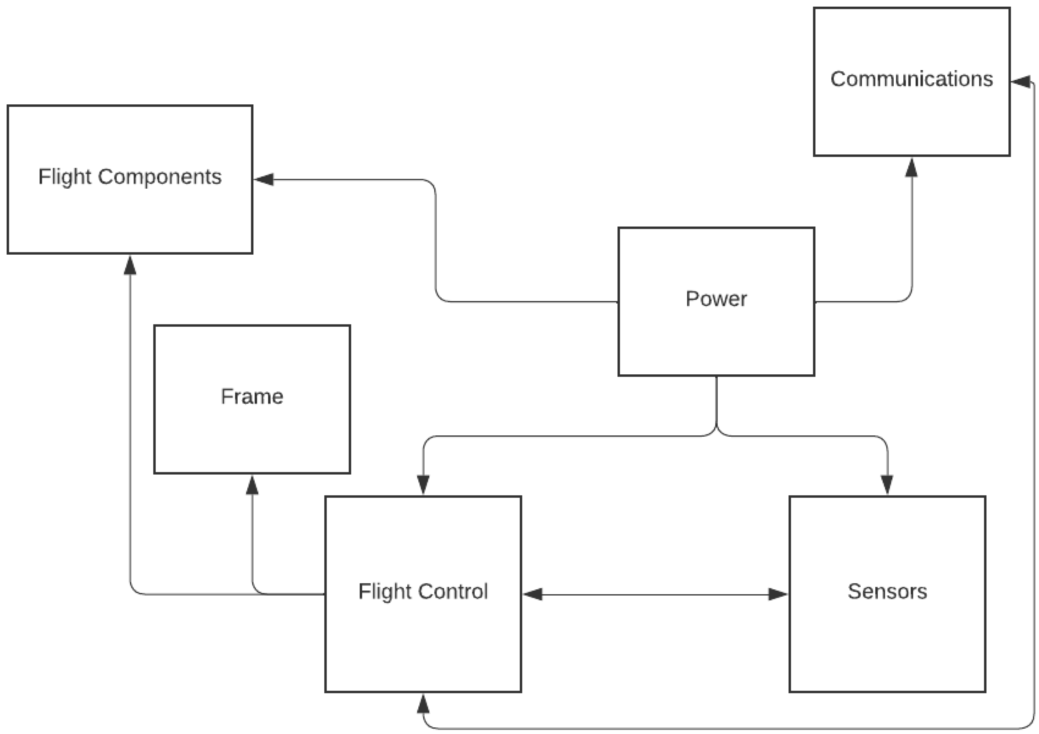

Figure 1: A high-level architectural diagram

2.1 Frame Description

The function of the water delivery system is to actuate a normally closed solenoid valve located at the base of a water reservoir, allowing water to fall below the UAV. The actuation of the valve is controlled by the Raspberry Pi, which analyzes the video feed from the camera to identify targets and turns on the solenoid valve when the drone is hovering above the target.

2.2 Flight Components Description

The flight components layer is responsible for generating the thrust required to lift the UAV off of the ground and to maneuver it through its airspace. Additionally, a subsystem of the flight components layer is responsible for protecting the environment from the rotating propellers, and the propellers from their environment.

2.3 Sensors Description

The function of the sensor system is to make a variety of measurements/calculations that allow the drone to operate autonomously. A multitude of these sensors are included within the CubeOrange+ as well as the Here3+ RTK gps with the only exception being the gimbal camera.

2.4 Communications Description

The communications layer is responsible for allowing data to exit the drone and be consumed remotely, or to facilitate the travel of data from one internal component to another. The communications subsystems distribute data to the on-board Raspberry Pi, the base station running Mission Planner, and to other ID transponder receivers.

2.5 Power Description

The power layer is responsible for providing all of the electrical components with the energy required for them to function appropriately.

2.6 Flight Control Description

The flight control Layer is responsible for the drone to properly function and carry out its tasks in regards to flight, image processing, target acquisition, and communications between the other layers. The CubeOrange controls the motors responsible for aerial flight and acts as the main hub between the communication and sensors layer. The RPi subsystem acts as the onboard computer in order to process images coming from the gimbal camera and target acquisition for the water delivery subsystem to deliver its payload.

3 SUBSYSTEM DEFINITIONS & DATA FLOW

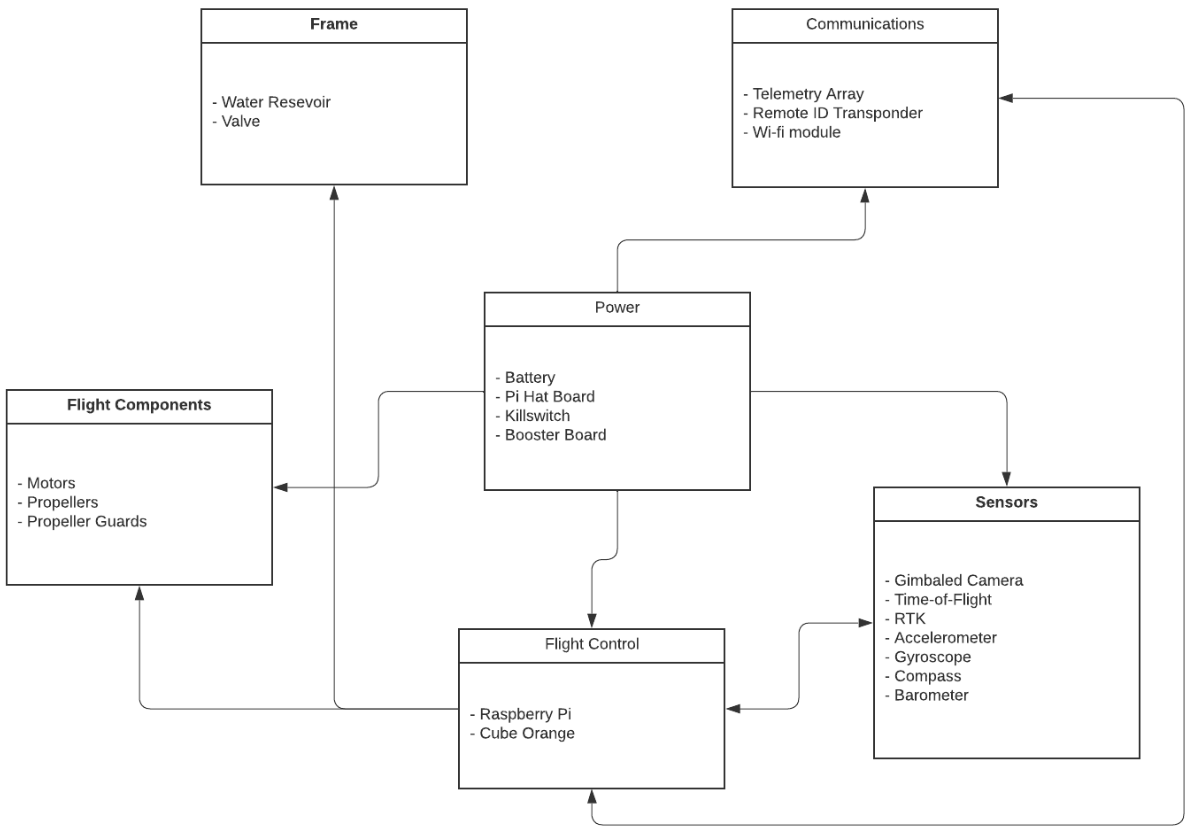

Figure 2: A high-level diagram with subsystems

4 Frame Subsystems

4.1 Power

The Raspberry Pi controls the gimbal and receives the output from the camera. It analyzes that video feed using computer vision, and when the UAV is hovering over a target, it turns on a solenoid valve at the base of a water reservoir to deliver a water payload to the target below.

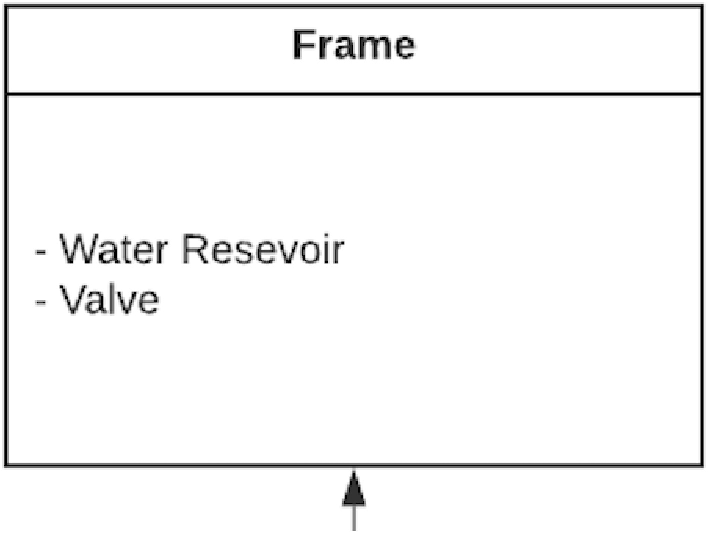

Figure 3: Frame layer diagram

4.1.1 Assumptions

- The battery has enough power to operate the system when it must be deployed
- No aspect of this system has been affected by some in-flight event, like a crash, that would damage or prevent it from operating as usual

4.1.2 Responsibilities

- The battery is responsible for providing power to all electronic components

4.1.3 Power Interfaces

Table 2: Power interfaces

ID	Description	Inputs	Outputs
#4.1	Boost Converter	11V	N/A
#4.2	Pi Connect Lite	11V	N/A

4.2 Raspberry Pi

4.2.1 Assumptions

- No aspect of this system has been affected by some in-flight event, like a crash, that would damage or prevent it from operating as usual

4.2.2 Responsibilities

- The Raspberry Pi is responsible for controlling the camera and gimbal, detecting targets, identifying when the UAV is hovering above them, and then providing power to the solenoid valve for the predetermined length of time necessary to deliver the water payload

4.2.3 Raspberry Pi Interfaces

Table 3: Raspberry Pi interfaces

ID	Description	Inputs	Outputs
#4.3	Pi Connect Lite	N/A	5V
#4.4	Siyi A8 Mini Gimbal and Camera	SBUS	SBUS
#4.5	Solenoid Valve	5V	N/A

4.3 Gimbal and Camera

4.3.1 Assumptions

- There is enough light for the camera to function normally
- No aspect of this system has been affected by some in-flight event, like a crash, that would damage or prevent it from operating as usual

4.3.2 Responsibilities

- The camera is responsible for capturing visual data and feeding it to the Raspberry Pi
- The gimbal is responsible for keeping the camera as stable as possible and aim it in the correct direction

4.3.3 Gimbal and Camera Interfaces

Table 4: Gimbal and Camera interfaces

ID	Description	Inputs	Outputs
#4.6	Boost Converter	11V	15V
#4.7	Raspberry Pi	SBUS	SBUS

4.4 Reservoir and Valve

4.4.1 Assumptions

- There is water in the water reservoir to be released by turning on the solenoid valve
- The solenoid the solenoid valve is free of any blockage that would restrict water flow through it
- The wind is not strong enough to blow the stream of water off target
- No aspect of this system has been affected by some in-flight event, like a crash, that would damage or prevent it from operating as usual

4.4.2 Responsibilities

- The solenoid valve is responsible for remaining closed and holding back water until it is actuated

4.4.3 Reservoir and Valve Interfaces

Table 5: Reservoir and Valve interfaces

ID	Description	Inputs	Outputs
#4.8	Raspberry Pi	N/A	GPIO

5 Flight Controls Subsystems

5.1 CubeOrange

The CubeOrange is the main flight controller and hub for the drone. There are various subsystems that are directly connected to the CubeOrange in order to facilitate communication between the sensors and communications layer.

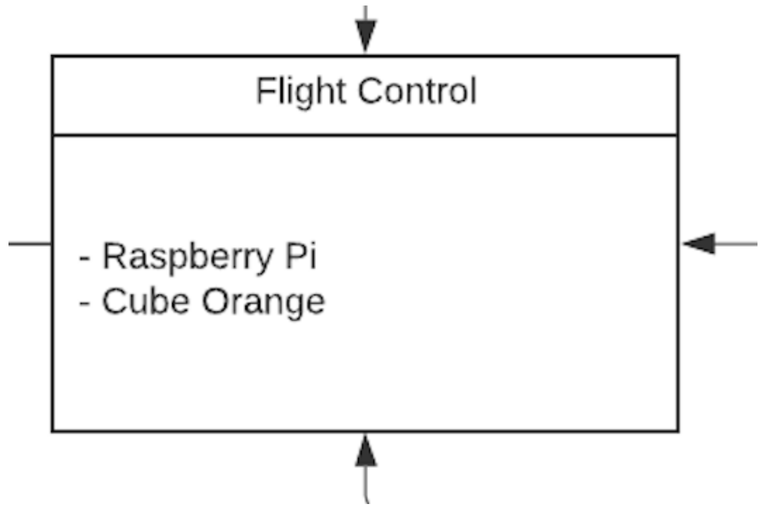

Figure 4: Flight Controls layer diagram

5.1.1 Assumptions

- All interfaces are working and the subsystem is receiving sufficient power to function properly
- May require changing some interfaces depending on further development of the project

5.1.2 Responsibilities

- This subsystem is responsible for controlling the motors that enable flight and is the main hub for connecting the RTK/GPS, telemetry, wifi/radio, and RPi subsystems
- The CubeOrange sends its flight data to the RPi so that the RPi can issue commands to fly to specific areas

5.1.3 CubeOrange Interfaces

Table 6: CubeOrange interfaces

ID	Description	Inputs	Outputs
#6.1	Power	Power	N/A
#6.2	CAN1	Positional Data from the RTK/GPS subsystem	N/A
#6.3	TELEM1	Command Input from the FrSky X8R	N/A
#6.4	USB	Commands from RPi	Flight Data to RPi

5.2 RPi Transponder

The RPi will act as the onboard computer that controls and directs the gimbal camera, processes image data coming from the gimbal camera and acquires targets for the water delivery system to function.

5.2.1 Assumptions

- All interfaces are hooked correctly and all other subsystems have been tested to work independently
- May require changing interfaces upon further development of the project

5.2.2 Responsibilities

- The RPi will control and receive video data from the installed gimbal camera and process it to determine targets of opportunity
- The RPi will then signal the water delivery layer to shoot at the target, completing its task
- The RPi sends command inputs to the CubeOrange to automatically fly and seek out targets of opportunity

5.2.3 RPi Transponder Interfaces

Table 7: RPi Transponder interfaces

ID	Description	Inputs	Outputs
#6.5	HDMI/Ethernet	Video Data from Gimbal Camera	N/A
#6.6	GPIO	N/A	Signals the Water Delivery Layer
#6.7	USB	Flight Data from CubeOrange	Commands to CubeOrange
#6.8	Serial0	N/A	Gimbal Control

6 FLIGHT COMPONENTS SUBSYSTEMS

6.1 MOTORS

The motors will be providing the rotational motion the drone requires for flight to take place. There are two sets of brushless motors being used. One set is rotating clockwise while the other is rotating counterclockwise. This will prevent any yaw from forming when in flight.

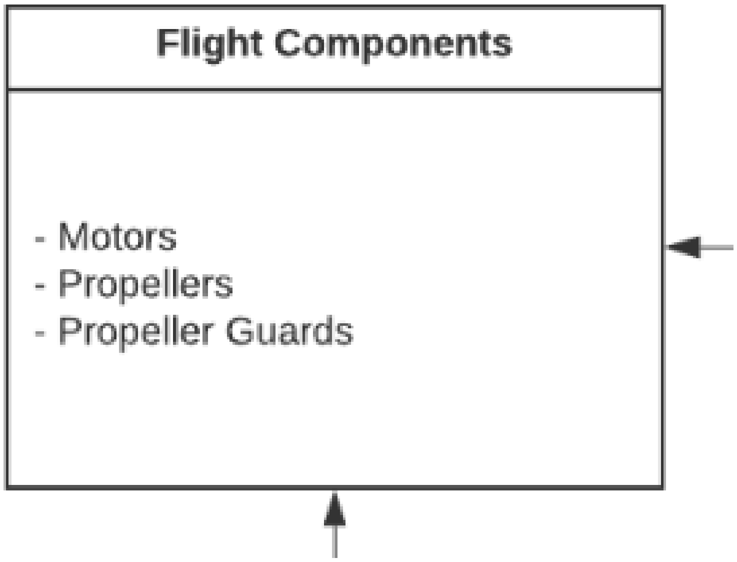

Figure 5: Flight Components layer diagram

6.1.1 ASSUMPTIONS

- Each motor will have be using an ESC, electric speed control, that is properly configured to allow for a full range of control
- The individual motors must all be rotating at the same speed for the yaw to be properly accounted for and corrected for
- The blades must also be installed in the correct orientation for lift to be produced

6.1.2 RESPONSIBILITIES

- The brushless motors responsibility is allowing the drone to take off

6.1.3 MOTORS INTERFACES

Table 8: Motors interfaces

ID	Description	Inputs	Outputs
#5.1	Electric Speed control	PWM	N/A
#5.2	Props	Rotational Velocity	Air

6.2 Props

Propellers are what the drone is using to produce the lift force needed to take off. As the props rotate at different speeds, they will push air downward at varying rates creating different upper movements. These varying movements will be used to control altitude, yaw, baking, roll, and pitch. The rotational motion will be caused by the brushless motors.

6.2.1 Assumptions

- The propellers will have two sets that produce lift at two different directions
- One must produce lift when rotating clockwise while the other needs to produce lift counterclockwise
- Since they are flimsy and dangerous when rotating, they must be protected by a guard

6.2.2 Responsibilities

- The propellers are responsible for thrust generation and movement control of the drone

6.2.3 Props Interfaces

Table 9: Props interfaces

ID	Description	Inputs	Outputs
#5.3	Brushless Motor	PWM from ESC	Angular velocity
#5.4	Propeller Guards	N/A	N/A

6.3 Prop Guards

The propeller guards do not move or do much of anything, but they provide for a marginal impact on forcing and directing air to move in a particular direction. Their primary purpose is as a safety device which protects people and the propellers from harm.

6.3.1 Assumptions

- The propellers must be rigid and durable to withstand impacts if the drone falls or crashes
- They must cover a considerable circumference length of the propellerś movement path

6.3.2 Responsibilities

- The responsibility of the propeller guards is to protect people
- It must also preserve the propellers in case of a crash

6.3.3 Prop Guards Interfaces

Table 10: Prop Guards interfaces

ID	Description	Inputs	Outputs
#5.5	Brushless Motor	PWM from ESC	Angular velocity
#5.6	Propeller	Angular velocity from motor	Air

7 Communications Subsystems

7.1 Telemetry Array

The telemetry array consists of a barometer, accelerometer, gyroscope, and compass within the Cube Orange module. The telemetry data will potentially be read by the Raspberry Pi, and will be communicated to our Mission Planner software.

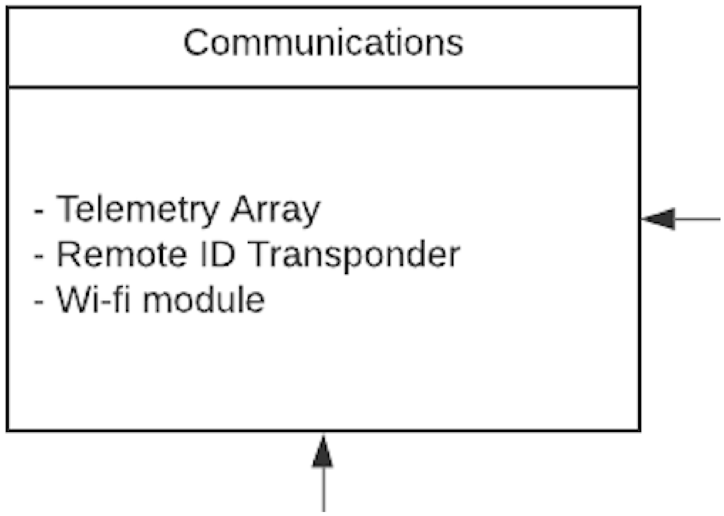

Figure 6: Communications layer diagram

7.1.1 Assumptions

- Wi-fi connectivity will be available at the competition field
- Telemetry sensor output is accurate
- Mission Planner is able to consume data provided by the array

7.1.2 Responsibilities

- The telemetry array shall be responsible for communicating accurate vehicle movement, heading, and environmental data to the flight control software

7.1.3 Telemetry Array Interfaces

Table 11: Telemetry Array interfaces

ID	Description	Inputs	Outputs
#7.1	USB connection to Raspberry Pi	N/A	Telemetry sensor data
#7.2	Wi-fi connection to Mission Planner	N/A	Telemetry sensor data

7.2 Remote ID Transponder

The remote ID transponder is responsible for broadcasting identifying information about the drone as required by the FAA.

7.2.1 Assumptions

- A compatible and approved broadcast module can be sourced
- The module can reasonably be attached to the frame

7.2.2 Responsibilities

- The remote ID transponder is responsible for broadcasting: registered drone ID, drone location/altitude, drone velocity, takeoff elevation/location, time mark

7.2.3 Remote ID Transponder Interfaces

Table 12: Remote ID Transponder interfaces

ID	Description	Inputs	Outputs
#7.3	Radio broadcast	N/A	Registered drone ID Drone location/altitude Drone velocity Takeoff elevation/location Time mark

7.3 Wi-fi Module

The wi-fi module shall be responsible for allowing communication between the Cube Orange and the base control station running Mission Planner.

7.3.1 Assumptions

- Wi-fi connectivity will be available at the competition field

7.3.2 Responsibilities

- The wi-fi module is responsible for providing facilitating bi-directional communication between the Cube Orange and Mission Planner

7.3.3 Wi-fi Module Interfaces

Table 13: Wi-fi Module interfaces

ID	Description	Inputs	Outputs
#7.4	Wi-fi connectivity between Cube Orange and base station	Flight commands from Mission Planner	Telemetry sensor data Log output

8 Power Subsystems

8.1 Battery

The unmanned aerial vehicle needs a light battery which allows it to hold prolonged flight. For this, a lithium polymer battery will be powering all equipment onboard the drone. With its higher energy density as compared to NiCad and NiMH batteries, the LiPo will output 11.1 V and will have a charge capacity of 7000 mAh. It will allow for a 10-minute flight time.

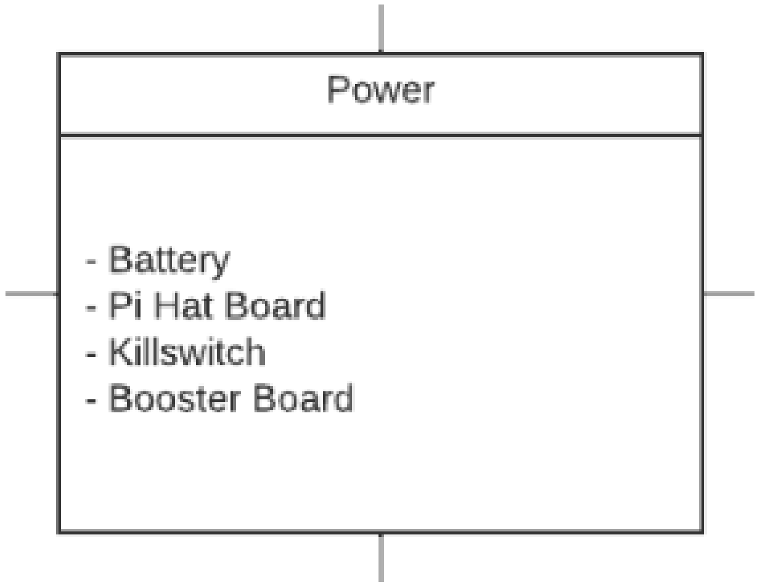

Figure 7: Power layer diagram

8.1.1 Assumptions

- The drone will have its voltage draw limited to an amount appropriate to keeping the drone in the air for 10 minutes or more
- There should only be one battery on the drone
- The battery is labeled 11.1 V with a charge capacity of 7000 mAh, and this voltage and charge is what is expected

8.1.2 Responsibilities

- The battery is responsible for providing all components on the aerial vehicle with power
- It needs to run motors, sensors, cameras, and computers such as the raspberry pi and microcontrollers

8.1.3 Battery Interfaces

Table 14: Battery interfaces

ID	Description	Inputs	Outputs
#8.1	Kill Switch	11.1 V DC (battery positive)	11.1 V DC or 0 V
#8.2	Power Distribution Board	0 V (battery ground)	0 V (ground)

8.2 HAT Board (PI Connect Lite)

The HAT board allows the drone to provide low noise power to the raspberry pi using a lithium polymer battery. The board uses the GPIO pins to transfer power and telemetry data using the Distribution board and the gimble camera.

8.2.1 Assumptions

- There will a configuration library provided by the developers of the Raspberry Pi HAT which will allow the use the GPIO pins to be configured correctly
- Since the HAT only has one telemetry, or serial, port for communication between raspberry pi and other devices, we will be using the USBs on the RPI board for other peripherals

8.2.2 Responsibilities

- The HAT board will be responsible for providing the raspberry pi with constant and reliable power through the flight of the drone
- It will be using its 6-pin serial port connector to communicate data with the camera gimbal

8.2.3 HAT Board (PI Connect Lite) Interfaces

Table 15: HAT Board (PI Connect Lite) interfaces

ID	Description	Inputs	Outputs
#8.3	Power Distribution Board	11 V	11 V
#8.4	Raspberry PI	Serial bus: Telemetry data from gimbal	Serial bus: Telemetry data to gimbal
#8.5	Gimbal	Serial Bus: Raspberry PI	Serial Bus: Raspberry PI

8.3 Kill Switch

To improve safety, a mechanical kill switch is installed on the drone. It is connecting the positive terminal of the battery to the power distribution board. This will allow all devices on the drone to always be grounded while only letting power flow to all device when there is a clear intension to do so. If the drone begins to malfunction, flicking a switch off is more reliable than yanking a battery when speed matters.

8.3.1 Assumptions

- All splicing used solder and shrink rap to prevent any possible shorts or open circuits
- The kill switch housing is completely covered by a 3D print shell
- No one should touch these terminals while there is a battery attached

8.3.2 Responsibilities

- The kill switchś main and only responsibility is to allow for a safe, quick, and secure toggling of the drones running state

8.3.3 Kill Switch Interfaces

Table 16: Kill Switch interfaces

ID	Description	Inputs	Outputs
#8.6	Battery	0 V	11 V
#8.7	Power Distribution Board	11 V	11 V

8.4 Booster Board

The power booster board is needed to help run the gimbal. The gimbal camera has a power input requirement of 14 volts. However, the drones can only use 11 volts provided by the batteries. Thus, the booster board will step-up the voltage to meet the gimbal needs.

8.4.1 Assumptions

- The gimbal camera will not be affected by the high frequency square wave signal produced by the switching behavior of the device
- Since the voltage increase comes by reducing the current, the device will still have sufficient current to function correctly

8.4.2 Responsibilities

- The booster board is responsible for providing the gimbal camera with the additional voltage for it to operate without issue

8.4.3 Booster Board Interfaces

Table 17: Booster Board interfaces

ID	Description	Inputs	Outputs
#8.8	Gimbal	14 V Serial Bus	Serial Bus
#8.9	Power Distribution Board	11 V	11 V

9 SENSORS SUBSYSTEMS

9.1 GIMBAL CAMERA

This subsystem is the dronés means of viewing the ground area specified in mission planner. OpenCV will be used in conjunction with the camera to identify and scan UGV targets.

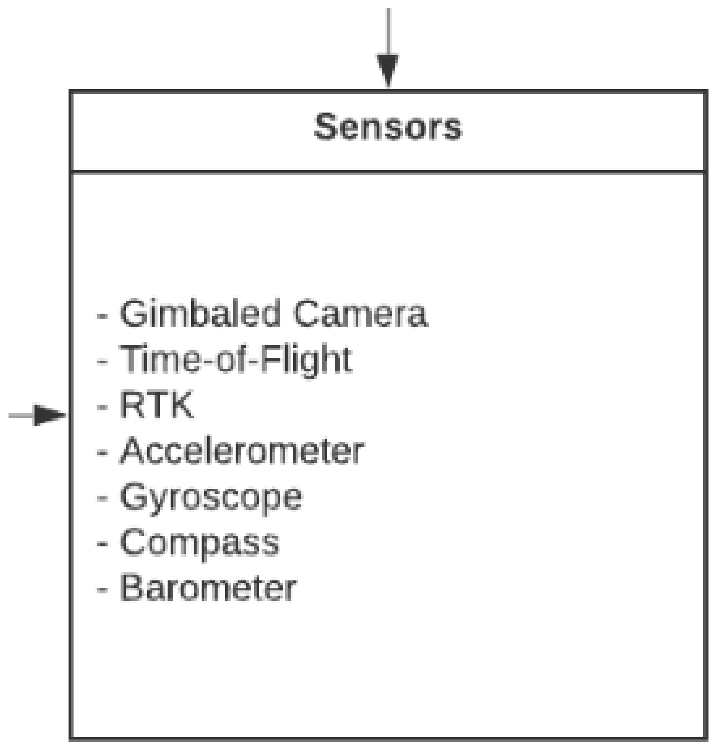

Figure 8: Sensors layer diagram

9.1.1 ASSUMPTIONS

- Within the power requirement for operation/use of camera
- Camera will be able to point directly downward, parallel with water deployment system
- Image quality is sufficient for target detection

9.1.2 RESPONSIBILITIES

- The gimbal camera is responsible for scanning the ground along the path taken by the drone set by mission planner
- OpenCV will be used to identify any UGVs with a scannable code on the top of the ground vehicle
- Once scanned, the UGV will be identified as a target for the water deployment system and mission planner must be notified in order to halt the current path and move to the new waypoint marking the UGV

9.1.3 Gimbal Camera Interfaces

Table 18: Gimbal Camera interfaces

ID	Description	Inputs	Outputs
#9.1	Siyi A8 Mini Gimbal and Camera	SBUS	SBUS

9.2 Time of Flight

The Time of Flight (ToF) subsystem will allow the drone to measure and record its current altitude during the mission.

9.2.1 Assumptions

- Within power requirements
- Will point directly downward, perpendicular with the ground
- Ground is ideal (flat)
- Data is accurate

9.2.2 Responsibilities

- The onboard Time of Flight sensor is responsible for calculating the distance between the ground and the UAV during the mission
- This data will be used for calculation in other subsystems including the water deployment system as well as the flight control
- We want to be at an ideal distance for target acquisition and elimination

9.2.3 Time of Flight Interfaces

Table 19: Time of Flight interfaces

ID	Description	Inputs	Outputs
#9.2	Time of Flight (ToF) sensor	GPIO	GPIO

9.3 RTK

The RTK gps subsystem provides a precise geolocation of the droneś position within a few centimeters.

9.3.1 Assumptions

- Within power requirement
- RTK hubs located on top of Nedderman hall and Professorś house are active
- Drone will take flight outdoors
- Data is accurate

9.3.2 Responsibilities

- The RTK gps is responsible for geolocating the drone at any given time within a very small error (a few centimeters)
- Geolocation of the drone will be utilized in mission planner for traversing from one waypoint to the next during the mission as well as staying within the set geobarrier

9.3.3 RTK Interfaces

Table 20: RTK interfaces

ID	Description	Inputs	Outputs
#9.3	Here3+ RTK gps	CAN1	CAN1

9.4 Accelerometer

The accelerometer subsystem measures the droneś speed and acceleration in a given direction.

9.4.1 Assumptions

- Within power requirement
- Data is accurate

9.4.2 Responsibilities

- The accelerometer is responsible for measuring the drone's linear speed/acceleration in X/Y/Z axes
- This data will be used in conjunction with the flight control subsystem for reaching each waypoint in a timely manner

9.4.3 Accelerometer Interfaces

Table 21: Accelerometer interfaces

ID	Description	Inputs	Outputs
#9.4	Cube Orange+ IMU	N/A	N/A

9.5 Gyroscope

The gyroscope subsystem measures and provides the tilt angle of the drone which can also be used for maintaining balance.

9.5.1 Assumptions

- Within power requirement
- Under normal earth conditions
- Data is accurate

9.5.2 Responsibilities

- The gyroscope is responsible for measuring the tilt angle of the drone as well as maintaining balance when hovering
- The tilt angle of the drone is a big factor in the speed of the drone
- The ability to maintain a near perfect angle when hovering is important when descending to scan/eliminate targets as well as for landing safely

9.5.3 Gyroscope Interfaces

Table 22: Gyroscope interfaces

ID	Description	Inputs	Outputs
#9.5	Cube Orange+ IMU	N/A	N/A

9.6 Compass

The compass subsystem gives the drone a bearing on its direction.

9.6.1 Assumptions

- Within power requirement
- Compass is calibrated and provides accurate data

9.6.2 Responsibilities

- The compass is responsible for providing a bearing and a sense of direction for the drone as well as the users controlling it
- The data from the compass will be important for traversing from one waypoint to the next

9.6.3 Compass Interfaces

Table 23: Compass interfaces

ID	Description	Inputs	Outputs
#9.6	Here3+ RTK gps	CAN1	CAN1

9.7 Barometer

The barometer subsystem measures and records the current pressure that the drone is experiencing at varying heights during a mission.

9.7.1 Assumptions

- Within power requirement
- Data is accurate

9.7.2 Responsibilities

- The barometer is responsible for accurately measuring atmospheric pressure that the drone is experiencing at different heights
- This data is correlated with flight control since thrust calculation could change based on changes in atmospheric pressure as the drone ascends during the mission

9.7.3 Barometer Interfaces

Table 24: Barometer interfaces

ID	Description	Inputs	Outputs
#9.7	Cube Orange+ IMU	N/A	N/A

REFERENCES