Search And Find Emergency Drone

“SAFE Drone”

Team 4
December 5, 2016

Advisor: Professor Leonard

Team Members

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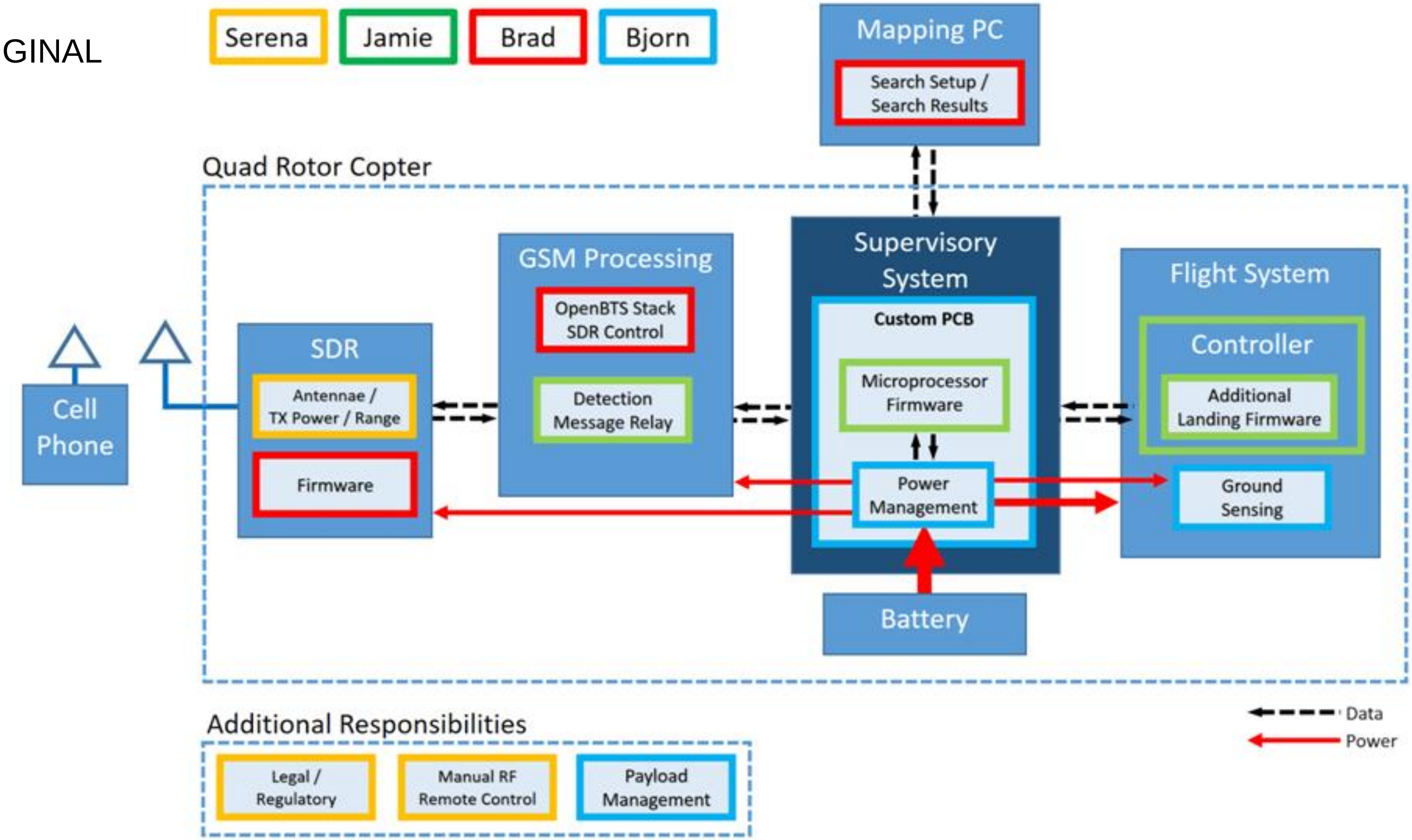
Review of Project

- Fly a drone over a predefined area in order to find lost and injured hikers who have a phone but no reception

- Detection of signal emitted by a cell phone searching for service/cellular tower

- For use in wooded areas with no reception. This could also be useful for winter sports in case of an avalanche

ORIGINAL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Jamie
Brad
Bjorn
Mapping PC
Search Setup / Search Results
Quad Rotor Copter
Cell Phone
SDR
Antennae / TX Power / Range
Firmware
GSM Processing
OpenBTS Stack SDR Control
Detection Message Relay
Supervisory System
Custom PCB
Microprocessor Firmware
Power Management
Battery
Flight System
Controller
Additional Landing Firmware
Ground Sensing
Additional Responsibilities
Legal / Regulatory
Manual RF Remote Control
Payload Management
Data
Power

What were the proposed MDR deliverables?

- Manual RF control of the drone that doesn't interfere with SDR

- Able to alert supervisory system upon IMSI identification

- Supervisory micro software functions complete: control flight waypoints, poll GPS

- Landing/Distance sensory able to detect distance accurately

What's New?

Old Approach

- Previously, project assumed capture of IMSI within cellular signal of GSM network phone
- Deemed unfeasible within time and budgetary constraints

New Approach

- Detection of handheld cellular signal via received signal strength
- "Heat map" (gradient) created by mapping signal strength levels to GPS coordinates together

Requirements

- UAV (Unmanned Aerial Vehicle) capable of autonomously scanning a pre-defined area.
- Ability to measure signal strength of 835-915MHz signals from 100’.
- Ability to record signal strength/GPS coordinates.
- Ability to return to home on completion.
- Present data to search teams by overlaying signal strengths onto map of mission.

… Revised MDR Deliverables

- ~~Manual RF control of the drone that doesn't interfere with SDR~~
- Demonstration of detector picking up GSM band without interference from drone transmitter for safety on campus

- ~~Able to alert supervisory system upon IMSI identification~~
- Generate "heat map" given GPS coordinates and signal strength levels detected

- Supervisory micro software functions complete: control flight waypoints, poll GPS

- Landing/Distance sensory able to detect distance accurately

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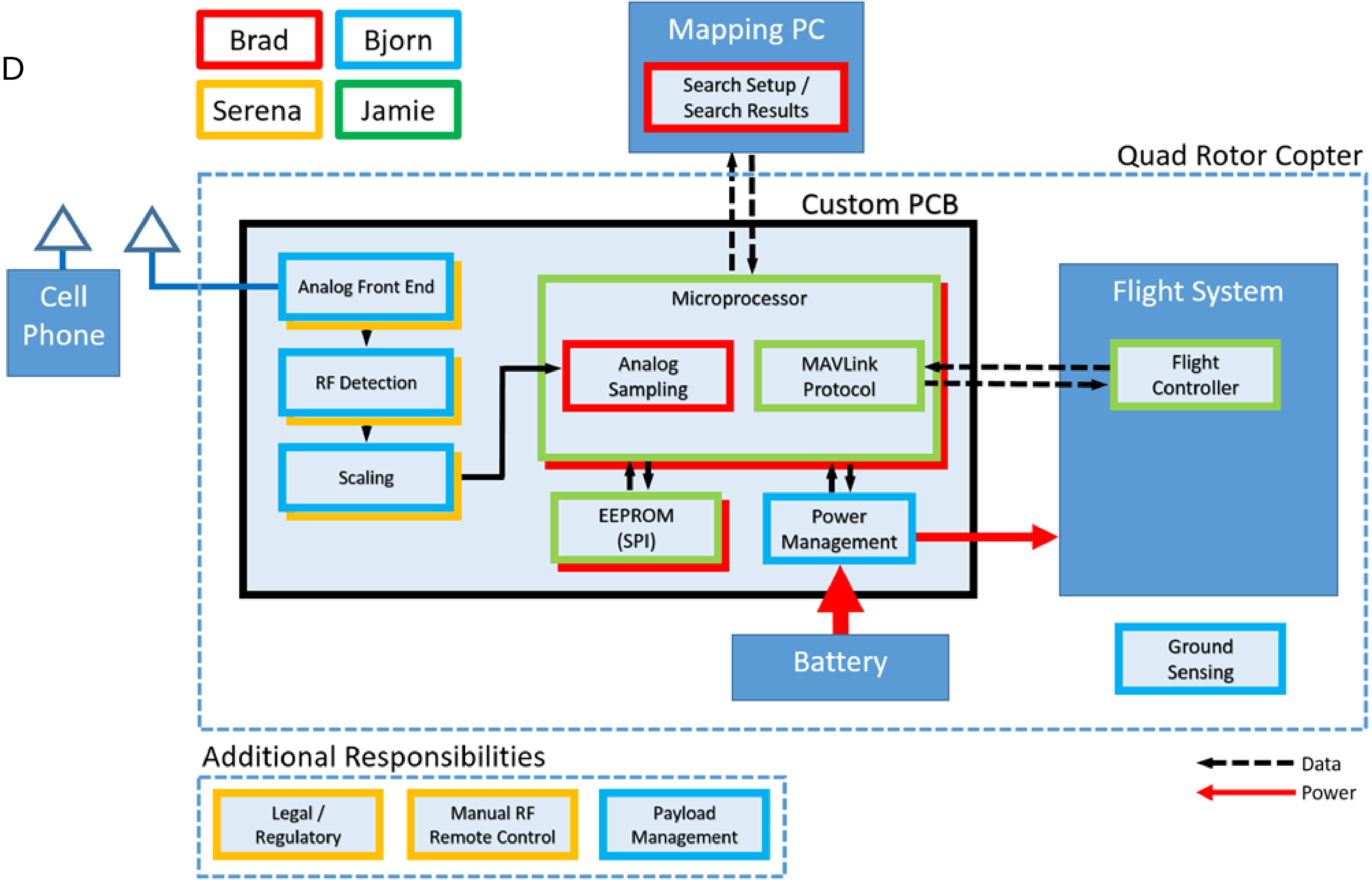
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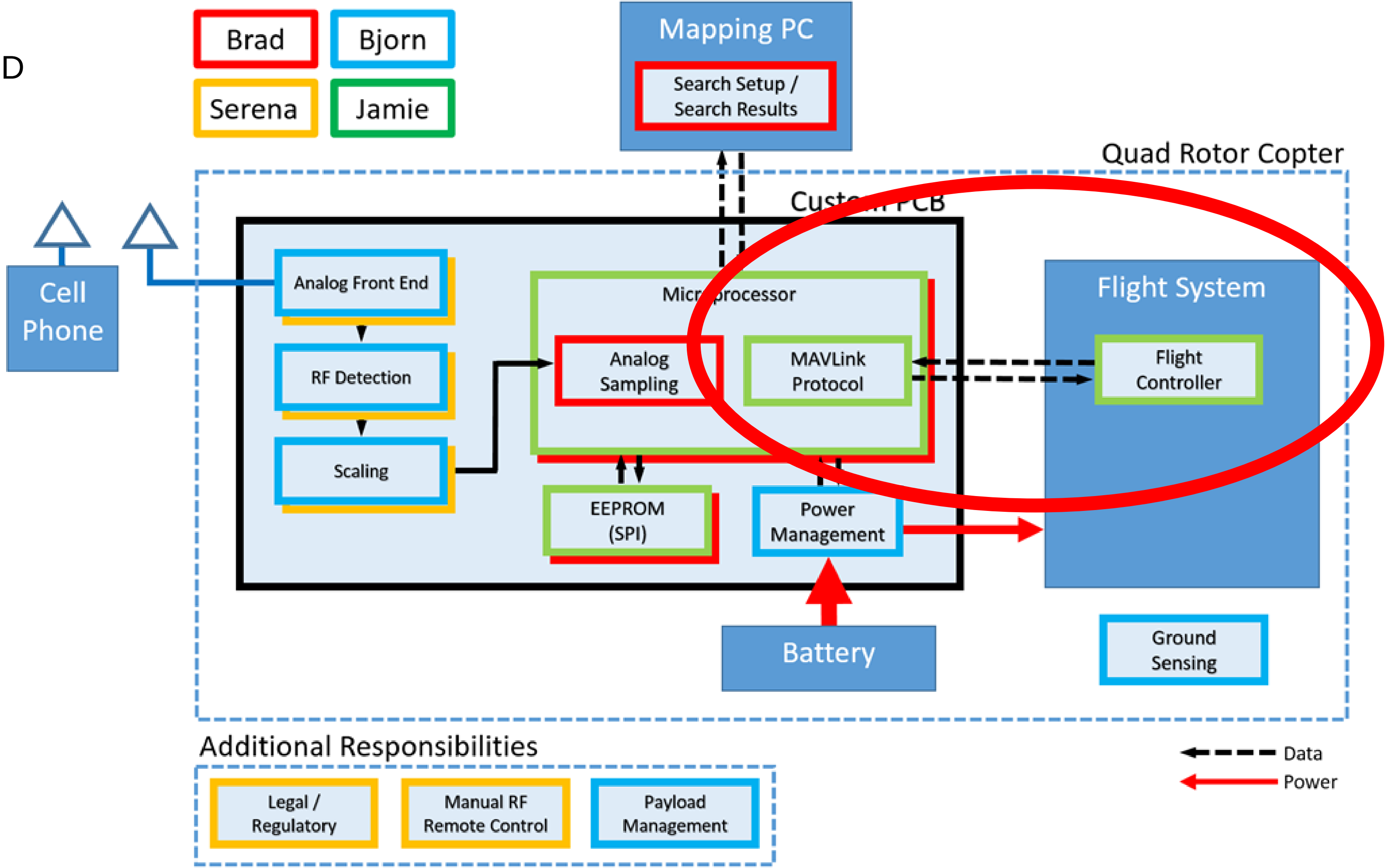
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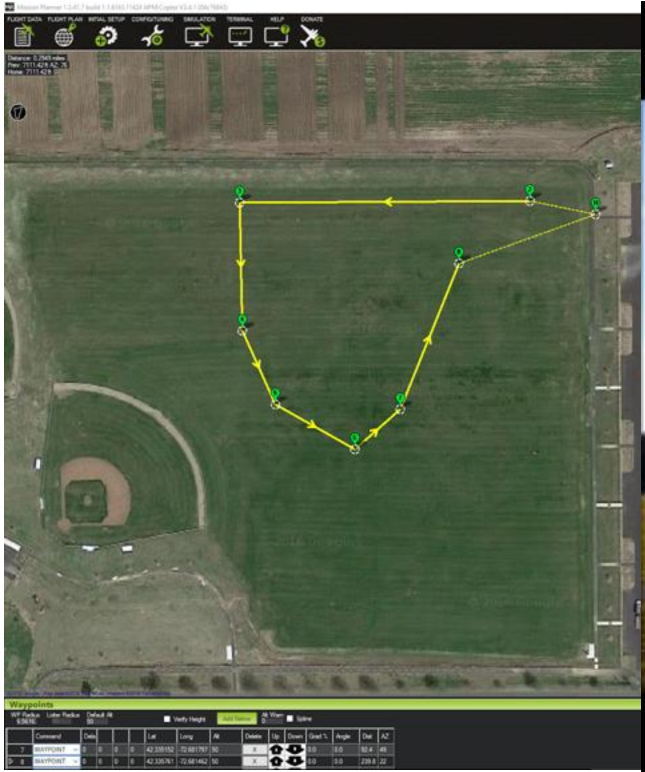
Flight System

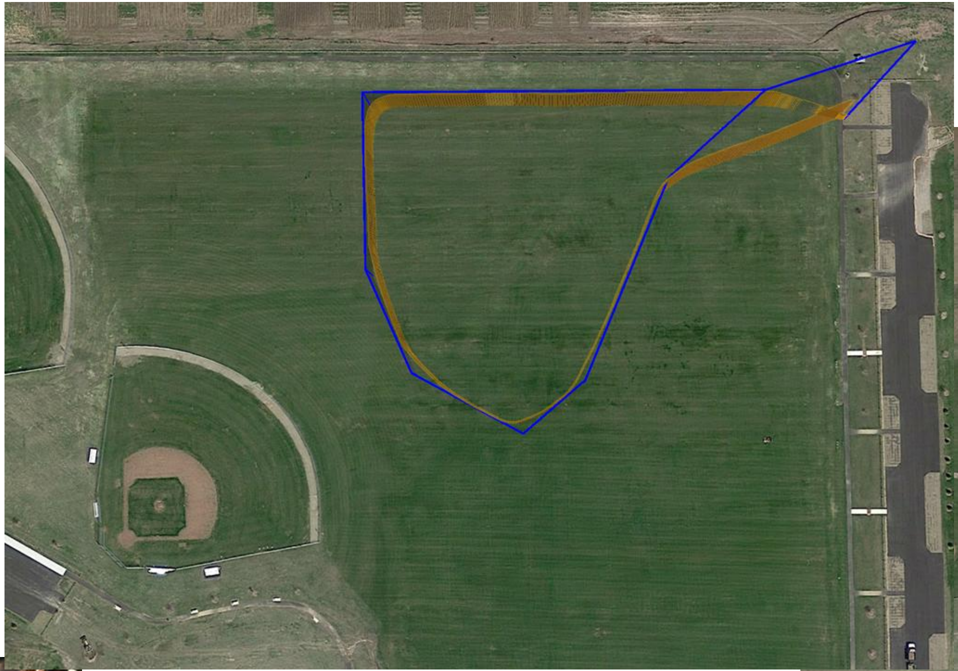
All objectives (then some) achieved:

- Demonstration of fully autonomous mission/flight
  - Including tuning of PID loops for stability
- Implement MAVLink protocol between micro and flight controller
  - Demonstration of receiving data incl. GPS, mode, etc
  - Demonstration of modifying flight mode

Flight System: Autonomous Mission

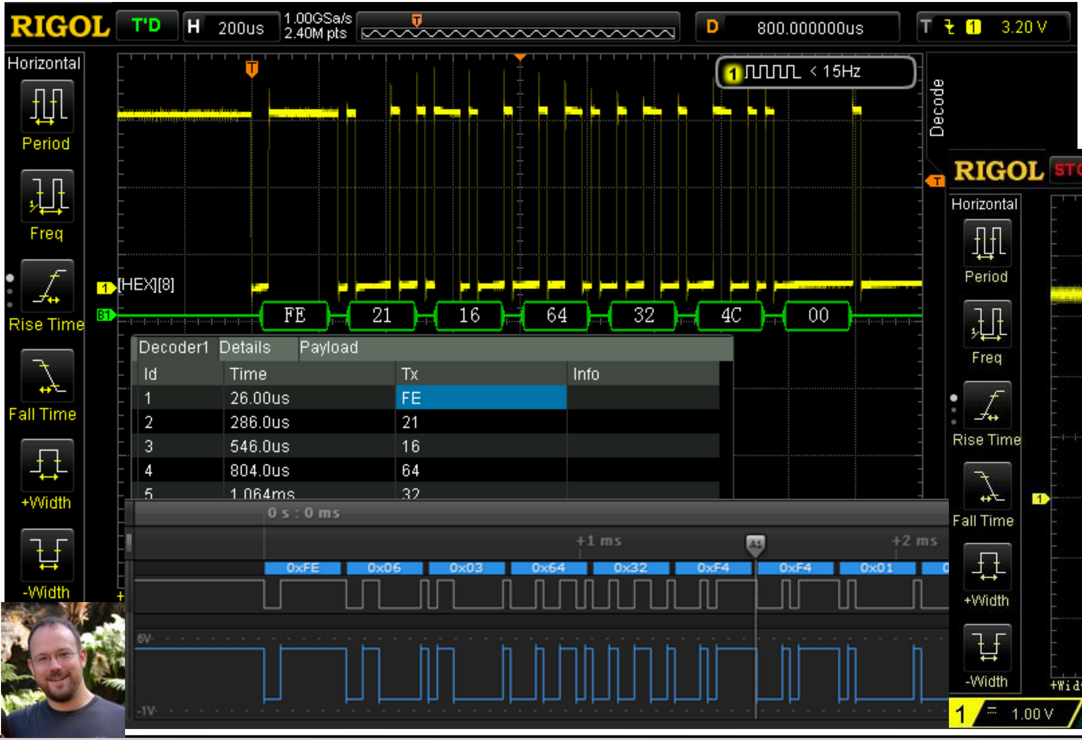


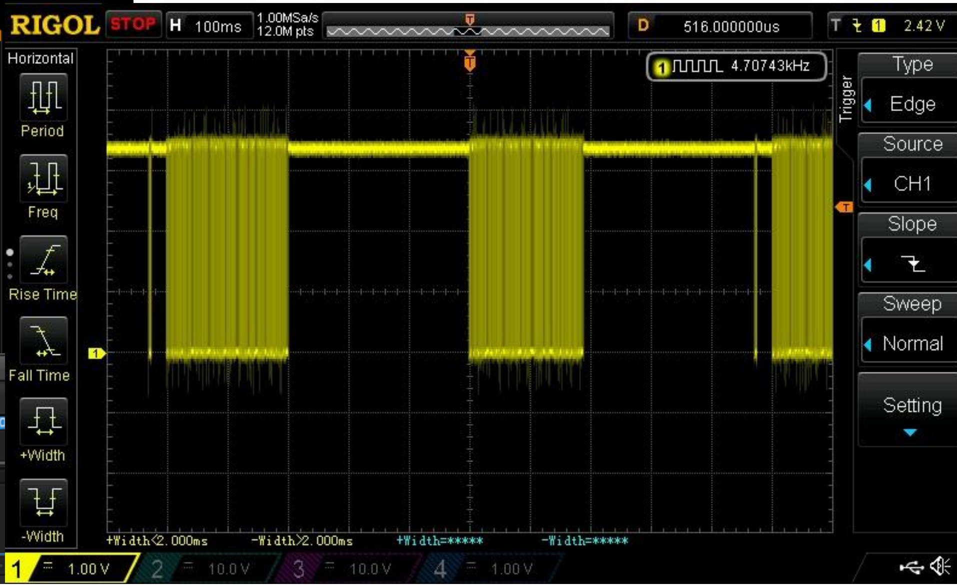
Flight System: Autonomous Results



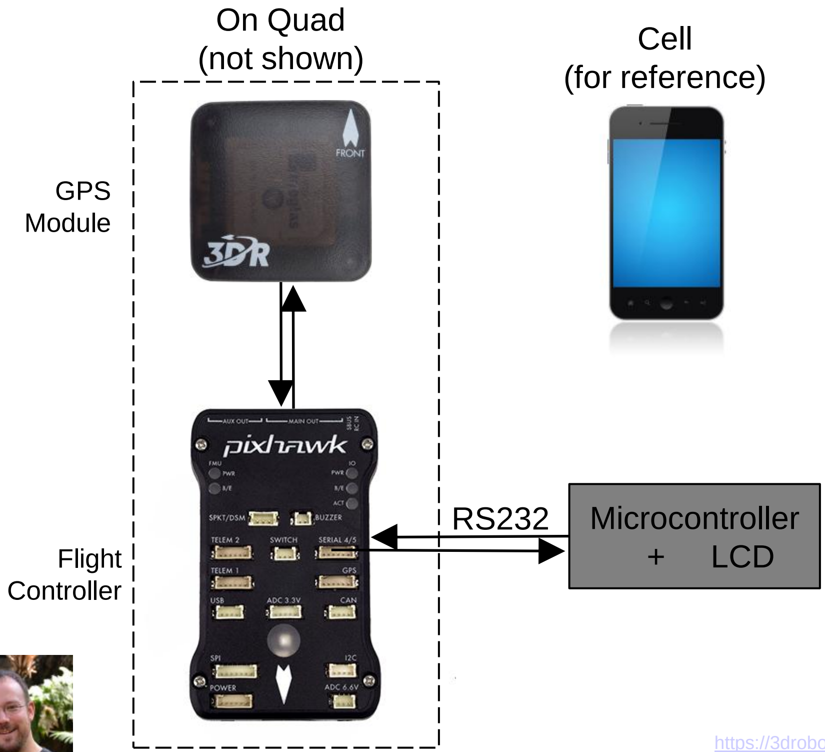
BLU = waypoints
ORG = recorded flight

Flight System: MAVLink madness





Flight System: Poll GPS Data



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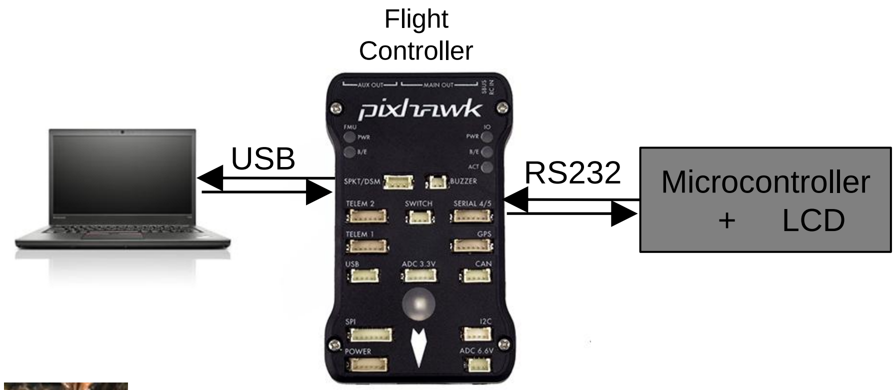
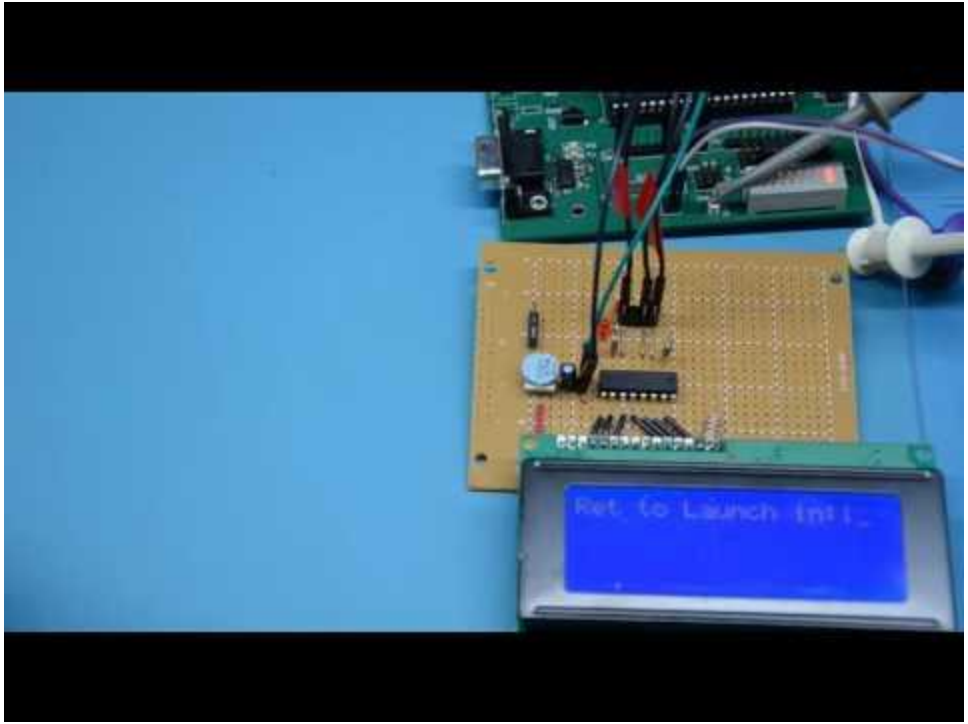
https://www.bhphotovideo.com/images/images1000x1000/3d_robotics_gps_kit_0003_gps_module_for_pixhawk_apm_1098161.jpg

Flight System: Active Control





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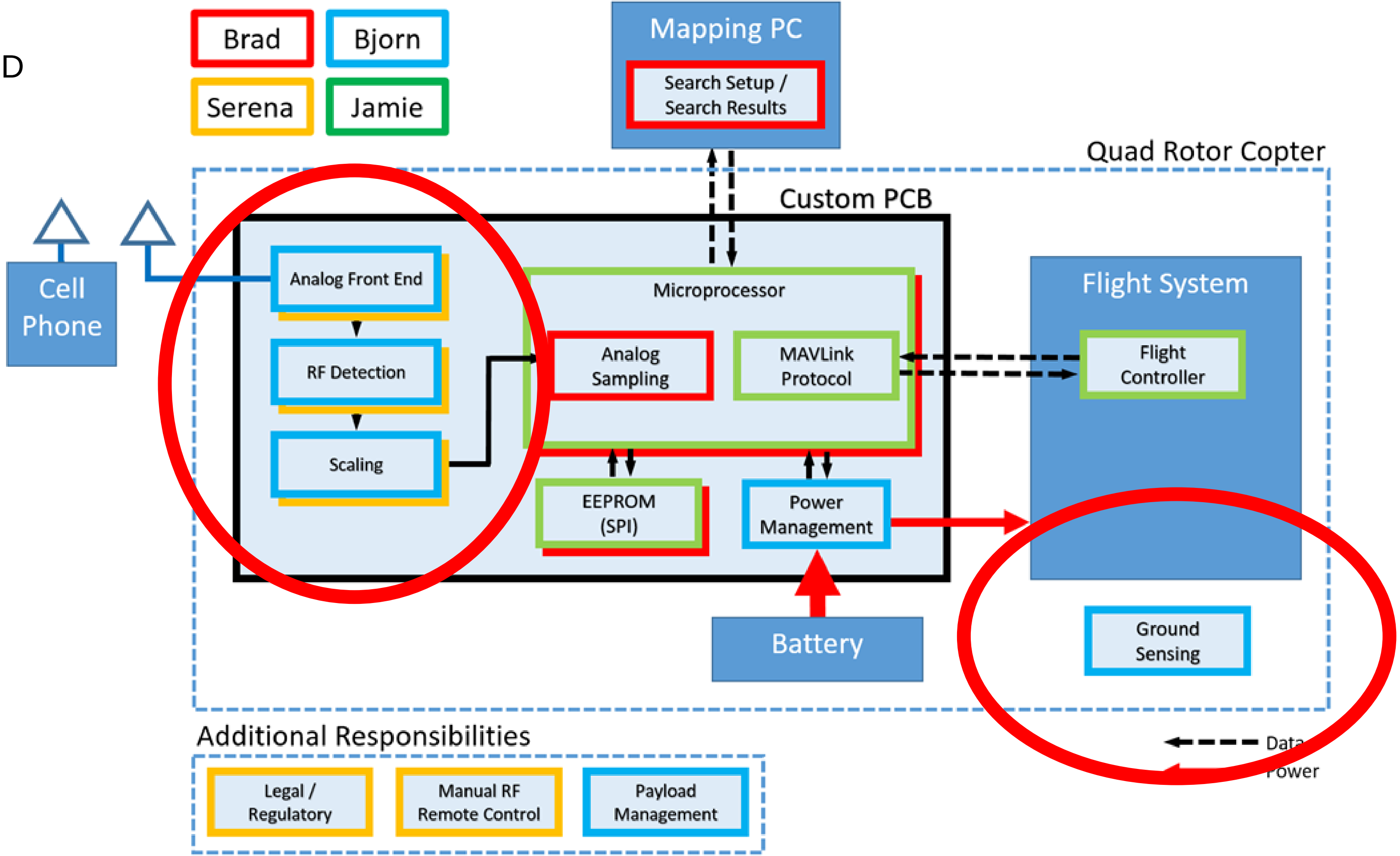
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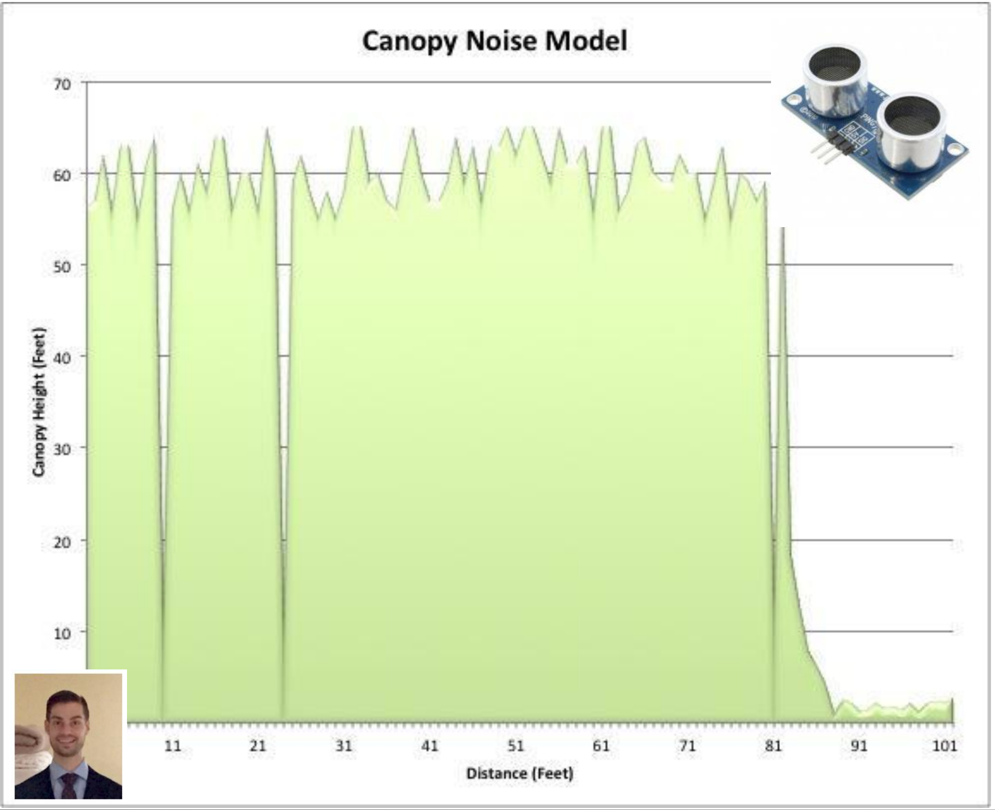
Distance Sensor



Landing Feedback Sensor

- Ultrasonic
  - MaxBotix
  - Sparkfun Ping

Landing Capability

- Smooth transition

Terrain Following

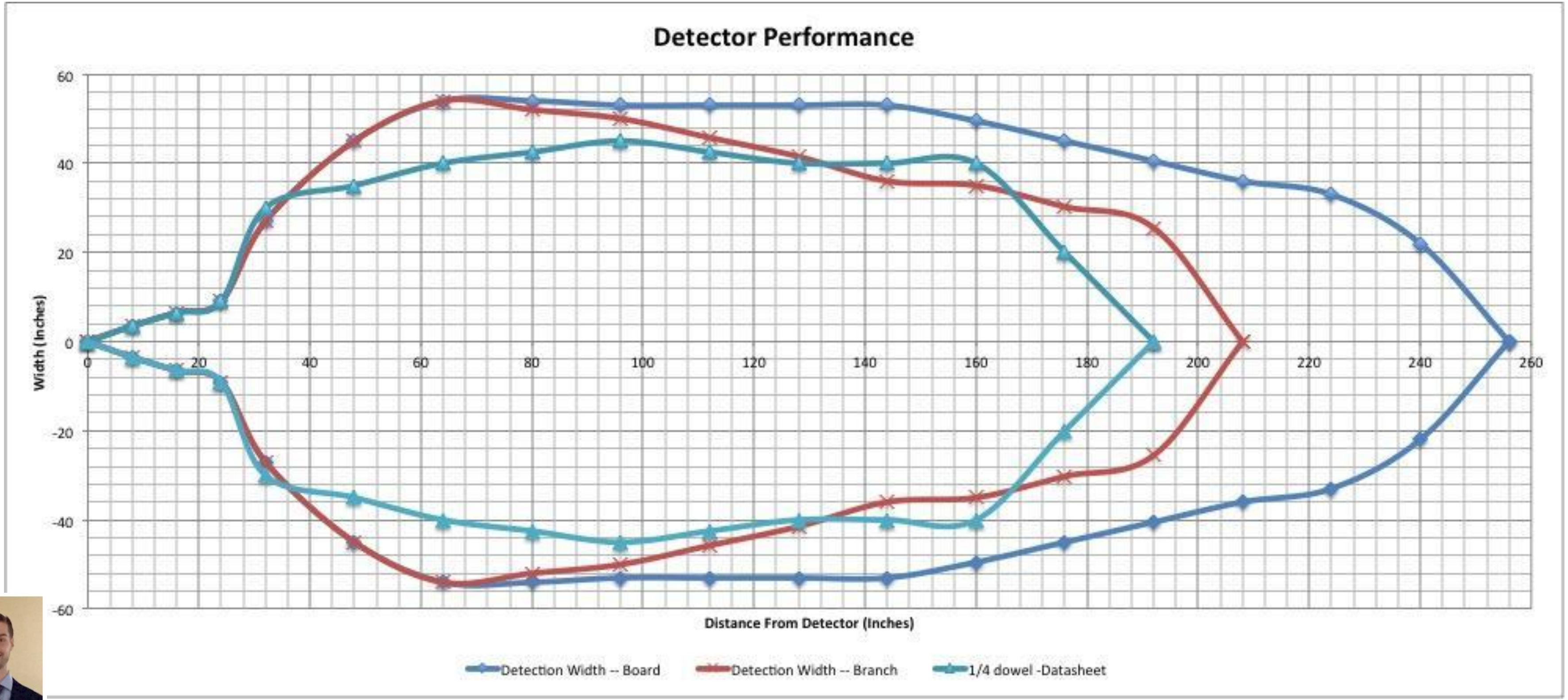
- Able to avoid a 10’ Canopy std dev

Distance Sensor -- Experiment Setup

10”x37.5” board

122” tree branch with appx ¼” girth (at detection point)

Distance Sensor -- Results



Power detection

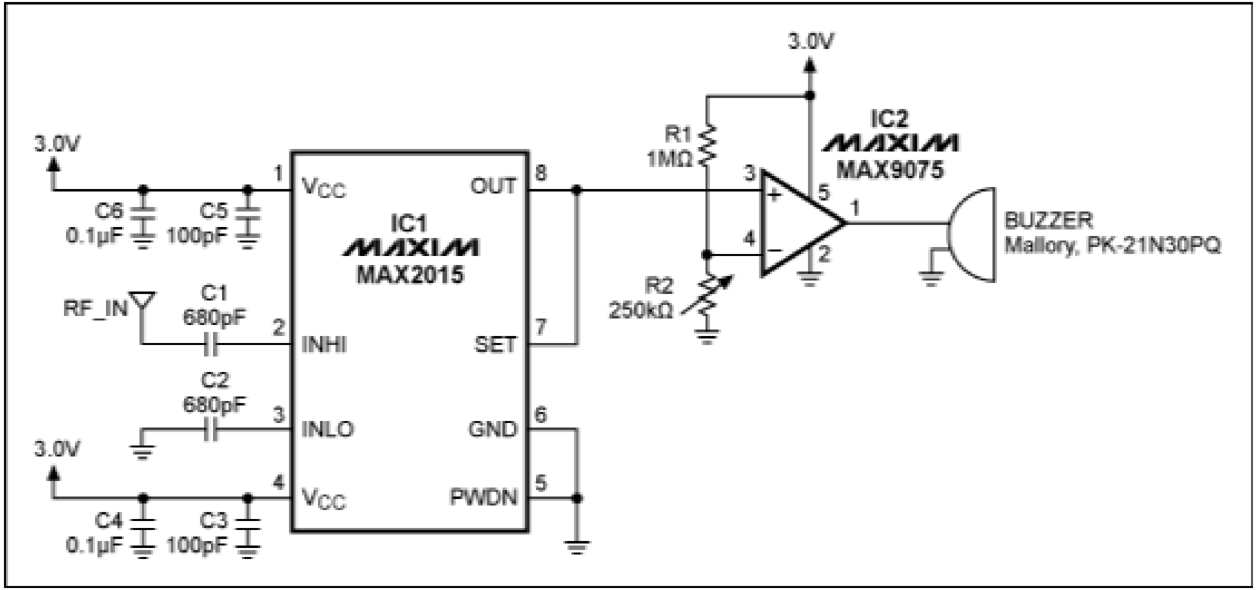


Figure 1. This circuit sounds a buzzer alarm when it detects an RF signal in the range 100MHz to 3000MHz, above approximately -35dBm.

Click here for an overview of the wireless components used in a typical radio transceiver.

MAX2015 Recieved Signal Strength Indicator (RSSI):

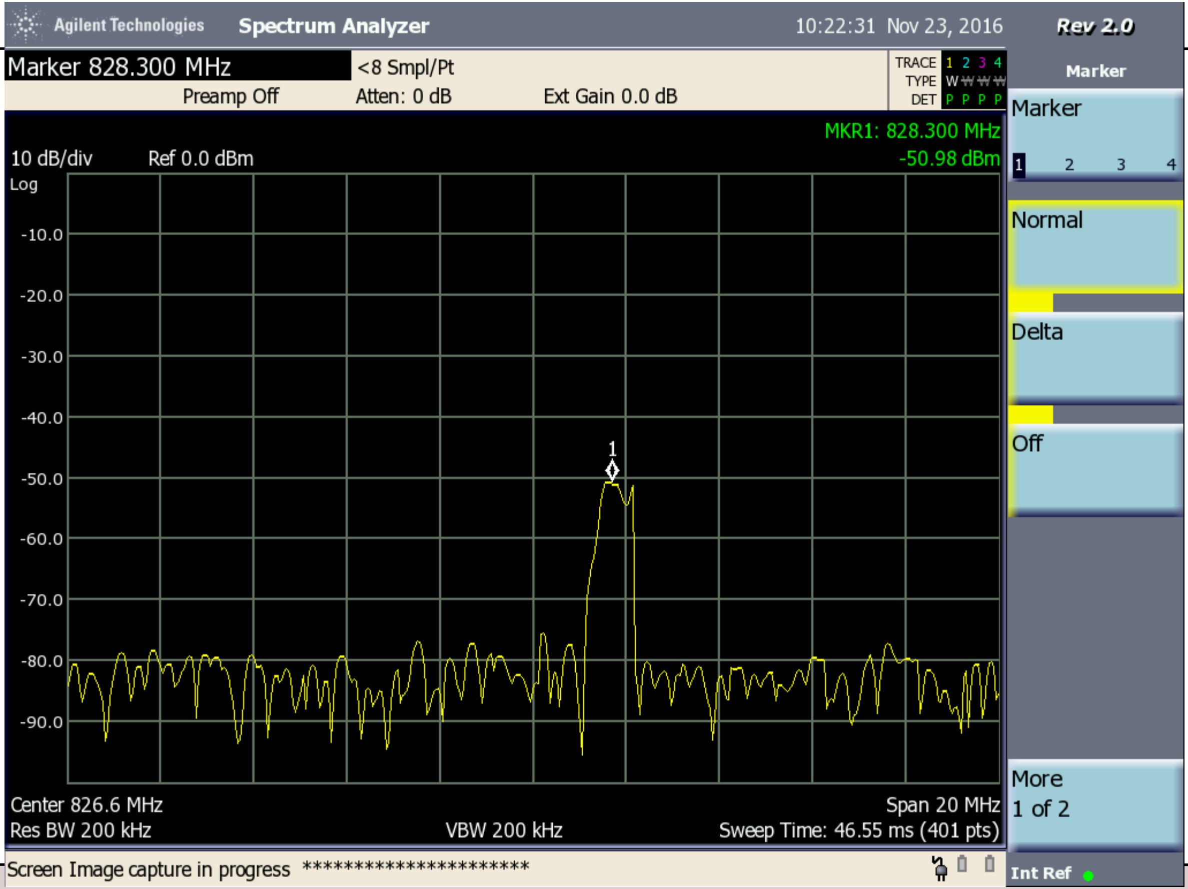
- -65 to 5 dBm RF input
- 0.5v - 1.8v Output
- 18.1 mV/dBm

dbm = 10log(P/1mW)
dbmV = 20log(V/1mV)

http://s.eeweb.com/articles/2011/10/20/rf-bug-detector-circuit-1319152903.pdf

Power detection

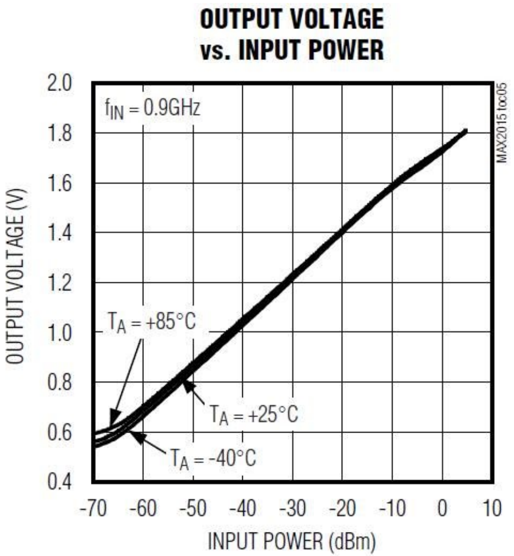
- Antenna from our circuit on spectrum analyzer
- Calling serena from my phone
- shows the frequency of the cell phone when placing a call
- 10uW transmitted -- decent reception



-50dBm at ~828 MHz

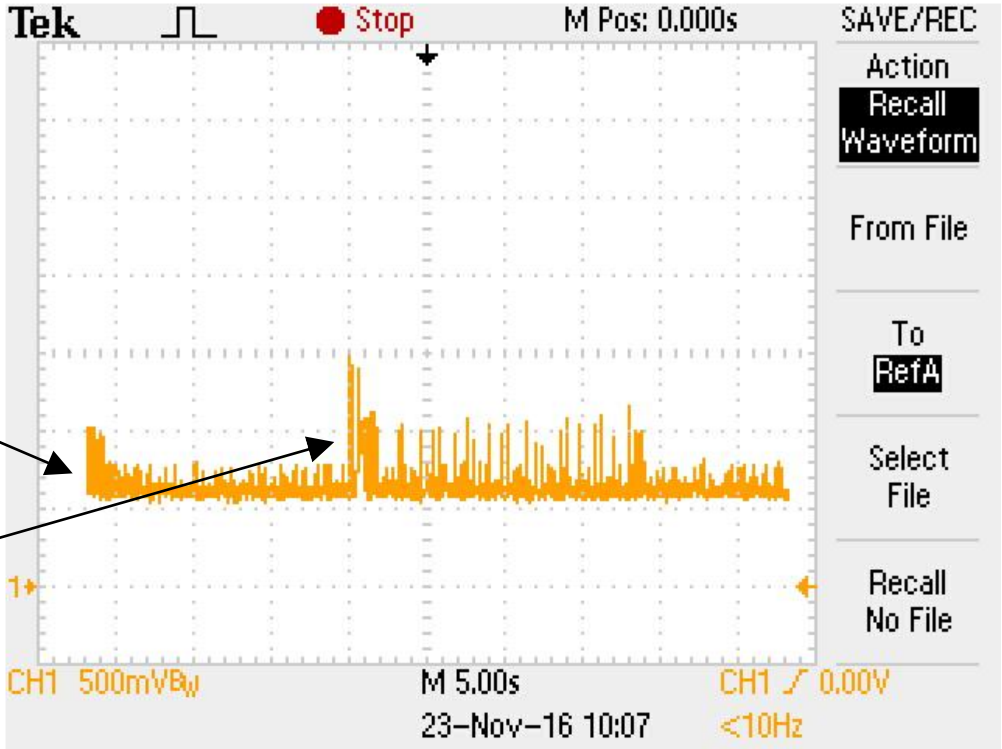
Power detection

Slope: 18.1 mV/dBm



Appx. 0.6V floor measured on Oscilloscope

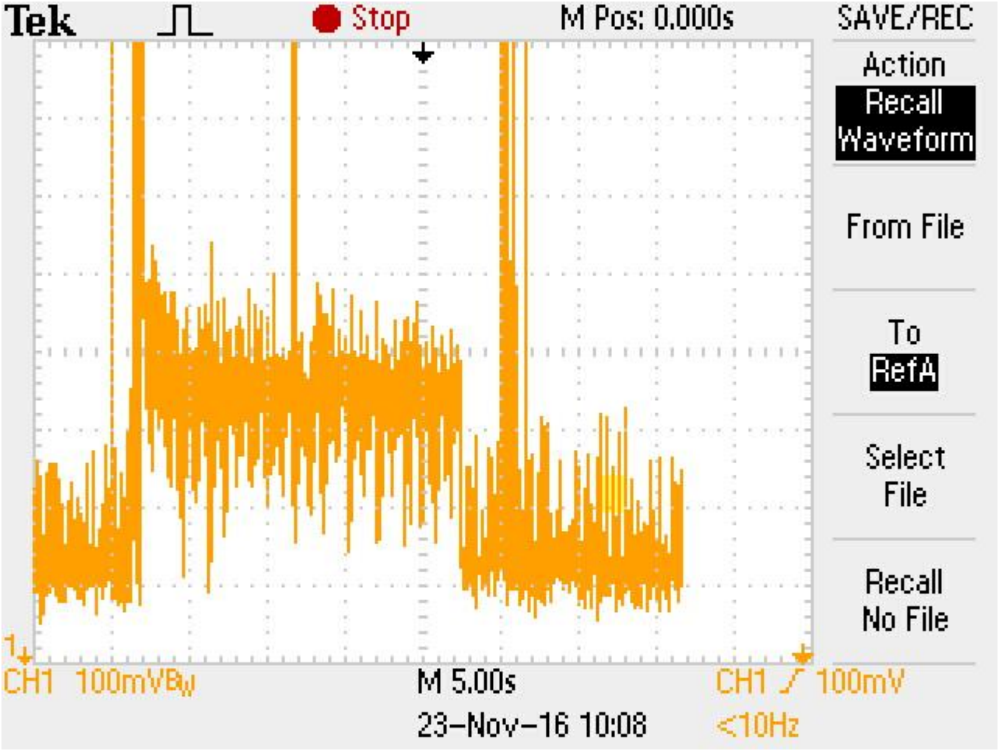
Appx 0.85V from Signal transmission



Results Comparable To Spectrum Analyzer Pwr Measurement ~50 dBm

Power detection

IMSI Captured



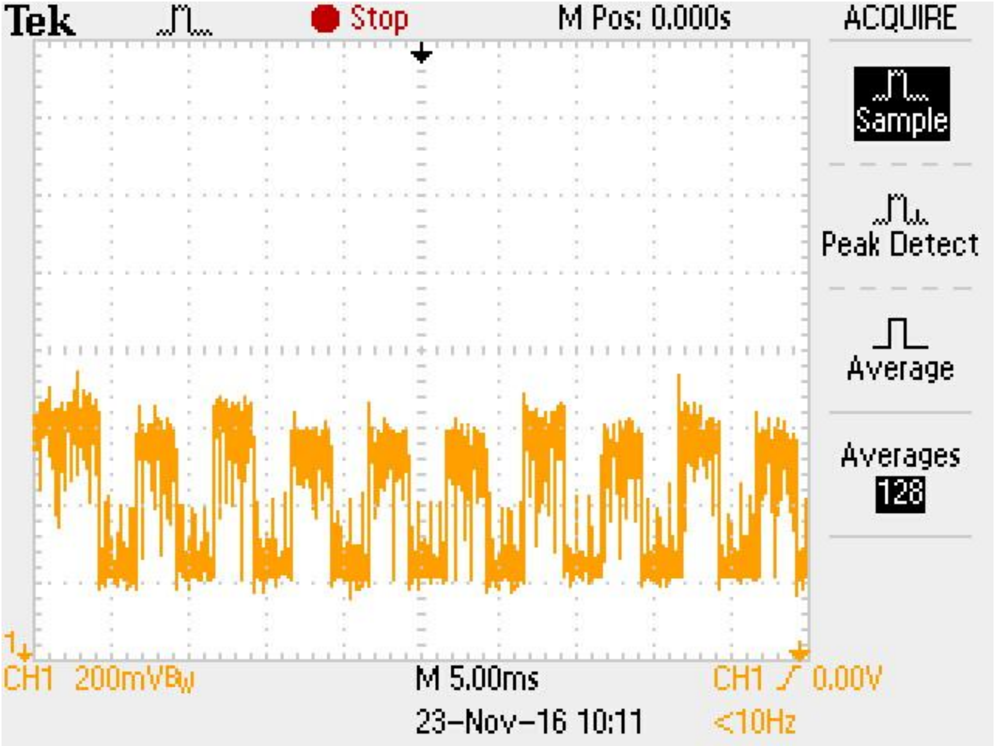
Power detection

Bjorn's cell phone contacting a tower almost every 5ms trying to secure a connection with Serena's cell phone.

This is the Raw output voltage from the MAX2015

Currently:
Comparator/Buzzer circuit for demonstration.

Serena is working on the gain stage into the ADC and filtering out unwanted signals.



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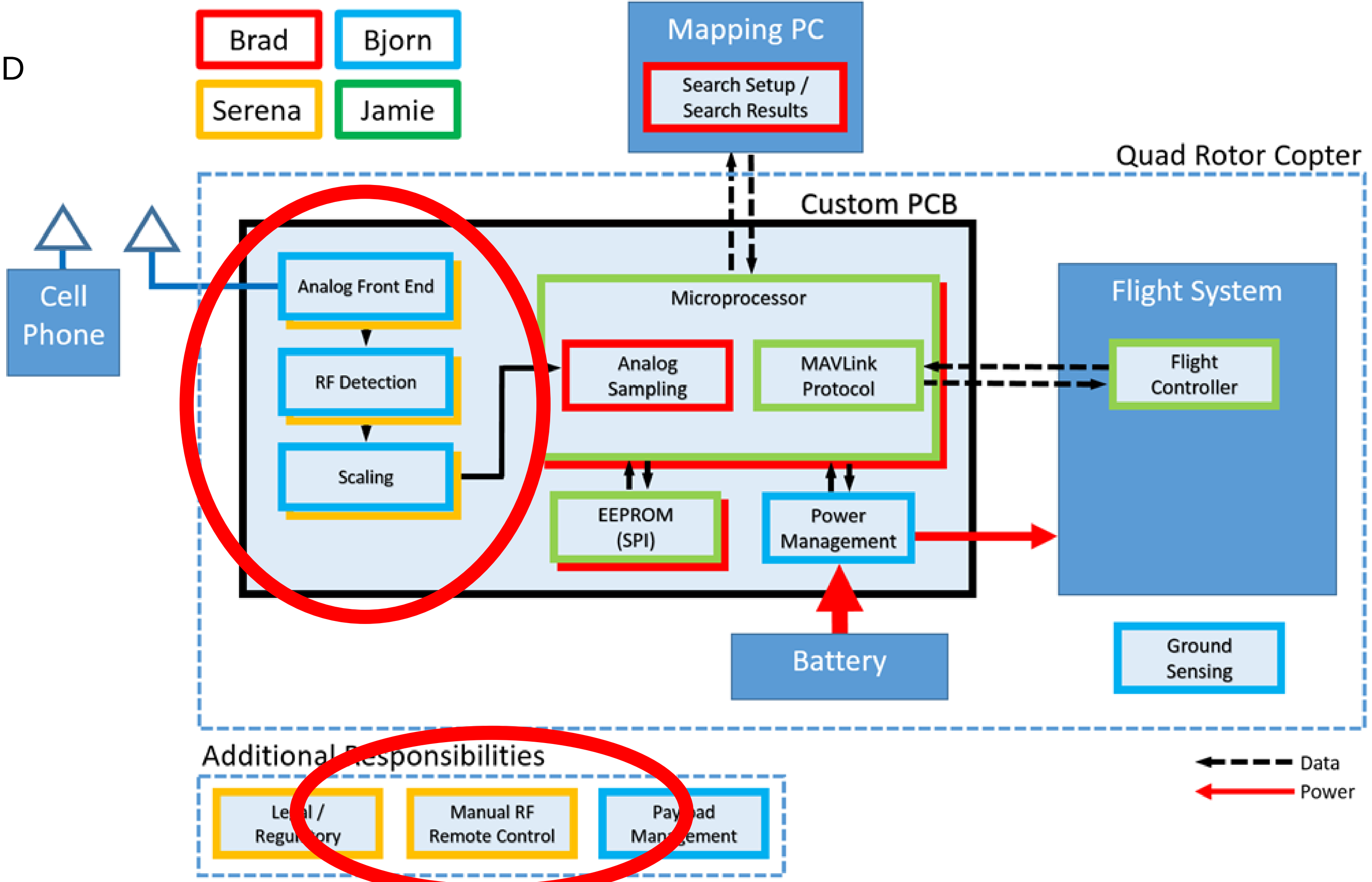
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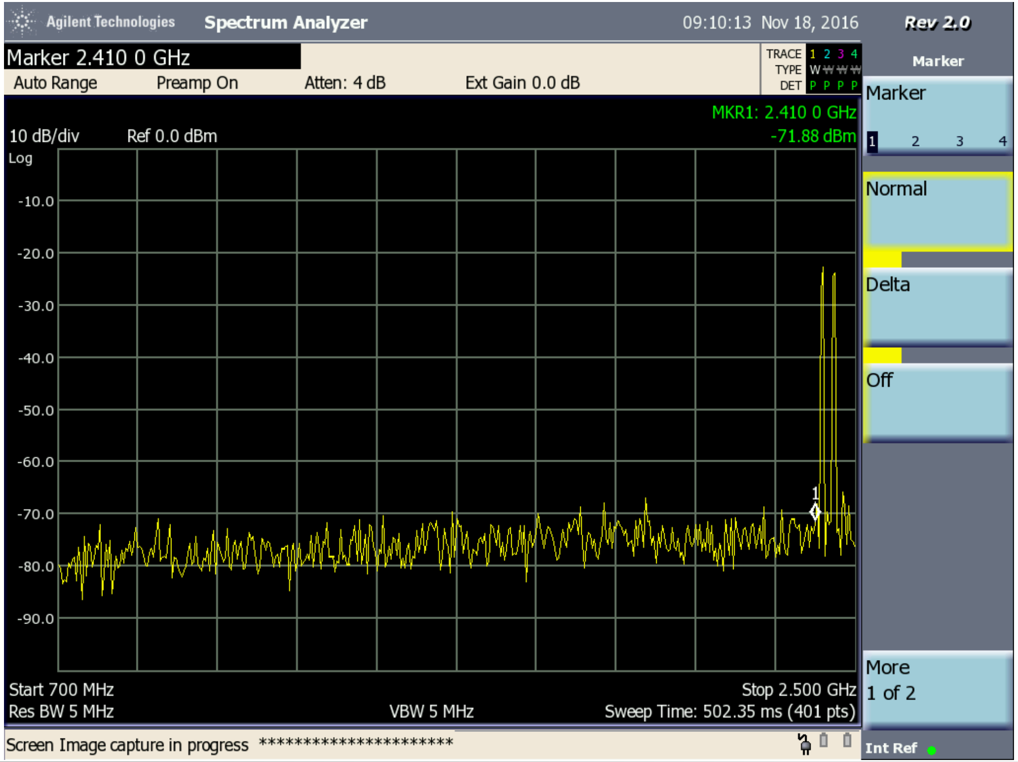
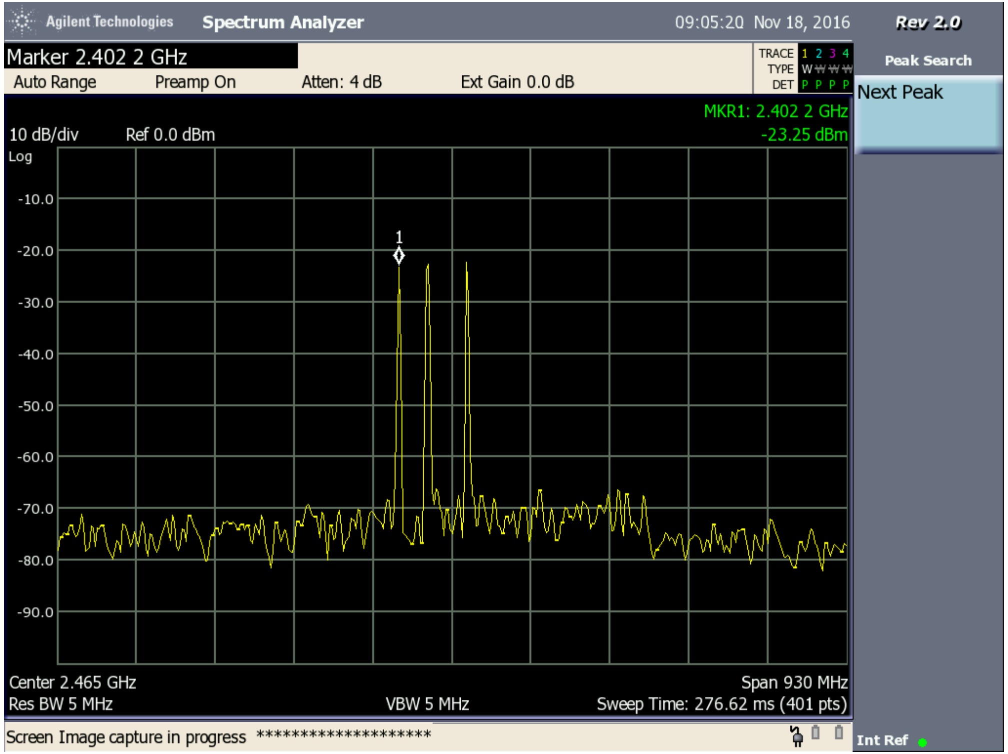
Manual "Control" of the Drone

- Needed for safety
- Using antenna from circuit, spectrum analyzer shows the remote control doesn't interfere with the 900MHz band



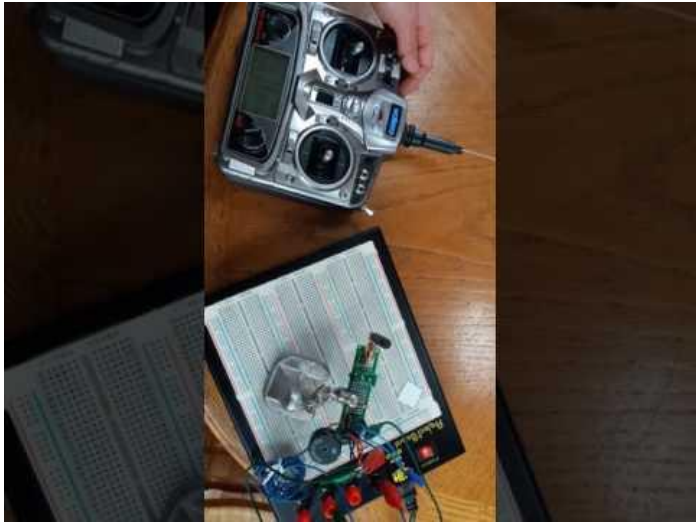
Manual “Control” of the Drone

- Spectrum analyzer shows the exact frequency the remote control interferes with



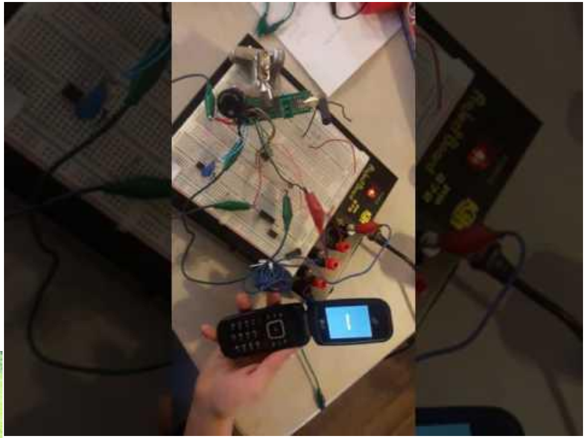
Manual "Control" of the Drone

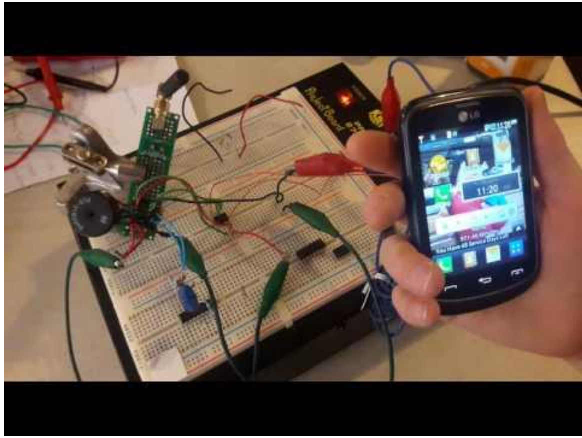
- To filter out the 2.4GHz remote control frequency from the power detector circuit, need filter (Used 1.3GHz LPF)



Manual "Control" of the Drone

- Now, can test the range of the circuit using a cell phone that doesn't have service
- Tested up to 85ft, circuit can detect cell phone signal trying to connect to the tower





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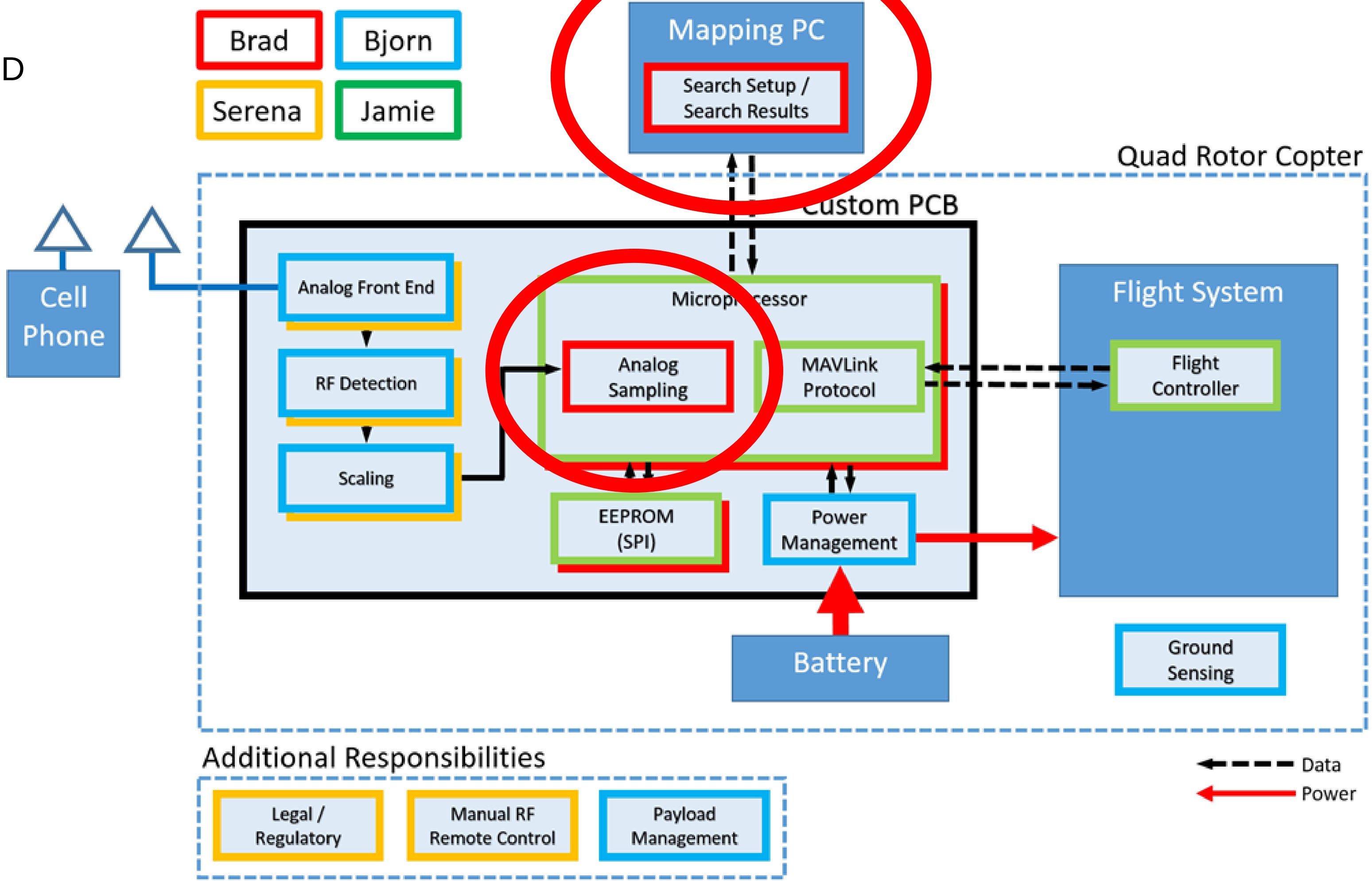
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Supervisory Microcontroller

Inputs:

- ADC in order to convert analog power signal to digital data
- USART in order to receive GPS,Speed, etc, from flight controller

Outputs:

- USART to EEPROM to save power level and GPS Coordinate data
- SPI to USB interface to download data file to host PC

Functions:

- Keep track of state
  - Lift off
  - Traveling (Without sampling)
  - Traveling (With sampling)
  - Landing
- Calculate sampling speed

Analog Sampling

Analog to Digital Converter

- Convert analog signal from power detector circuit
- High resolution (10 bit ADC)
- Sample 500mV to 1.8V with 3.3V reference voltage
- Minimum 500KSPS

403 distinct power levels!

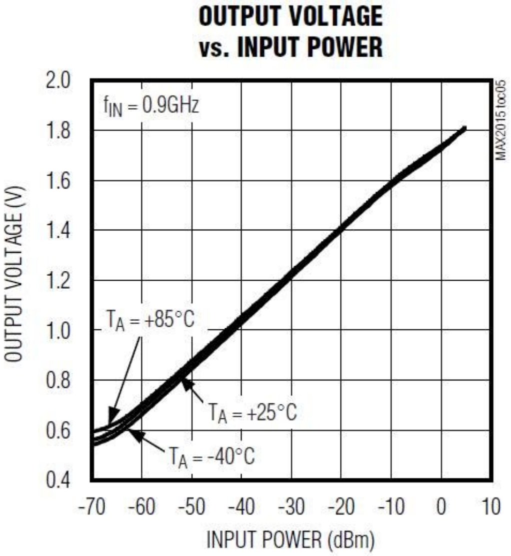
$$\left(\frac{.5V}{3.3V}\right) \times 1024 = 155$$

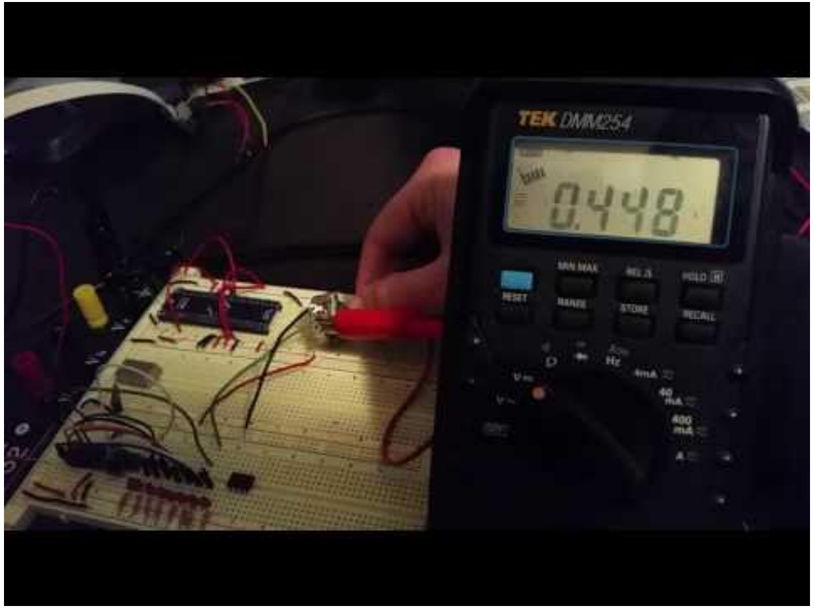
$$\left(\frac{1.8V}{3.3V}\right) \times 1024 = 558$$

$$558 - 155 = 403$$

0x09B to 0x22E

<u>.1861 dBm per bit</u>





Data

Power Level & GPS Data

- Power level data saved as 4 byte integer representation of power level
- GPS coordinate data is in decimal degree format, saved as 4 byte floating point
- Data file saved on EEPROM as list of Power Level & GPS Coordinate tuples
- Used by host PC to create visual representation of power signatures

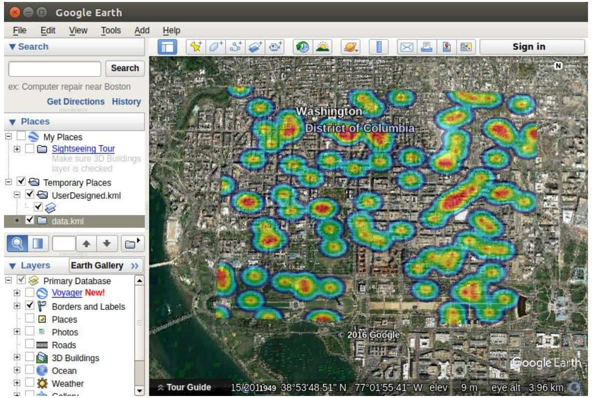
Example Data File

```
155,(42.393960,-72.528880)
175,(42.393930,-72.528962)
250,(42.393900,-72.529044)
318,(42.393870,-72.529126)
400,(42.393840,-72.529208)
558,(42.393810,-72.529290)
400,(42.393780,-72.529372)
318,(42.393750,-72.529454)
250,(42.393720,-72.529536)
175,(42.393690,-72.529618)
150,(42.393615,-72.529576)
```

Heat Map

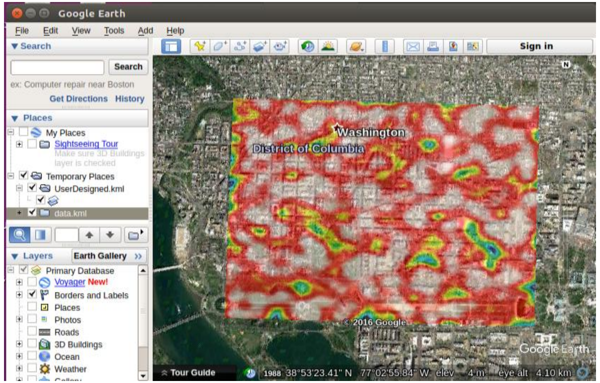
Requirements:

- Software needs to be easy to run.
- Heat map needs to be customizable.
- Visualization needs to be accurate.
- End result needs to be flexible for various situations.
- Rendering needs to be automatic given any GPS/power data file.
- Image needs to be able to be overlaid on top of satellite map.



Challenges:

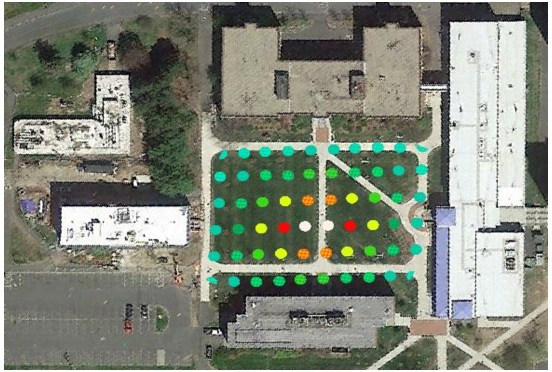
- No plug and play code available.
- Generic point merge model not sufficient:
  - Resolution not small enough to eliminate inaccuracies.
  - Too many data points saturate the image.
  - Based on quantity of points, not a weighted system.



Heat Map

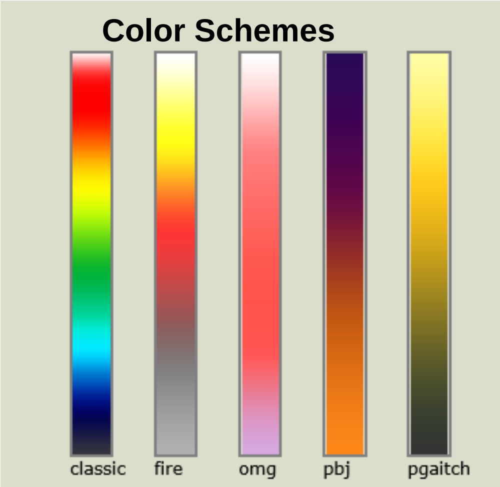
Solution:

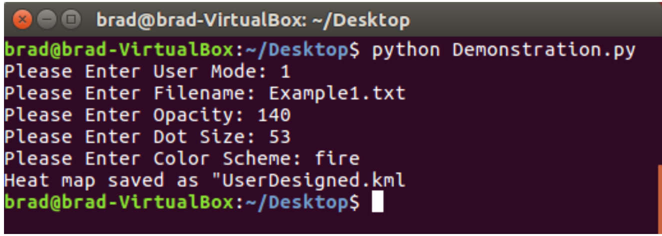
- Points are based on power level measured, not quantity of points.
- Program takes few parameters.
- Visualization pinpoints location of signal with error congruent with number of data points (aka: more data points=more accuracy)
- Data is averaged out so few erroneous signals won't throw off entire map.



Customization Options:

- 5 Different Color Schemes w/ varying degrees of temperature gradient.
- Opacity from clear to opaque (0-255).
- Dot size = to number of pixels (1-P).
- User defined data file.





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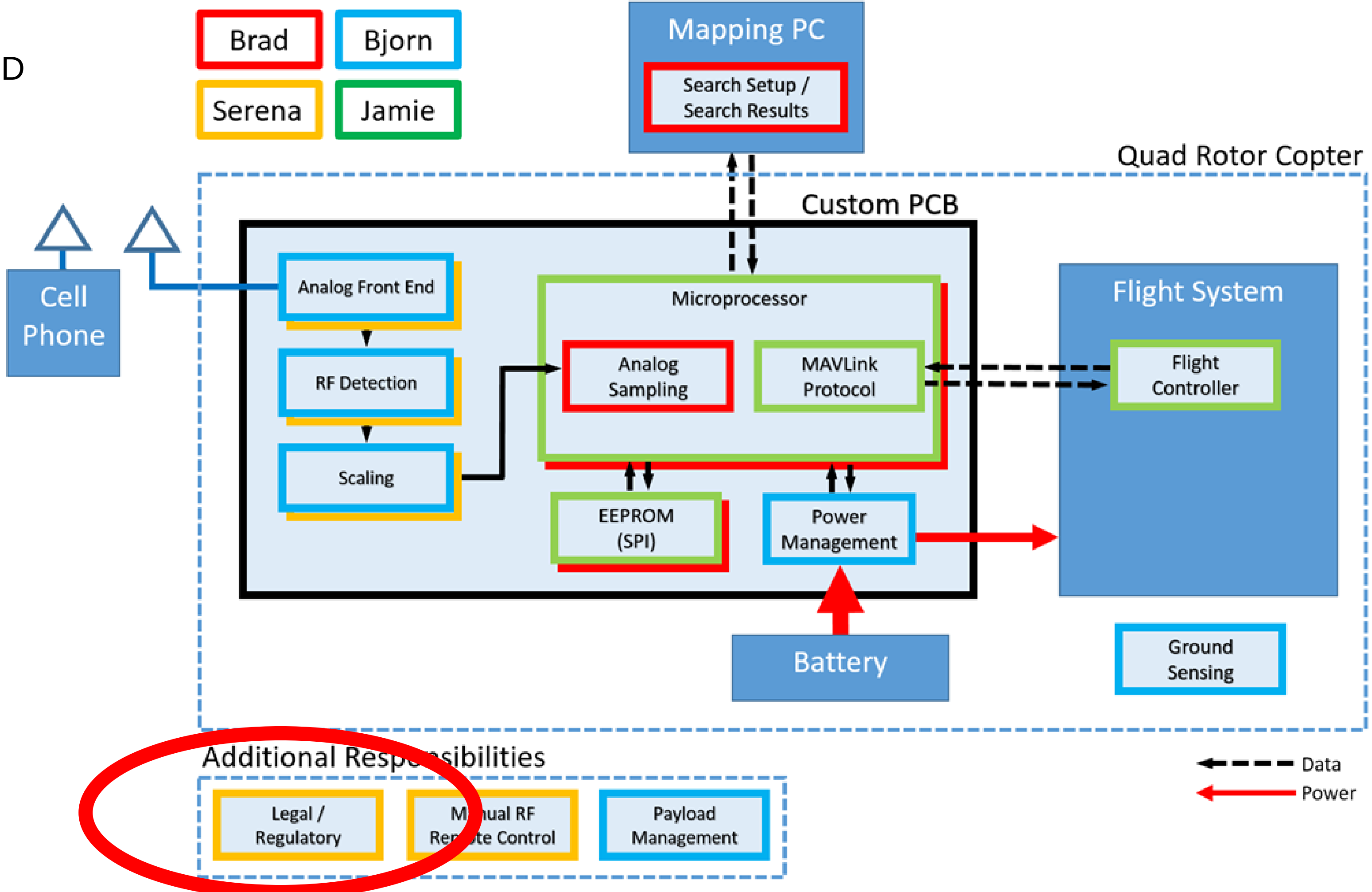
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Legality Issues Solved

- To transmit on the 900MHz band, which may be necessary later, need a technician class HAM radio license, which is in progress
- The drone is registered as a UAS (Unmanned Aircraft System) with the FAA, which is needed in order to fly

UMassAmherst

Path to Project Completion

By MDR (completed):

- Autonomous flight: sensor polling, control of craft
- Detector circuit sensing GSM band w/out interference from manual controller
- Generate "heat map" given simulated GPS/detected signal levels
- Landing/Distance sensory able to detect distance accurately

By CDR (critical subsystem integration):

- Microcontroller code complete
- Sensing circuit output scaled for A2D
- Flight-ready system prototype
- Mainboard + sensing PCBs drafted

By FPR (tuning + final touches)

- User interface software complete
- Signal level detection at range spec.
- Energy consumption/reserve algorithms
- Mechanical fixturing/wiring/enclosures

Budget

Under and on track:

Flight controller	$69.86
Propellers	$16.00
New Receiver	$30.48
Telemetry cable	$22.00
RTL-SDR	$25.95
Range sensor	$62.00
Components/Parts	$108.92
Total Used:	$335.21

Budget Remaining: **$164.73** (PCBs + parts)

Proposed CDR Deliverables

1. Output of signal detection circuit compatible with the ADC; comparator portion of signal detection circuit designed/routed ("daughterboard")

1. Microcontroller functions completed: Capability to write ADC and GPS data to EEPROM, Ability to output data from EEPROM to host PC, Sampling functions complete, Finite State Machine Complete.

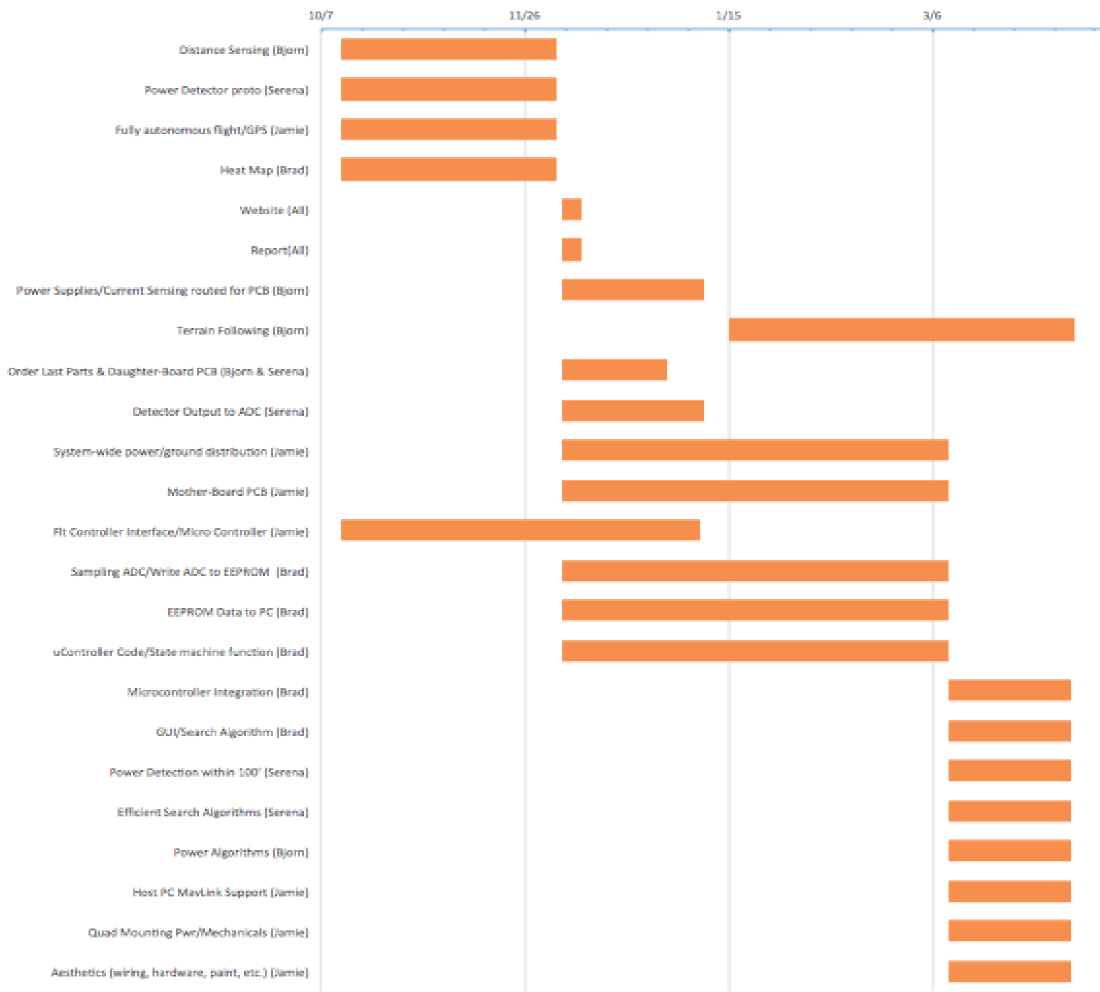
1. Main PCB routing complete: board/system mechanicals, microcontroller, PC interface, EEPROM, battery connections. Integrate "daughterboard" support and power supply routing (Bjorn).

1. PCB power supplies and RF portion of signal detection circuit designed/routed ("daughterboard")

SAFE DRONE Team 4: Serena Thomas, Jamie Kline, Bjorn Galaske, Brad Marszalkowski

Voltage Regulator

START DATE	END DATE	DESCRIPTION	DURATION (days)
10/12/16	12/5/16	Distance Sensing (Bjorn)	53
10/12/16	12/5/16	Power Detector proto (Serena)	53
10/12/16	12/5/16	Fully autonomous flight/GPS (Jamie)	53
10/12/16	12/5/16	Heat Map (Brad)	53
12/5/16	12/10/16	Website (All)	5
12/5/16	12/10/16	Report(All)	5
12/5/16	1/10/17	Power Supplies/Current Sensing routed for PCB (Bjorn)	35
1/15/17	4/10/17	Terrain Following (Bjorn)	85
12/5/16	1/1/17	Order Last Parts & Daughter-Board PCB (Bjorn & Serena)	26
12/5/16	1/10/17	Detector Output to ADC (Serena)	35
12/5/16	3/10/17	System-wide power/ground distribution (Jamie)	95
12/5/16	3/10/17	Mother-Board PCB (Jamie)	95
10/12/16	1/10/17	Flt Controller Interface/Micro Controller (Jamie)	88
12/5/16	3/10/17	Sampling ADC/Write ADC to EEPROM (Brad)	95
12/5/16	3/10/17	EEPROM Data to PC (Brad)	95
12/5/16	3/10/17	uController Code/State machine function (Brad)	95
3/10/17	4/10/17	Microcontroller Integration (Brad)	30
3/10/17	4/10/17	GUI/Search Algorithm (Brad)	30
3/10/17	4/10/17	Power Detection within 100' (Serena)	30
3/10/17	4/10/17	Efficient Search Algorithms (Serena)	30
3/10/17	4/10/17	Power Algorithms (Bjorn)	30
3/10/17	4/10/17	Host PC MavLink Support (Jamie)	30
3/10/17	4/10/17	Quad Mounting Pwr/Mechanicals (Jamie)	30
3/10/17	4/10/17	Aesthetics (wiring, hardware, paint, etc.) (Jamie)	30



Gantt Chart

Thank You

Questions?