MicroCART Project Plan

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1 Problem Statement

The current Micro-Controller Aerial Research Team (MicroCART) platform in the Distributed Sensing and Decision Making Laboratory, while sufficient for demoing, does not meet the client's wants. The old system requires a revamp to a new platform that removes a bulky radio controller (RC) mixer from the physical quadcopter. The client also feels the current system does not have adequate data analysis tools to enable the system to become autonomous, so the team will be focused on getting the new system running with better analysis tools.

2 Concept Sketch

The end goal of the project is to remove the cameras from the system so the quad will need to provide adequate data from its sensors to help locate and control the quad. The simplified diagram below provides an example of how the communication flows across the entire system with the cameras included.

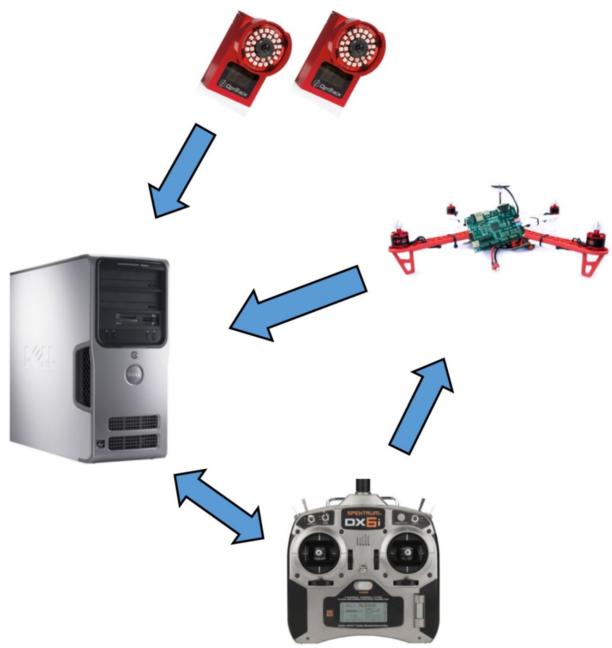


Figure 1: The high-level structure of the new system when using the labs OptiTrack cameras. Blue arrows indicate communication flow

2.1 Hardware Block Diagram

For the quad to fly properly and safely, a programmable processing board will handle computations required to operate the quadcopter. Specifically, the team will be using a Diligent ZyBo board to program the interconnections between sensors and peripherals. An example configuration of a flying functional system will appear similar to the diagram seen in Figure. 2.

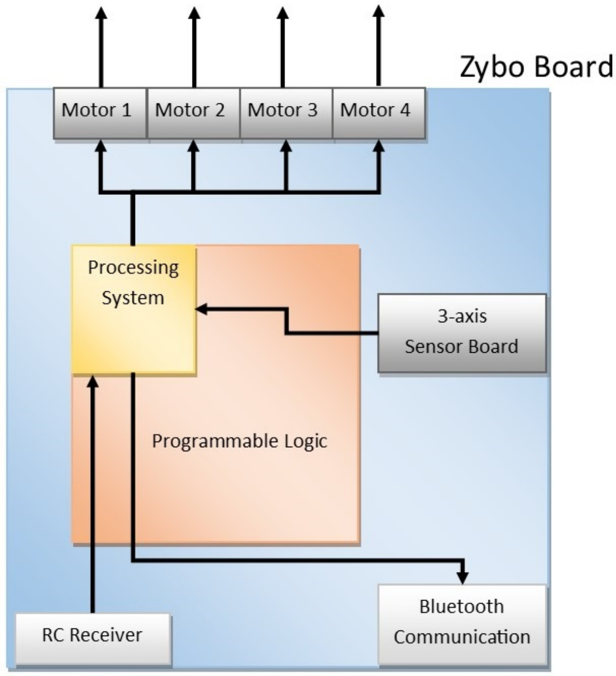


Figure 2: The high-level architecture of the Zybo board when communicating received controls to the motors and sending positional data to Bluetooth transmitter.

2.2 Software & Controls

To control the new system, a software graphical user interface (GUI) will be used to communicate with the quad through a radio controller. An example of the how the GUI will look can be seen in Figure 3.

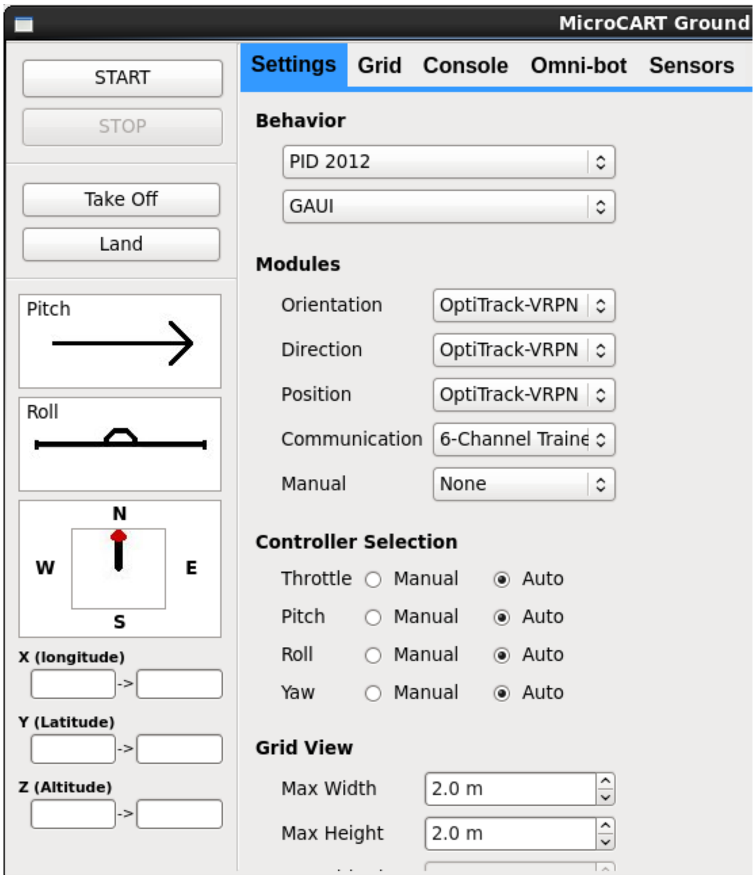


Figure 3: A sample layout of the GUI

2.3 Operating Environment

It should be noted that the operating environment for the quad will be within the lab which does not contain natural weather conditions. In other words, nearly all testing and flight runs will be done in a controlled, ideal environment.

3 Specifications

The client has provided several specifications and criteria that the new system will need to have.

3.1 Sensors and Peripherals

The on-board sensors for the quad need to provide consistent accelerometer, magnetometer, and gyroscope readings for the base station to safely conduct the quads movements. Additionally, the sensor needs to be placed near the quad's center of gravity in order to obtain useful data.

3.2 Physical Quadcopter

The quad chassis needs to be sturdy and provide a platform for a computing board, power supplies, and sensors. The chassis needs to be able to protect the items it is carrying while not being too closely bound that can cause disruptive vibrations on the systems.

3.3 ZyBo Board

The main processing component on board the quad system, the Zybo board, needs to perform an ample amount of functions including operating each of the four quad motors, mixing the throttle, pitch, roll, and yaw signals received from the RC receiver, and sending sensor data back to the base station appropriately.

3.4 Data Analytics

The new system requires data analytics that pull from multiple sources and compares the different measured points to gauge the accuracy of the on-board sensors. In other words, the OptiTrack camera system will be the basis for the quadcopter's location and will used as the control dataset since it provides precise measurements at a fast pace. The data analytic tools will need to be robust enough to effectively communicate to users what errors or outliers occur in readings received from the Zybo board.

3.5 Power Management

For a functional system, several problems regarding power management need to be addressed. First, the system needs to accurately relay current battery level information back to the user so the system can be controlled appropriately based on its current status. Second, the system should independently handle cases when their is not enough power and should drop altitude at a safe rate rather than stop mid flight and crash. Third, the system needs to regulate voltage levels of the batteries as they can be permanently damaged if the drained too much.

3.6 IR Camera System

While one of the client's goal is to move outside of the refined environment of the lab, the quadcopter still needs to operate with the high-speed IR cameras and use the data collected in conjunction with the data received from the quad's sensors. The differences between the two data sets must be analyzed and tested in order for the quad to be decoupled from the camera system.

4 User Interface Description

4.1 Hardware

The new quadcopter system, when complete, will consist of the programmable Zybo board mounted on the quad-chassis, 4 ESCs - each connected to a propeller, a Gyroscope/Accelerometer/Magnetometer sensor peripheral, and bluetooth and WiFi communication modules. A microSD card will be inserted into the board, containing a proper boot binary file, in order for the board to program its FPGA and correctly utilize and communicate with external peripherals. The board provides power to all these components on the quad, and therefore needs to be plugged into a power source in the form of batteries to be able to be flown. The board and its sensors will not need to be tampered with in order to fly, unless modifications to a component need to be made.

Additionally, a base station, either a desktop computer or other device, will need to be running the main MicroCART program in order to communicate, compute, and analyze flight data as needed.

4.2 Software

The platform's main program will have a GUI for configuring automatic or manual controls as well as information of the quad system's positional data: pitch, roll, yaw, altitude, latitude, and longitude. The GUI will also provide users with a command line interpreter for the user to enter control commands, a grid for users to draw paths for the quad to move through, and an option for the system to playback a flight.

4.3 Functional Requirements

- Zybo board generates PWM signals to each motor
- Zybo board receives RC signals from controller
- Zybo board boots from microSD card
- Camera system relays positional data to base station
- Quad and Zybo board are powered by 2 or 3-cell batteries
- Motors and Zybo board are powered by independent supplies
- Software plots data collected

4.4 Non-Functional Requirements

- Easy board and sensor accessibility when mounted on chassis
- Easily maintainable if new parts are required
- Board and sensor protection and stability during flight runs
- Easily expandable with additional peripherals and board configuration
- Easily usable and demoable for operators and curious people
- Quad doesn't immediately fall and crash when battery is low
- System is reliable and doesn't change parameters after every run
- System can be deployed with proper program and RC controller

4.5 Control & Automation

The MicroCART platform will allow for two modes of RC: manual and automatic. Manual control allows a user to use the RC device to maneuver the quad. Users who opt to manually fly the system should have previous experience flying RC quadcopters and know proper procedure to stop the system nicely. In Automatic mode, the base station computer will send commands through the RC device.

5 Deliverables

Based off the clients' end goals, the team has formulated steps and checkpoint deliverables required to complete the minimum requirements. Specifically, milestones have been created for each semester to help guide the team to success.

5.1 First Semester

- Fully programmed Zybo quad board
  - Working Hello World program demonstrating basic LED and button usage
  - Reading data from 3-axis sensor board
  - Controlling the quads motors
  - Software-implemented RC Mixer
  - Communicates positional data to base station through Bluetooth
- Mounted Zybo board and sensors on new chassis
- Working power and voltage regulators for systems batteries
- Implement a system to record high-speed camera data
- Implement a system to record on-board data for comparison to camera data
  - On-board data will initially be captured via on-board SD card
- Flyable demonstration of new system using old systems demo program
- Collected system data is parsed, analyzed, and visualized post-flight

5.2 Second Semester

- Demonstrate additional peripherals on quad
  - GPS
  - Camera
  - Wifi
- Demonstrate flight playbacks and full autonomous flights
- Demonstrate quad flight removed from camera environment
- Show integration with sister project
  - Tethering machines together and having them travel synchronously
  - Collecting data from both machines and integrating them
  - Running test flights and plotting the data
  - Enabling the quadcopter to fly outdoors
- Visualize flight data in real-time

6 Work Breakdown Structure

To maximize parallel development and workloads, project members have been assigned technical positions that they are responsible for and will help the team with regard toward the area. By specific request of the client, team members should have at least a little understanding of each component that others are working on, so work on that section can be done if the student is absent.

The team has decided the following roles for each member based on previous experience and interest:

Joe Benedict: Physical System Design and Controls Lead; Communication Officer

Adam Campbell: GUI and Platform Software Lead; Webmaster

Paul Gerver: Data Collection and Analysis Lead; Key Concept Holder

Tyler Kurtz: Mixing and Motor Lead; Key Concept Holder

Ravi Nagaraju: Power, Controls Management Lead; Webmaster

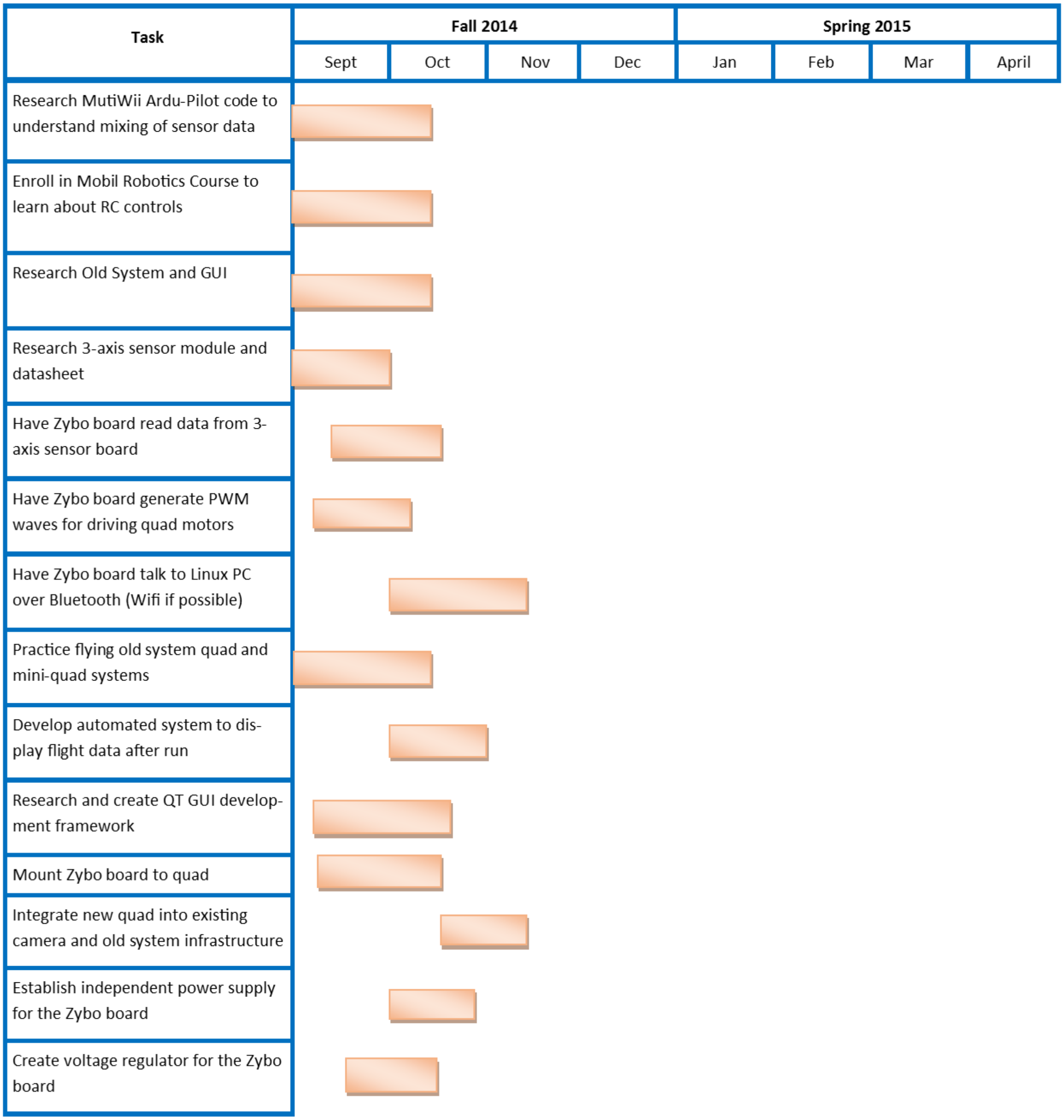
Jacob Rigdon: Quad Communications Lead; Communication Officer

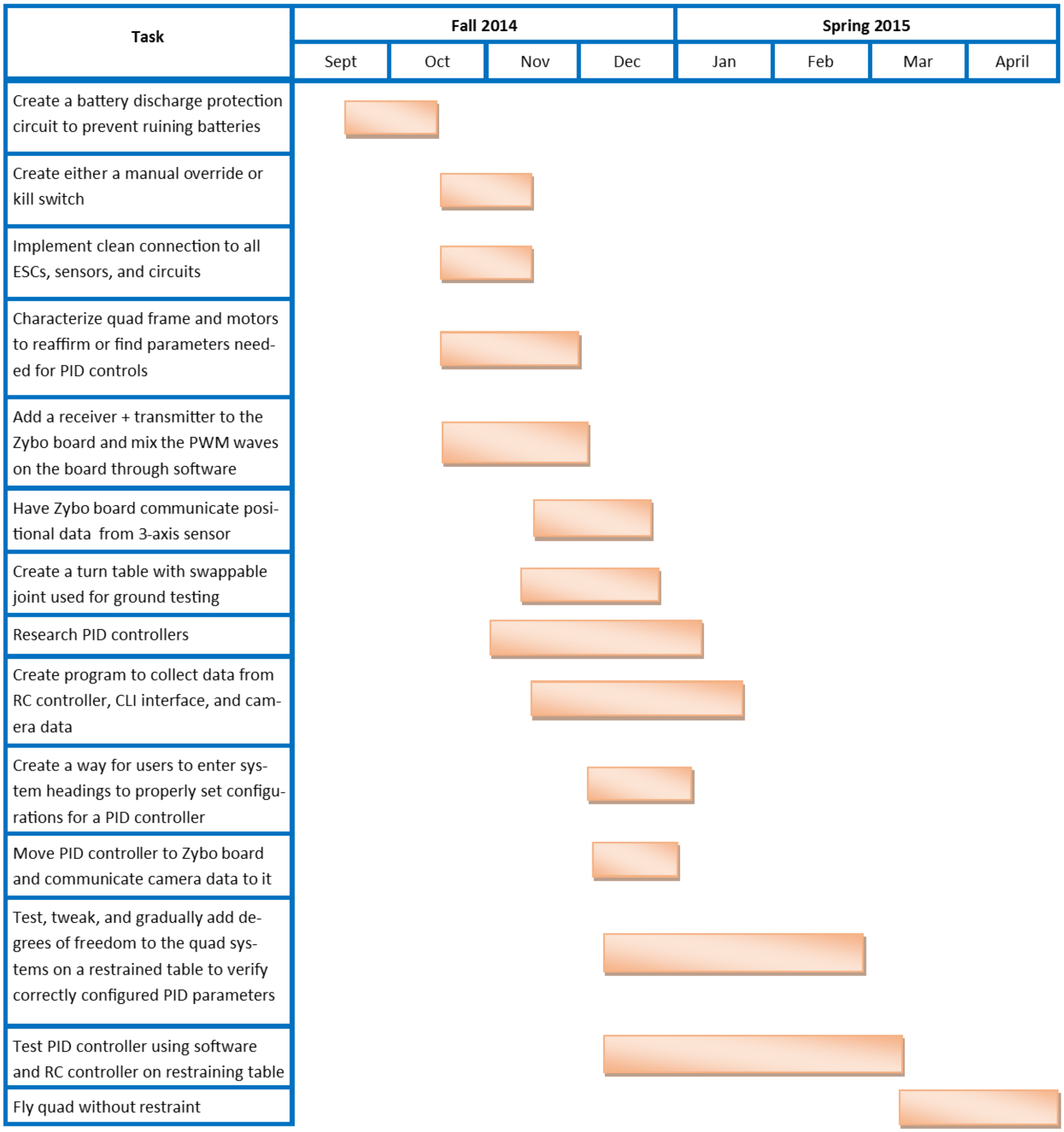
Matt Vitale: Sensor and Peripheral Lead; Team Lead

7 Resource Requirements

Resource	**How will team obtain it?**	**Estimated Cost**
DJI FlameWheel F450	Provided by Client	$32
ZYBO Zynq-7000 Development Board	Provided by Client	$125
SparkFun MPU-9150	Provided by Client	$34.95
Set of Batteries (Zippy 2100, Hyperion)	Provided by Client	N/A
4GB Micro SD Card	Provided by Client	$3
USB to MicroSD converter	Provided by Client	$13
MicroUSB cable	Provided by Client	$1
IR Mirror Balls	Provided by Client	N/A
OmniTrack IR Cameras	Provided by Client	N/A
Nexys2 Spartan-3E FPGA Board	Provided by Client	$140
SpekTrum DX6i RC Controller	Provided by Client	$130
InterLink Elite Controller	Provided by Client	$170
Electrical Speed Controllers (ESCs)	Provided by Client	N/A
DJI Motors	Provided by Client	N/A
Simulink Simulation Software	Provided by Client	N/A
MATLAB Software	Provided by Client	N/A
Various Small Hardware Items (connectors, screws, electrical tape, etc.)	Provided by Client	TBD
Workspace/Testing Area	Provided by Client	N/A
Various Hand Tools (screwdrivers, pliers, soldering iron, etc.)	Provided by Client	N/A

8 Project Schedule




Task
Fall 2014
Spring 2015
Sept
Oct
Nov
Dec
Jan
Feb
Mar
April
Create a battery discharge protection circuit to prevent ruining batteries
Create either a manual override or kill switch
Implement clean connection to all ESCs, sensors, and circuits
Characterize quad frame and motors to reaffirm or find parameters needed for PID controls
Add a receiver + transmitter to the Zybo board and mix the PWM waves on the board through software
Have Zybo board communicate positional data from 3-axis sensor
Create a turn table with swappable joint used for ground testing
Research PID controllers
Create program to collect data from RC controller, CLI interface, and camera data
Create a way for users to enter system headings to properly set configurations for a PID controller
Move PID controller to Zybo board and communicate camera data to it
Test, tweak, and gradually add degrees of freedom to the quad systems on a restrained table to verify correctly configured PID parameters
Test PID controller using software and RC controller on restraining table
Fly quad without restraint

9 Risks

9.1 Physical Dangers & Equipment Safety

The quad systems, both old and new, spin plastic propellers extremely fast, and safety should be regarded for all people and the systems themselves. People operating the quads should be aware of all personnel around them and ensure the quad controller is disarmed when done flying. Similarly, everyone in the quadcopter vicinity should be cautious when near the quadcopter.

For the physical systems, team members should make sure the equipment on the quad cannot be easily damaged from a short fall or flip. This mentality is important to keep in mind when designing the placement of the board and the peripherals on the new chassis.

9.2 Risk to Project Timeline

There always exist a risk to the timeline if equipment is broken and part ordering takes time. To avoid such risks, caution should be taken when handling equipment and when designing and testing components for the system electronically and physically. Likewise, it's important to know where any existing parts were sourced, so their replacement can be expedited if needed. Budget constraints can slow down the progress of the project or cause it to fail completely. The foundation of proper financial management is appointing a secretary and keeping meticulous records. Planning expenditures for the entire project timeline will avoid any unforeseen shortfalls.

Additionally, team members can cause a risk to the project timeline if they do not communicate with other team members, clients, and advisers or seek help when getting blocked by obstacles.

10 Market/Literature Survey

While many ready-to-fly quadcopters exist commercially today, the MicroCART project is not intended for market in the near future. Rather, this project establishes a better platform for unmanned aerial vehicle applications and research as the system will be versatile and provide ample amounts of data for analysis. For example, this platform can be used to improve CprE 488: Embedded System Design and further research for the Distributed Sensing and Decision Making Lab at Iowa State. For other universities performing this kind of research, University of Pennsylvania, Stanford University, and Georgia Institute of Technology have different approaches to quadcopter research.