Prepared by: Conrad Obeng, Mark James jr., Lexi McMinn, Ehab Afsoonko, Matthew Moubray

Product Requirements And Specifications Document (PRSD) Drone2Rover (D2R)

Approvals

Title	Print	Signature	Date

Revision History

Revision	Summary of Change	Originator
X0	New Document	UTSA-ECE

1. Introduction

This document contains the system requirements for ***Drone2Rover***. These requirements have been derived from several sources, including past documentation from a previous project, market research, and lab documents.

1.1 Purpose of This Document

This document is intended to guide development of ***Drone2Rover***. It will go through several stages during the course of the project:

1. **Draft:** The first version, or draft version, is compiled after requirements have been discovered, recorded, classified, and prioritized.
2. **Proposed:** The draft document is then proposed as a potential requirements specification for the project. The proposed document should be reviewed by several parties, who may comment on any requirements and any priorities, either to agree, to disagree, or to identify missing requirements. Readers include end-users, developers, university faculty, course instructor, and any other stakeholders.
3. **Validated:** Once the various stakeholders have agreed to the requirements in the document, it is considered validated.
4. **Approved:** The validated document is accepted as an appropriate statement of requirements for the project. The developers then use the requirements document as a guide to implementation and to check the progress of the project as it develops.

1.3 Scope of the Product

This project aims to expand the number of vehicle transportation modalities traditionally associated with QuadCopter Drones, so that customers are not pigeonholed into one method of transportation. Specifically, the project aims to bring VTOL Fixed-Wing and Rover transportation modes to a drone, allowing for longer flight times with less battery, and ground-based transportation, respectively.

1.4 Case for the Product (Need)

If an end-user only has a single UAV/UGV/unmanned system, that machine is limited to just one transportation modality. However, having separate re-attachable modules for different movement options allows the operator to change the functionality of the unmanned system without needing to purchase an additional system. Currently, most professional Fixed-Wing VTOL UAVs can cost anywhere from $1,000 to $20,000. By creating a Fixed-Wing VTOL and Rover re-attachable module, we enable the ModiFly Drone to be an extremely versatile and adaptable UAV versus its competitors, while also saving the consumer both time and money.

2. General Description

The way an unmanned system is designed and built changes the way it moves. Some design configurations can allow a machine to fly, others allow it to travel underwater, and still others allow it to drive across land. There can even be design differences when it comes to the same travel medium, such as building a drone that can hover and move indoors, versus building a drone that can travel long distances. The differences in these designs and travel modalities means that if you require a wide breadth of different system modes, you will have to obtain multiple systems with varying designs. Not only does this add cost and complexity, it also significantly increases the number of potential failure points. Our team is developing a way to avoid this issue. We're doing this by creating Transportation Modules for a drone, that will allow you to have the benefits of multiple transportation modes without having to get wholly separate systems. Specifically, we are making a Fixed-Wing VTOL Module and a Rover Module.

2.1 Product Perspective

The client has asked for this product to be developed due to their desire for increased transportation options for their drone system. Specifically, the Fixed-Wing VTOL Module will allow for longer transportation times and reduced battery consumption, and the Rover Module will allow for land-based movement. This will allow for increased military, commercial, and law enforcement usage.

2.2 Product Functions

The transportation modules that we are developing will allow for increased flight time, reduced battery consumption, and ground transportation. User will be able to switch between land and air modes without physically interacting with the device, and be able to easily convert the drone from strictly Quadcopter into Fixed-Wing VTOL mode. The Rover module will also have the ability to detach from the drone and be driven separately.

2.3 User Characteristics

The product is expected to be used by researchers, commercial users, and potentially the military. The users will need to have the technical skills to operate and maintain a drone, while also having the ability to attach and remove simple modules. Users might run into issues with module attachments if the drone has been damaged.

2.4 General Constraints

The project's constraints include the weight of the drone, the drone's battery life, limited flight controller serial ports, cost, development environment, and the Ardupilot firmware package. The weight of the drone is vital as the heavier the drone is, the more power is needed to fly which ties in with the drone's battery life. In addition, with current Federal Aviation Administration (FAA) laws drones are required to stay below certain altitudes making testing the drone limited. Lastly, our project needs to be compatible with the Ardupilot firmware package and is limited in how many serial ports the flight controller offers.

2.5 Assumptions and Dependencies

Current assumptions are that the product will be utilized by users with knowledge on drone piloting, and that the drone will have minimum ports required for the transportation modules. Dependencies include Ardupilot (open source), the existing ModiFly drone system, and other drone functionalities.

2.6 Objectives

1) Fixed Wing VTOL:
    a) Modify Ardupilot firmware to be compatible with the fixed wing VTOL module and controls.

   b) Incorporate a tilt rotor such that the propellers begin in a vertical position, then transition to horizontal position after a certain altitude or airspeed. This will increase forward thrust and assisting the wings to generate lift and forward thrust further reducing power consumption.
   c) 3-D print Module attachment and ensure the detachment processs does not interfere with the structural integrity or flight efficiency of the drone.
   d) Design an effective aerodynamic body and wings for gliding which will reduce the batteries power consumption after takeoff and increase flight duration.
2) Rover Module:
   a) Modify Ardurover firmware to be compatible with the child rover module and controls.
   b) Design a child rover module that is able to detach from the parent drone and operate as a separate independent module.
   c) Establish child rover's weight limit such that it does not interfere with the drones operable thrust to weight ratio.
   d) Configure an automated self-landing sequence for the parent drone to land and reattach to the child rover.

Figure 1: Functional Block Diagram

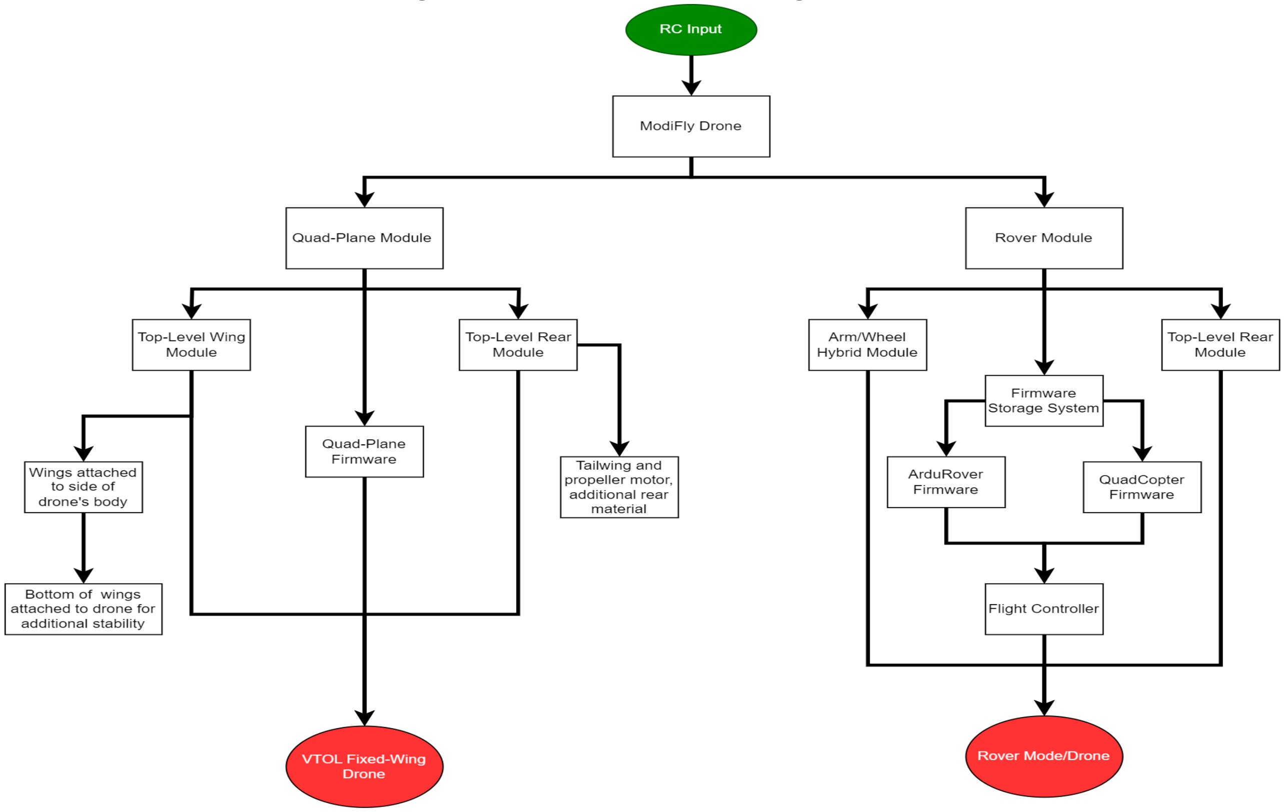
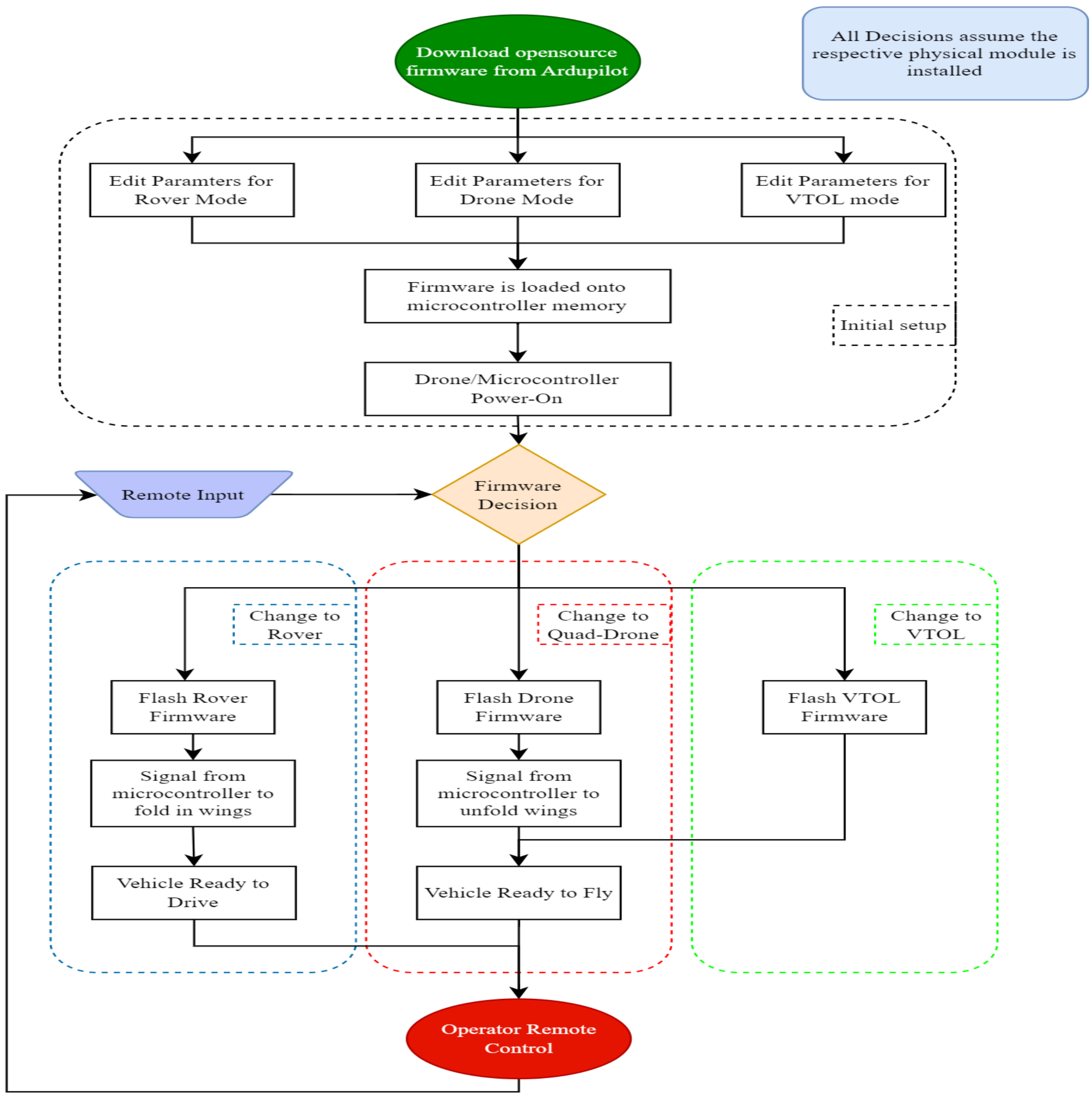


Figure 2: Software Flowchart



2.7 Plan

Initial Configurations

- The base drone will first be reviewed in order to verify compatibility with the Fixed-Wing VTOL and Rover modules, and any necessary modifications to the drone will be made. Compatibility verification will include confirming the number of servo ports available, confirming PWM motors will work with the drone, and aerodynamics checks for the Fixed-Wing VTOL module, using eCalc software. The maximum firmware size the flight controller can hold will also be checked.

- Fixed-Wing VTOL and Rover Firmware from Ardupilot will be researched in order to gain a firm understanding of each set of parameters, so that the correct parameters can be set in the firmware.

Design Phase

- The first sketch of the Rover module will be created. This will include coming up with an initial design that is both low weight and low power. Components such as the wheel axles, and steering considerations will be initialized here. Components that cannot be 3D printed, such as the wheels, will be bought during this stage.
- Fabrication and testing of the Rover module prototype will be done to ensure the drone's ability to take off, stay in the air, and land are not hindered. Flight time will also be tracked here as an initial benchmark. The majority of fabrication will be done through 3D printing. Research into plane design and aerodynamics for the Fixed-Wing VTOL module will begin here by one member of the team.
- At this stage, one to two members of the team will continue working on the Rover module, while the rest of the team transitions to begin work on the Fixed-Wing VTOL module. The first draft of the module will be made here, and necessary components will be ordered, such as styrofoam to create the wings and servos.
- Final design of the Rover module should be created here, and fabrication will begin. The Fixed-Wing VTOL module prototype will begin testing here. Key factors that will be noted are transition between VTOL and glide mode speed, flight time, stability, and airspeed.

Final Design Steps and Project Wrap-Up

- Final testing and verification of the Rover module will be done, as well as continued testing of the Fixed-Wing VTOL module. It is anticipated that designing and testing of the Fixed-Wing VTOL module will take significantly longer than that of the Rover module, so at this point the team members that had been working on the Rover module will transition in to aiding with the Fixed-Wing VTOL module, as well as writing required documentation for the final product.
- Final design and fabrication of the Fixed-Wing VTOL module will be concluded, and team will transition project and any out-of-scope work to members of the USL Lab, for continued work at their discretion.

Project Description

- High-Level Task Description
  - Verify that existing drone design can support new modules
    - Make changes to design if necessary
  - Develop and produce the fixed-wing and rover physical modules and detachment mechanisms
  - Establish firmware package compatibility with each separate module and flight controller
- Principles and Theories

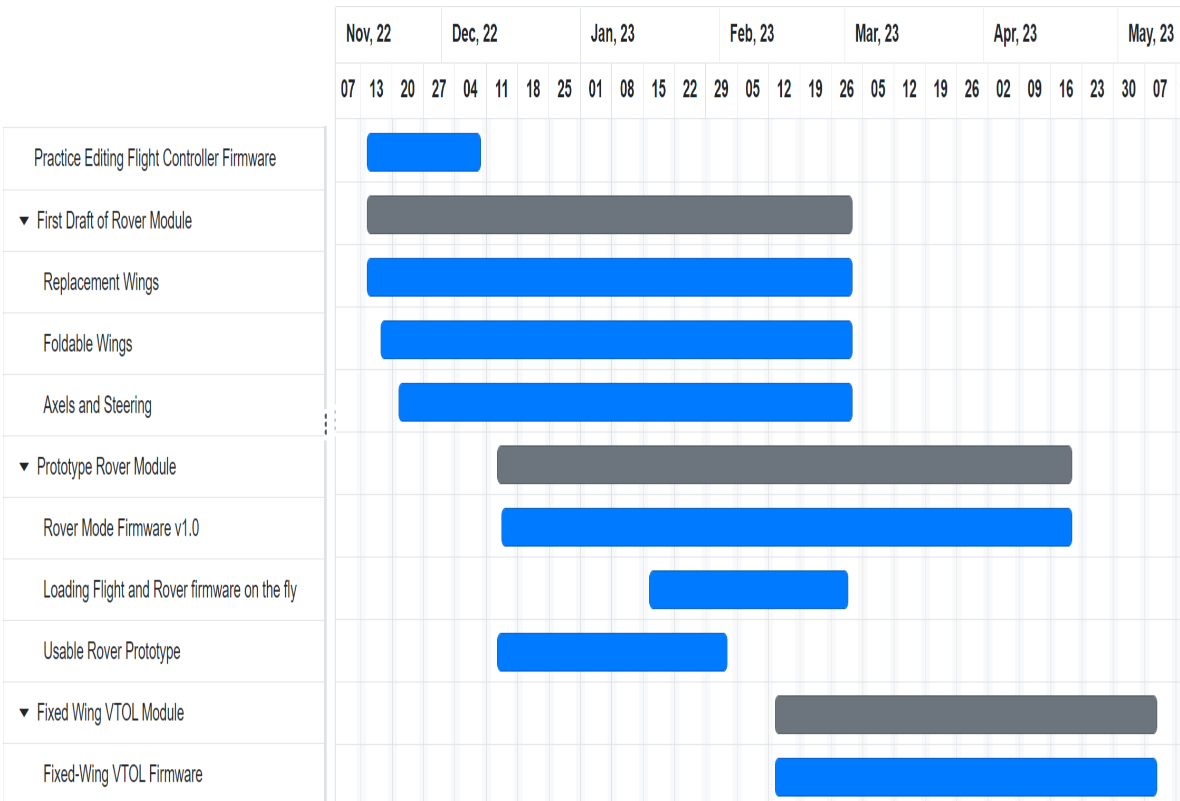
  - Aerodynamics Principles
    - Lift
    - Gliding
    - Acceleration
  - Thrust to Weight Ratio
  - Ohms law
  - Boolean Theory
- Compications
  - Additional weight may hinder ability for drone to takeoff and stay in the air
  - The lack of readily available flight locations and the FAA approval process to fly drones outside
  - Parent drone being able to recognize proper landing position
  - Communication between the child rover and parent drone
- Design Approach
  - Calculate the different combinations of modules and their associated weight limits based on selected rotors to ensure operable thrust to weight ratio
    - Including minimum and maximum number of modules/module weights
  - Virtually design and test physical 3-D modules structural integrity, aerodynamics, and assembly process before production
  - Modify Ardupilot and Ardurover firmware packages to be compatible with their associated module
- Implementation
  - Establish that the fixed-wing VTOL module is able to achieve lift
  - Integrate the child rover and parent drone module
- Validation and Verification
  - Testing physical modules virtually
  - Lab approval of design and implementation
  - Testing with a prototype before finalized product
  - Verifying engineering requirements are satisfied with finalized product
  - Testing the durability and max operating parameters of the finalized product

2.6 Schedule Requirements

1. Month 1 - November:
   1.1. Download and familiarize with flight controller firmware
   1.2. Begin first design of Rover mode modules
2. Month 2 - December/January
   2.1. Prototype of Rover module
   2.2. First firmware modification test
   2.3. Implement Firmware swapping
3. Month 3 - February
   3.1. Begin prototyping Fixed-Wing VTOL & firmware
   3.2. Continued development of Rover module
4. Month 4 - March
   4.1. Rover Module in final state, firmware close
   4.2. Fixed-Wing VTOL development continued

5. Month 5 - April to End
    5.1. Rover Module with switching capability implemented and fully document
    5.2. Fixed-wing VTOL module and firmware fully implemented

Figure 3: Gannt Chart for Workflow



3. Specific Requirements and Specifications

This section of the document lists specific requirements and specifications for Drone2Rover. Requirements and specifications are divided into the following sections:

1. User requirements and specifications. These are requirements and specifications written from the point of view of end users, usually expressed in narrative form.
2. System requirements and specifications. These are detailed requirements and specifications describing the functions the system must be capable of doing.
3. Interface requirements and specifications. These are requirements and specifications about the user interface, which may be expressed as a list, as a narrative, or as images of screen mock-ups.

3.1 User Requirements and Specifications

3.1.1 User interface

The user interface will showcase each separate modules camera display allowing the user to operate each module individually through the flight controller. This is done through the pre-existing Ground Station that is compatible with Ardupilot.

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3.1.2 Ergonomics

The Fixed-Wing VTOL module and child rover will be designed to reduce drag and maximize lift. The materials used to construct the structure will need to be light yet durable.

3.1.3 Training or skills required

A working knowledge of how to operate the drone in each different modulare combination. There will be a need for a technical understanding of how the firmware works and how to modify different parameters to achieve desired results through Python. In addition, a basic understanding of aerodynamics and how to test 3-D models virtually. As well as training on how to use a 3-D printer will be needed.

3.2 System Requirements and Specifications

3.2.1 Physical Characteristics

Fixed-Wing VTOL Module: A pair of wings with control surfaces and two propellers at the head, as well as a tail portion with additional control surfaces and a fixed propeller.
Rover Module: Detachable Rover with standard track wheels and access points at the top for connection with parent drone.

3.2.2 Material Requirements

Fixed-Wing VTOL Module: Styrofoam (or other building material), 3D printer plastic, propellers
Rover Module: Wheels, 3D printer plastic, steering rod.

3.2.3 Electrical Requirements

Fixed-Wing VTOL Module: Servos for rotating mechanism, servos for control surfaces
Rover Module: Microcontroller, battery, receiver.

3.2.4 Abilities

Fixed-Wing VTOL Module: Rotate propellers to enter plane form
Rover Module: Detach from parent drone for independent driving, guided landing for drone (pending further testing to determine capability), send/receive information from parent drone.

3.2.5 Limitations

Fixed-Wing VTOL Module: Aerodynamics concerns (weight, lift, etc), size, Flight Controller
Rover Module: Battery life, wheel size.

3.2.6 Equipment or materials required to use the product

Fixed-Wing VTOL Module: Modifly Drone, Ground Station, Remote.
Rover Module: Modifly Drone, RC Controller, Ground Station, Remote.

3.2.7 Equipment interface requirements

Both modules will be interacted with using the Mission Planner Ground Station. This is an open source software that has numerous training manuals and instruction sets existing on the internet.

3.2.8 Handling and storage requirements

Careful handling is necessary for both modules to ensure all parts stay structurally sound. Both modules should be stored in areas that are large enough to house each one without causing any bending or breaks. Modules should not be stored in extreme hot or cold environments.

3.2.9 Cleaning and Sterilization
N/A

3.2.10 Product maintenance and serviceability
Prior to any flight ensure the drone's structure is not damaged.
Prior to any flight verify that the electronic assembly is properly connected and damage free.
Batteries need to be disconnected prior to any maintenance.
Remove and replace any damaged components and conduct flight tests after any installation.

3.2.11 Operating parameters
Must comply with FAA Part 107 operating standards.
Do not operate in winds stronger than 5 MPH

3.2.12 Repeatability and reproducibility
Modules will be continuously reusable as long as there is no damage to the structure or electrical circuits being exposed to water.

3.2.13 Reliability
Modules may fail before, during, or after flights due to any variety of factors. It is the customer's responsibility to ensure all flights are done in a safe environment, and that all modules are correctly attached and secure. Failing to do so may result in damage to the drone, modules, or property.

3.2.14 Mechanical safety features
Structural frame will been designed to safeguard the electronic assembly from collisions that occur under 5 mph

3.2.15 Electrical safety features
LIDAR object avoidance
Kill switch on remote and Ground Station

3.3 Interface Requirements and Specifications
System Interface will primarily be done through the use of an open-source Ground Station called Mission Planner. A pre-existing UI will be utilized for the purpose of uploading parameters for modules pre-flight. These interfaces used in tandem will mean that a new one will not have to be developed for the purposes of this product.

3.4 Environmental Conditions

3.4.1 Temperature
3.4.1.1 Operating: 23°F - 104°F

3.4.1.2 Storage: 68-77°F

3.4.2 Humidity
3.4.2.1 Operating: less than 80% non-condensing
3.4.2.2 Storage: less than 65%

3.4.3 Shipping, transportation vibration
- N/A

3.4.4 Pressure and Altitude
- 400-foot altitude limit (FAA Part 107)

3.4.5 Electromagnetic Interference
- N/A

3.4.6 Electrostatic Discharge
- N/A

3.4.7 Impact Resistance
- N/A

3.5 Manufacturing

3.5.1 Cost
- Motors (Exact number unknown): $30-$60
- Pixhawk 4: ~$100
- 4x Wheels: $20
- Fixed Wings: ~$20
- 3D printing parts (Exact number of plastic unknown): $20-$50

3.5.2 Environmental requirements for production
- Source, containment, and disposal of lithium-ion batteries.

3.5.3 Raw materials and suppliers
- 3-D printer filament

3.5.4 Test methods, standards
- Virtual testing
- Prototype testing
- Incremental Testing
- Durability testing

3.6 Packaging

3.6.1 Packaging configurations
- All modules and rotors need to be detached from the drone's made body.

3.6.2 Packaging materials
- A large enough box to house all the modules and the drone. Bubber wrap all larger items. Place a cushioning material on the top and bottom and fill empty space with packing peanutes.

3.6.3 Special shipment requirements
- Appropriate marking due to the shipping of lithium batteries.

3.7 Labeling

3.7.1 Detail intended use, warning, directions for use, cleaning, expiration date
- Do not fly above 400 feet

3.7.2 Identify target audience for labeling
- Researchers, military, commercial, and law enforcement.

3.7.3 Language requirements
- English

3.8 Regulatory

3.8.1 Clinical trials
- N/A

3.8.2 Submission type
- N/A

3.8.3 CE mark
- N/A

3.8.4 US and international standards
- FAA Part 107

3.8.5 Patent issues
- N/A

3.8.6 Existing technology to avoid
- N/A

4. Appendices

- N/A

5. Glossary

Ardupilot: Firmware for interacting and setting parameters with Fixed-Wing systems
Ardurover: Firmware for interacting and setting parameters with Rover systems
FAA: Federal Aviation Administration
UAV: Unmanned Aerial Vehicle
UGV: Unmanned Ground Vehicle
VTOL: Vertical Take Off and Landing

6. References

1) IEEE Standard for Drone Applications Framework. IEEE, 2021.
2) IEEE Standard Interface Requirements and Performance Characteristics of Payload Devices in Drones. IEEE, 2021.
3) IEEE Standard for Wireless Local Area Networks. IEEE, 2016

7. Index

- N/A