Microprocessor-Controlled Aerial Robotics Team
(MicroCART)

IOWA STATE UNIVERSITY
College of Engineering

Project Team

Matt Vitale (CprE)
Documentation Lead

Paul Gerver (CprE)
Sensor and Peripheral Lead

Jacob Rigdon (CprE)
Communications Lead

Adam Campbell (SE)
Ground Station Software Lead

Tyler Kurtz (EE)
PID controller, Motor, Mixing Lead

Matt Post(EE)
Controls Lead

Ravi Nagaraju (EE)
Power and Controls Management

Joe Boldrey (EE)
Physical System Design

Sponsors and Support

Client

- Dr. Phillip Jones III
- Distributed Sensing and Decision Making Laboratory

Advisers

- Dr. Phillip Jones III
- Dr. Nicola Elia

Support

- RADA Project

Problem Statement

Old MicroCART system

- Inertia measurement unit (IMU) is a black box
- RC mixer is slow
- Constrained camera environment

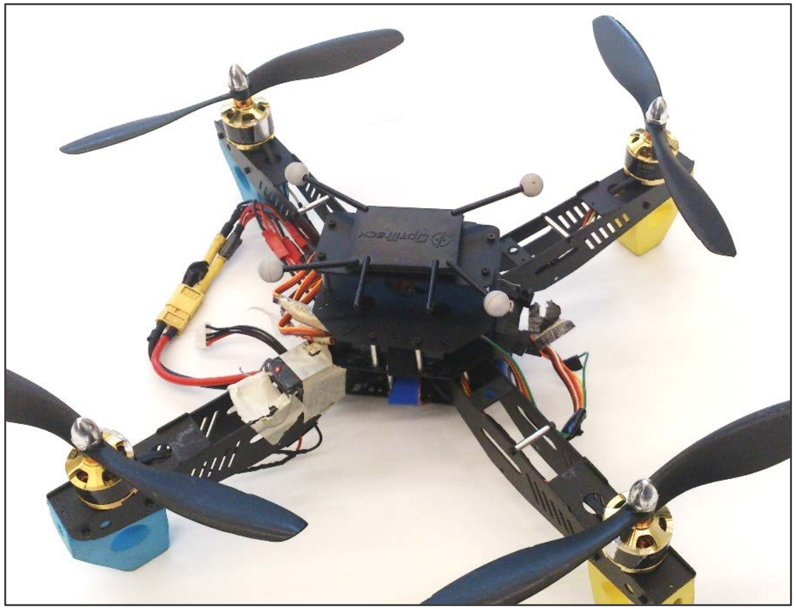
Data analytics

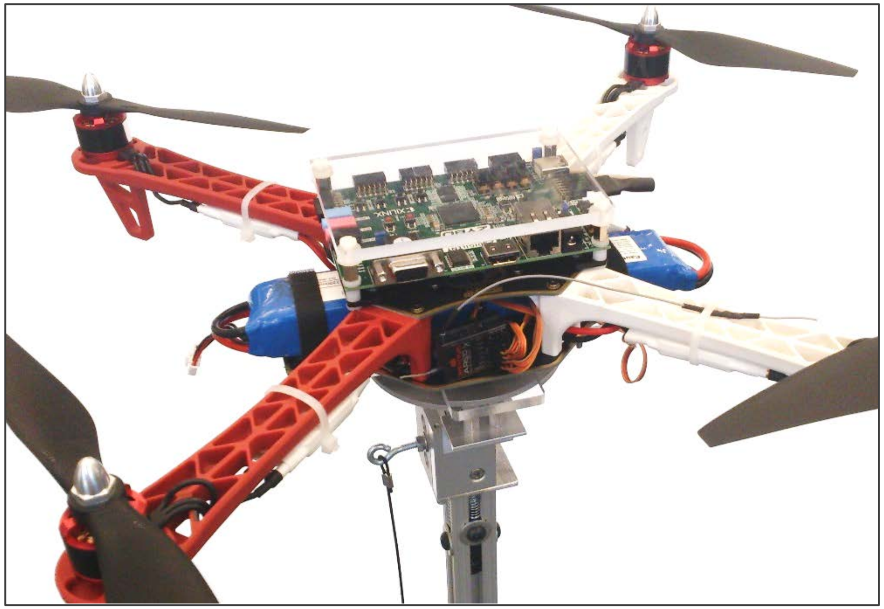
- Sparse, scattered, or incomplete
- Poor documentation

How will we fix these problems?

- Fully accessible and programmable IMU – white box
- New expandable quadcopter platform
- Improved data capture and plotting
- Thorough documentation for future teams

Project Plan





- Quad is static; no room for further development
- Dependent upon camera system
- Slow feedback response

- FPGA board for flexibility
- On-board feedback via 3-axis sensor
- On-board signal mixing

Project Application

Research

- Expand Distributed Sensing and Decision Making Lab's research capabilities

Education

- Supplementary course work for CprE 488: Embedded System Design and EE 476: Automatic Control Systems

Application

- Monitoring agricultural resources

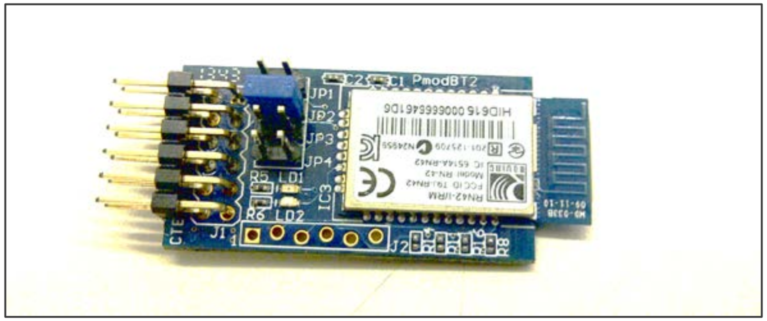
Functional Requirements

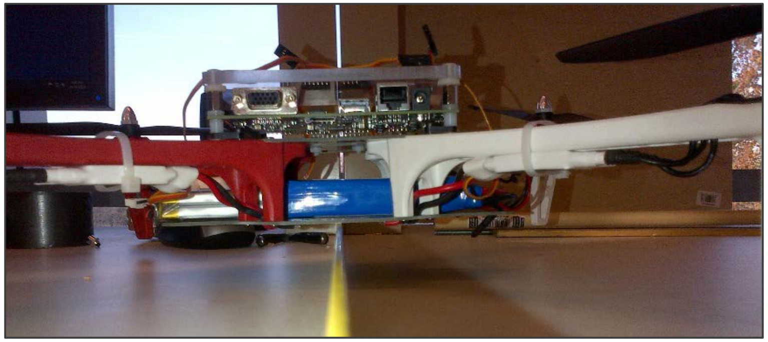
- On-board collection gyroscope, accelerometer, and magnetometer data
- Two-way Bluetooth communication from quad to ground station desktop
- On-board PID controller for steady flight
- Motors and processing board are powered by on-board batteries
- Circuits regulate battery voltage, detect reverse polarity, and prevent over-drain
- On-board manual/auto kill switch

Non-Functional Requirements

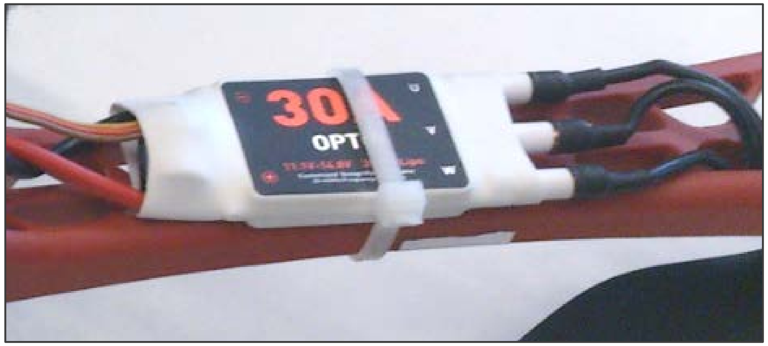
- Easy FGPA board and peripheral accessibility
- Robust component connections
- Stable PID controller with data plots
- Quad's data bottleneck is minimal (~ 1ms)
- Demonstrations should be easy to perform
- Quick start guides for lab tools, processes, and testing

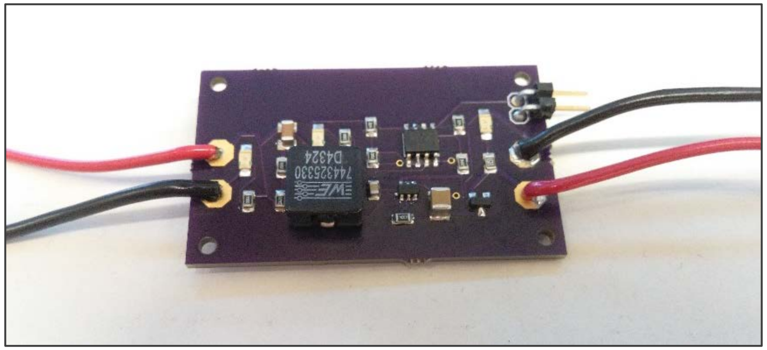
Technical & Other Constraints





- Bluetooth baud rate 921600
- Weight of quad vs. thrust of motors
- Quads center of gravity
- Quad motor’s ESC max at 450Hz
- Zybo board voltage input 4.5 - 5.5V





Project Milestones

First semester

- Assemble new quad
- Integrate peripherals
- Start PID controllers for yaw, pitch, and roll

Second Semester

- Data capture and analysis
- Stable PID controller and better sensor filtering
- Battery monitoring and control boards
- Free manual flight

Potential Risks & Mitigations

Quad Safety

- Parts can be damaged (secure or tether quad when testing)
- Over-draining battery (power management circuits)

Human Safety

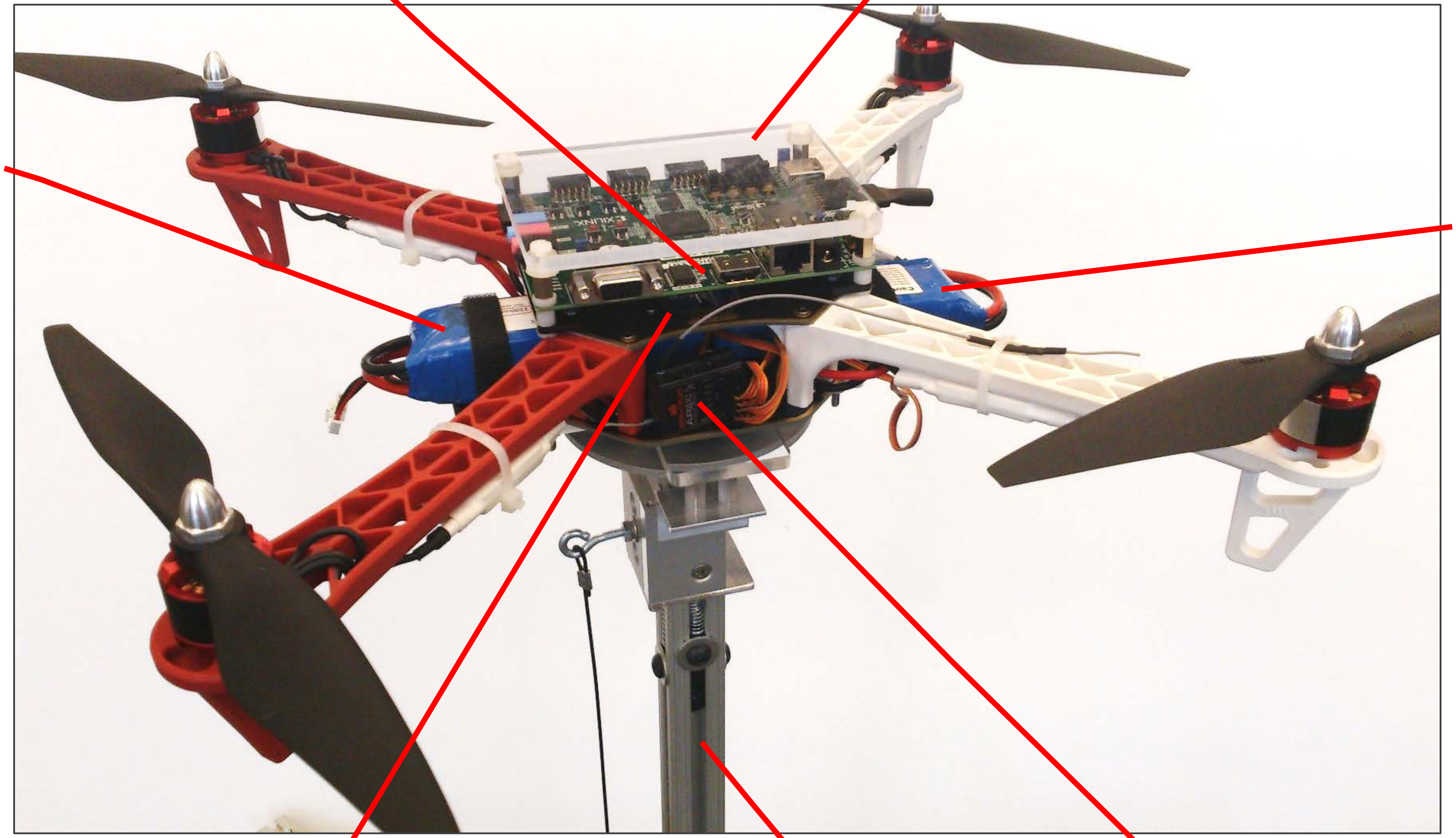
- Always be careful
- Be respectful and aware of others
- On-board kill switch

Timeline

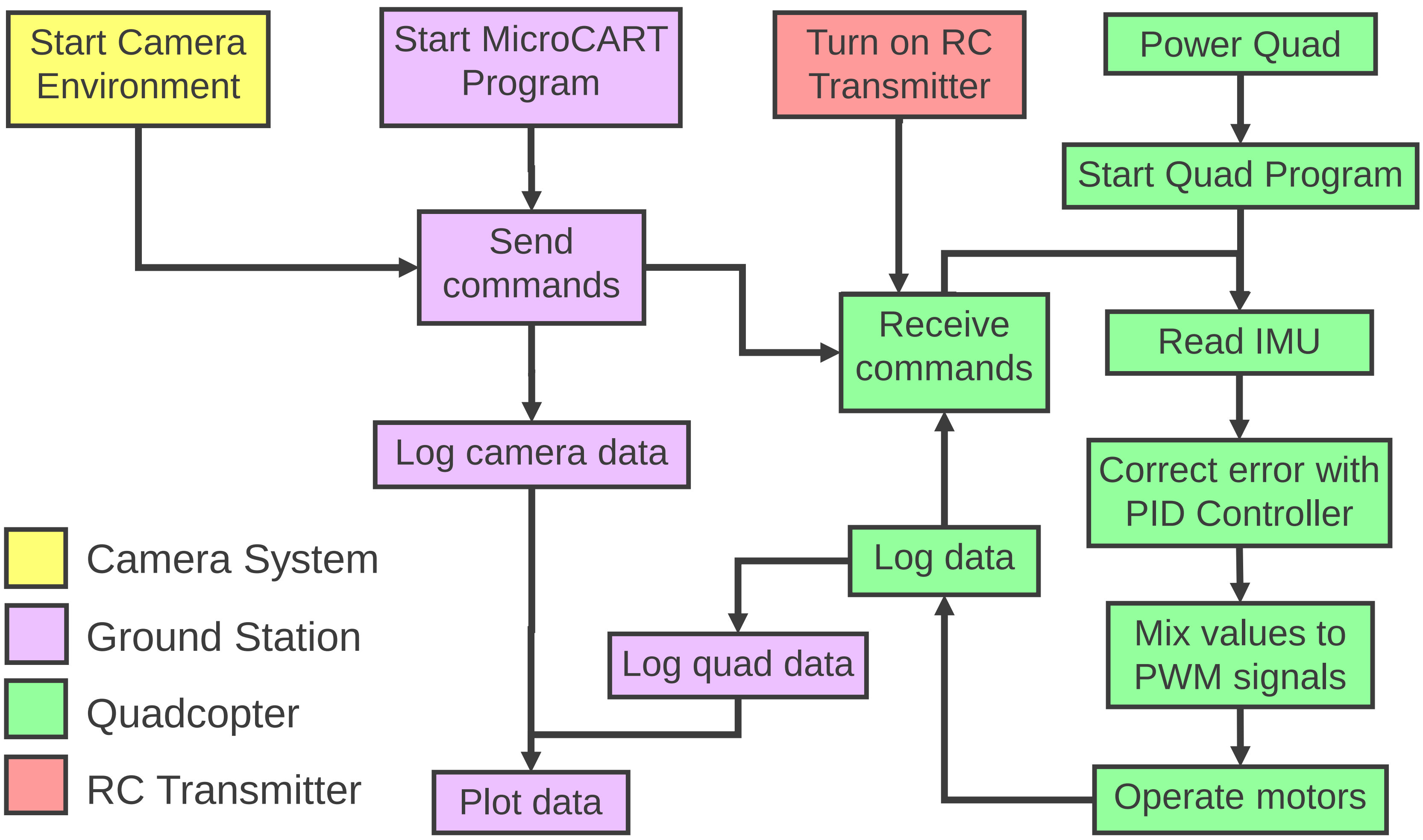
- Unforeseen obstacles (ask for help early and often)
- Integration of separate tasks (communication is key)

System Design

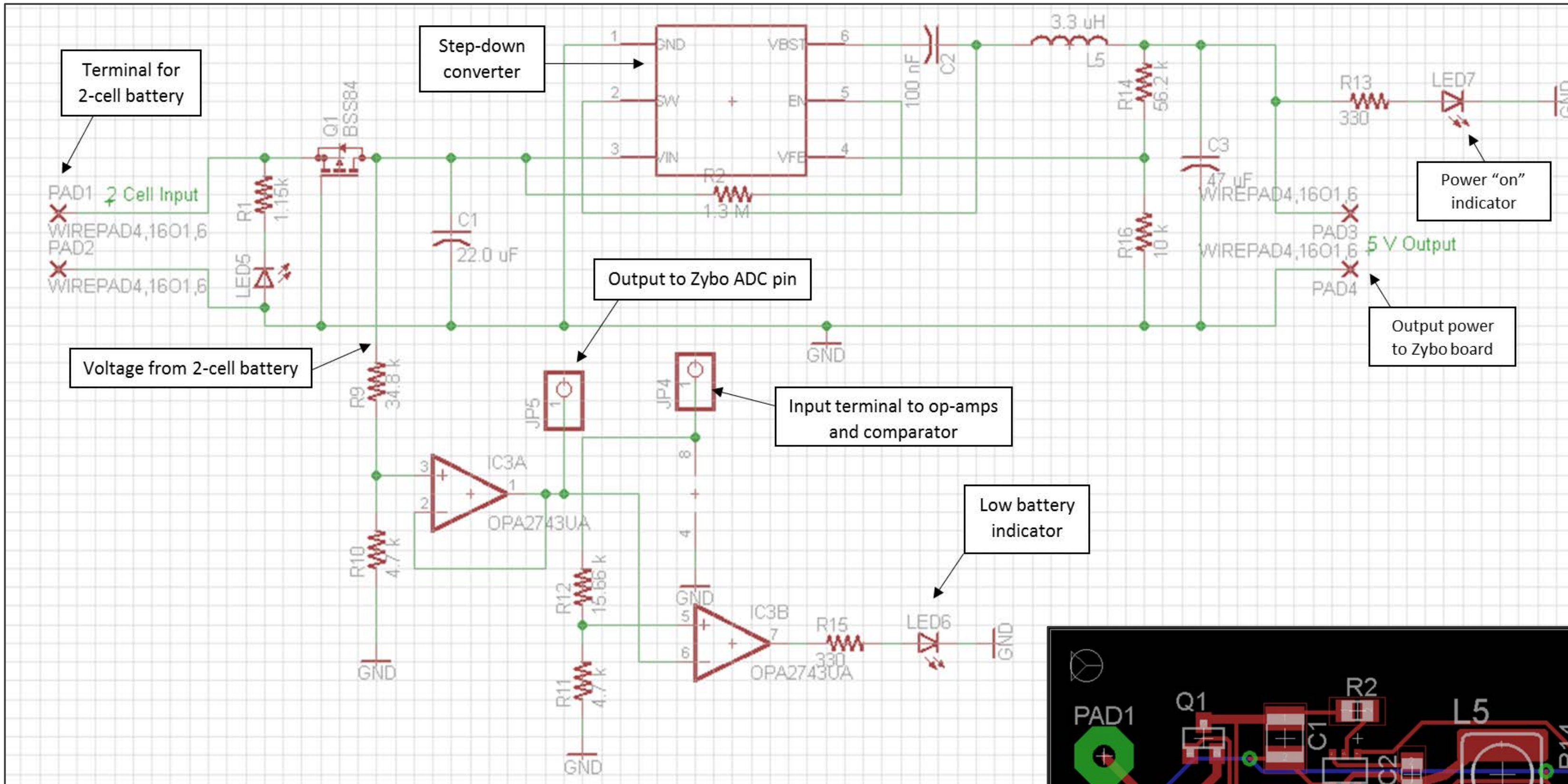
Implementation

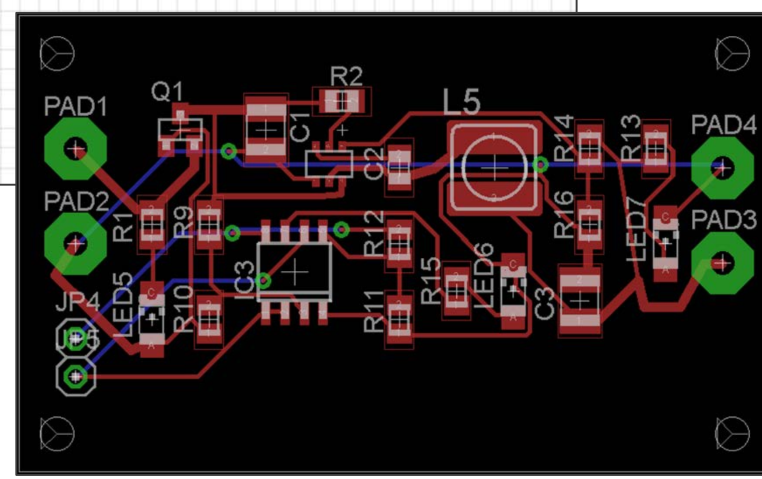


Functional Decomposition

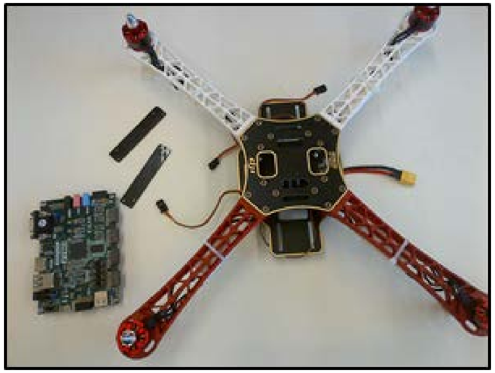


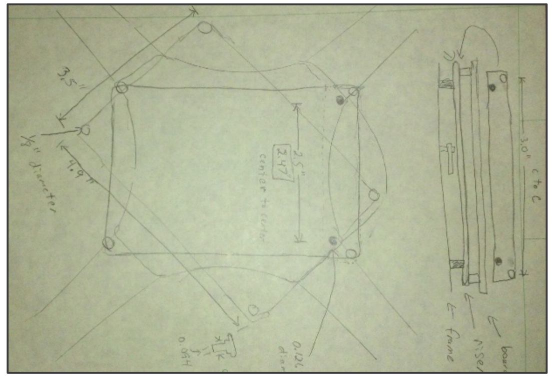
Detailed Design: Power Management

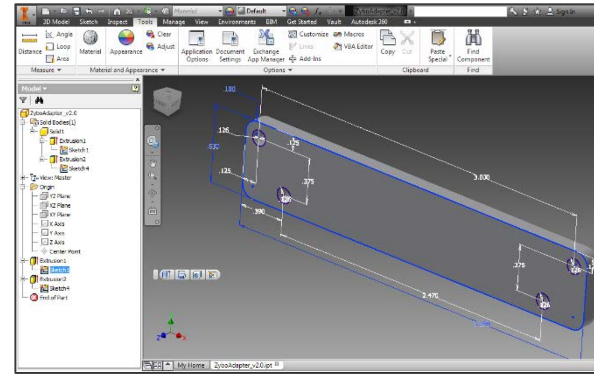


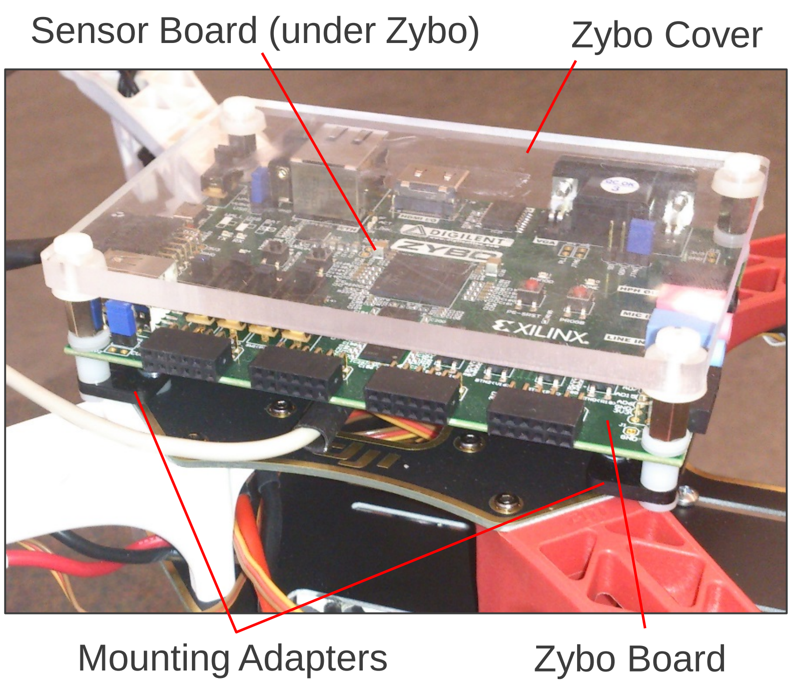


Detailed Design: Chassis

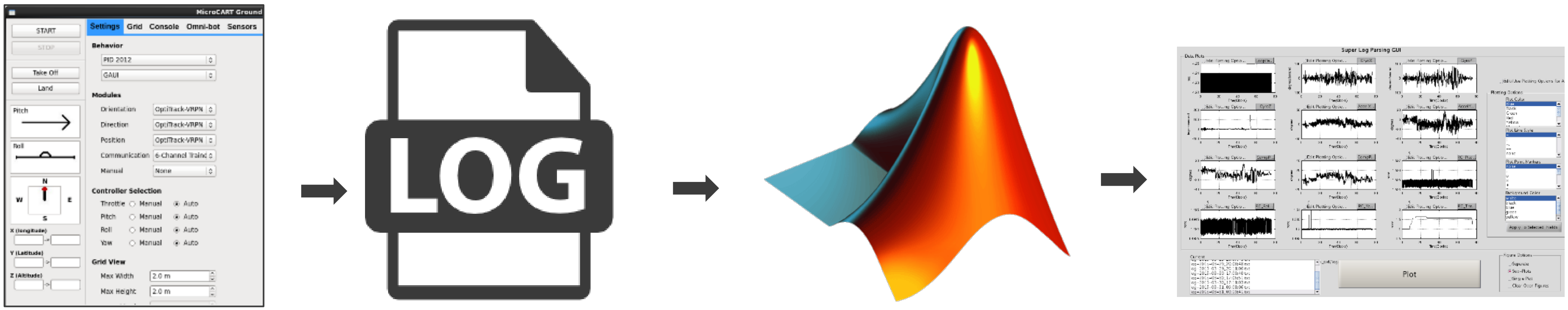


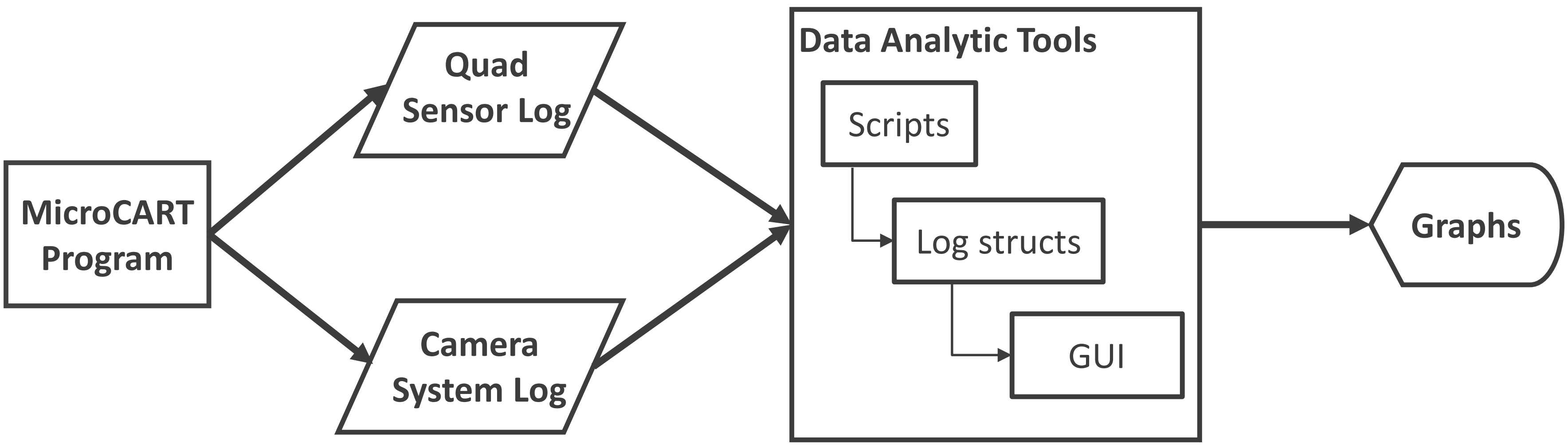






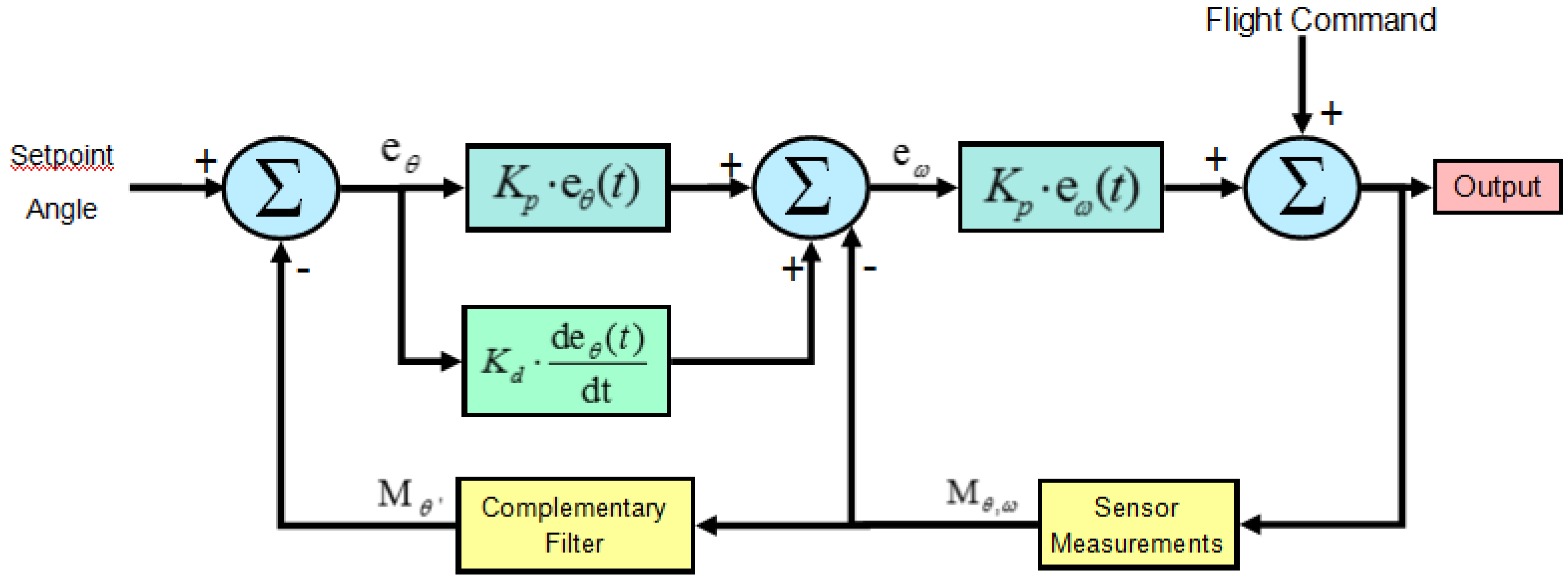
Detailed Design: Data Analytics





Detailed Design: PID Controllers

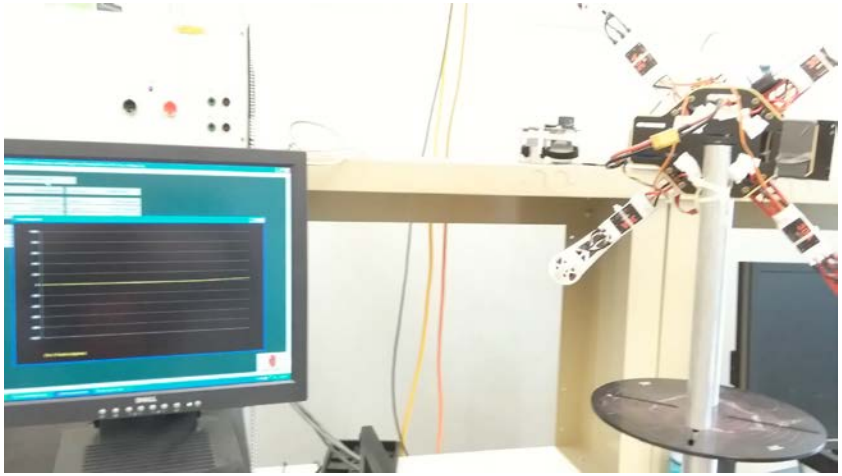
- Nested PID approach for error handling
- Outer PID adjusts quad based on angle
- Inner PID adjust quad based on angular velocity

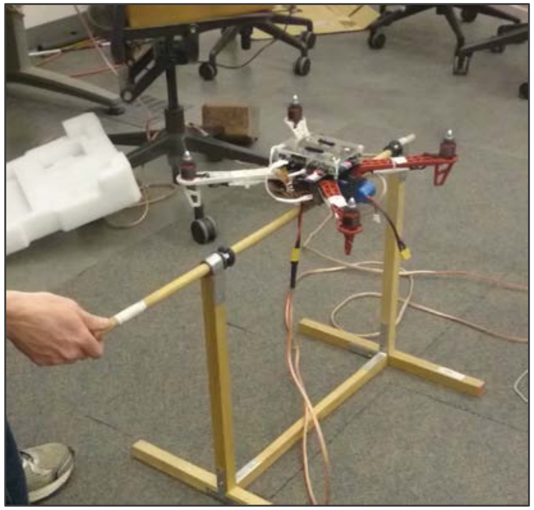


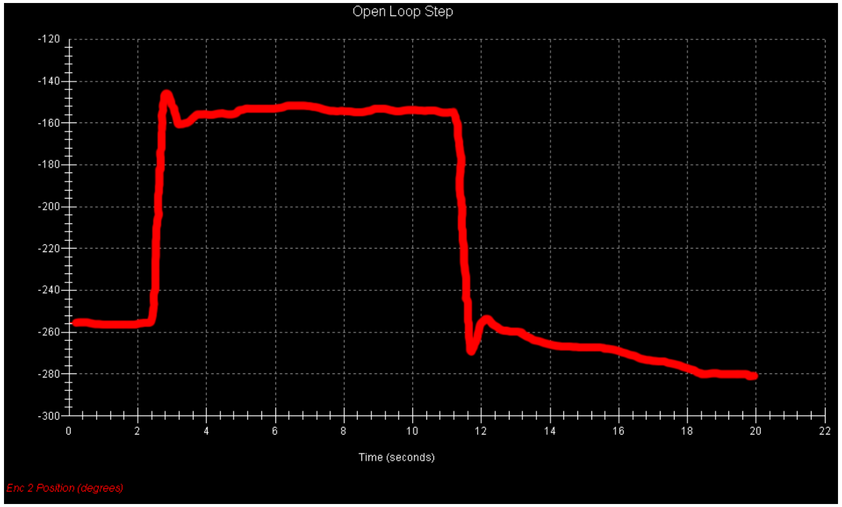
Test Plan: PID Tuning

Procedure

1. Get quad to flight throttle
2. Create disturbance
3. Let quad settle
4. Plot on-board and/or camera data
5. Tweak controller coefficient
6. Repeat for each controller and axis

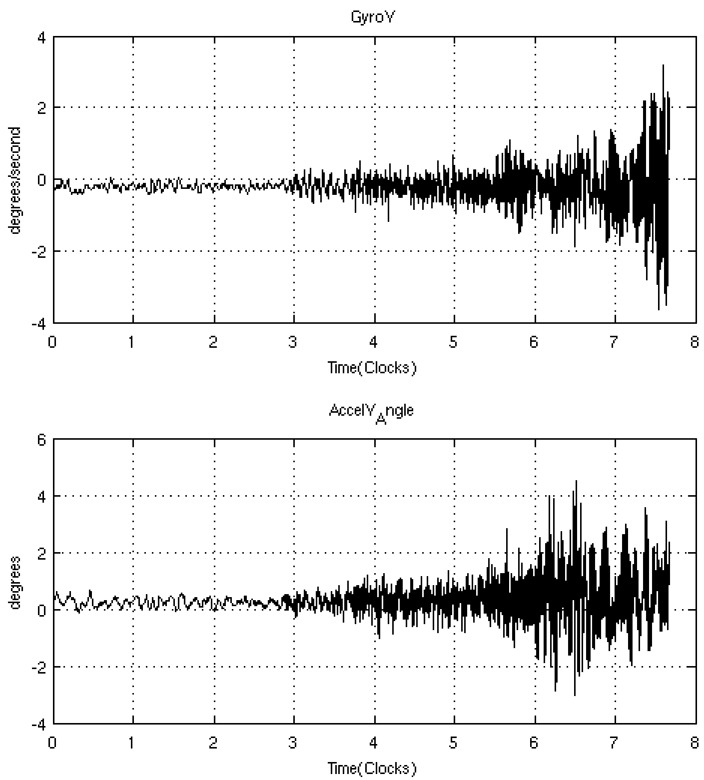




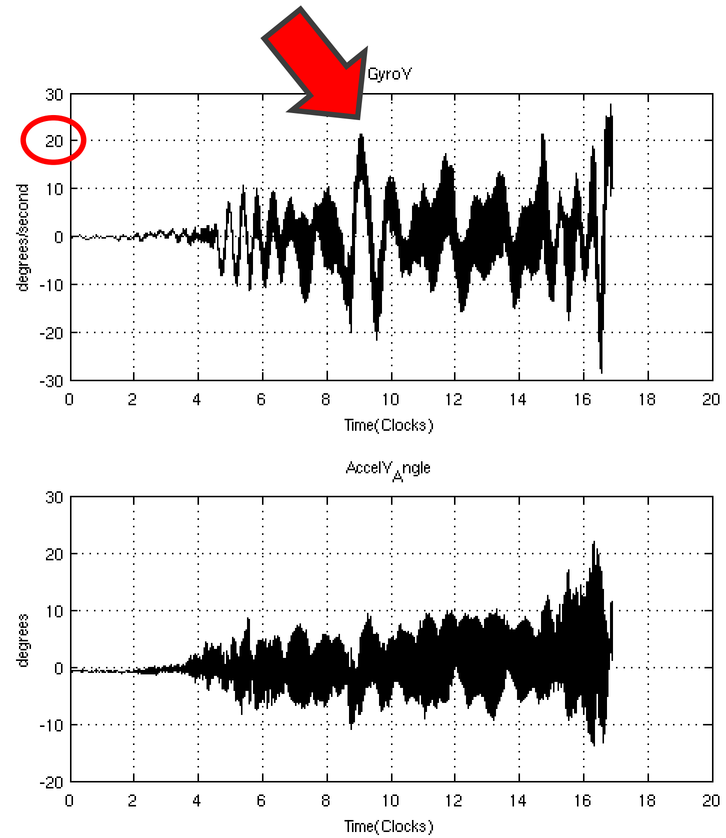


Test Results: Propeller Issues

Original DJI Propellers



Carbon Fiber Propellers



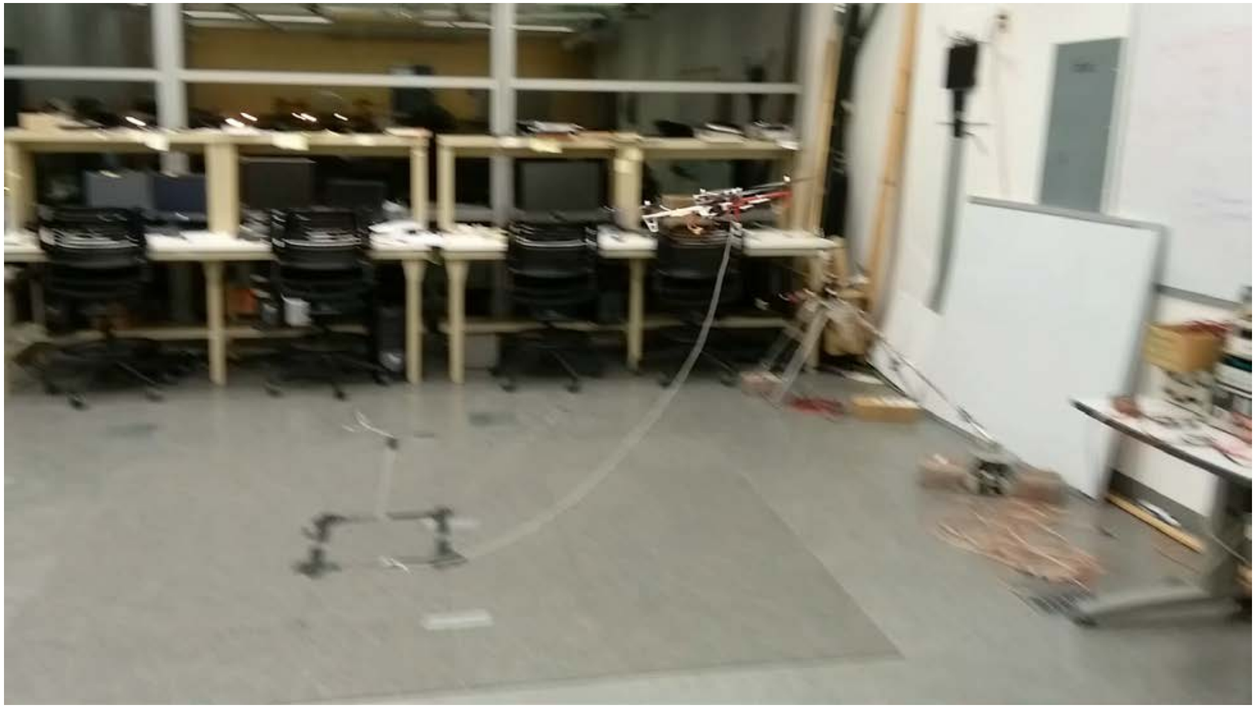
Conclusion

Project Status

- Keyed and robust hardware connections
- On-board sensor and RC data capture and analysis
- Internal (angular velocity) and Outer (angle) PIDs tuned
- Integration of external camera environment
- Steady manual flight

Technical Challenges

- Project components were provided
- Connection issues between components locked up software
- Limited airspace for flight tests

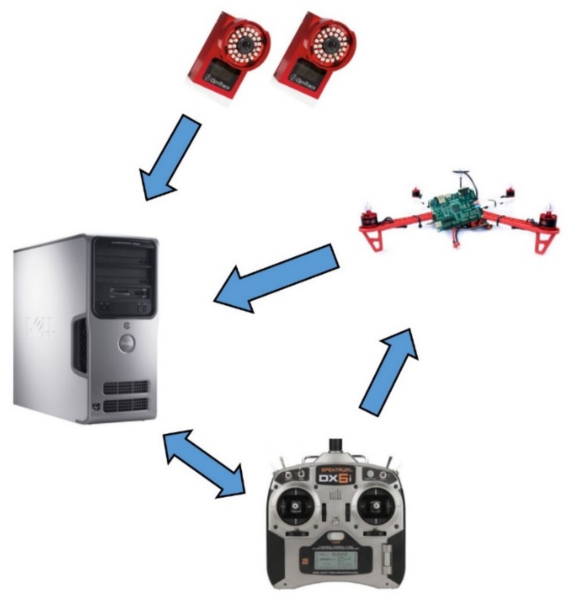


Questions?

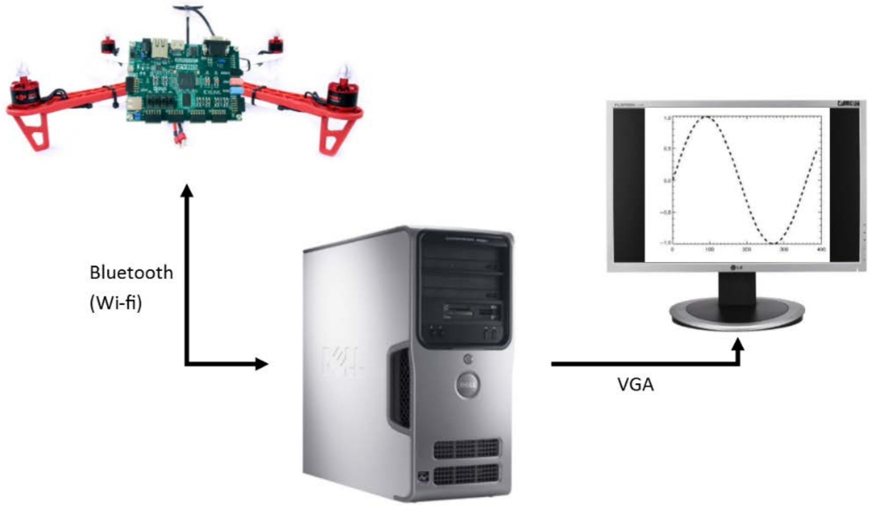
Backup Slides

Early Conceptual Sketch

Old System



New System



Resource Cost Estimate

Resource	Source	Estimated Cost
DJI Flame Wheel F450	Provided by Client	$32.00
ZYBO Zynq™-7000 Development Board	Provided by Client	$125.00
SparkFun MPU-9150	Provided by Client	$35.00
Set of Batteries (Zippy 2100, Hyperion)	Provided by Client	$245.00
4GB Micro SD Card	Provided by Client	$3.00
USB to Micro SD converter	Provided by Client	$13.00
Micro USB cable	Provided by Client	$1.00
IR Mirror Globes	Provided by Client	$25.00
OmniTrack IR Cameras	Provided by Client	$600.00
Nexys™2 Spartan-3E FPGA Board	Provided by Client	$140.00
SpekTrum DX6i RC Controller	Provided by Client	$130.00
InterLink Elite Controller	Provided by Client	$170.00
Electrical Speed Controllers (ESCs)	Provided by Client	$80.00
DJI Motors	Provided by Client	$80.00
Simulink Simulation Software	Provided by Client	$500.00
MATLAB Software	Provided by Client	$500.00
Various Small Hardware Items (connectors, screws, electrical tape, etc.)	Provided by Client	$100.00
Various Hand Tools (screwdrivers, pliers, soldering iron, etc.)	Provided by Client	$250.00
Workspace/Testing Area	Provided by Client	N/A
Power Regulator Circuits	Order Parts	$58.00
	Total	**$3,087.00**

Technology Platforms

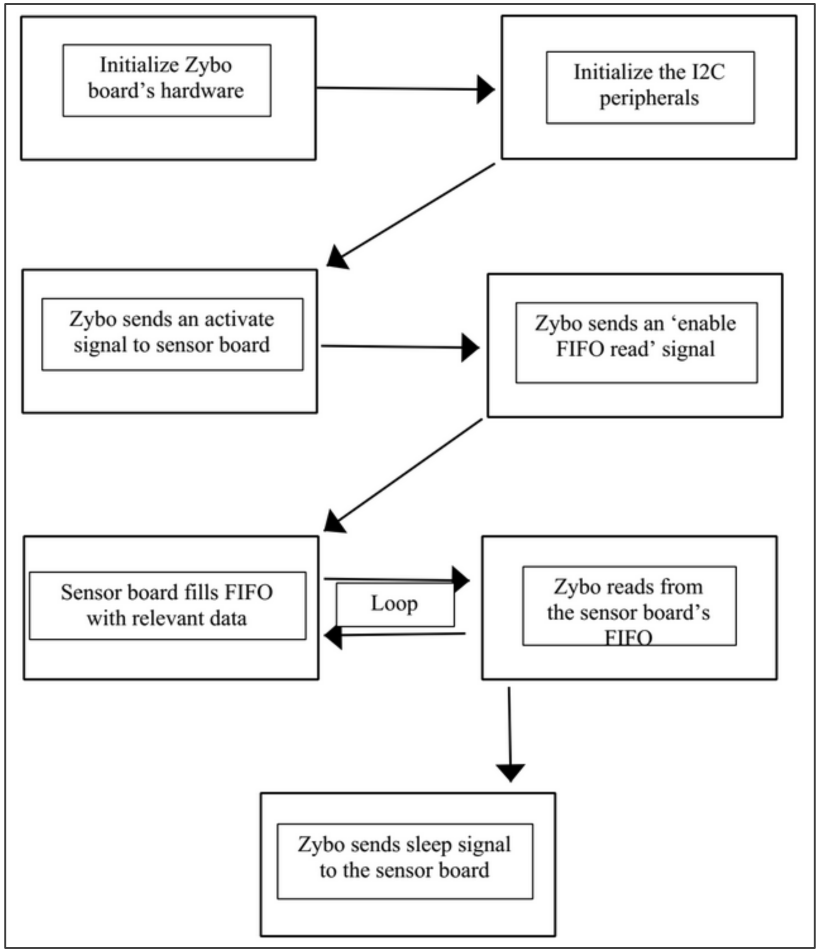
Hardware

- DJI Flame Wheel F450
- Diligent ZYBO development board
- SparkFun 9-Degrees of Freedom (MPU9150)
- PmodBT2 - Bluetooth Interface
- OptiTrack IR Cameras
- DX6i RC Trainer and Receiver

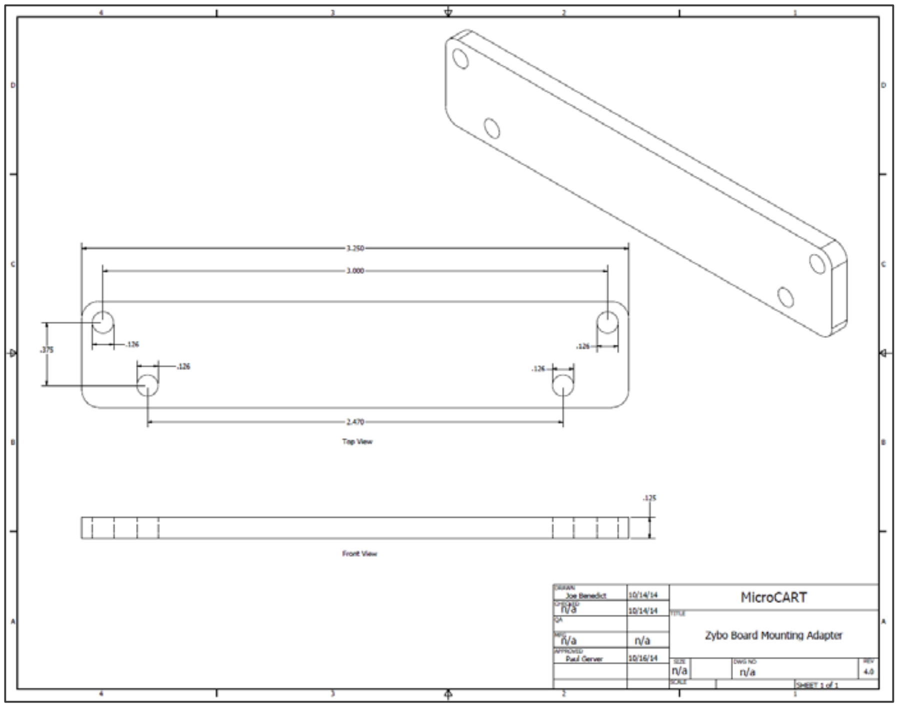
Software

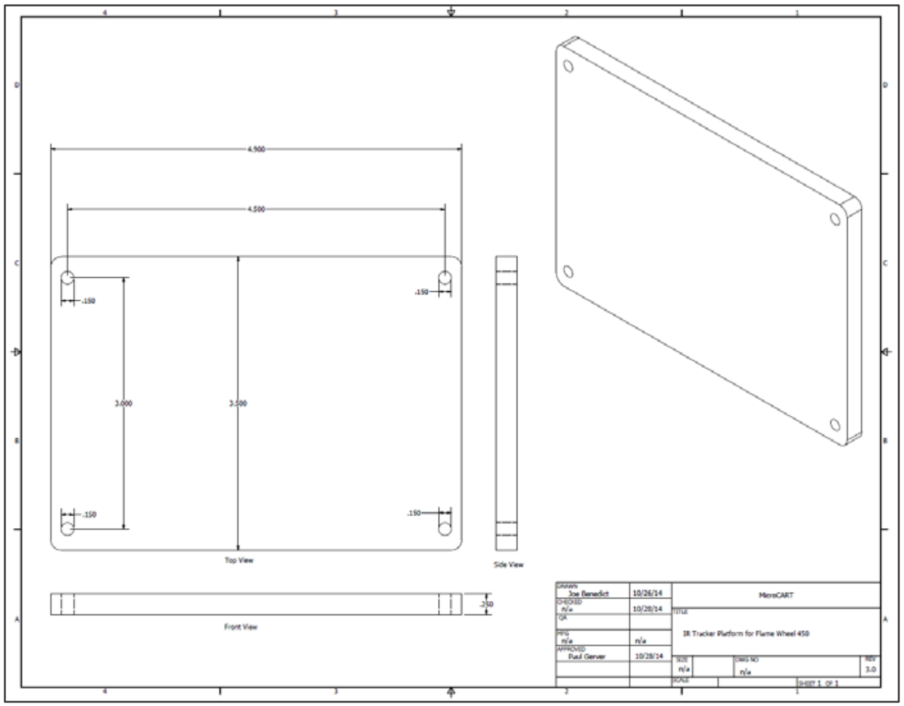
- C++ QT GUI
- Serial Terminal

Sensor Board: I2C communication

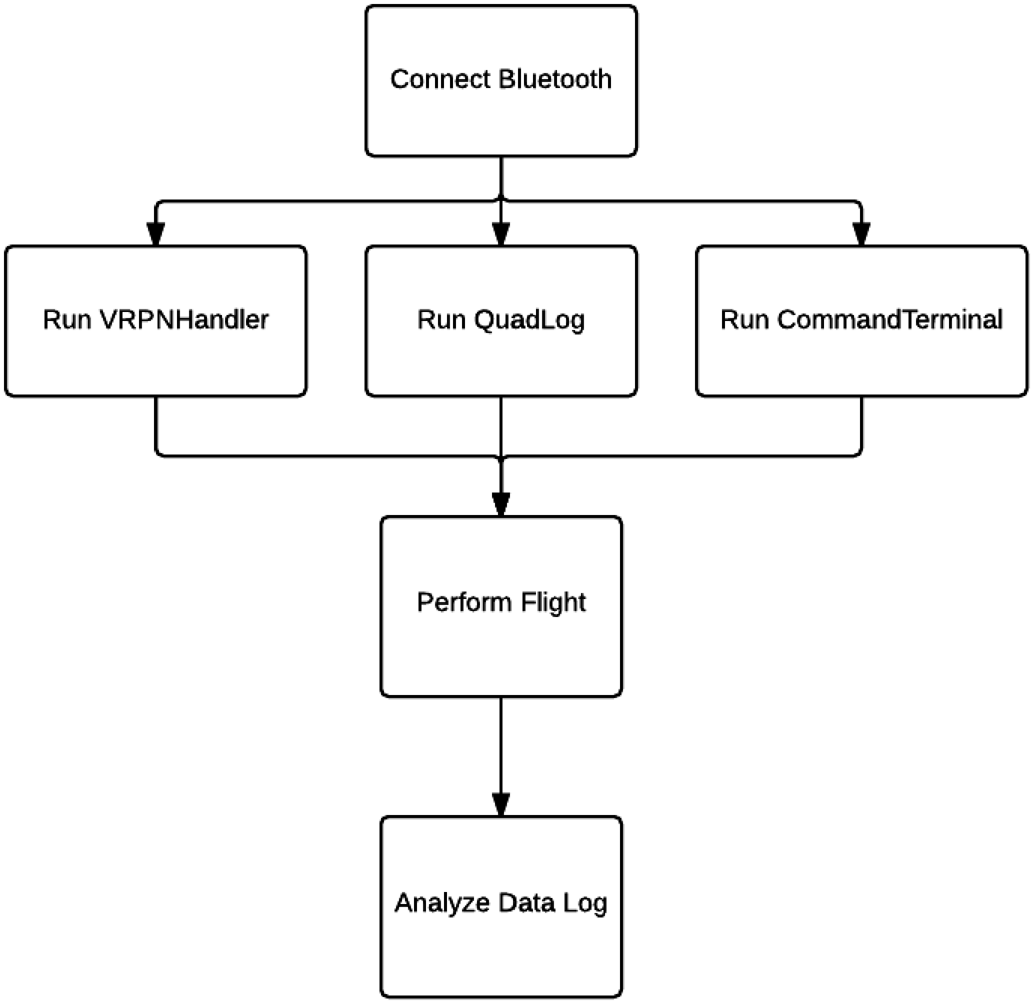


Mounting CAD Designs





Ground Station Software



Quad Data Packet Communication