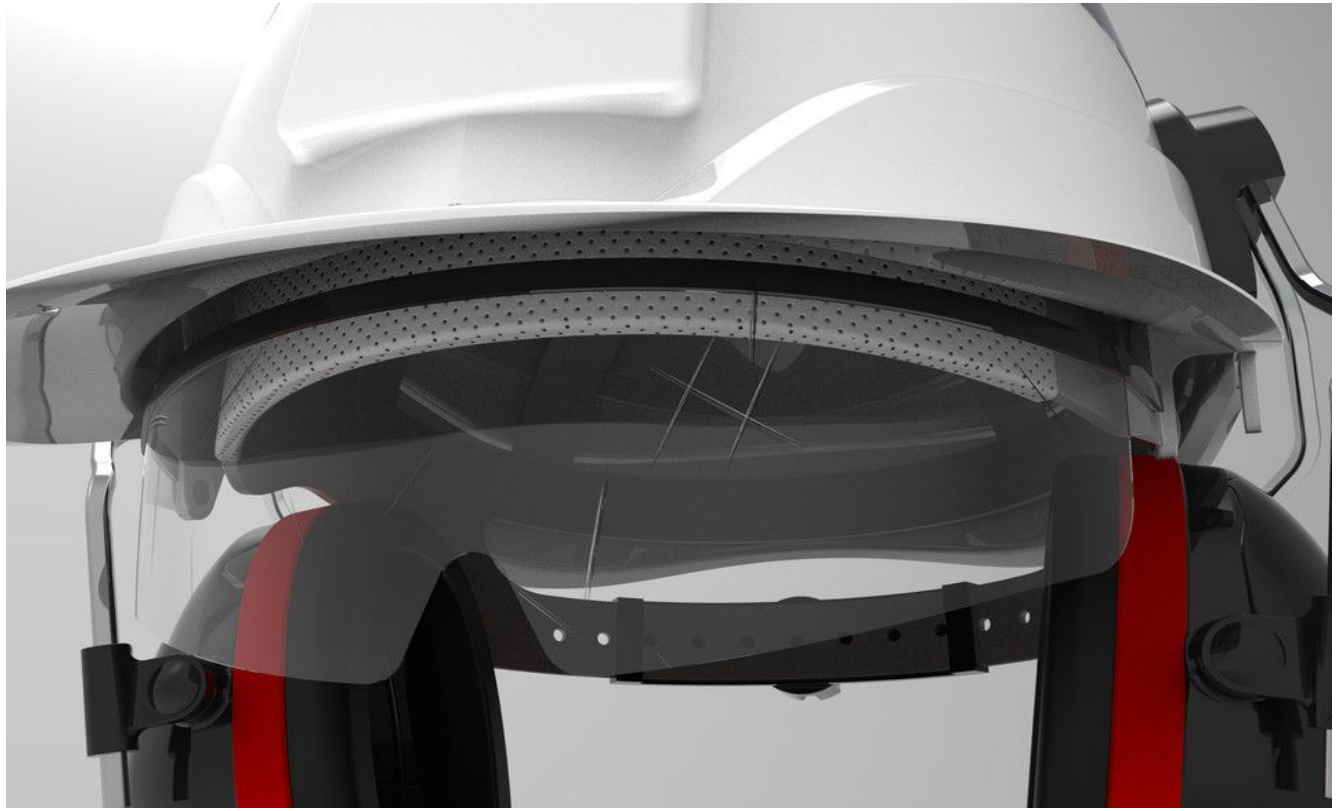
Search and Rescue Helmet for Enhanced Situational Awareness (SARHesa)

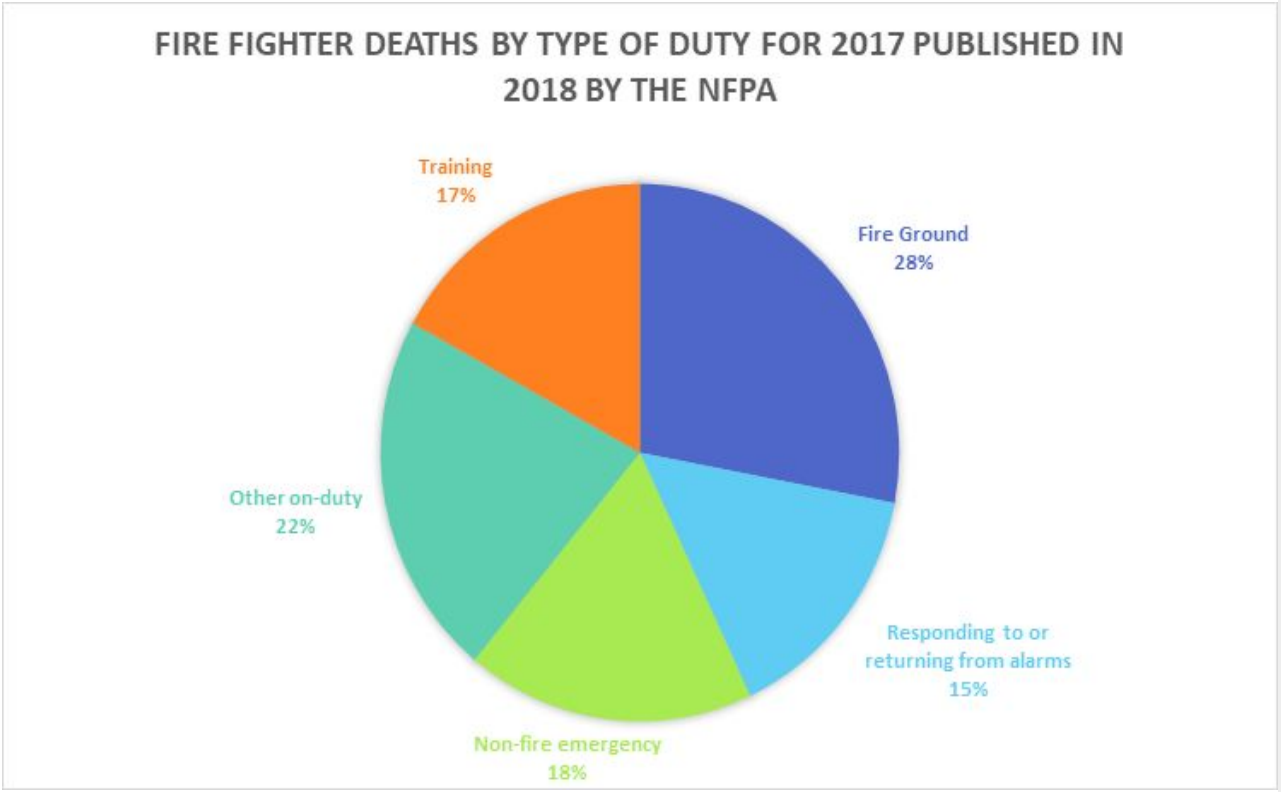


Group 21

Harriet Medrozo	EE	Stephen Hudson	EE
Jacob Anthony	EE	Shakira Cummings	CpE

Photo courtesy of: https://grabcad.com/library/safety-helmet-1

MOTIVATION



*Not endorsed by any organization.

https://www.nfpa.org/News-and-Research/Data-research-and-tools/Emergency-Responders/Firefighter-fatalities-in-the-United-State

An integrated solution that could save lives

GOALS AND OBJECTIVES

- Establish a localized location using GPS
- Send localized location to helmet user’s screen and communication module
- Transmit and receive voice using Communications module
- Navigate in the dark and display high near infrared (NIR) sources
- Run all operations with as little power as possible

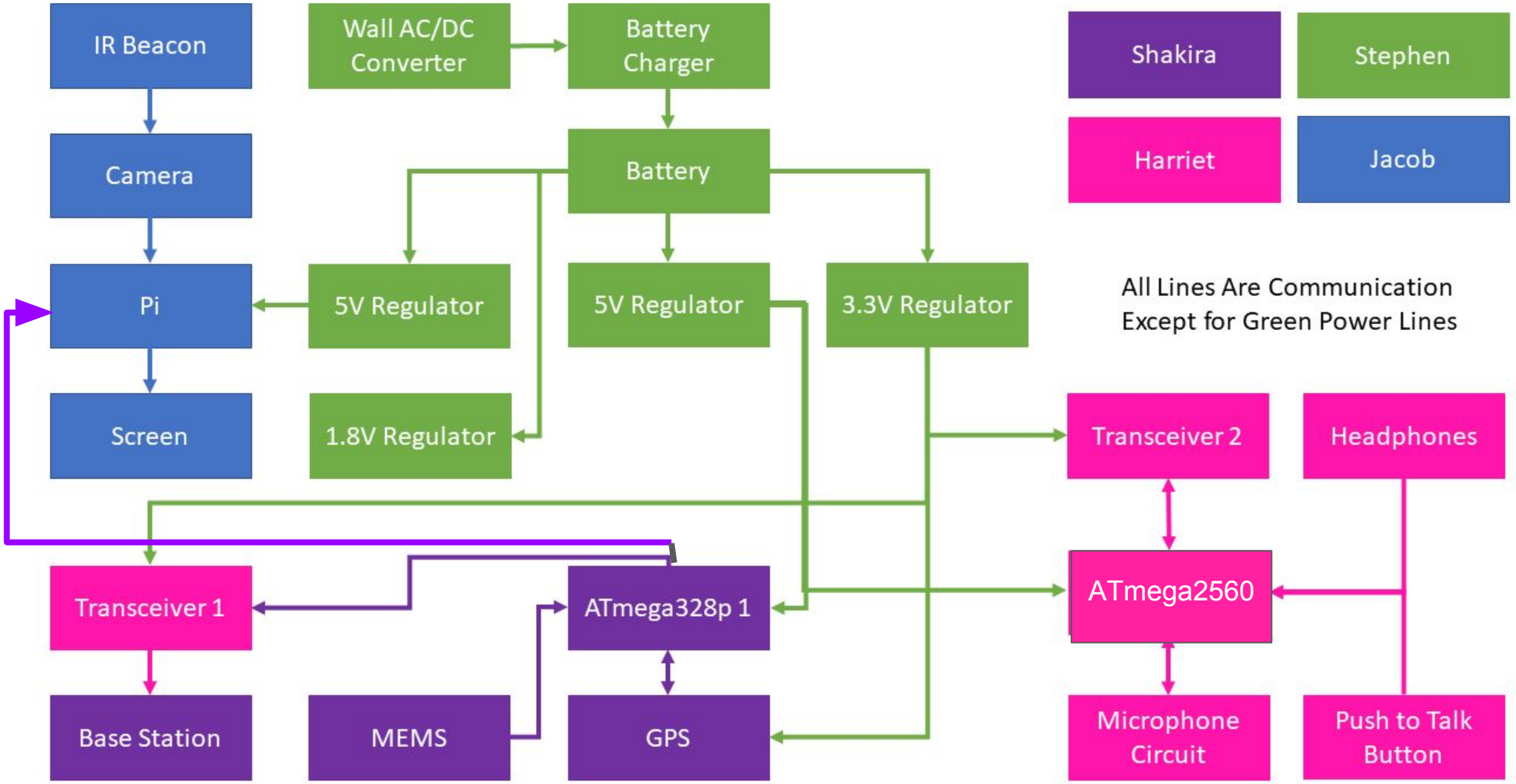
SPECIFICATIONS

Component	Parameters	Design Specification	Units
GPS	Accurate within	3	meters
Transceiver, RFM69HCW	Minimum Range	3	meters
Transceiver, nRF24L01+	Minimum Range	2	meters
NIR Camera	Minimum Range (NIR band)	5	meters
NIR Beacon detection	Minimum Range	10	meters
Batteries	Charge Time	4	hours
Batteries	Run Time	3.85	hours

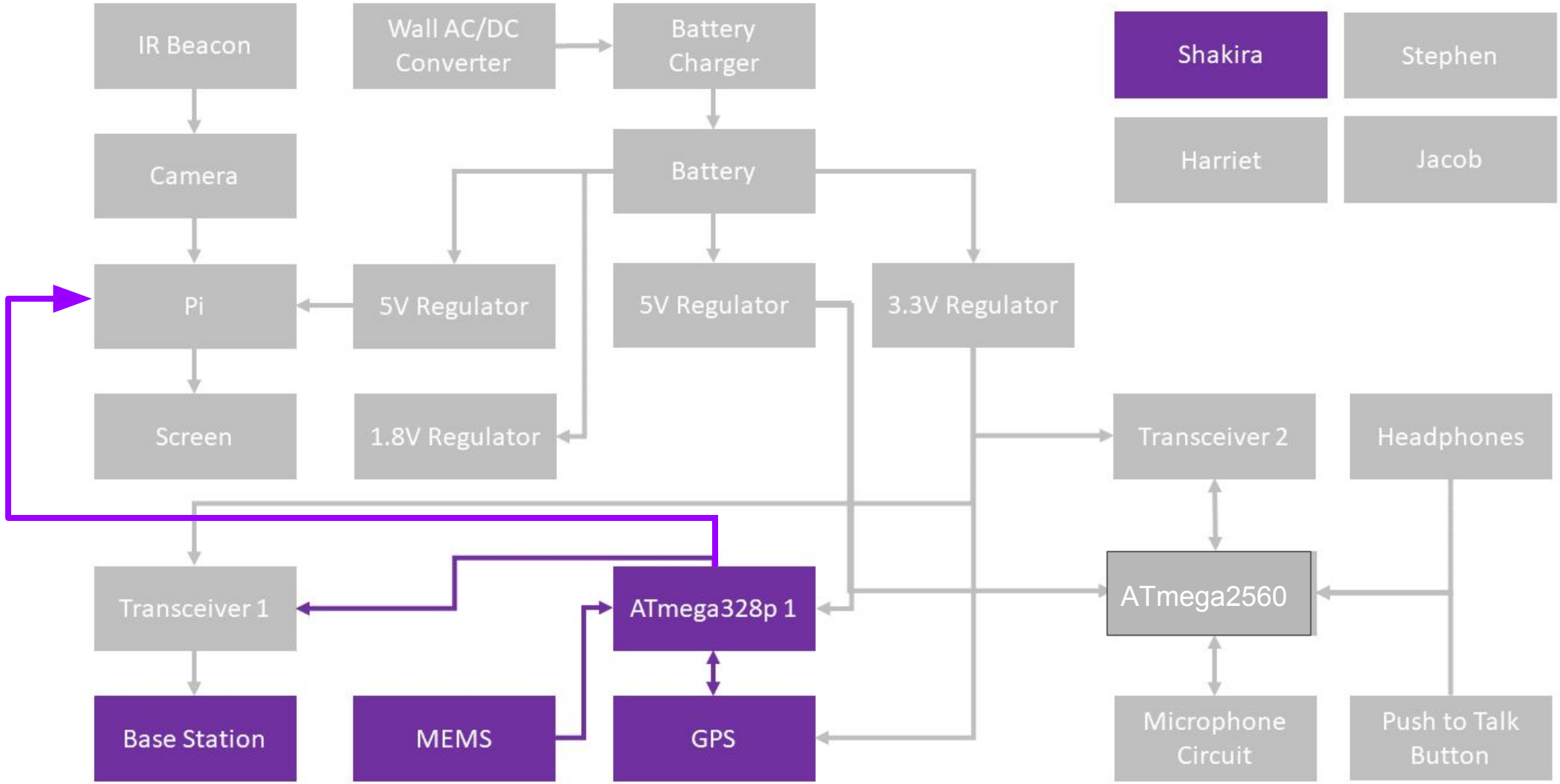
REALISTIC DESIGN CONSTRAINTS

- GPS needs time to warm up
- Signal attenuation caused by noise, environmental settings, and distance
- Operation of device between 32 to 113 °F
- Radio waves can interfere with RF circuit
- NIR can be reflected on many surfaces

OVERALL BLOCK DIAGRAM



LOCATION MODULE



Purpose: to track the helmet user using the Global Positioning System (GPS).

DIMENSIONS:
25 x 25 mm

PACKAGE:
surface mount device (SMD)

https://www.u-blox.com/en/product/neo-6-series

DIMENSIONS:
4.57 x 34.8 mm

PACKAGE:
Throw hole

https://www.quora.com/What-is-the-pin-names-mapping-from-Arduino-to-the-actual-AVR-pin-mapping-I-need-to-use-the-board-for-pure-AVR-programming-The-Arduino-board-uses-an-ATmega328P-PU-chip

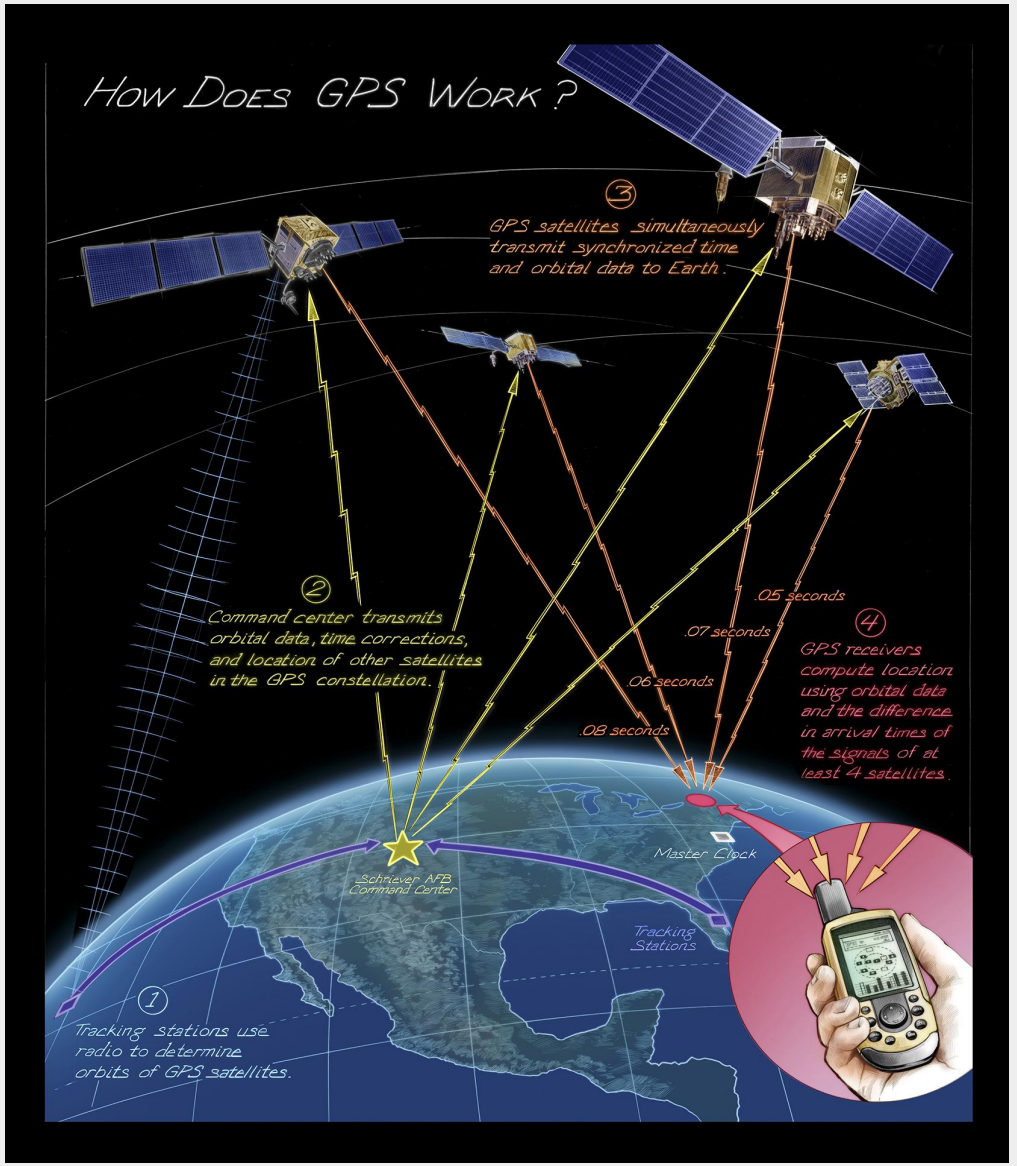


Photo courtesy of: timeandnavigation.si.edu

LOCATION

LOCATION TECHNOLOGIES

Technology	What it does	Range	Pros	Cons
GPS	Calculates position by finding distance from 30 satellites orbiting earth using trilateration.	unlimited	not expensive. Accessible. Unlimited range. Used in many applications: tracking cars, tracking sports players. low powered.	operates on large scale, which is better use for micro-level tracking. Need a good view of the sky.
BEACON	Short-range wireless technology. Transmitters that send out unique identifiers.	1m-100m	reduced power consumption. Good data speeds. Used in retail, bus stop information, smart houses	effective range can be compromised by physical objects and reflections blocking signal. Too many beacons = signal noise and reduced accuracy.

resource courtesy of: www.theregister.co.uk, blog.lighthouse.io

LOCATION TECHNOLOGIES

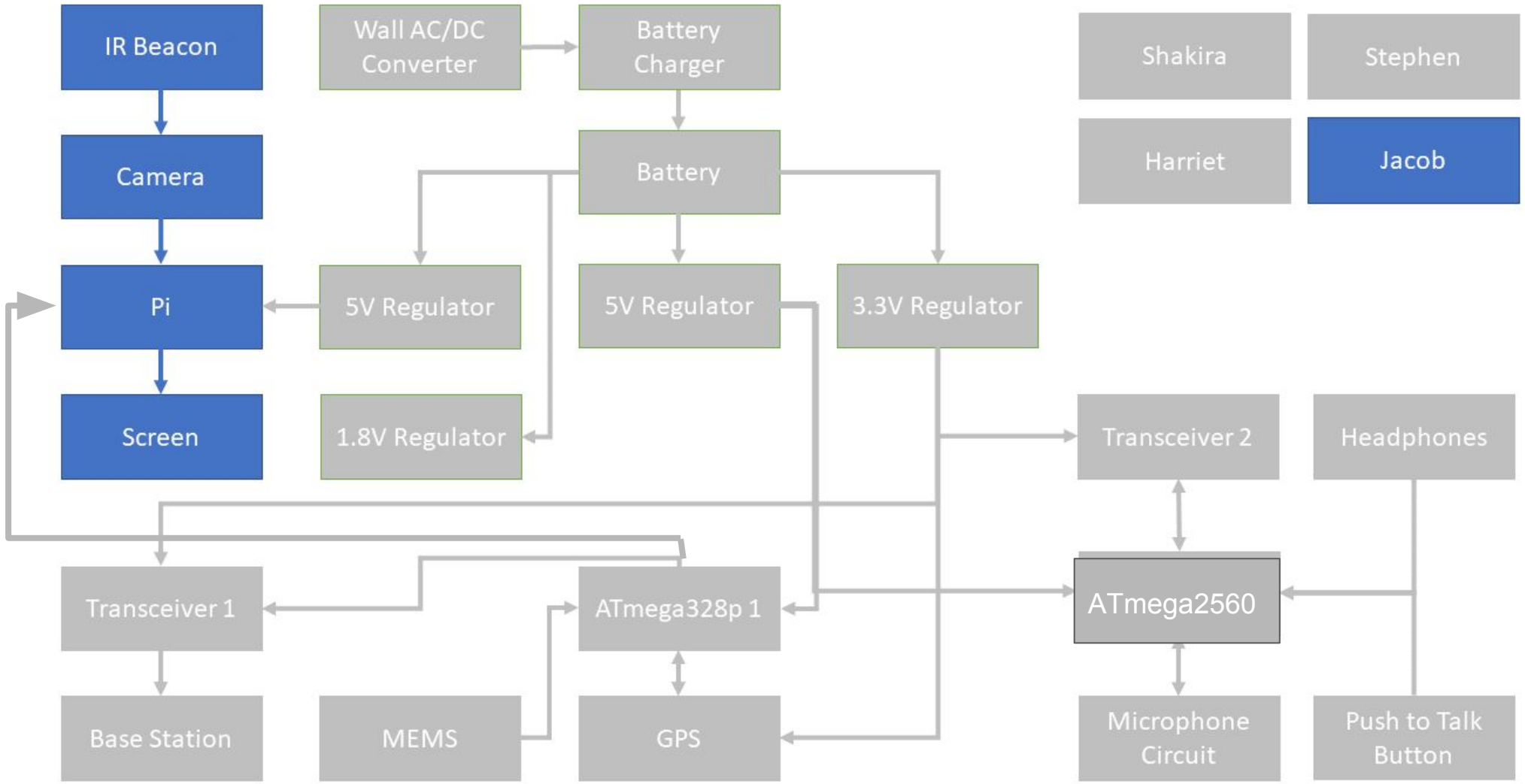
Technology	What it does	Range	Pros	Cons
RFID	Radio-frequency identifiers send out a signal that can be transmitted or read.	1cm-100m	Passive RFID good for inventory management, contactless payments, access control	Expensive, because of readers, not useful for hands-off operations for responders.
Wi-Fi	location-based tracking. Makes use of radio waves to transmit information across a network. Wireless adaptors create hotspots for access	20m-100m	to deliver personalized content to customers	Not secure. Not as accurate as RFID and beacons. Need to be in a remote location to access hotspot.
NFC	Near Field Communication. Close proximity communications chip technology. Tagging, key cards	10cm or less	Not very expensive. Secure. accurate, low powered	near range only for accuracy. Need distance for location module.

resource courtesy of: www.theregister.co.uk,, ccm.net, blog.lighthouse.io

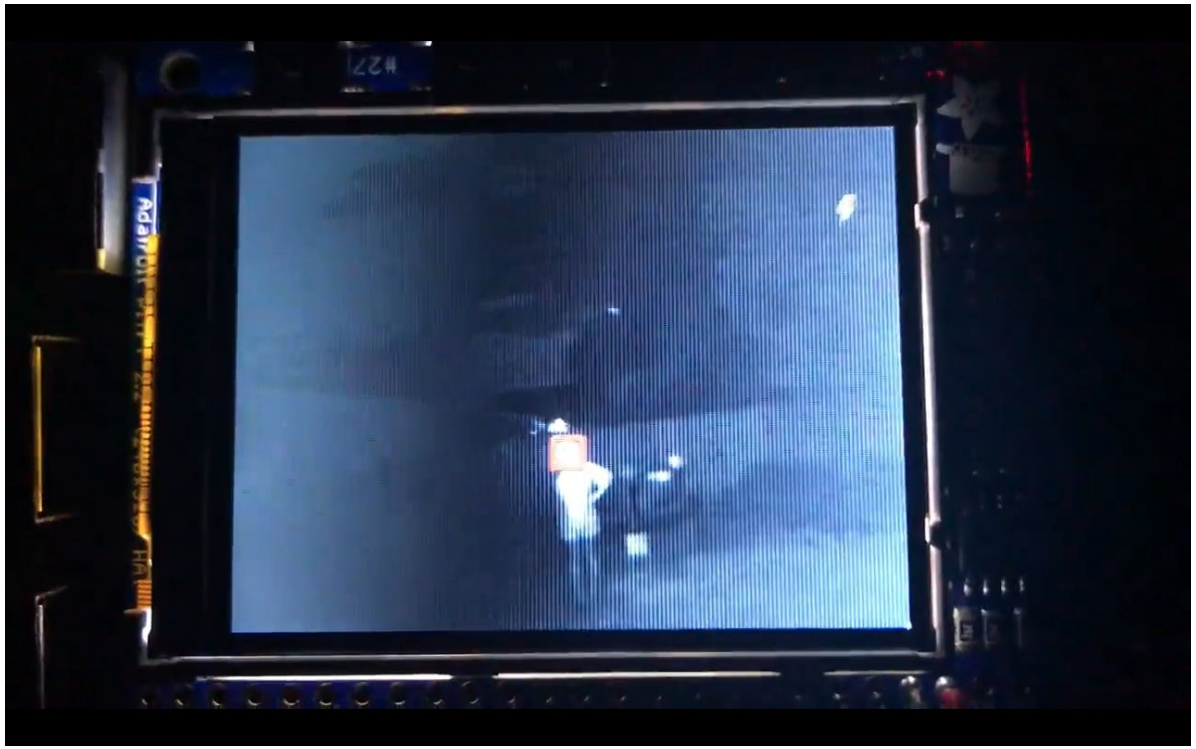
GPS

Properties	EM-506	GPS Module-Neo-6M	LS20031 5HZ
dimensions	30x30x10.7mm	25x25x4mm	N/A
cost	$39.95	$49.00	$69.95
hot start	1s	1s	less than 1s
cold start	35s with CGEE	27s	32 w/out AGPS less than 15 w/ AGPS
max amps consumption	44-55mA at 4.5V-6.5V	39mA at 3.0V	41mA at 3.1V
Tracking sensitivity	-163dbM	-161dbM	not on datasheet

VISION MODULE



Purpose: to show the location of the user, to show a video feed in NIR instead of regular visible light.



VISION

CAMERA TECHNOLOGIES

Technology	How it works	Pros	Cons
Low Light	Amplifies incoming visible light	Works very well outside	Dependent on external lighting, often needs extended exposure
Near IR cameras often called Infrared	Detects infrared waves, just outside visible light	Cheaper than Thermal cameras and is not ITAR controlled	Often has to self illuminate with a Near IR light
Thermal also often called Infrared	Detects thermal radiation	Does not use any illumination	ITAR controlled and very expensive with limited resolution

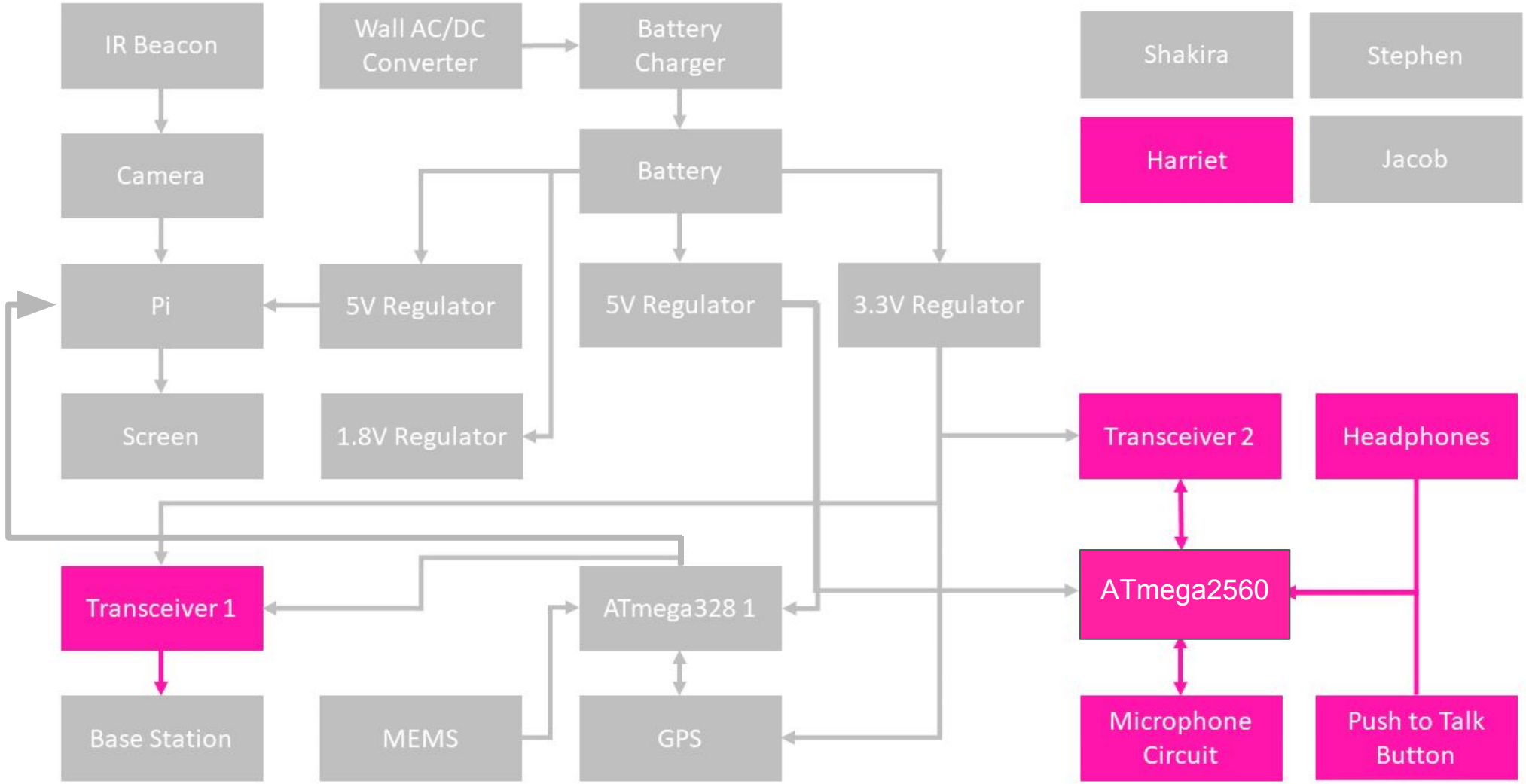
CAMERA

Camera	Company	Technology	Frame Rate	Resolution	Cost
Boson	FLIR	Thermal	30 or 60	640x512 or 320x256	$1800
Lepton	FLIR	Thermal	8.7	160x120	$200
USB IR Camera	ELP	NIR	10-30	160x120 - 1280x720	$40

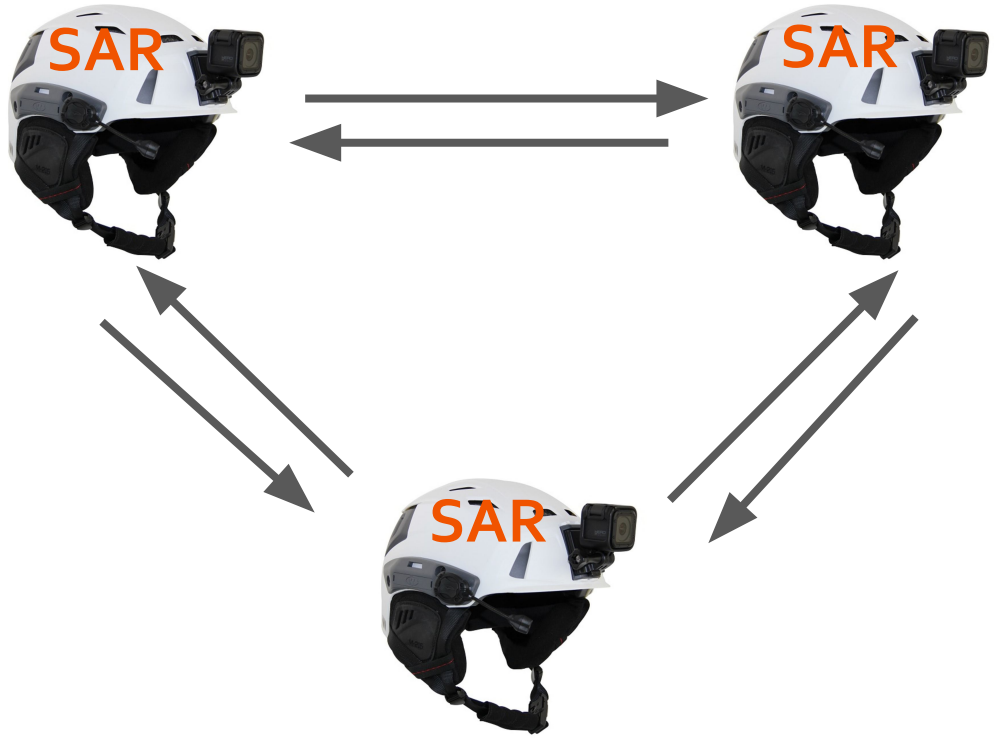
PROCESSOR

PROCESSOR	PACKAGE	COST
STMf469	LQFP / BGA	$12.64-17.21
PIC32MZ	BGA	$11.48-21.15
TI Davinci	NFBGA	$54.08
Raspberry Pi	Complete Board	$35

COMMUNICATIONS MODULE

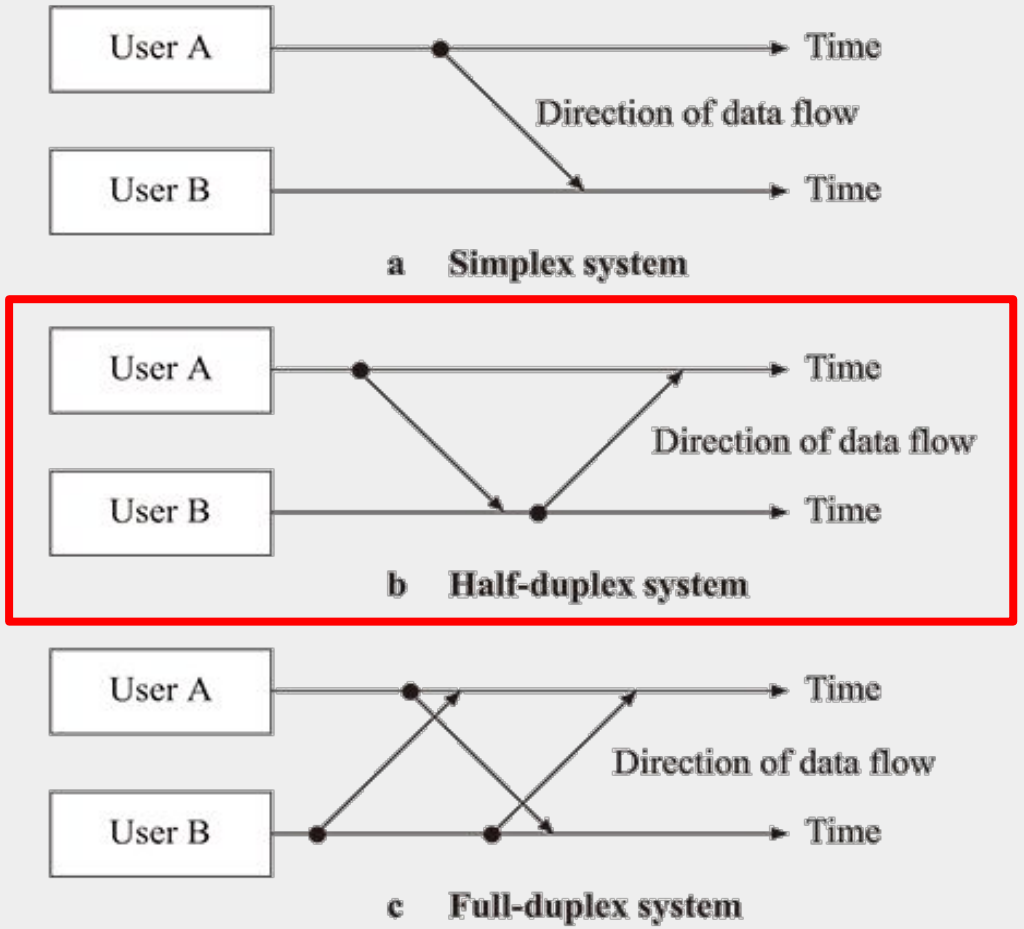


Purpose: provide clear, reliable voice and GPS data communications between users.



WALKIE-TALKIE WITH LOCATION CAPABILITIES

3 Types of Channels for Voice Transmission



COMMUNICATIONS

TRANSCEIVERS

PART NAME	OPERATING FREQUENCY	OPERATING VOLTAGE	MAX OUTPUT POWER	POWER CONSUMPTION	RECEIVER SENSITIVITY	DATA RATE
CC1352P	sub-1 GHz, 2.4 GHz	1.8V-3.8V	+20 dBm for 863-930 MHz, +5 dBm for 2.4GHz	sub-1 Rx - 5.8mA sub-1 Tx - 14.3mA 2.4 Tx - 8.2mA	-122 dBm	4Mbps
nRF24L01	2.4 GHz	1.9V-3.6V	+4 dBm	Rx- 12.3mA Tx-11.3mA	-85 dBm	250 kbps-2Mbps
RFM69HCW	sub-1 GHz	1.8V-3.6V	+20 dBm	Rx- 16mA Tx- 20mA	-120 dBm	300 kbps

Why Two Transceivers?

- FCC REGULATION: 2.4 GHz available for short range voice communications
- FCC REGULATION: Sub-1 GHz good for passive data transmission
- MISSION CRITICAL SYSTEM: dedicated channels to prevent system crippling and signal mixing

Purpose: transmit and receive voice at 2.4 GHz

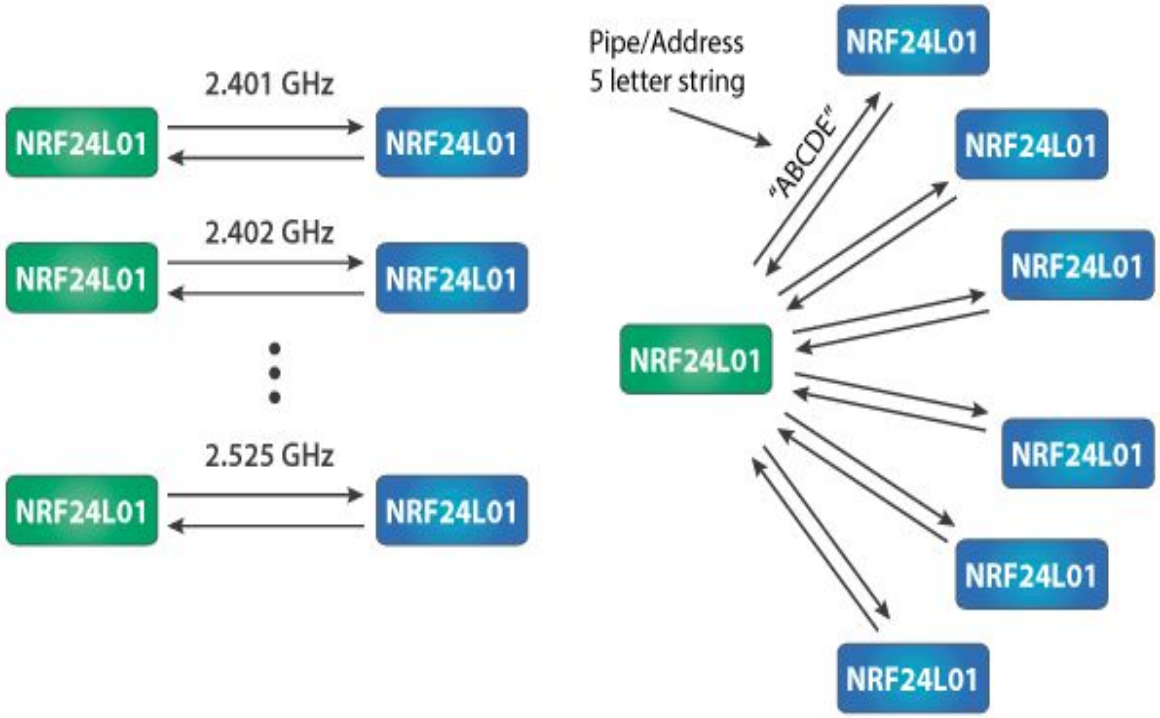
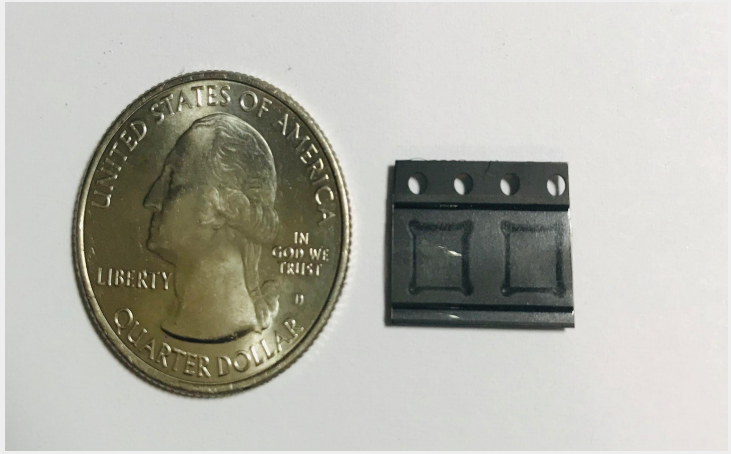


Photo courtesy of: howtomechatronics.com



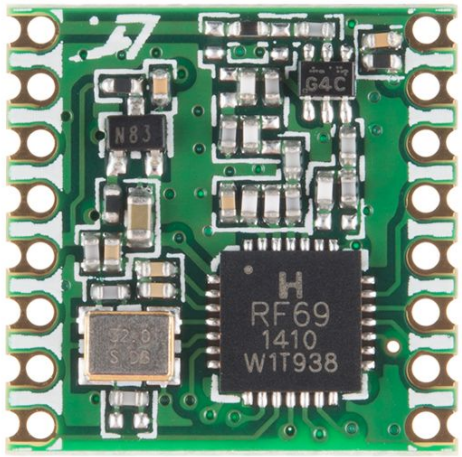
DIMENSIONS: 4 x 4mm

- Price - $3.50 each
- 16 channel, 10-bit ADC
- Low power consumption
- Gaussian Frequency Shift Key modulation

nRF24L01+

Purpose: transmit and receive data at sub-1 GHz (915 MHz)

- Price - $5.95 each
- Excellent receiver sensitivity
- Low power consumption
- Frequency Shift Key modulation



DIMENSIONS:
16 x 16 mm

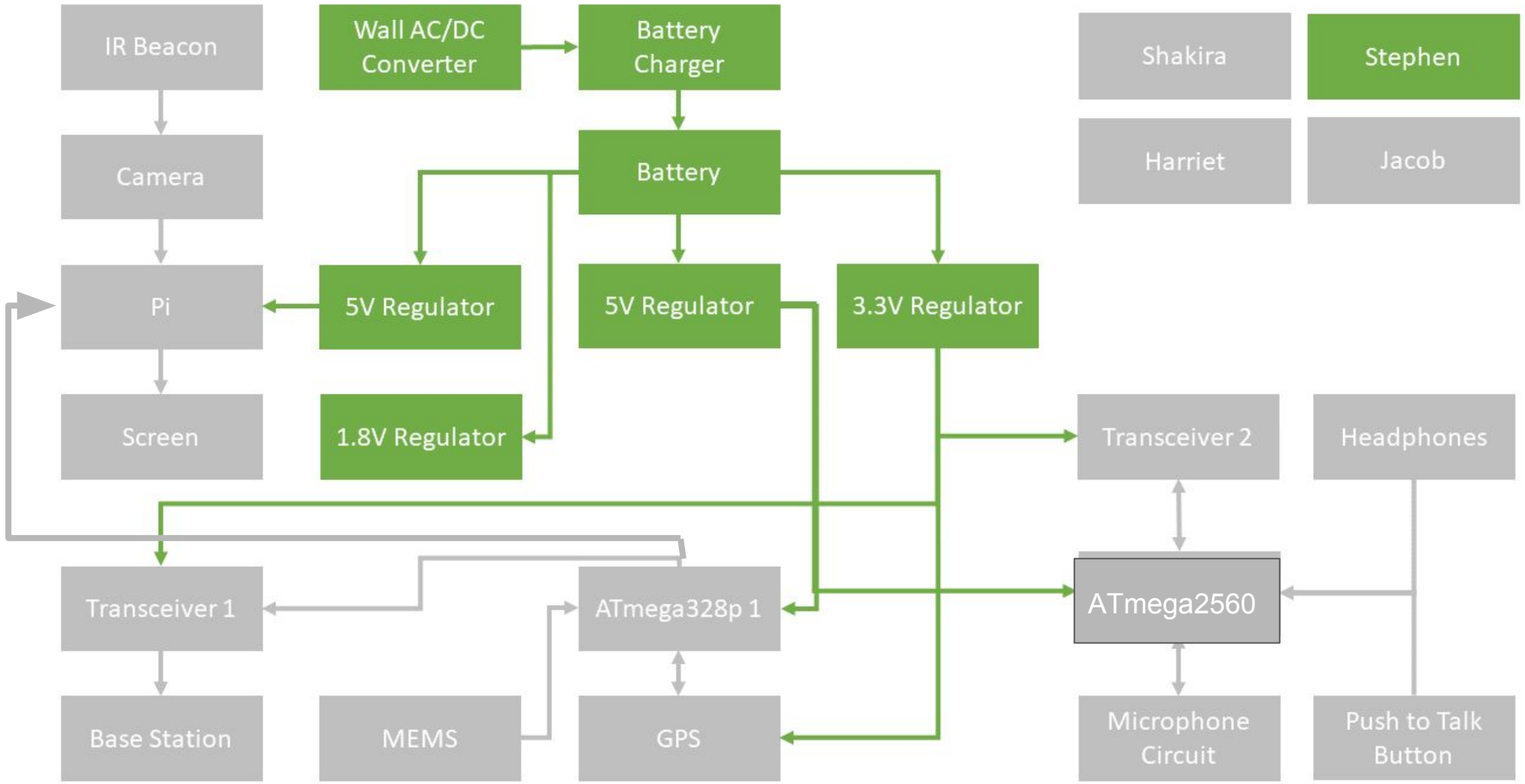
PACKAGE: surface mount device (SMD)

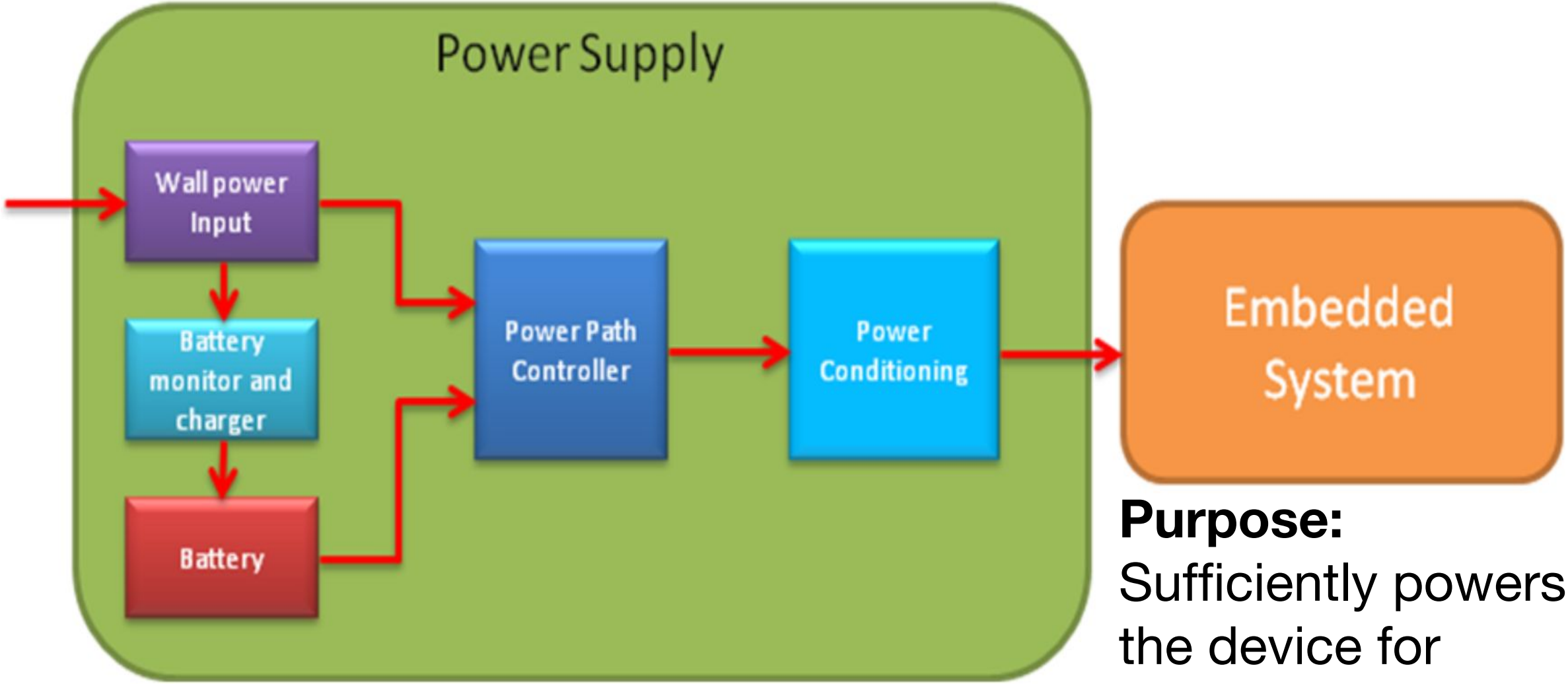
RFM69HCW

PROCESSOR FOR COMMUNICATIONS AND LOCATION MODULES

PART NAME	POWER CONSUMPTION	THROUGHPUT	MEMORY SIZE	SUPPORTED PROTOCOL	SRAM	CLOCK SPEED
ARM CORTEX M4F, M0	2.82 mA at 48 MHz	1.25 DMIPS per MHz, at 48 MHz operation	323-KB Flash, 80-KB RAM	(2) UART, (2) SSI, (1) I2C, (1) I2S	(5) 16-KB blocks, 8-KB cache, 4-KB SRAM for sensor control engineer	48 MHz
ATmega328P	0.3 mA at 1 MHz	20 MIPS at 20 MHz	32-KB Flash, 2-KB RAM	(1) UART, (2) SPI, (1) I2C	1-KB EEPROM, 2-KB	20 MHz
ATmega2560	0.5 mA at 1 MHz	16 MIPS at 16 MHz	16/32/64KB Flash	(4) USART (1) SPI	4-KB EEPROM 8-KB SRAM	16 MHz

POWER MODULE





Type:
Switch mode power supply

Purpose:
Sufficiently powers the device for sustained periods of time.

POWER

Photo courtesy of http://www.embien.com/blog/embedded-system-design-power-supply-design/

BATTERY MANAGERS

PART NAME	INPUT SUPPLY VOLTAGE RANGE	PROGRAMMABLE CHARGE CURRENT RANGE	CHARGE VOLTAGE ACCURACY	TRICKLE CHARGE CURRENT	EXTERNAL COMPONENTS	ANALOG PROGRAMMABLE
TP4056	4-8V	130-1000mA	1.5%	120-140mA	10	Yes
LT1512	2.7-25V	1000mA	1%	-	13	No **
BQ25606	3.9-13.5V	1000-2500mA	0.5%	-	14	Yes

- Input supply voltage: **5V**
- Desired charging current range: **1000-2600mA**
- Acceptable charge voltage accuracy: **0.5-1.5%**

**programmed with a PWM signal from a processor

Battery Charger: BQ25606

MANUFACTURER	NANJING TOP POWER ASIC CORP.
Part No.	BQ25606REGR
Price	$2.68
Current Required	3mA
Program Charge Current	1000mA
accuracy within	0.5%

DIMENSIONS:
4 x 4 mm

Photo courtesy of: https://www.amazon.com/dp/B071RG4YWM/ref=nav_timeline_asin?_encoding=UTF8&psc=1

Lithium Ion or Nickel-Metal Hydride?

LITHIUM ION

- Higher energy density
- Rechargeable cycle is 4 times faster than NiMH
- Higher self discharge rate
- Smaller and lighter
- More resistant to varying temperatures

NICKEL METAL HYDRIDE

- Found anywhere

Photo courtesy of: https://www.sensorsmag.com/components/demand-for-lithium-ion-batteries-outpacing-supply and https://shop.telegraph.co.uk/buy/miscellaneous/duracell-batteries/80/no/86541

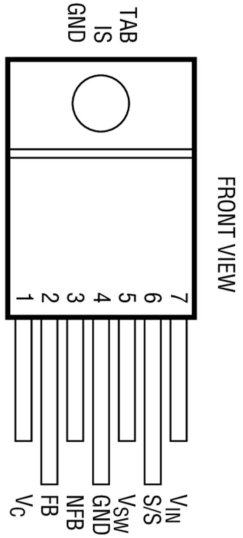
Lithium Ion 18650 3.7 Volt

REGULATORS

PART NAME	OPERATING SUPPLY CURRENT	SUPPLY VOLTAGE RANGE	OUTPUT VOLTAGE	IOUT RANGE	EXTERNAL COMPONENTS	SWITCHING FREQUENCY
LT1108	.11mA	2-12V	Adjustable	.8A	5	19kHz
LT1371	4mA	2.7-25V	Adjustable	3A	8	500 kHz
TCR2EF	22mA	1.5-5.5V	Not Adjustable	35uA	2	**
LT1111	.3mA	2-12V	Adjustable	.8A	4	72kHz
MIC4685	5mA	4-30V	Adjustable	3A	7	200kHz

- Needed low input voltage
- Needed high output current

Regulator: LT 1371

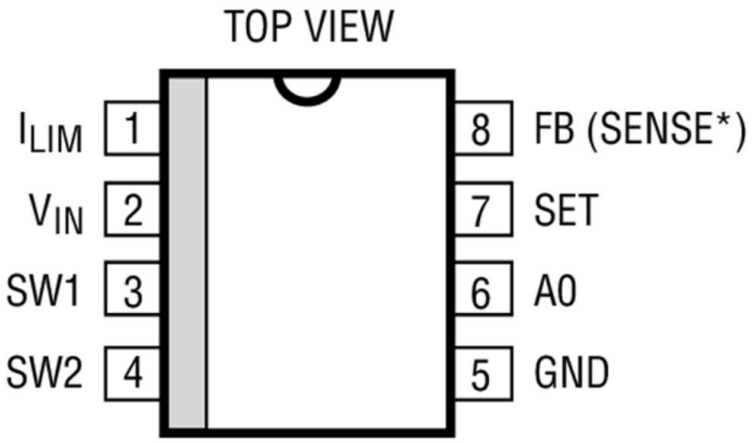


DIMENSIONS:
16 x 10 mm

PACKAGE: 7-DD

Manufacturer	Analog Devices/ Linear Technology
Part No.	LT1371CR#PBF
Price	$10.14
Voltage supplied	5V

Regulator: LT 1108



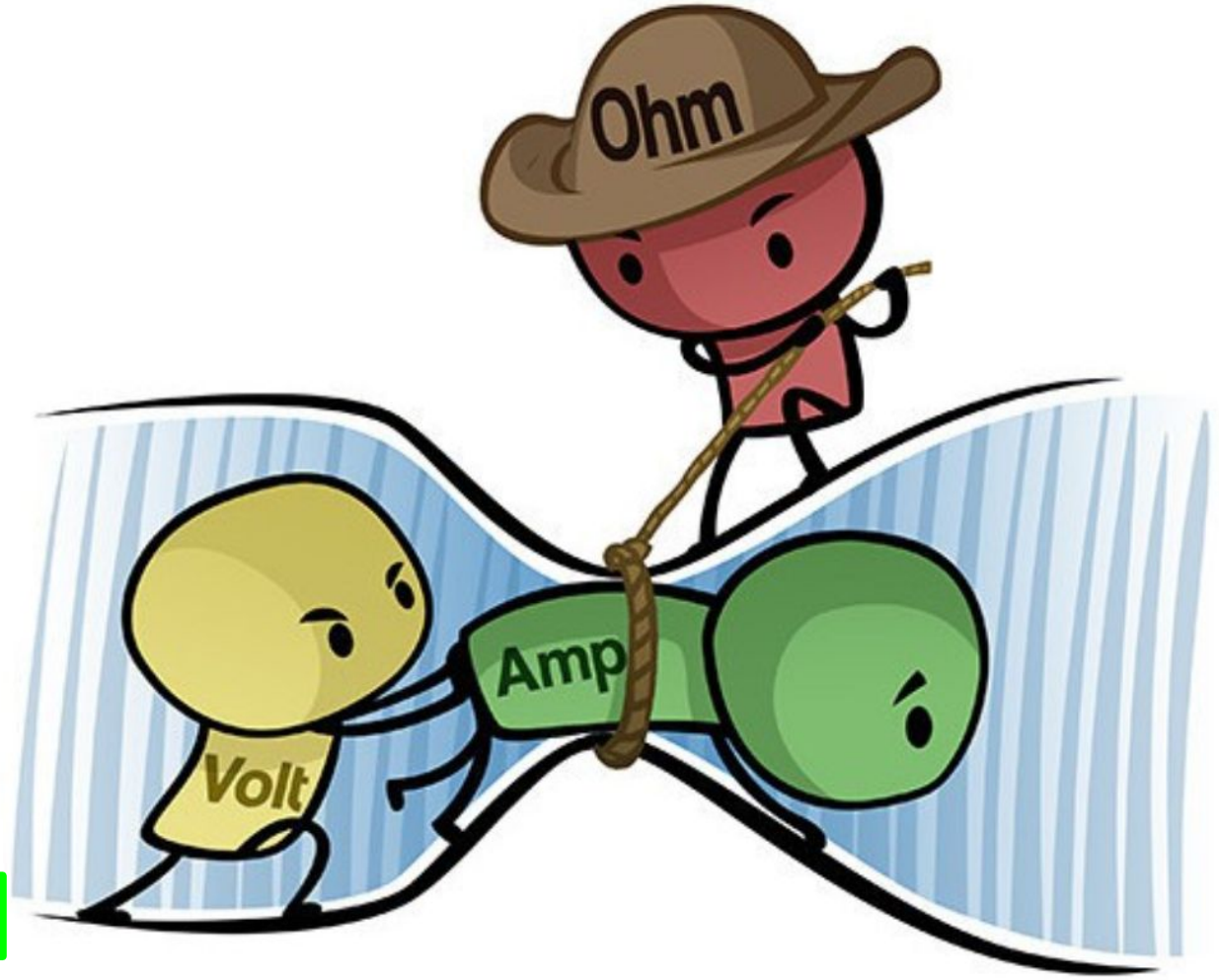
DIMENSIONS:
4 x 5 mm

PACKAGE:
8-SOIC

Manufacturer	Analog Devices/ Linear Technology
Part No.	LT1108CS8#PBF
Price	$5.26
Voltage supplied	1.8V & 3.3V

Power Draw per Component

Device	Current in
RFM69HCW Transceiver	130mA
nRM24l01 Transceiver	12.3mA
Neo-6M	39mA
ATmega328p x 2	0.6mA
Raspberry Pi	2500mA*
MEMS GPS	3.11mA
TOTAL CURRENT	2684.71mA

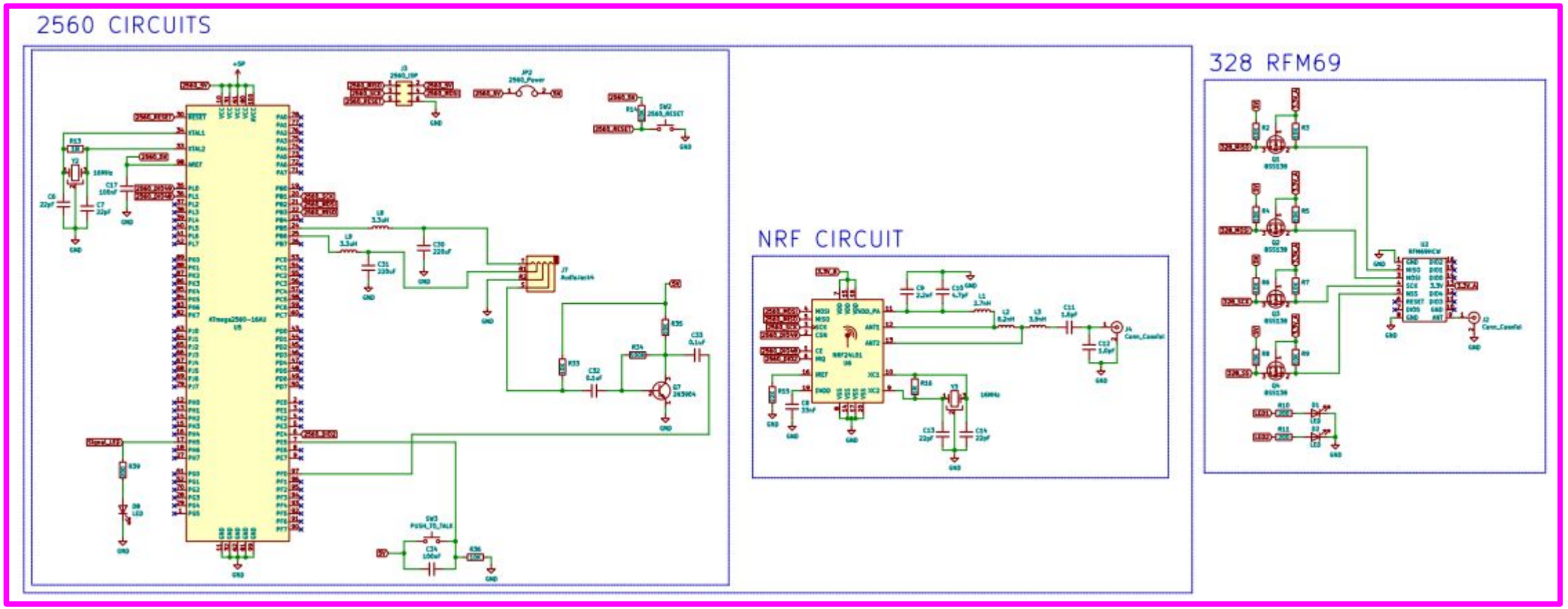


$$\frac{10400}{2684.71} = 3866 \approx 3.8\ hours\ of\ runtime$$

Photo courtesy of: http://voltamperetomeiga.blogspot.com/2017/08/volt-ampere-ohm-cartoon.html

Anticipated current draw is from 1000-1000mA

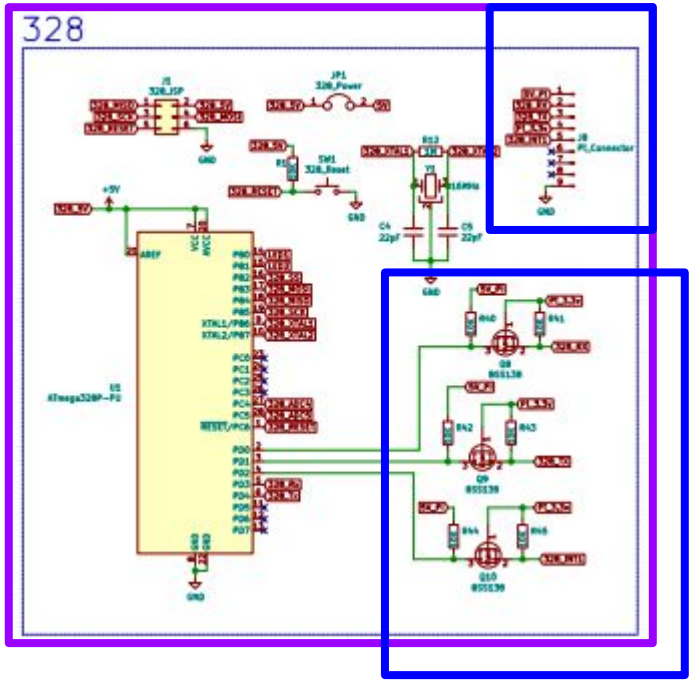
MAIN PCB SCHEMATIC

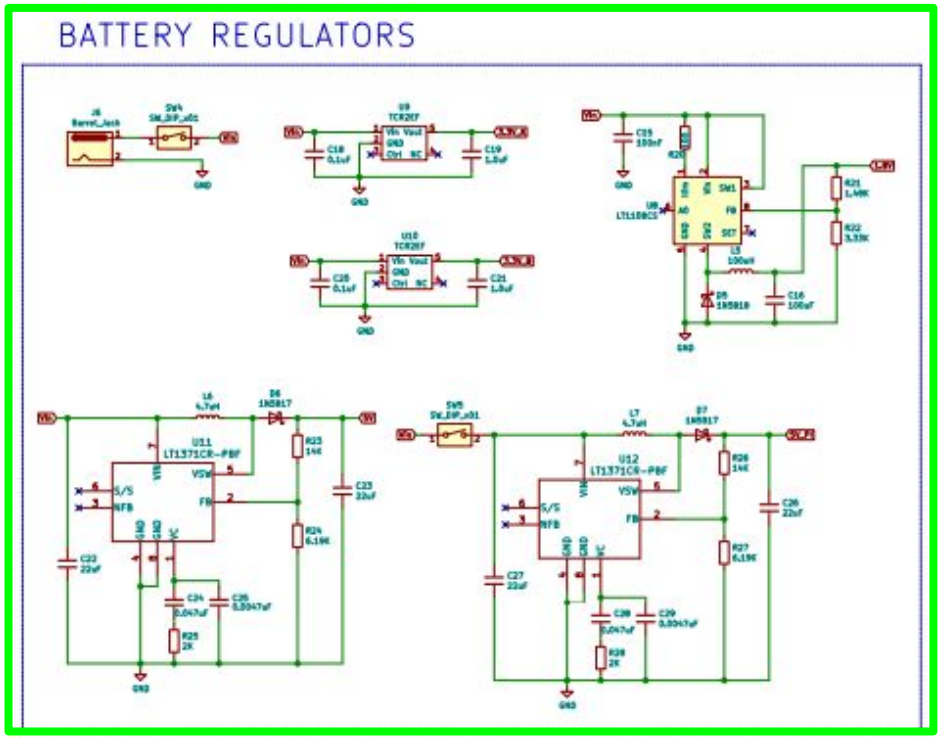


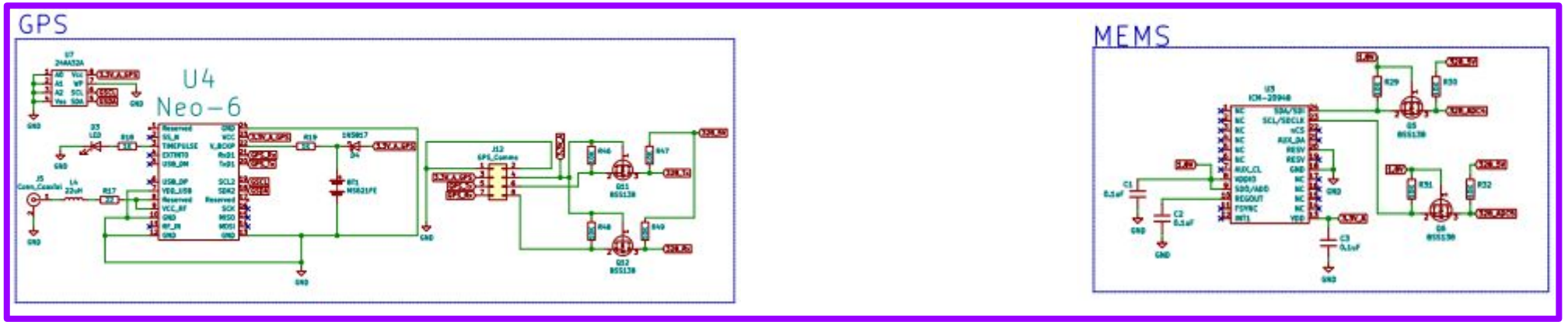
Major Components and circuits:

- Location Module
- Vision Module
- Communications Module
- Power Module

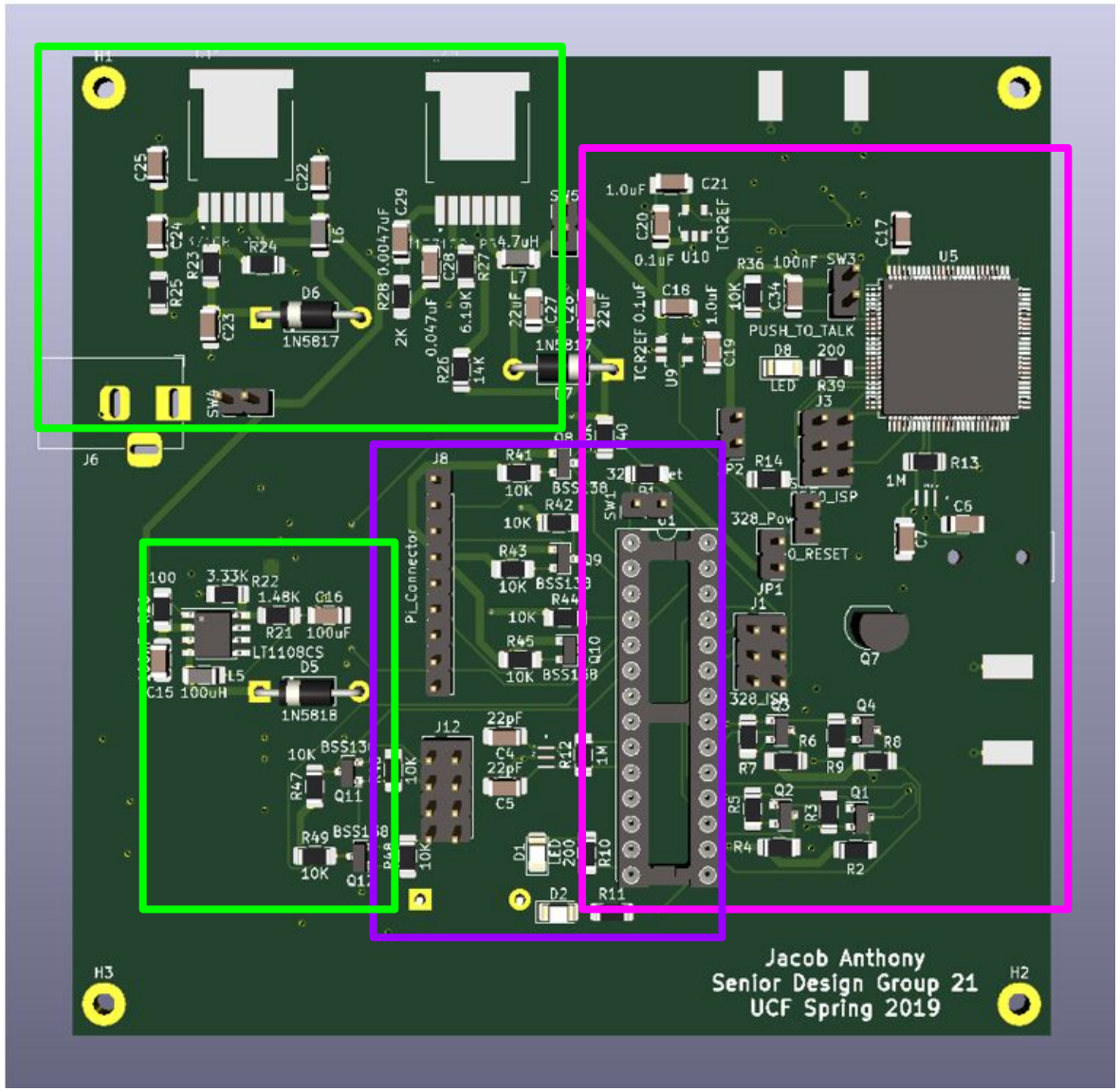
MAIN PCB SCHEMATIC CONTINUED

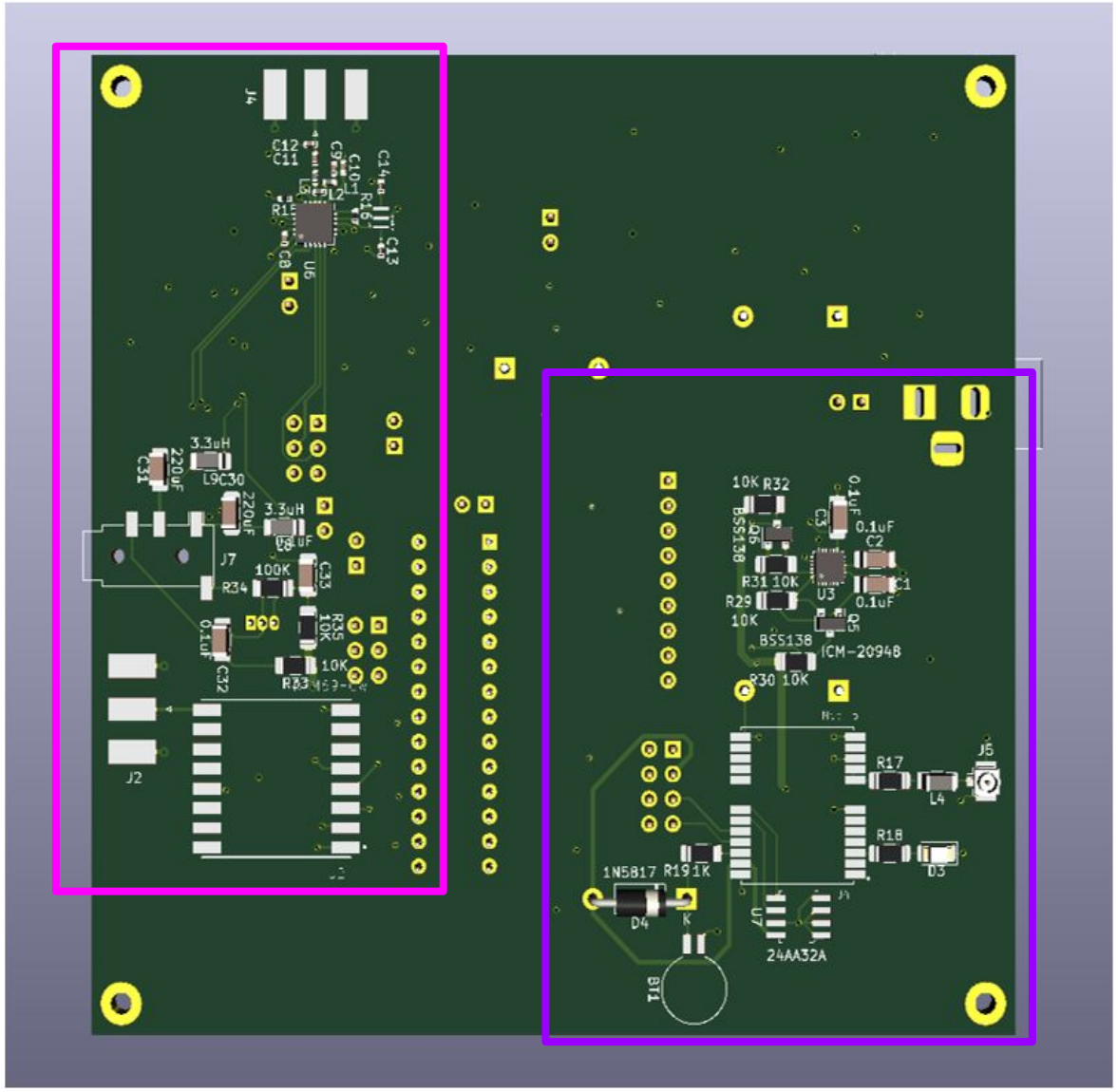




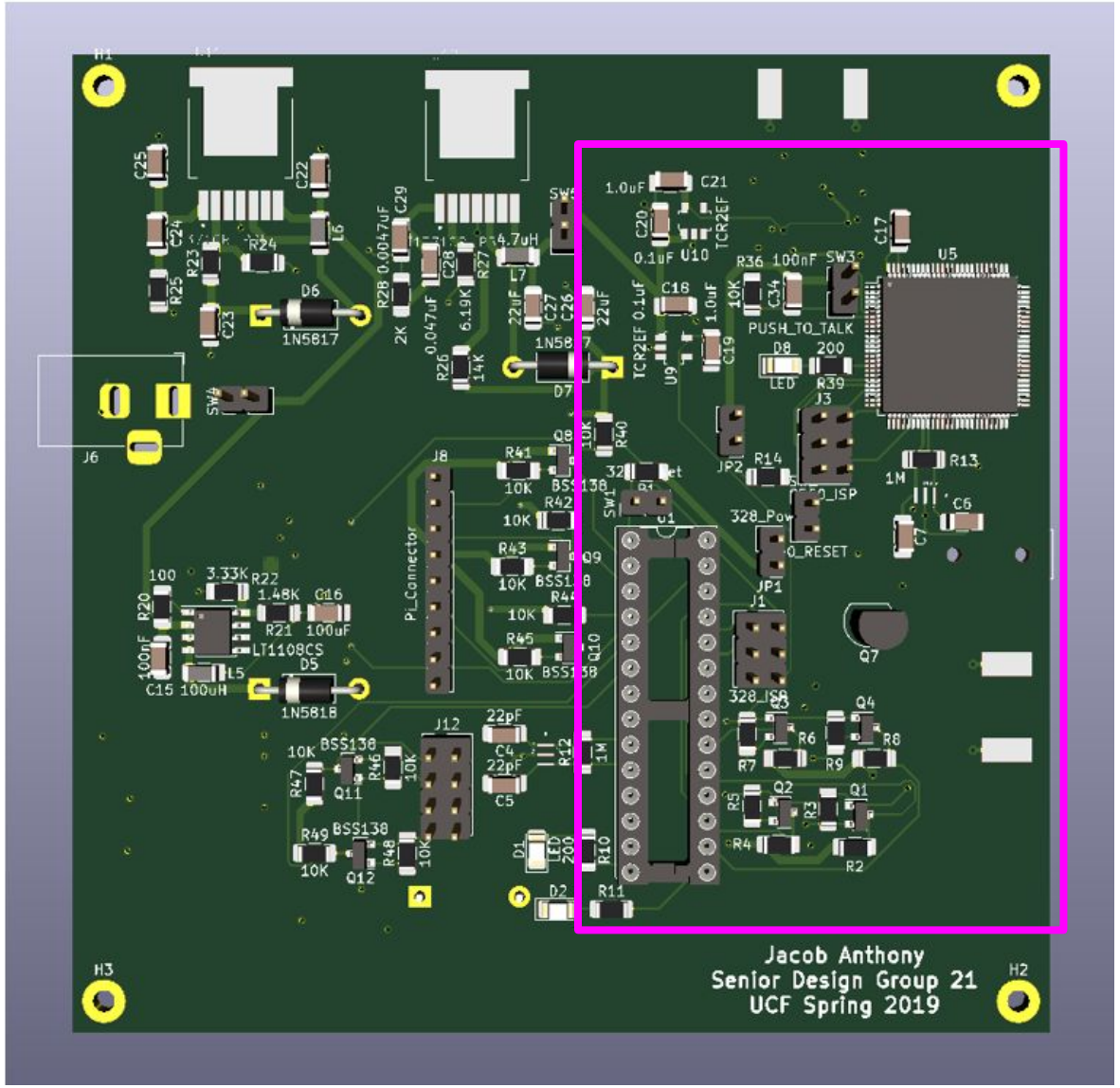


MAIN PCB LAYOUT



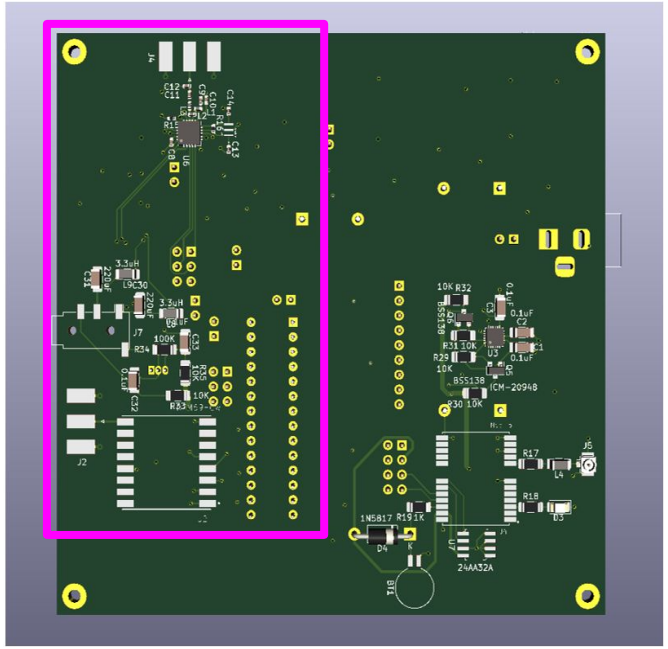


MAIN BOARD CONSIDERATIONS

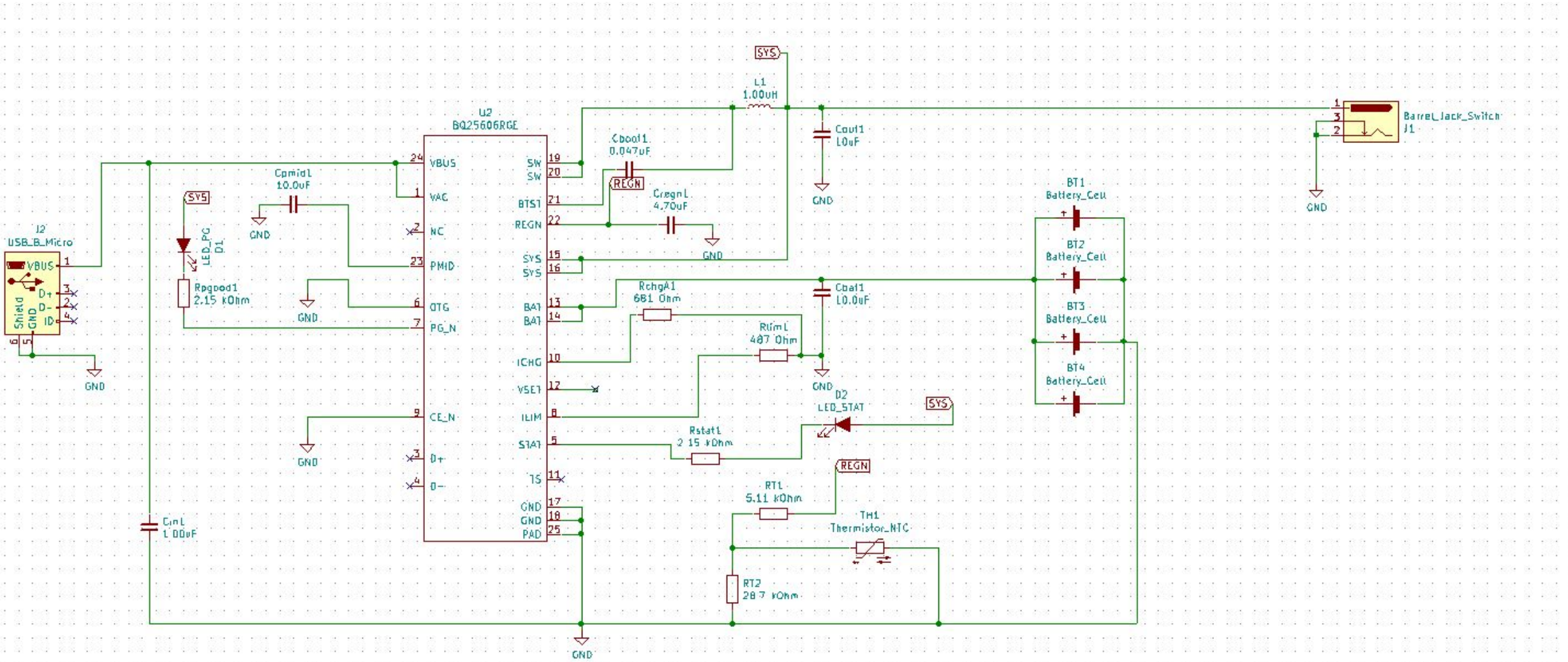


COMMUNICATIONS MODULE

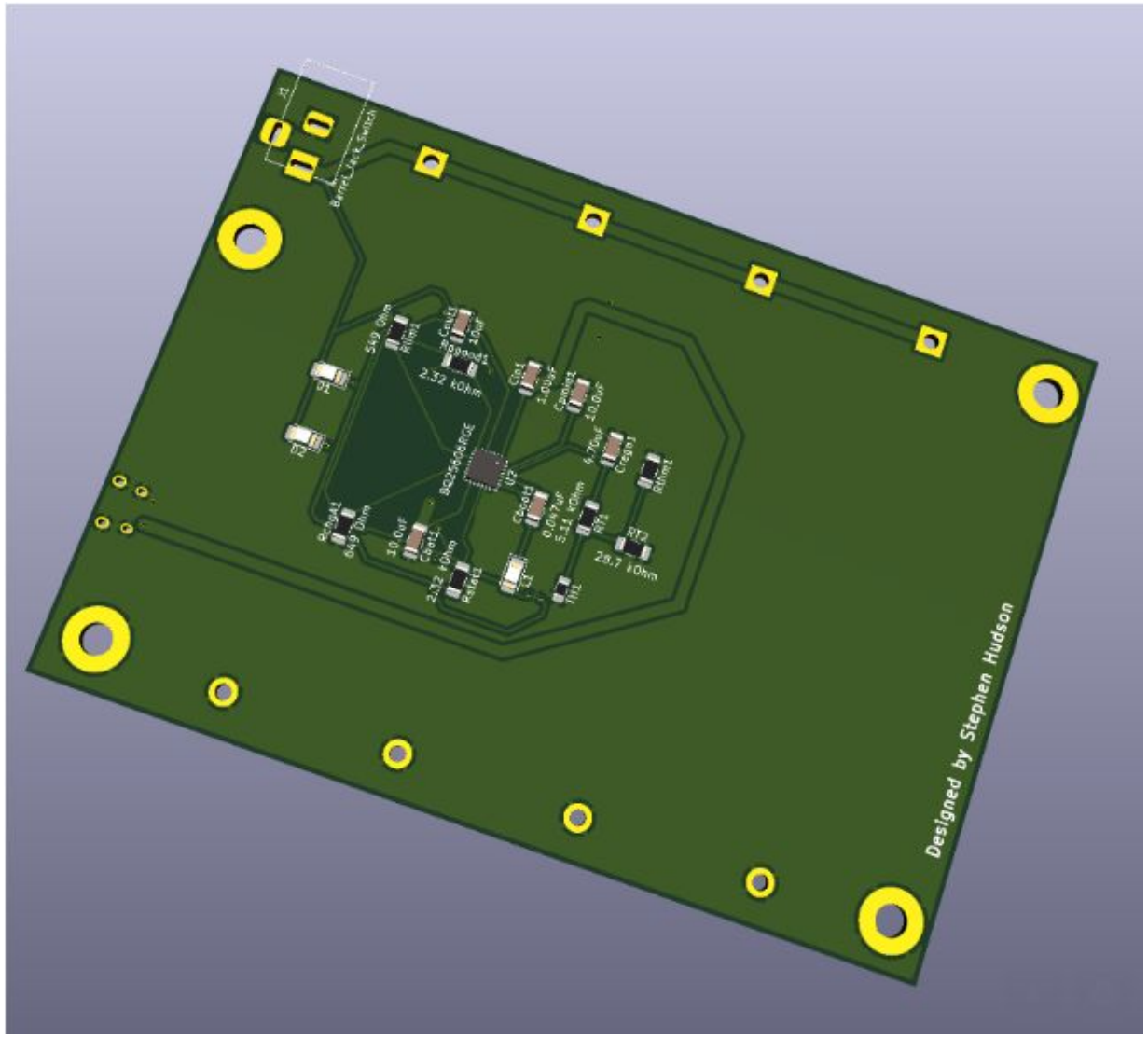
- Insulative Ground Plane
- 50Ω transmission line to antenna for max power transfer
- Separate radio placement
- Short Trace distance

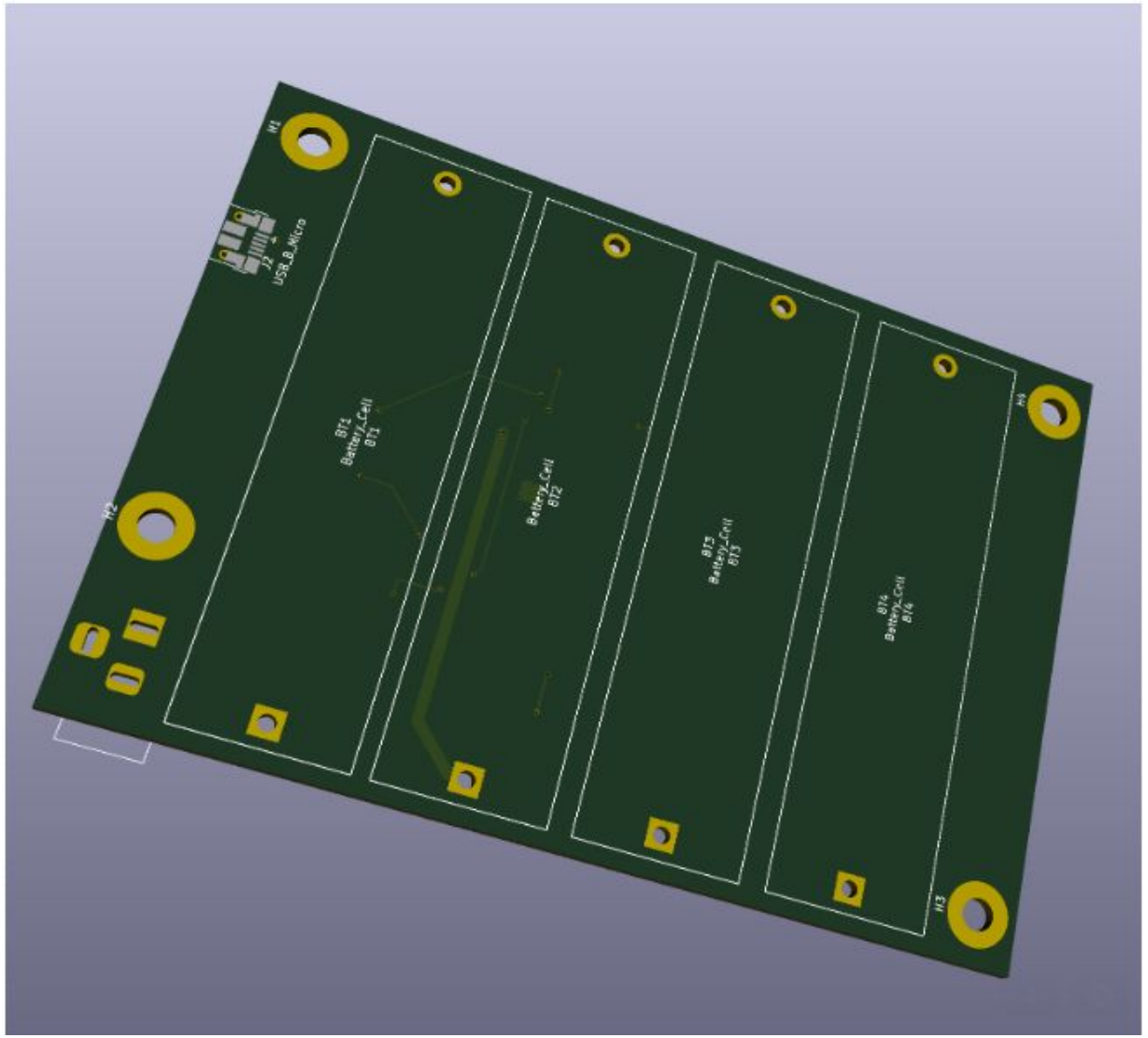


POWER PCB SCHEMATIC

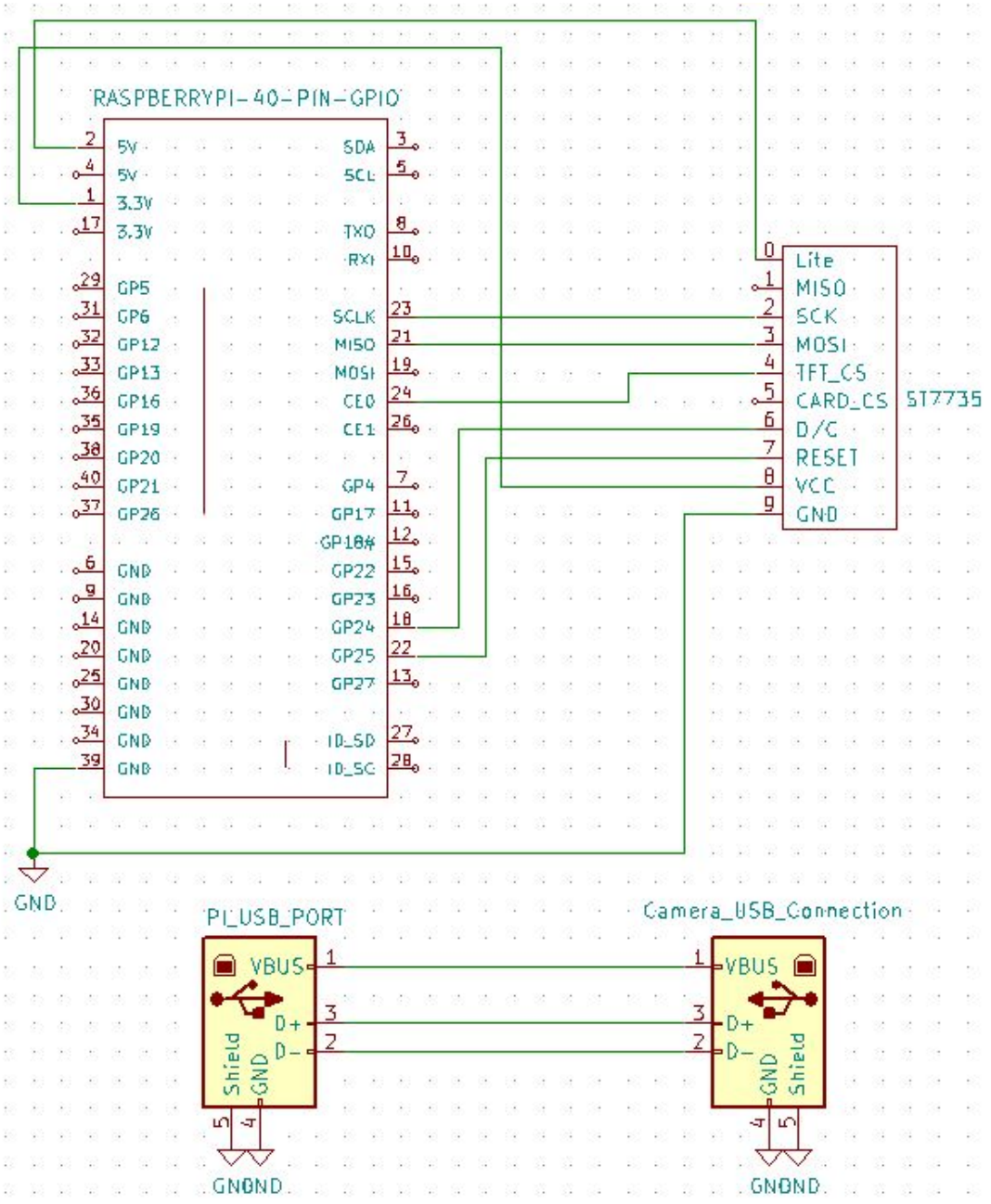


POWER PCB LAYOUT





VISION SCHEMATIC



SOFTWARE TOOLS FOR ATmega CHIPS

- ATmega chips run on C++
- Arduino IDE is native. There are other IDE's but they are modified versions of the Arduino IDE
- Open Source Arduino Libraries are readily available
- National Marine Electronics Association(NMEA) Regulates GPS communications and GPS data formats

OPERATING SYSTEMS

OS	PROS	CONS
Raspbian	Native OS for Raspberry Pi	Bloated with extra software
Arch Linux	Less extra programs than Raspbian	Not as optimized as Raspbian
Windows	Easiest to use	Slowest and least optimized

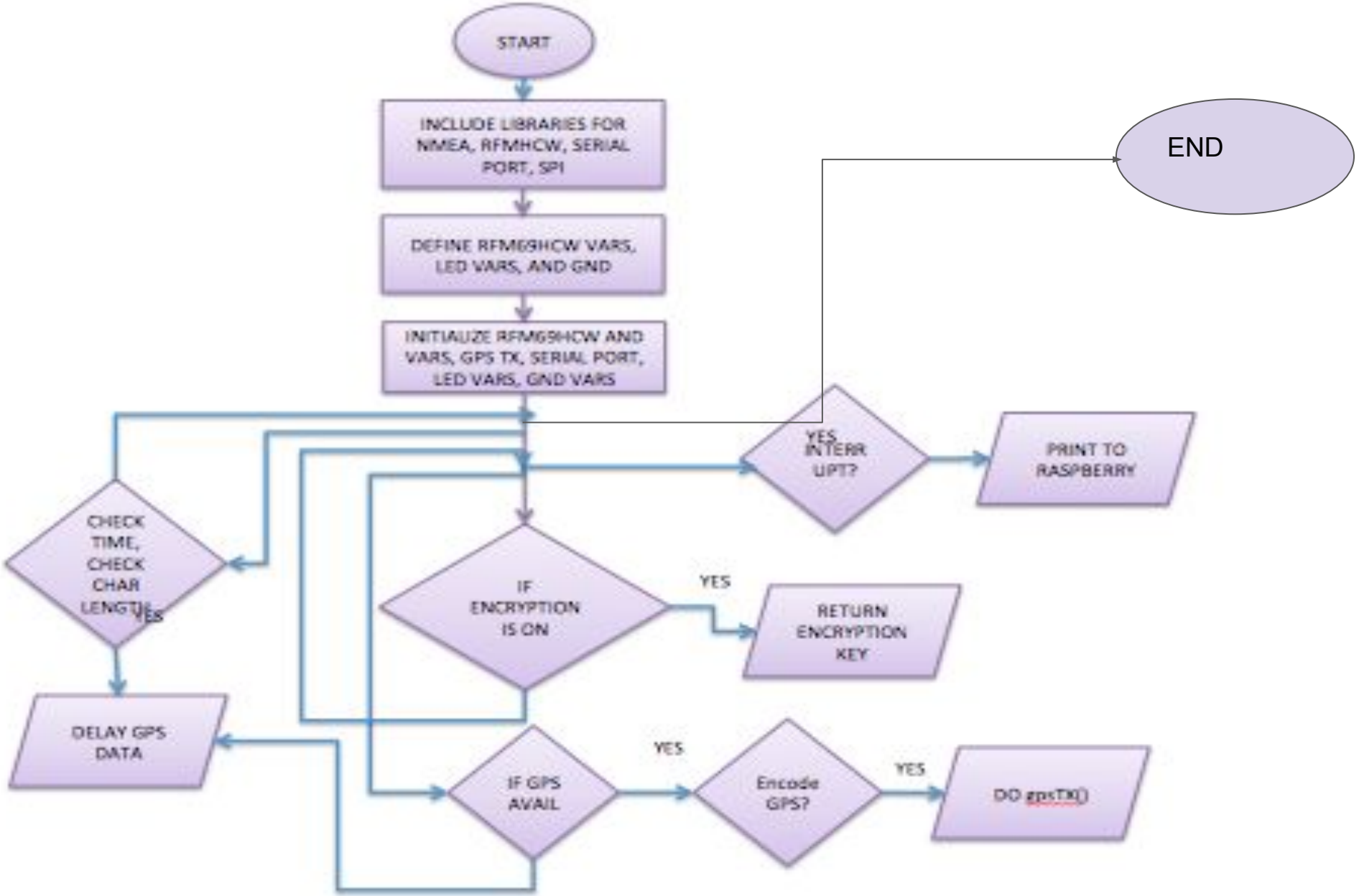
COMPUTER VISION LIBRARY

LIBRARY	PROS	CONS
OpenCV	Documentation and large number of functions	Can be harder to learn
Mahotas	Easier to start than OpenCV	Fewer Optimizations than OpenCV
Skimage	Easiest option	Fewest Functions

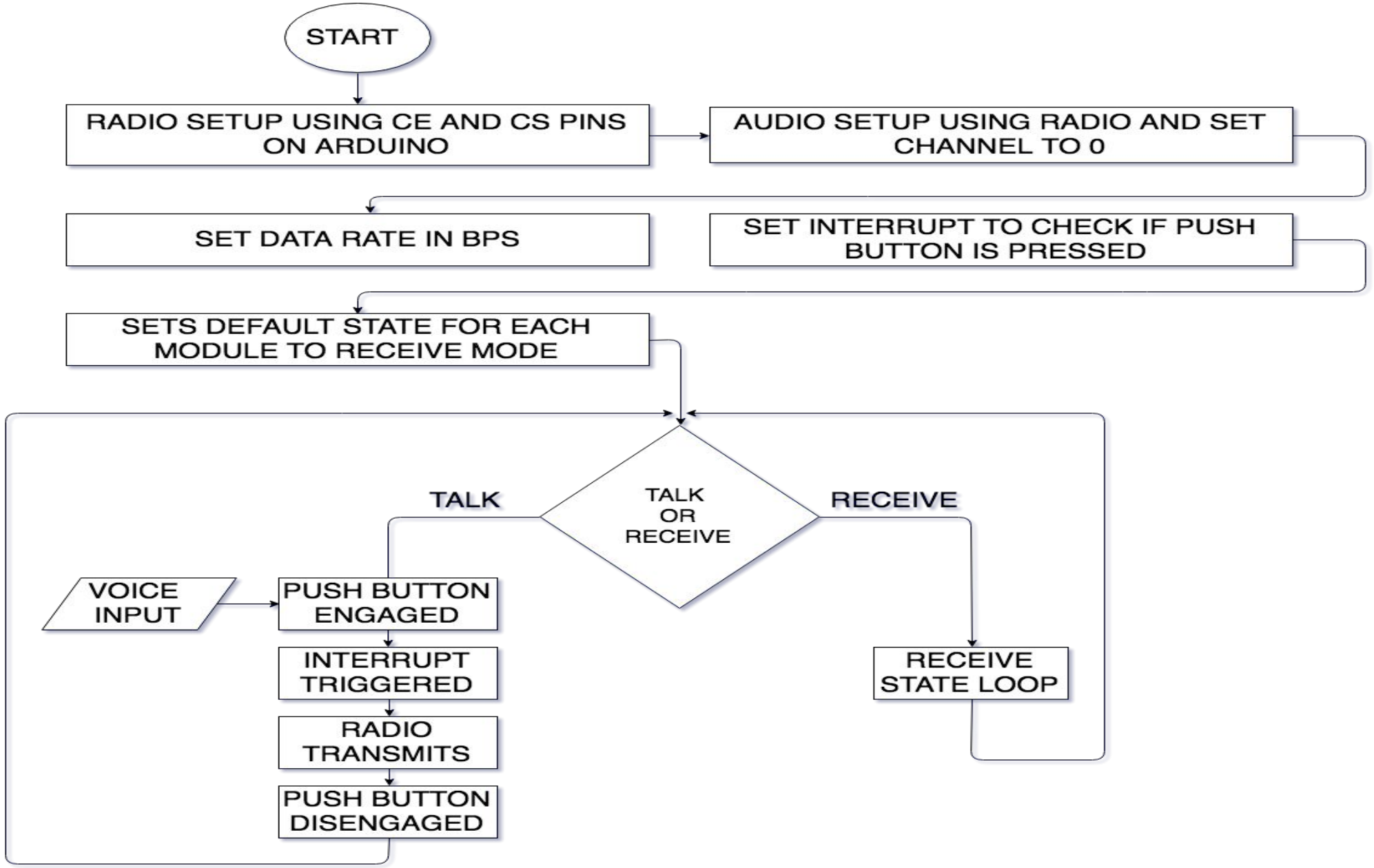
Version of OpenCV

LIBRARY	PROS	CONS
C++	Original OpenCV library	C++ is not as easy to code in as Python
Python	Easier to use, uses the C++ code	Can be slower if code is not optimized
Java	Easiest to use for those familiar with Java	Slowest of the three

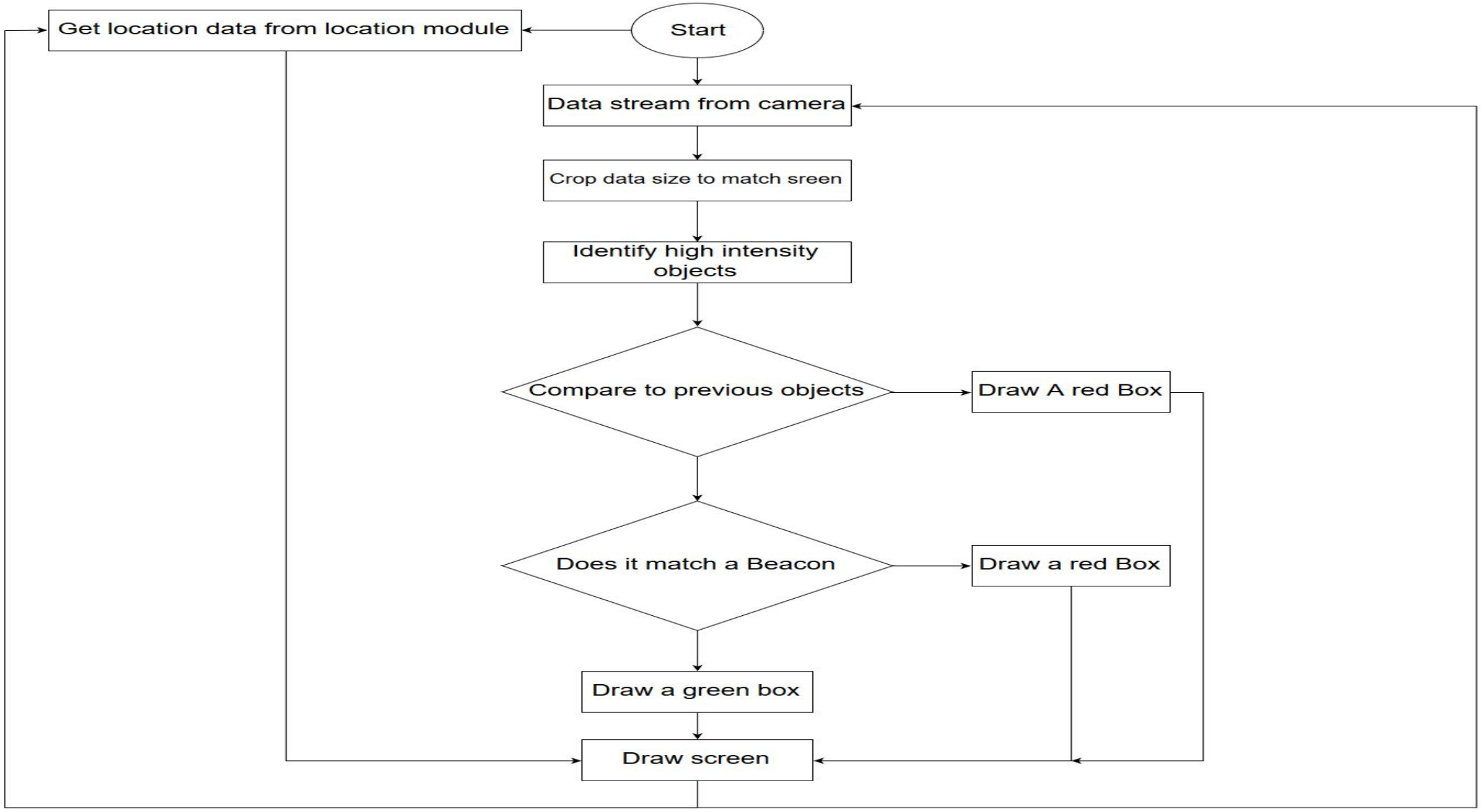
SOFTWARE FLOWCHART - LOCATION



SOFTWARE FLOWCHART - COMMUNICATIONS



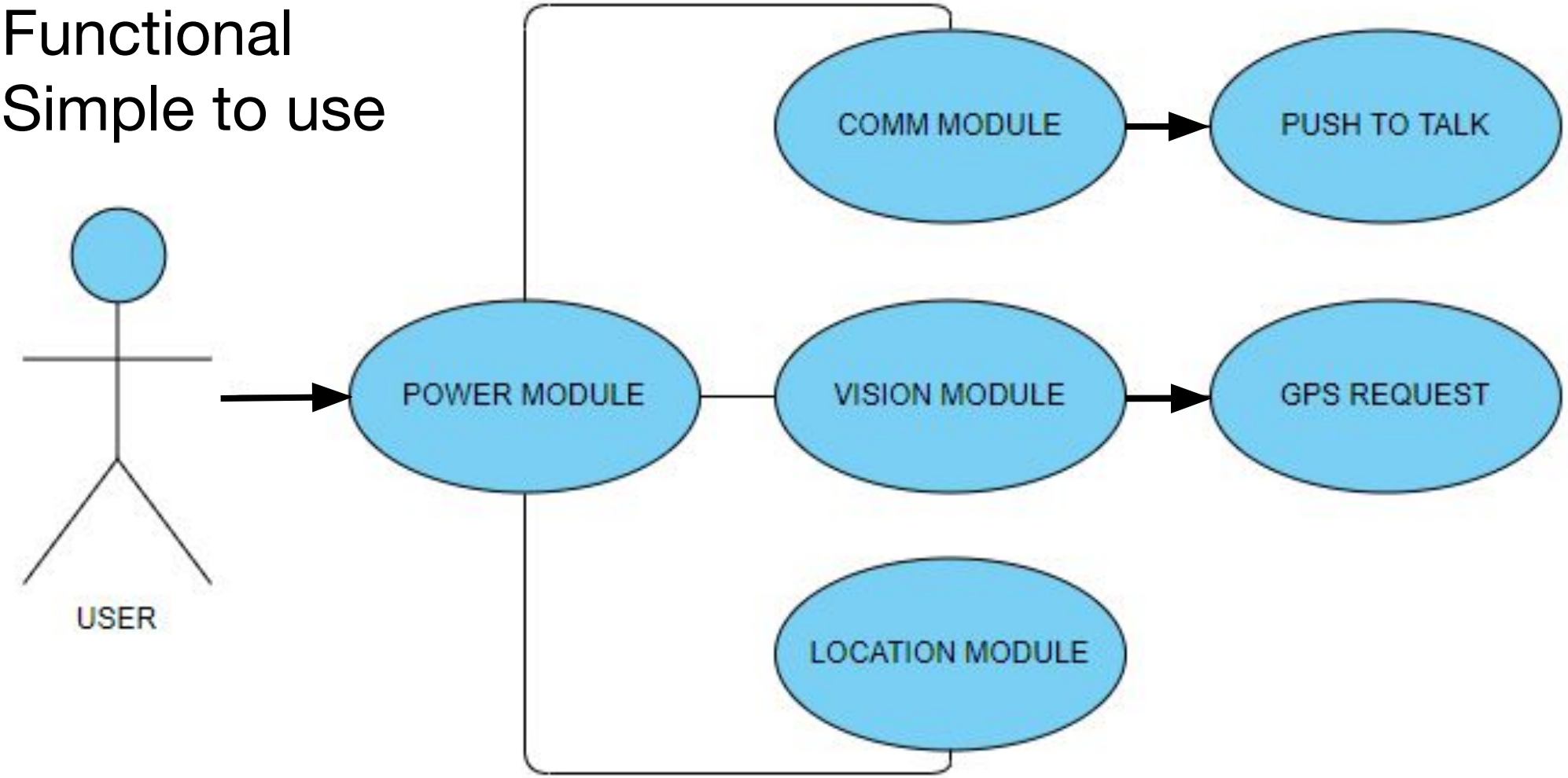
SOFTWARE FLOWCHART - VISION MODULE



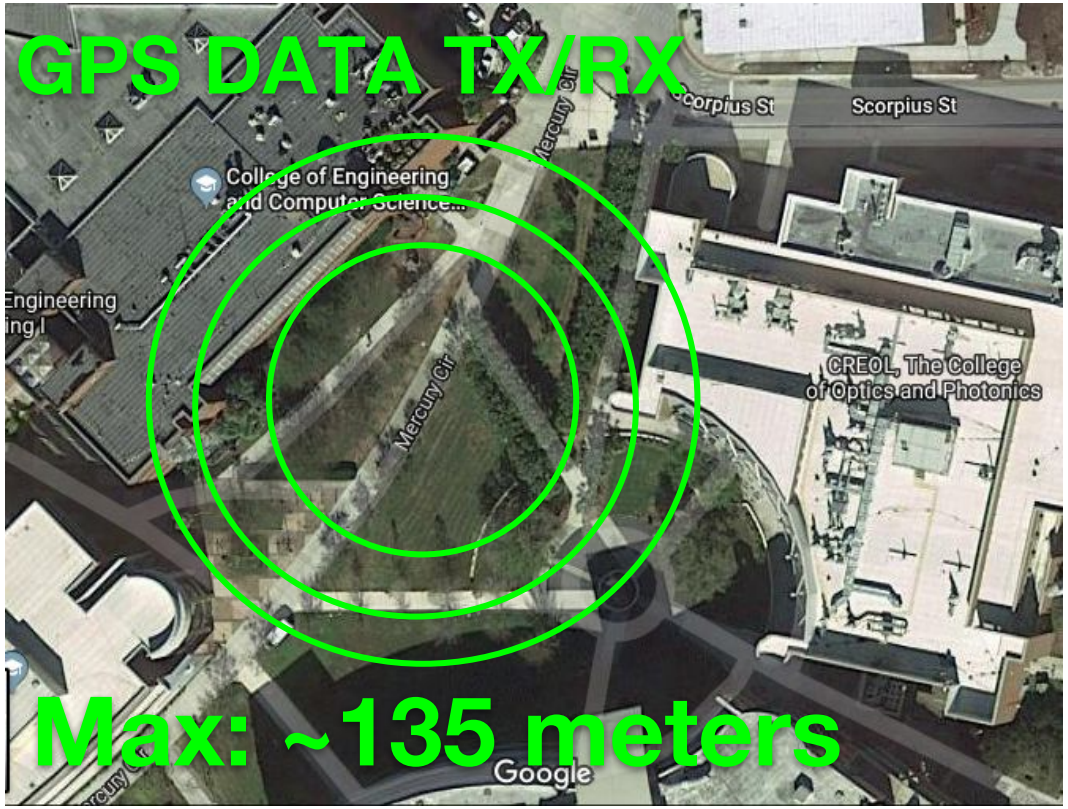
USE-CASE DIAGRAM

Goal:

- Functional
- Simple to use



COMMUNICATIONS MODULE
RANGE TESTING



RFM69HCW TRANSCEIVER
DATA COMMUNICATIONS RANGE TEST
NTS

NRF24LO1+ TRANSCEIVER
VOICE COMMUNICATIONS RANGE TEST
NTS

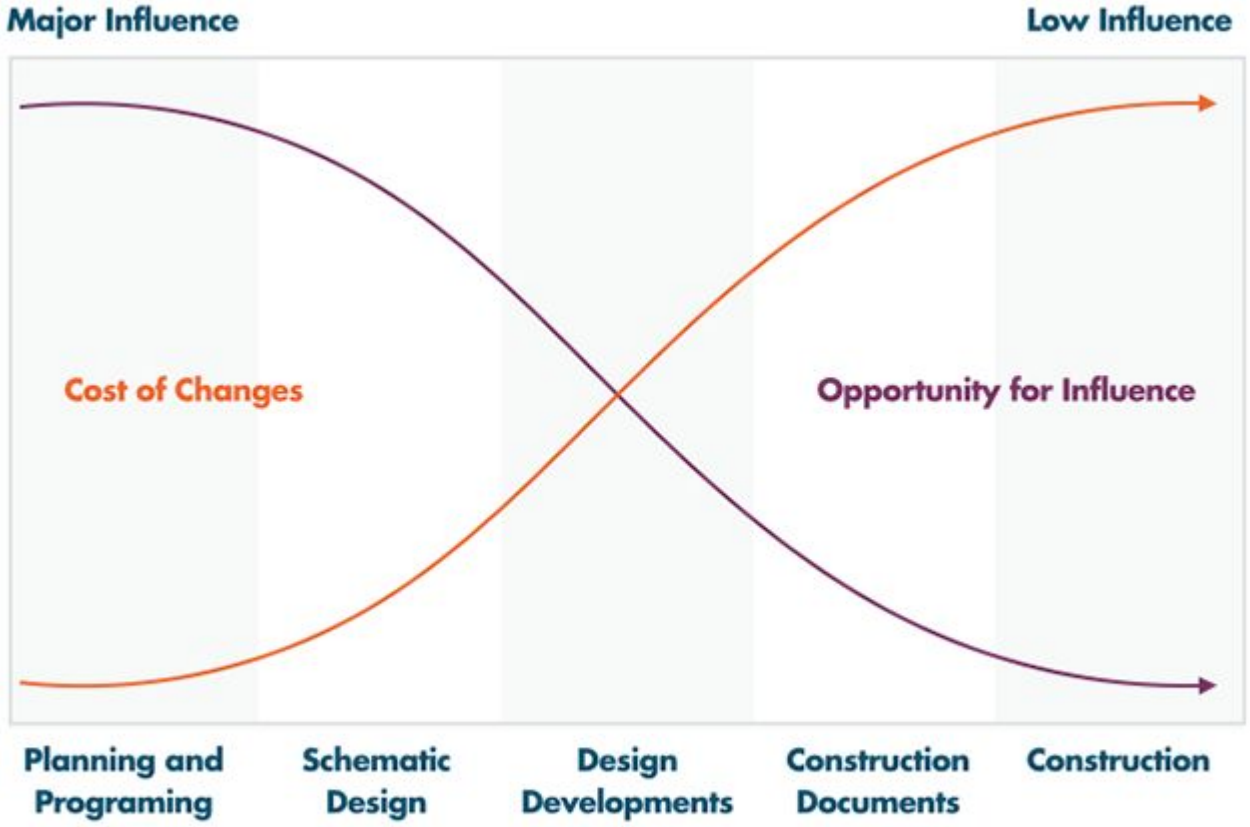
WORK DISTRIBUTION

	Location	Vision	Communication	Power	TeamLead	PCB	CDR	CAD	Conference Paper	SD2 Paper	WEBSITE
Harriet	✖		▲		▲		✖		▲	▲	✖
Stephen			✖	▲		✖	✖	▲	✖	✖	
Jacob		▲				▲	✖		✖	✖	
Shakira	▲		✖				▲		▲	✖	▲

▲ Lead

✖ Secondary

Project Management Insight - Cost vs. Influence



Source: WBDG, www.wbdg.org

Minimum Viable Product(MVP)

Opportunity for Influence Insights:

- As the project gets closer and closer to construction, there is much less opportunity to influence changes in design

Cost of Changes Insights:

- As the project gets closer to the construction phase, the cost of changes to the design increase significantly

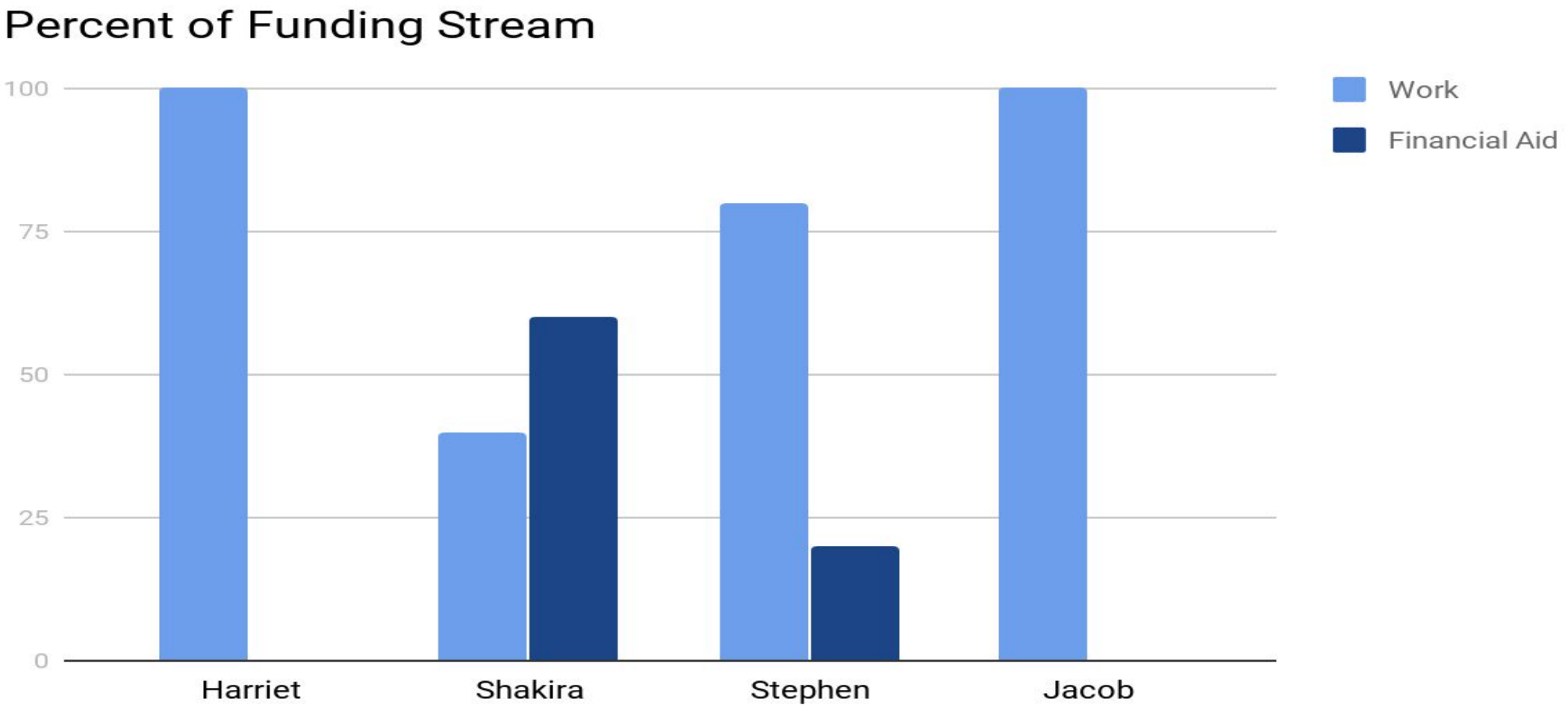
BUDGET

Part Name	Quantity	Price Each	Price Total
Other components	varies	varies	~$208.24
PCB	1	$54.88	$54.88
ATMEGA328P	4	$2.14	$8.56
POWER			
Batteries	4	$5.95	$46.56
Battery chargers	8	$0.60	$4.80
Regulators	6	$5-10	$24.00
Breadboard testing parts	varies	varies	~$60.00

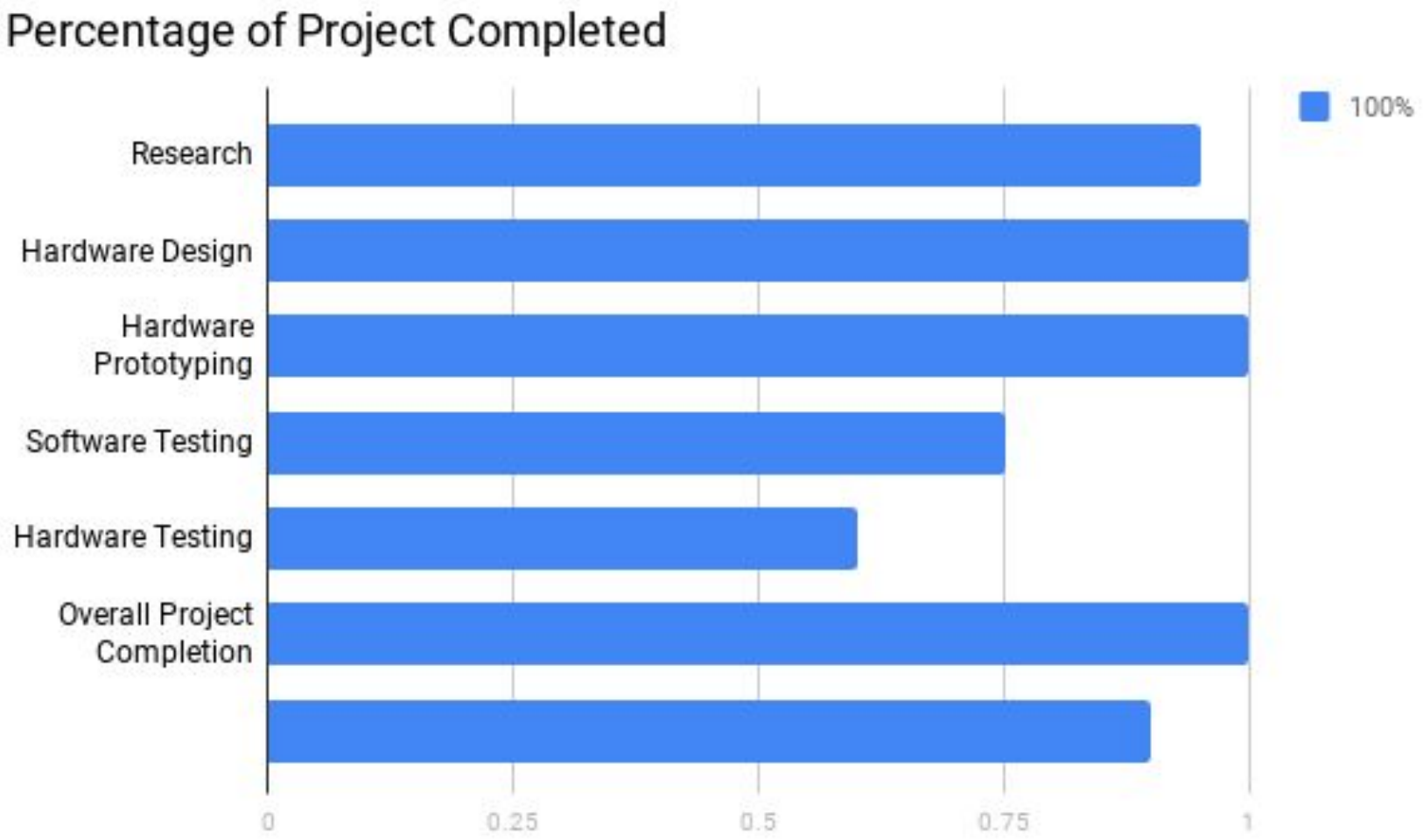
FINAL BUDGET: ~$1500

Part Name	Quantity	Price Each	Price Total
COMMUNICATION			
n24L01+ transceiver	2	$3.50	$7.00
RFM69HCW transceiver	2	$5.95	$11.90
Headphones	1	$5.99	$5.99
VISION			
Raspberry Pi	2	$35.00	$70.00
Camera	2	$40.00	$80.00
Screen	2	$19.99	$39.98
LOCATION			
GPS	2	$49.00	$98.00
MEMS Motion Tracking Device	2	$15.00	$30.00
Total Price			~$763.90

FINANCING


Percent of Funding Stream
100
75
50
25
0
Harriet
Shakira
Stephen
Jacob
Work
Financial Aid

PROGRESS CHART



ISSUES

ISSUE	RESOLUTION
Noise on receiving end of voice comms	LC filter for each speaker
FCC Title 47 Part 15.231	FCC Title 47 Part 15.231 Part B
Integration between Pi and UART	Corrected settings
Low charging issue	Improved charging current
GPS not locking on signal	Corrected settings
PCB design	improved traces, changed design

THANK YOU!