Micro-Controller Aerial Research Team

(MicroCART)

IOWA STATE UNIVERSITY
College of Engineering

Project Team

Matt Vitale (CprE)
Team Lead

Joe Benedict (EE)
Communication Chair

Tyler Kurtz (EE)
Key Concept Holder

Adam Campbell (SE)
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Ravi Nagaraju (EE)
Webmaster

Paul Gerver (CprE)
Key Concept Holder

Jacob Rigdon (CprE)
Communication Chair

Sponsors and Support

Client

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

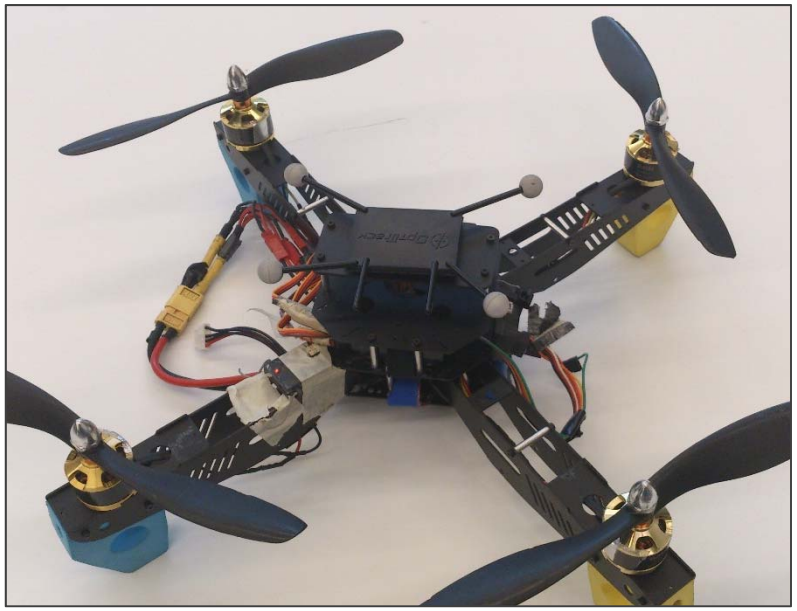
Advisers

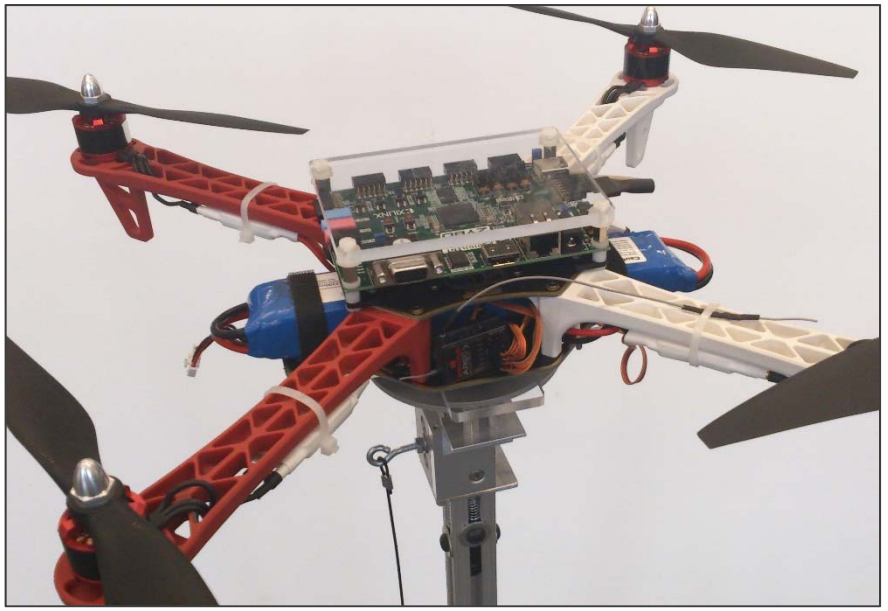
- Dr. Phillip Jones III
- Dr. Nicola Elia

Graduate Lab Advisers

- Matthew Rich
- Paul Uhing

Project Plan





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

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

Market Survey

Used purely for learning and research

- Expand Distributed Sensing and Decision Making Lab's research capabilities
- Use for CprE 488: Embedded System Design and EE 475: Automatic Control Systems
- Monitoring agricultural resources

Other University research

- Georgia Tech – autonomous vehicles
- University of Pennsylvania – distributed robotics

No current plan to bring to commercial market

Problem Statement

Current MicroCART system

- Gyroscope is a “black box”
- RC mixer is slow
- Too constrained - camera environment

Data analytics

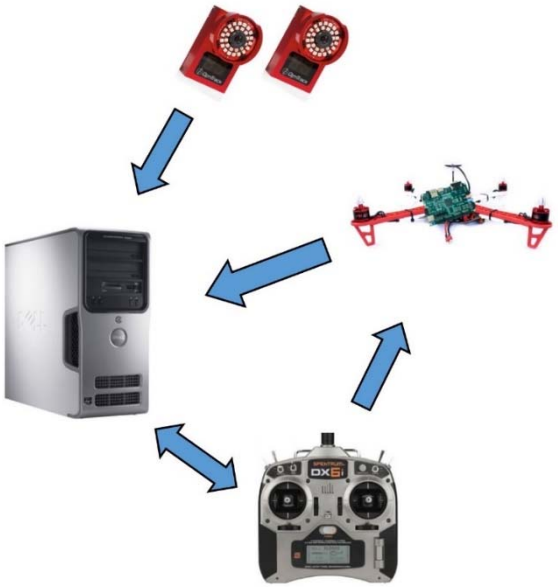
- Sparse, scattered, or incomplete
- Poor documentation

How will we fix these problems?

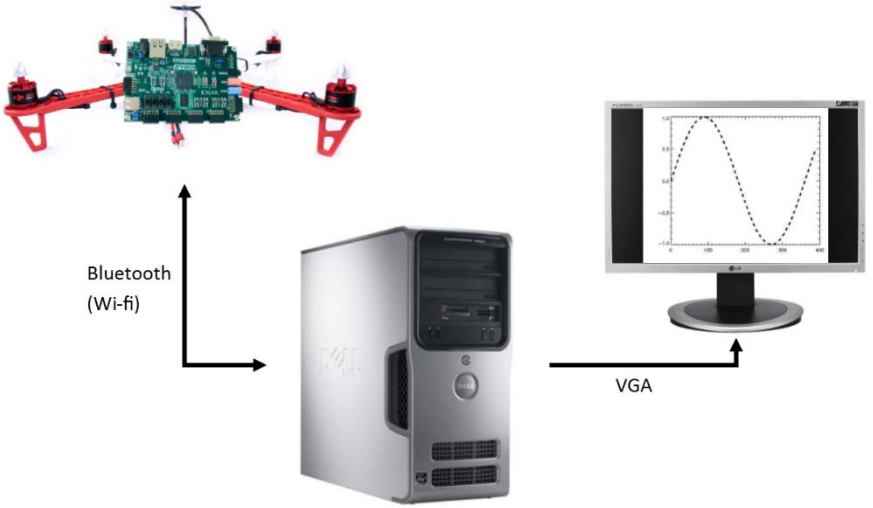
- New quadcopter platform
- FPGA development platform
- Reduce dense dependency system

Conceptual Sketch

Old System



New System



Functional Requirements

- Quad collects accelerometer and gyroscope data
- Quad communicates information to base station
- Functional PID controller for steady flight
- Motors and processing board are powered by onboard batteries
- Battery regulates voltage, detects reverse polarity, and doesn’t over drain
- Onboard safety switch for manual override

Non-Functional Requirements

- Quad doesn’t immediately fall when battery is low
- Easy board and peripheral accessibility
- Fine-tuned PID controller
- Quad’s data bottleneck is minimal (~ 1ms)
- Demonstrations should be easy to perform

Technical & Other Constraints

- Bluetooth baud rate 115200
- 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 & Schedule

First semester

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

Second Semester

- Data analysis
- Remove camera constraint
- Fine-tune PID controller and better sensor filtering

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
- Onboard safety switch for manual override

Timeline

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

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**

System Design

Technology Platforms

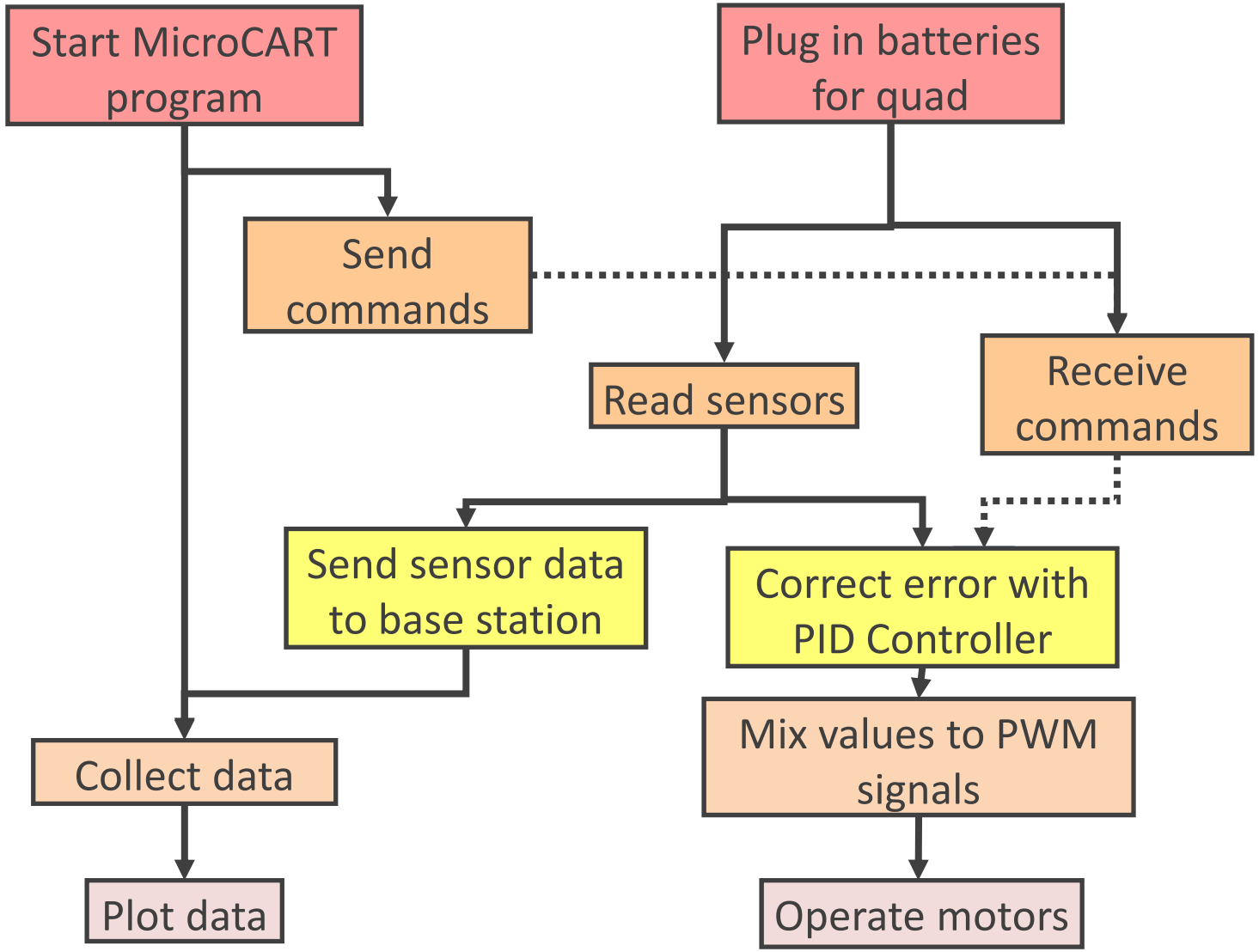
Hardware

- DJI Flame Wheel F450
- Diligent ZYBO development board
- SparkFun 9-degrees of freedom (MPU9150)
- BT2PMOD
- OptiTrack IR Cameras
- DX6i RC Trainer and Receiver

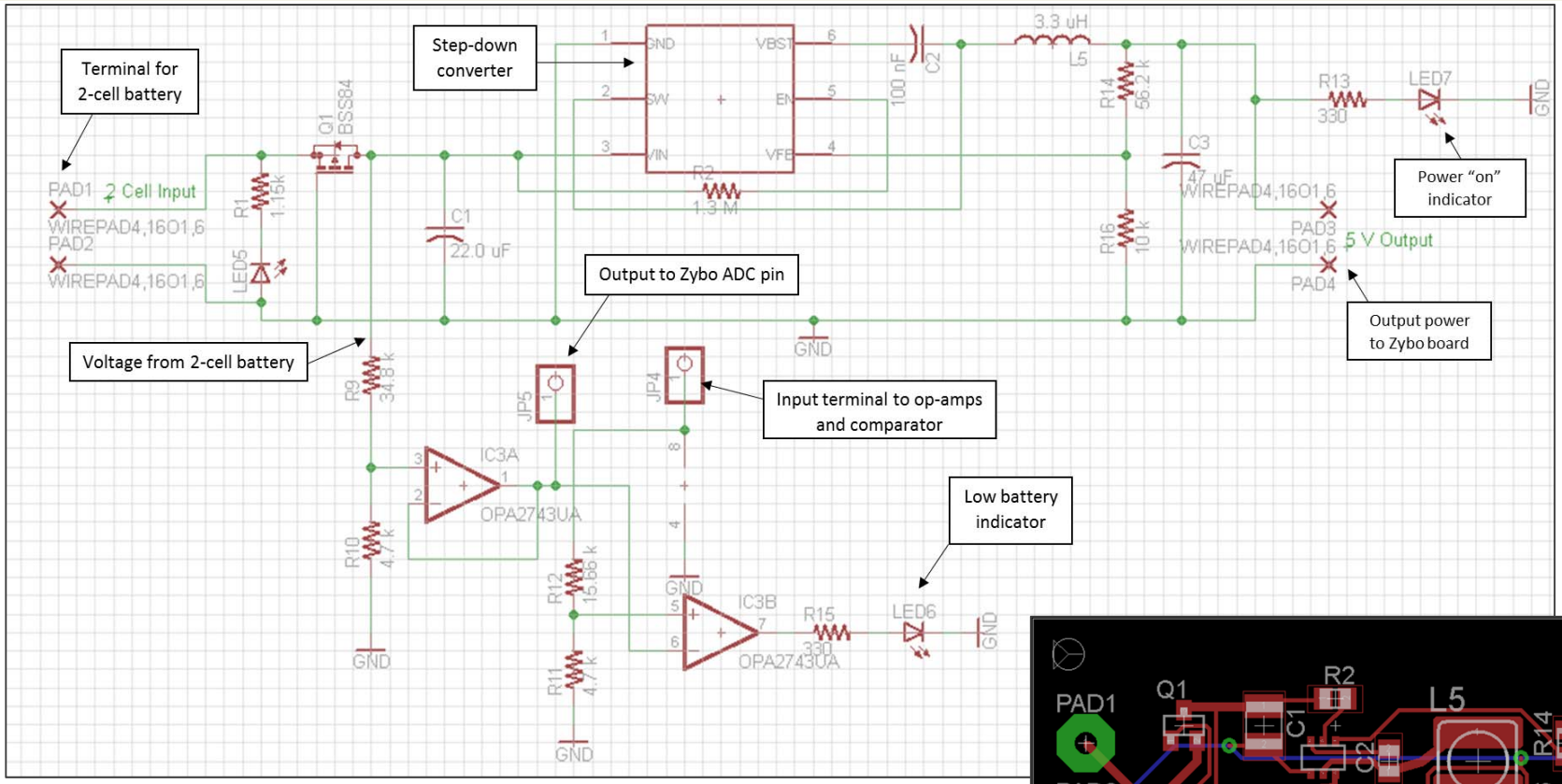
Software

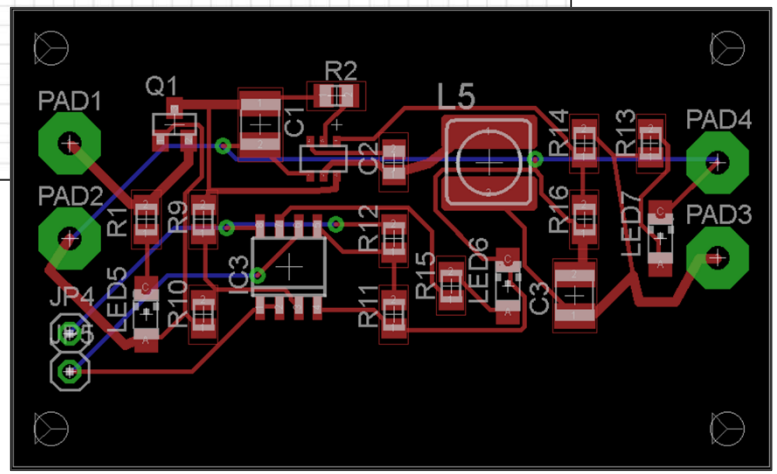
- C++ QT GUI

Functional Decomposition

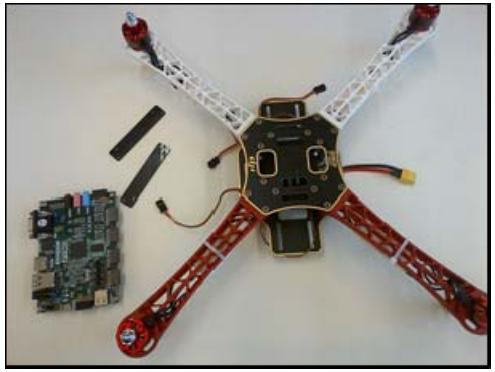


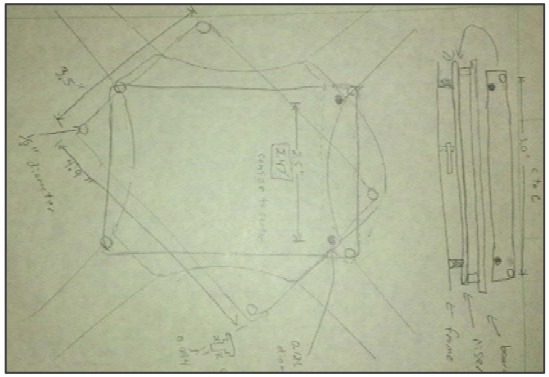
Detailed Design: Power Management

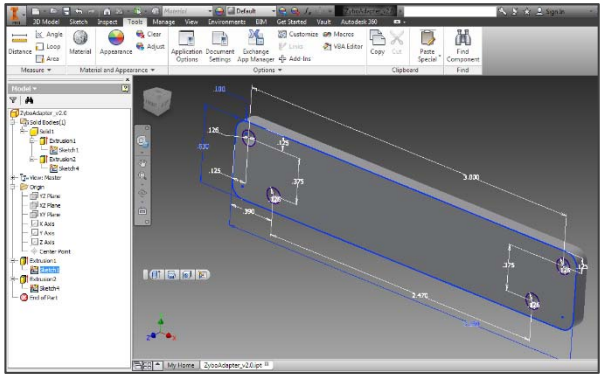


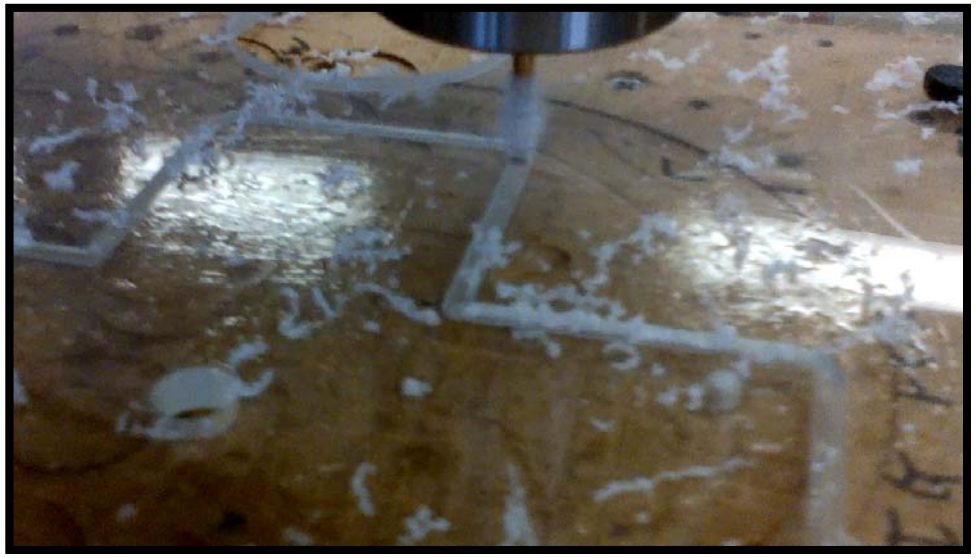


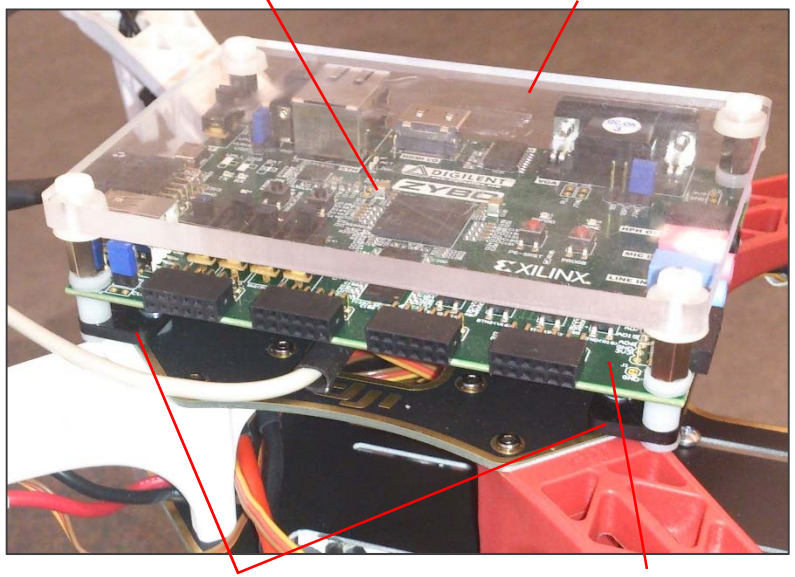
Detailed Design: Chassis











Detailed Design: GUI

Settings View

- Set parameters and connect

Grid View

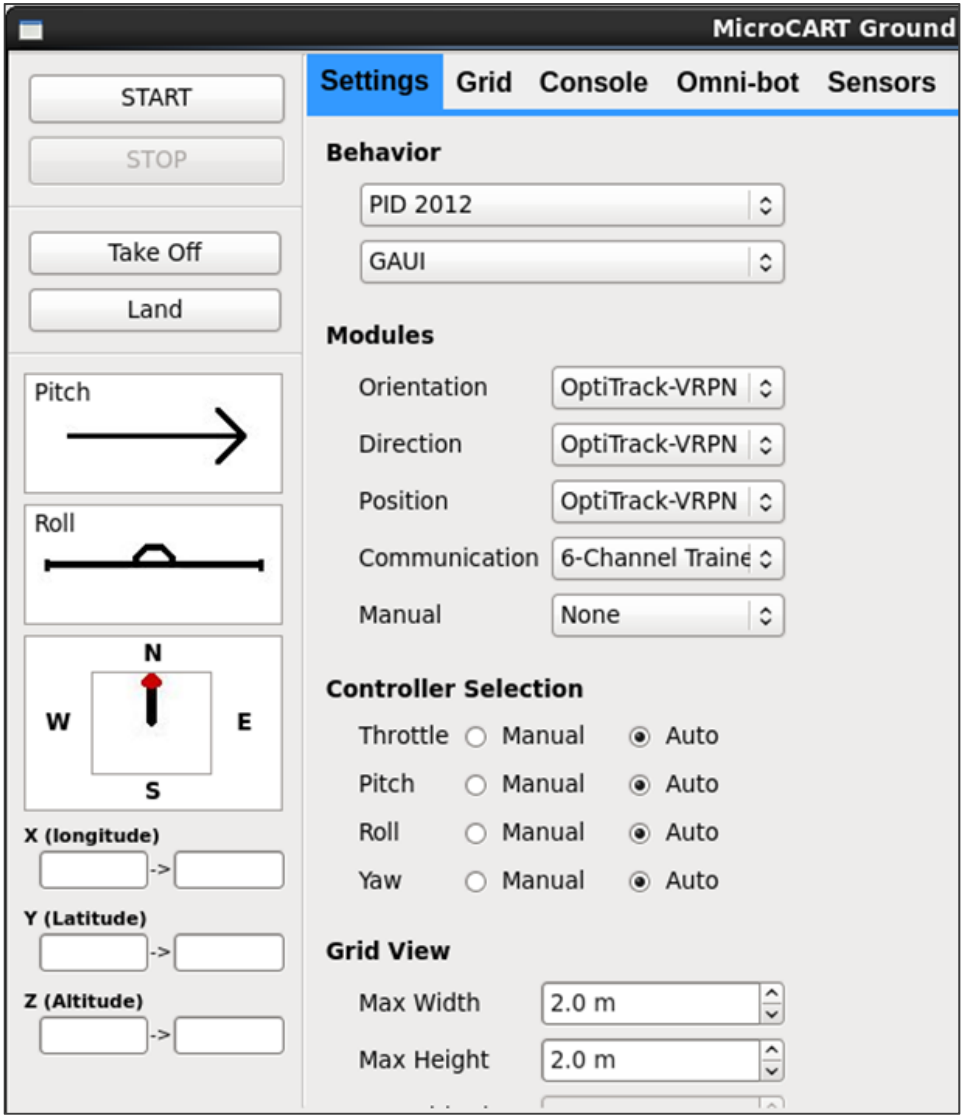
- Draw paths to follow

Console View

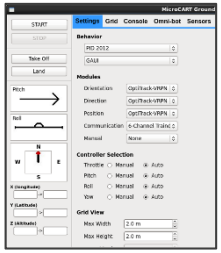
- Manual control using command prompt

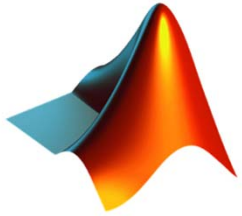
Future Ideas

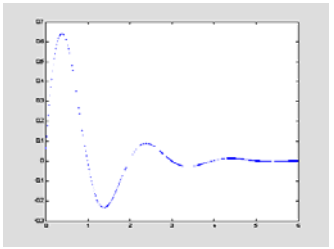
- Save and load trajectories
- Real-time plotting

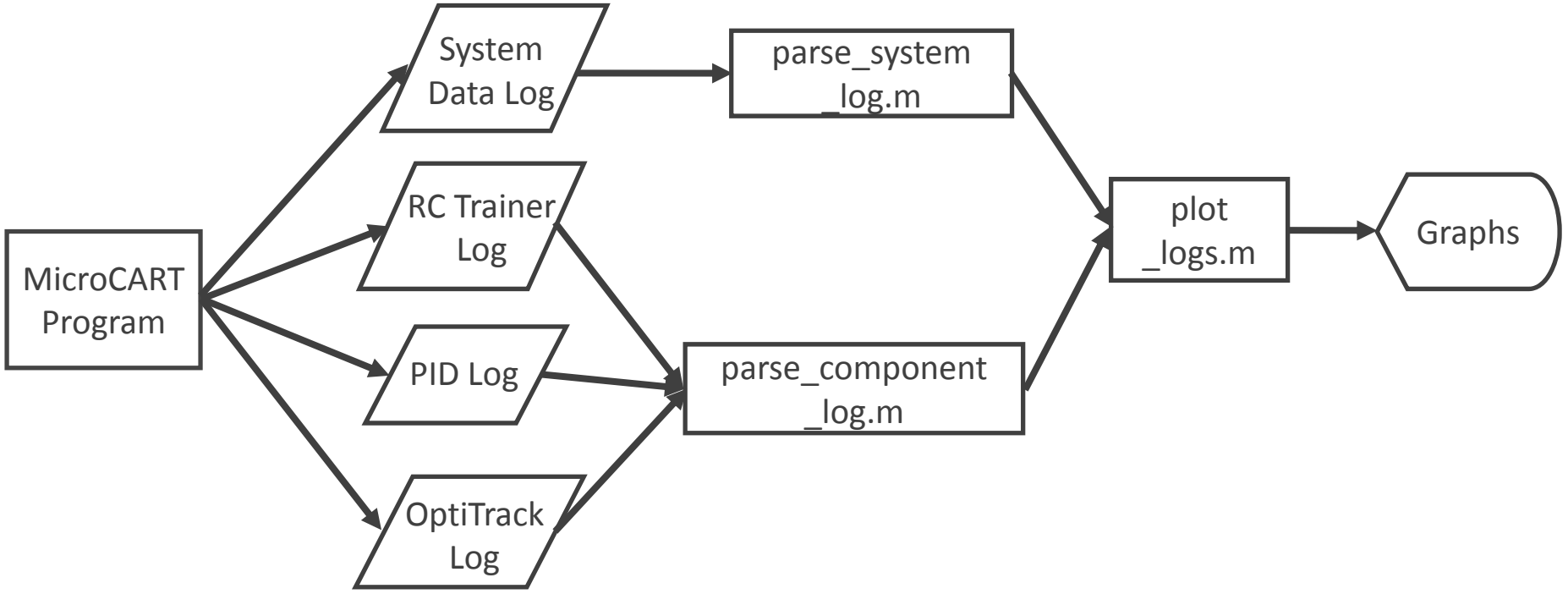


Detailed Design: Data Analytics









Test Plan

Hypothesis, Simulation, Metrics, etc.

PID Tuning

- Manual P, I, and D coefficient tuning

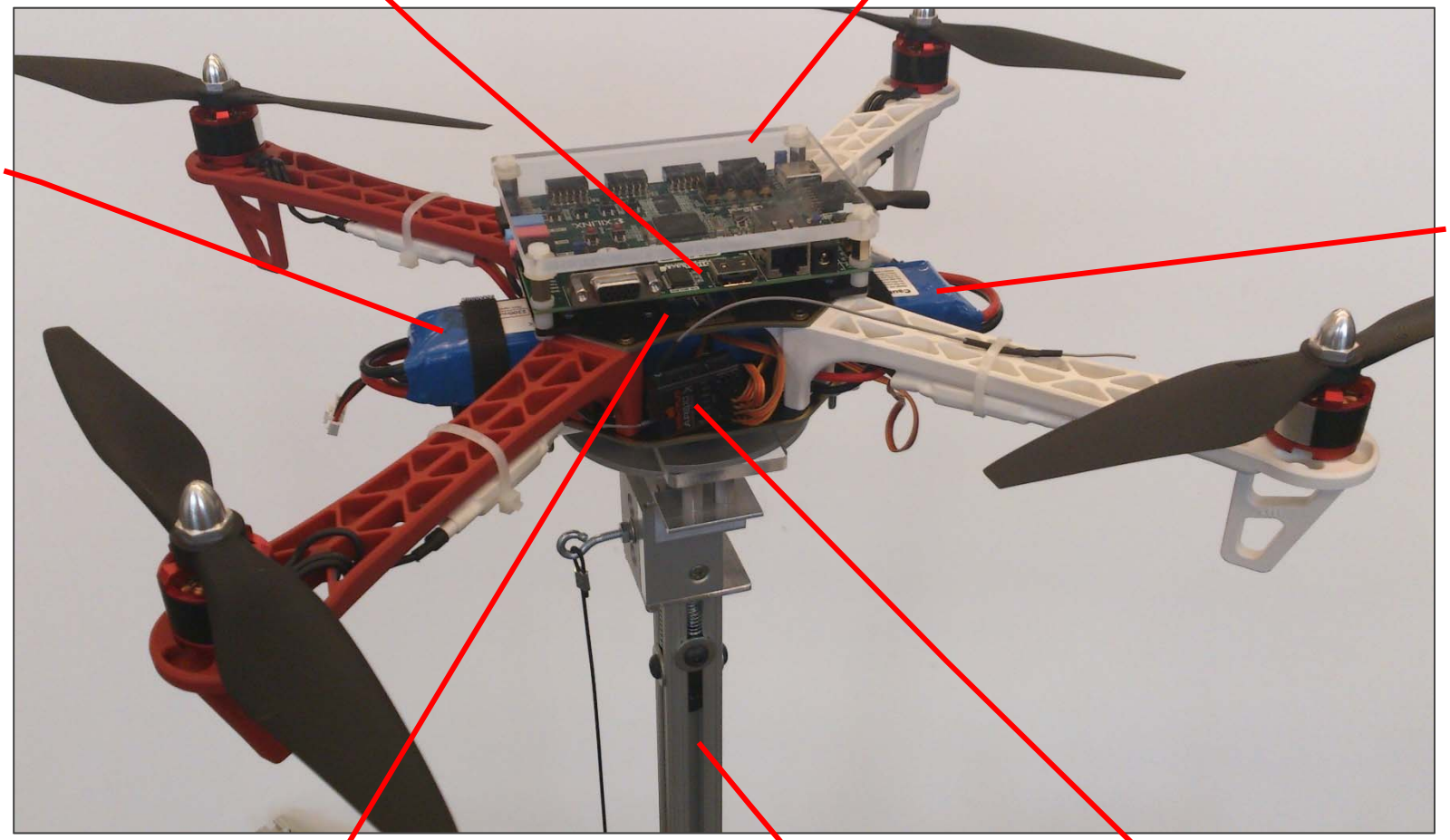
Peripheral Testing

- Function and Unit verification - does communication work and are expected values being collected?
- Find latency of obtaining all data
- Simulate dynamic environment - shake device
- System verification - test peripheral usage in high-level program

Characterization

- Create a model of the current system in MATLAB
- Modify parameters and run simulations to determine PID tuning

Prototype Implementation



Conclusion

Current Project Status

- Quad is assembled with Zybo processing board and peripherals
- Motors can be controlled by RC transmitter or Bluetooth
- Camera system and base station handle yaw PID control
- Zybo and sensor boards handle pitch and roll PID control

Responsibilities & Contributions

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

Ravi Nagaraju (EE)
Power and Controls Management

Jacob Ridge (CprE)
Quad Communications Lead

Matt Vitale (CprE)
Sensor and Peripheral Lead

Adam Campbell (SE)
GUI and Platform Software Lead

Paul Gerver (CprE)
Data Collection and Analysis

Joe Benedict (EE)
Physical System Design and Characterization

Plan for Next Semester

Remove reliance on cameras

- Magnetometer, GPS

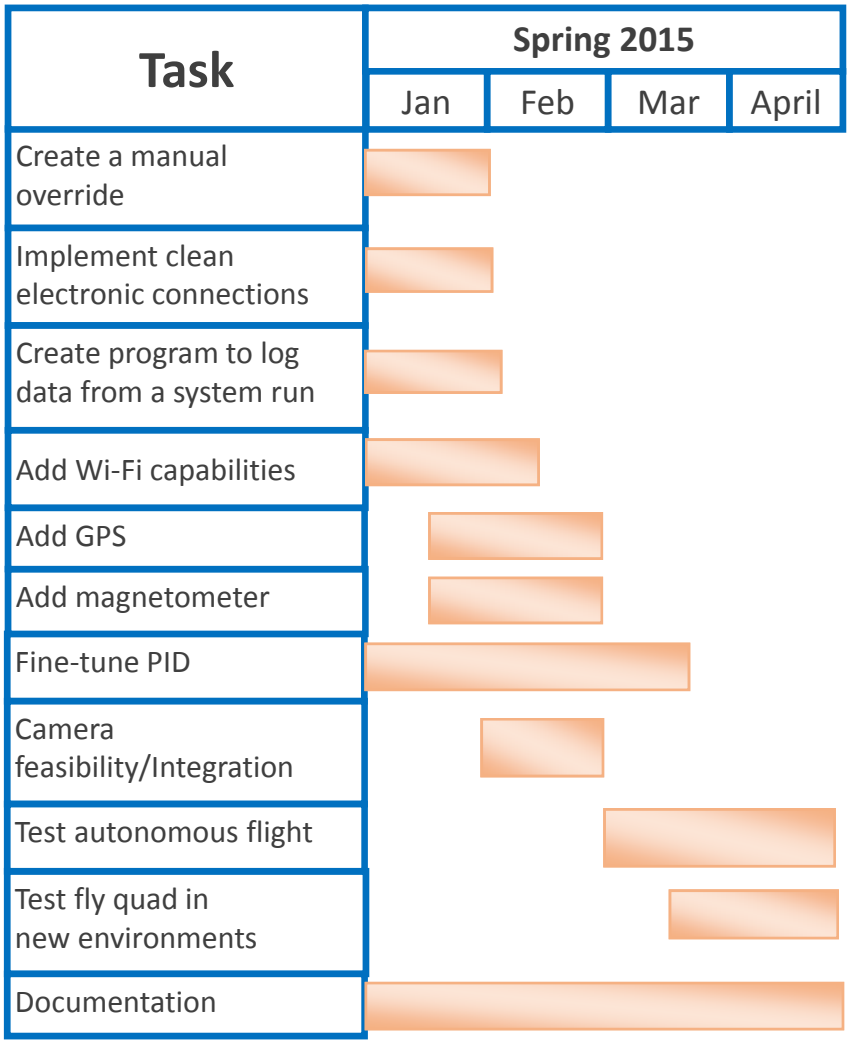
Wireless communications

- Wi-Fi and Bluetooth
- Transmit data from quad to base station

Build platform

- Operating system
- Camera
- Image Processing

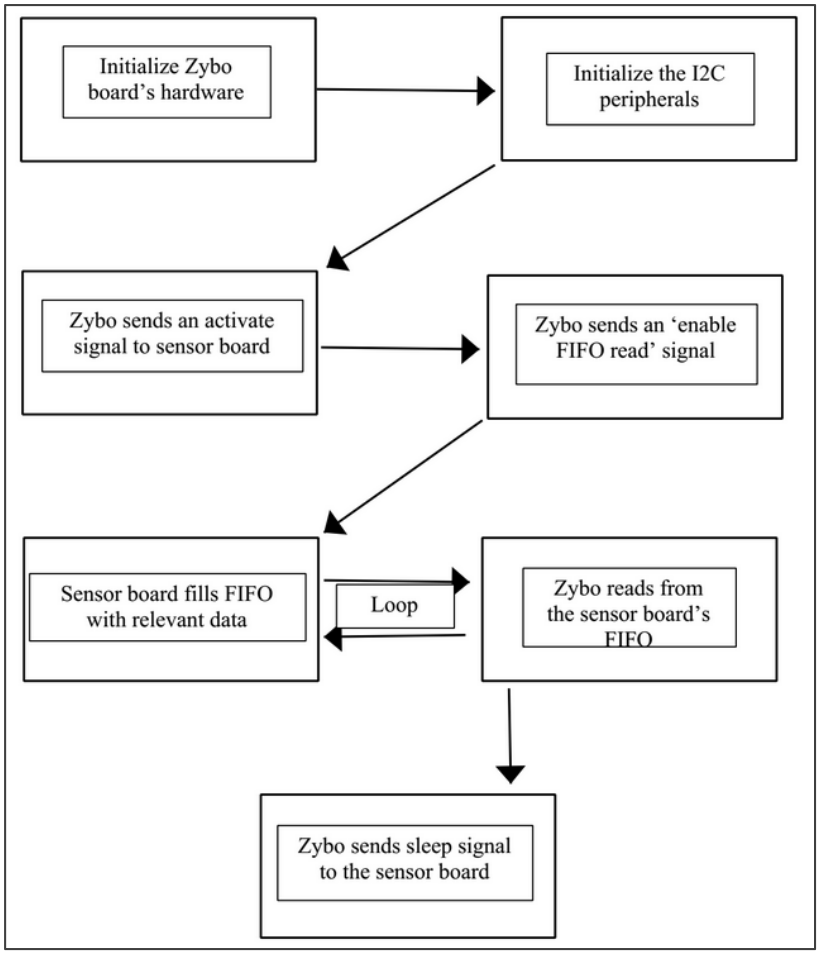
Outdoor Flight



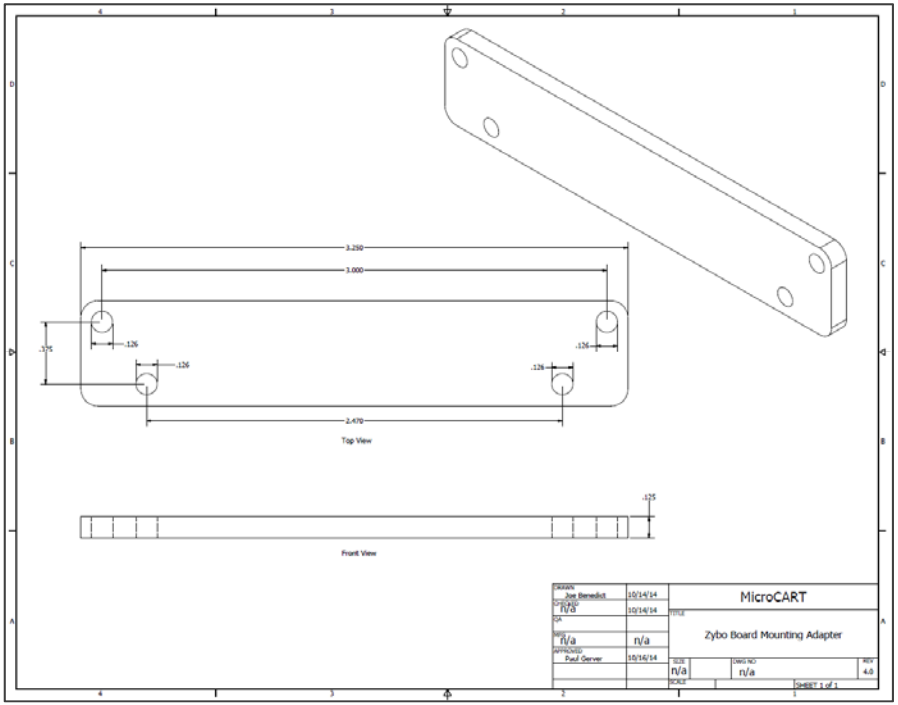
Thank You!

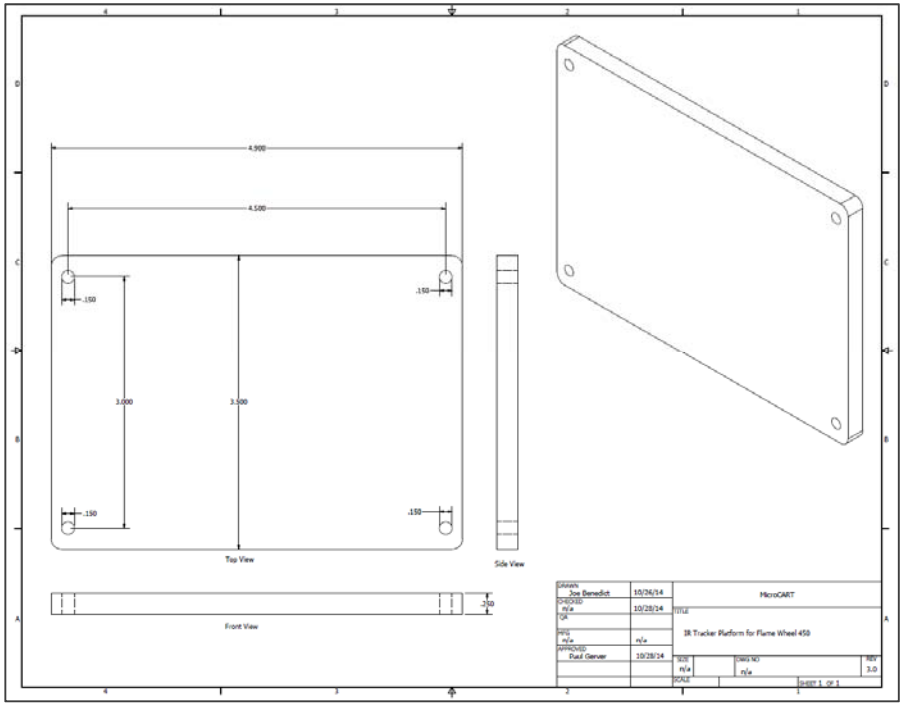
Backup Slides

Sensor Board: I2C communication



Mounting CAD Designs





Bluetooth: UART Communication