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Cold Chain Tracking
SDP 2021
Team 25

November 19, 2020

Original Problem Statement and Solution

- Need to monitor temperature during transit for accountability - cold chain tracking
- Current cold chain tracking products are not waterproof, solely single use, and high end ones are too expensive to use with many shipped items

Our Solution:

- Will provide accurate timing, location, and temperature in real time to all parties involved in supply chain via web service
- Will be low cost and reusable for oyster farmer
- Will be durable and waterproofed to be stuffed in oyster bags

Problem with Approach in PDR

- Cost needs to implement a single device with cellular and gps tracking for each individual oyster bag are unrealistic
- Very inefficient process due to shipping back and forth of individual devices
- Temperature sensors could be inaccurate due to the heat generated from the device if they are on the PCB with other components

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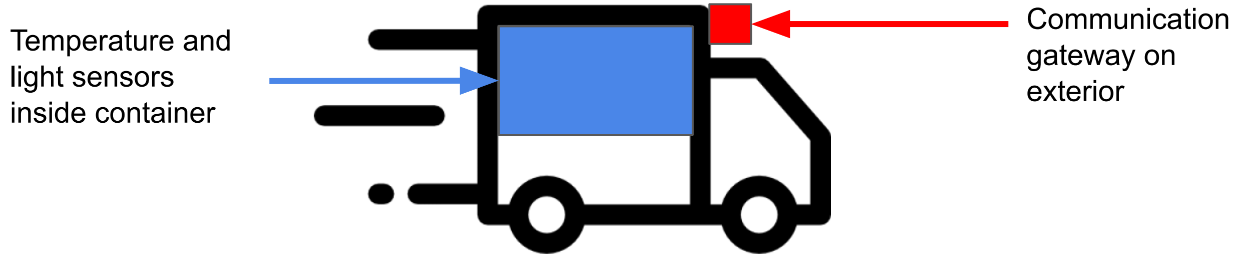
Changes in Approach

- Study found minimal differences in oyster temperature vs. ambient temperature [1]
- Shifting focus/perspective from oyster farmer to distributor
- Single gateway device for truck with cellular and gps communication
- Internal temperature sensors all report to gateway for transmission of temperature and location data to the web server
- Internal light sensor to help explain discontinuity



[1] D. Love et al., "Supply chains for aquacultured oysters: enhancing opportunities for businesses and shellfish growers, and examining traceability and food safety," CLF., JHSPH, Baltimore, MD, USA, Project Number: NA16NMF4270230, Final Rep., Oct. 25, 2019. Accessed: Sept., 21, 2020. [Online]. Available: https://clf.jhsph.edu/sites/default/files/2019-11/NOAA-grant-report.pdf

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Changes in Approach (Continued)

- New system must link products to measurements
- Solution:
  - QR codes on each product detailing origin, destination, product number
  - QR code on gateway/truck to link measurements
  - Mobile scanner application to store and upload to server
- Shipments will be scanned during loading and unloading
- QR info will correlate records with authorized parties

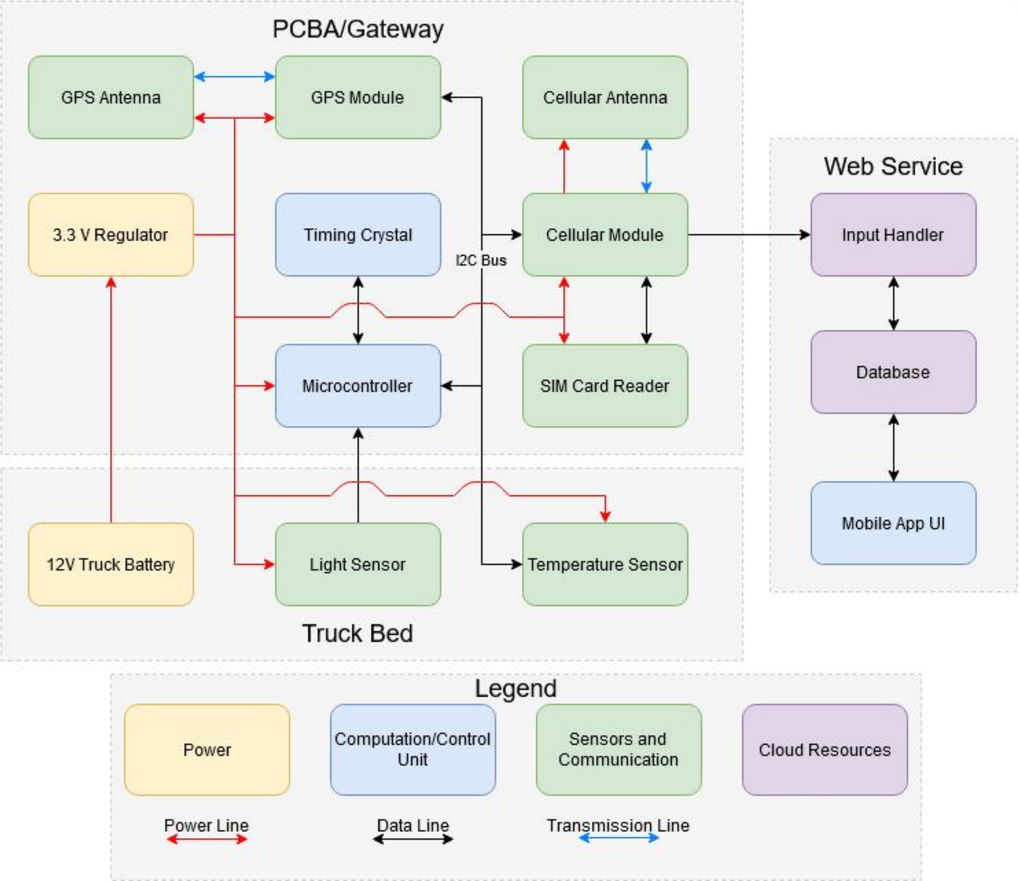
Security Model/Assumptions

- Entirety of current industry built on years of trust and human measurement
- Parties will be able to view records for their goods in transit
  - Records signed for integrity and non-repudiation from distributor
- Web server has user authentication to keep supply chain data confidential
- No malicious individuals with physical access
  - If sensor moved, obstructed, or modified, data can no longer be trusted

Updated System Specifications

- Power: Must run off of 12V lead acid source (truck battery)
- Must be able to provide real time tracking to user with the following parameters:
  - Temperature: within 1 degree Fahrenheit
  - Location: within 25 ft
  - Light: Above or below a set threshold (daylight/darkness)
  - Time: Record the correct time in Eastern Standard Time within 1 sec
  - Updated every 15 minutes with connection
- Cost: Less than $284 for materials for final prototype
- Size: Gateway no larger than 6”x6”x3”

Block Diagram



Microcontroller

Requirements:

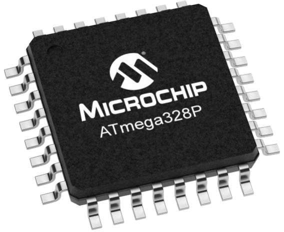
- Query peripherals for necessary measurements
- Format data for communication with server

Currently: Arduino Uno

- Microcontroller based board with the Atmega328p.
- Easy to prototype with.
- Has all the onboarded peripherals
- Easy to use IDE
- Libraries to leverage from the community

Next Stage: Atmega328p

- 8-bit AVR RISC-based microcontroller
- 32 KB of programmable flash memory
- Digital communication: 1-UART, 2-SPI, 1-I2C
- 23 GPIO lines
- Real time counter



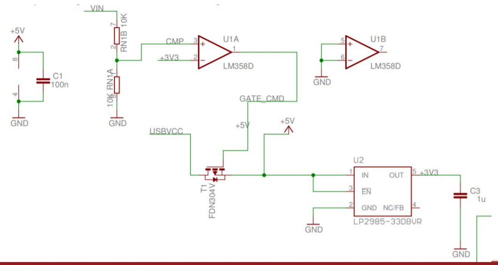
Power

Requirements:

- Stepping down from 12V lead acid battery. Voltage ranges from 12.9V-11.4V.
- Peripherals and microcontroller takes input of 3.3V.
- Must be able to deliver required current draw.

Currently: Arduino Uno’s Onboard Regulators

- Voltage input is already regulated to 3.3V
- LP2985-33DBVR LDO regulator
- 150mA max draw
- 280 mV dropout @ 150mA



Next Stage: SMD Voltage Regulators

- Planning on LD1117.
- LD1117 - 3.3V output
- Max of 15 V input
- Typical min of 4.3V input
- 800mA max current supply

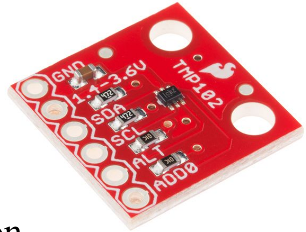
Temperature Sensor

Requirements:

- Measure temperature of the system (±1℉)
- Communicate with the microcontroller

Currently: Sparkfun Breakout Board with TMP102 Temperature Sensor

- Easy to prototype with
- Available libraries with Arduino IDE
- I2C communication
- 0.5°C/0.9°F Accuracy
- –25°C to +85°C/-13°F-185°F
- 12 bits of resolution
- Current Draw - ~3mA during acquisition
- Low IQ - 10uA active (max)



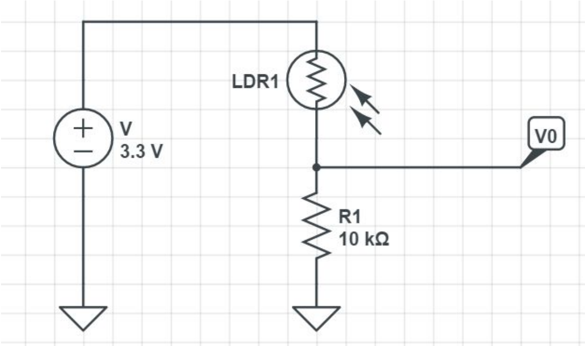
Light Sensor

Requirements:

- Detect the difference in environment with lights on versus lights off

Photoresistor and GPIO Reading

- Resistance value of ~2kΩ with lights on/~50kΩ with lights off
- Reads voltage output of voltage division circuit and outputs LOW/HIGH



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GPS Module

Requirements:

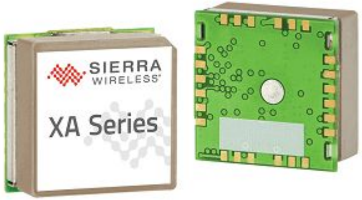
- Measure latitude and longitude within 25 feet
- Communicate with the microcontroller

Currently: Botletics™ SIM7000 LTE CAT-M1/NB-IoT + GPS Shield

- Arduino shield - easy for prototyping
  - Easy integration
  - Leverage libraries
- u.FL antenna connectors
- GPS and GLONASS capabilities with 2.5m (~8.2ft) accuracy

Next Stage: Sierra Wireless XA1110 Module

- Accuracy: 3m(~9.8ft)
- GPS+GLONASS
- Patch on top antenna
- Low noise amplifier(LNA), SAW filter onboard
- Supports I2C/UART/SPI



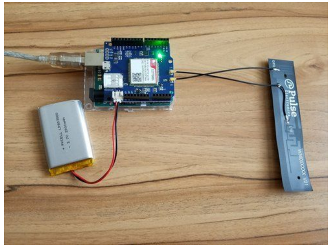
Cellular Module

Requirements:

- Facilitate communication between microcontroller and server
- Establish persistent connection to ensure reception

Currently: Botletics™ SIM7000A LTE CAT-M1/NB-IoT + GPS Shield

- LTE CAT-M1 and NB1-IoT connectivity
- Supports entirety of the US



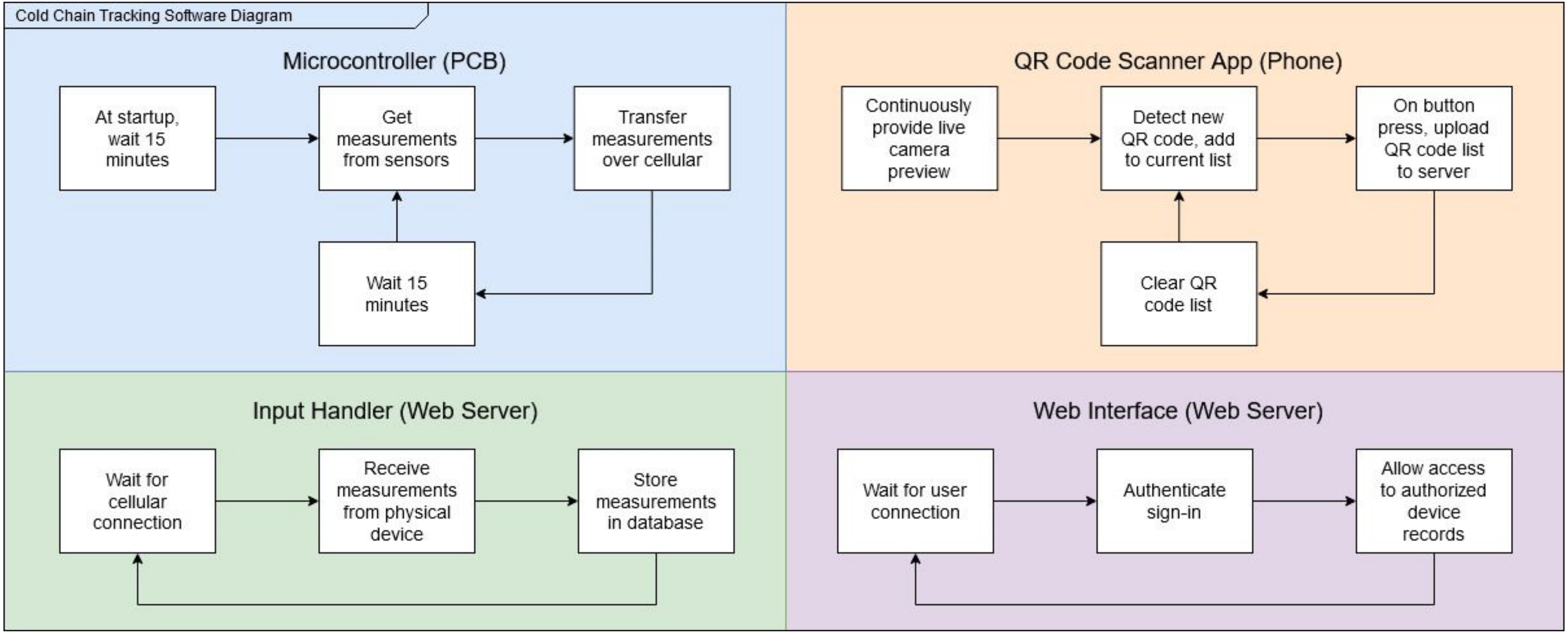
Next Stage: SARA-R410M-02B Modem

- LTE CAT-M1 and NB1-IoT connectivity
- Global/multi-regional support with multiple bands in the US
- Supports I2C/UART/SPI

Cellular Communication

- Using the Hologram Global IoT SIM card
- Common in cellular-enabled IoT devices
- 2G/GPRS, 3G HSPDA, 4G LTE, LTE CAT-M1 coverage within the US
- Automatic carrier switching
- Free 1MB/month + $0.40/MB over
- More plans for industry and multi device use

Software Block Diagram



Current and Future Software List

Current:

- Adafruit FONA Library for GPS/Cellular breakout board*
- Sparkfun TMP102 Arduino Library
- Google MLKit Library for QR Code Scanner
- MongoDB Atlas for storing information
- Node.js for web server hosted on Google Cloud

Future:

- Sierra Wireless Software Library for SMD GPS module
- ATtention (AT) commands for SMD cellular module

* Only used for prototyping

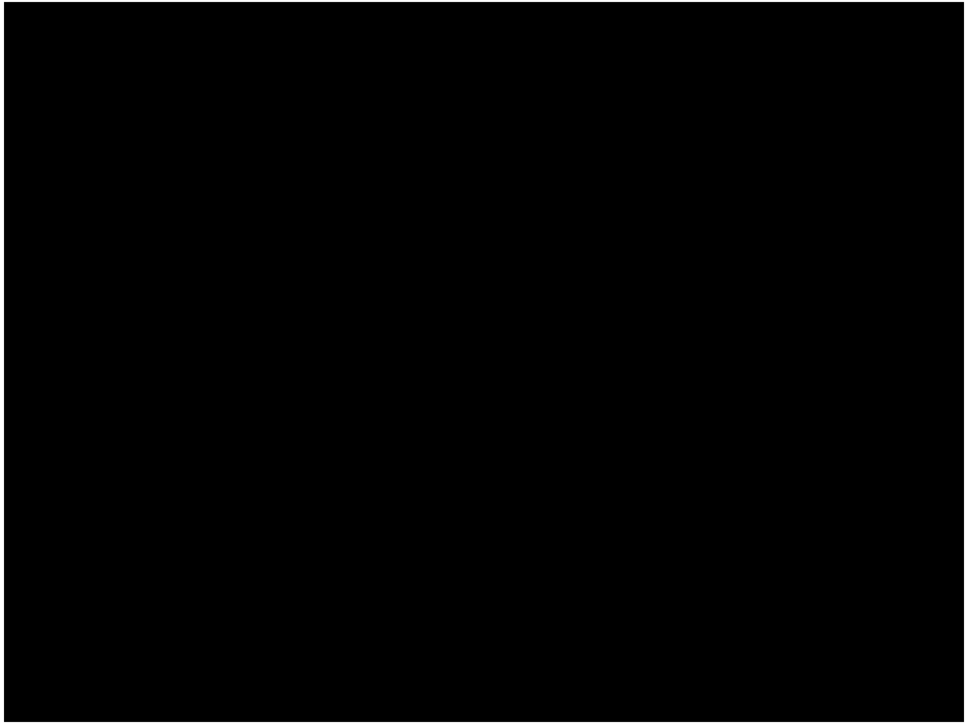
Live Demo: GPS, Light, and Temperature Readings

Live Demo: Cellular Communication with Server

Live Demo: Web Service User Interface

Live Demo: QR Code Reader Mobile App

Demo: Component Power Analysis



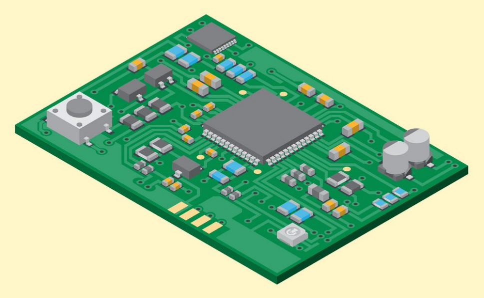
Power Consumption/Current Draw

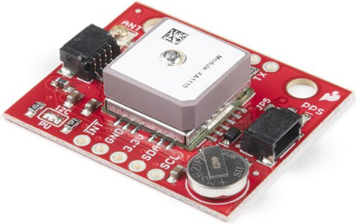
Component	Current Draw
SIM7000A Shield	- Connected to LTE CAT-M1 network, idle: ~12mA - GPS adds ~32mA - Data transmission over LTE CAT-M1 is ~96mA
TMP102 Sensor	3mA during active operation and active SDA
RTC IC	200uA during active operation and active SDA
Light Sensor Setup	275uA/55uA for light/dark environment
Peak Total Current Draw	~143mA

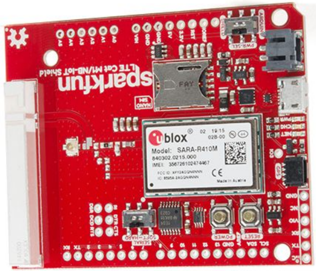
Custom Hardware for FPR

PCBA system

- Connect and integrate our physical system
  - Microcontroller
  - Timing Crystals
  - Proper voltage regulation
  - GPS module
  - Cellular modem
  - SIM Card reader
  - External Antenna

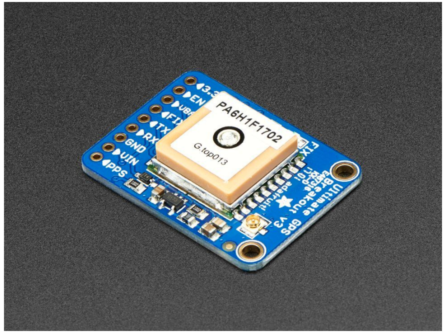






Expenditures

Current Expenditures	
Component/Material	Cost
Cell/GPS Module*	$65
Total:	**$65**

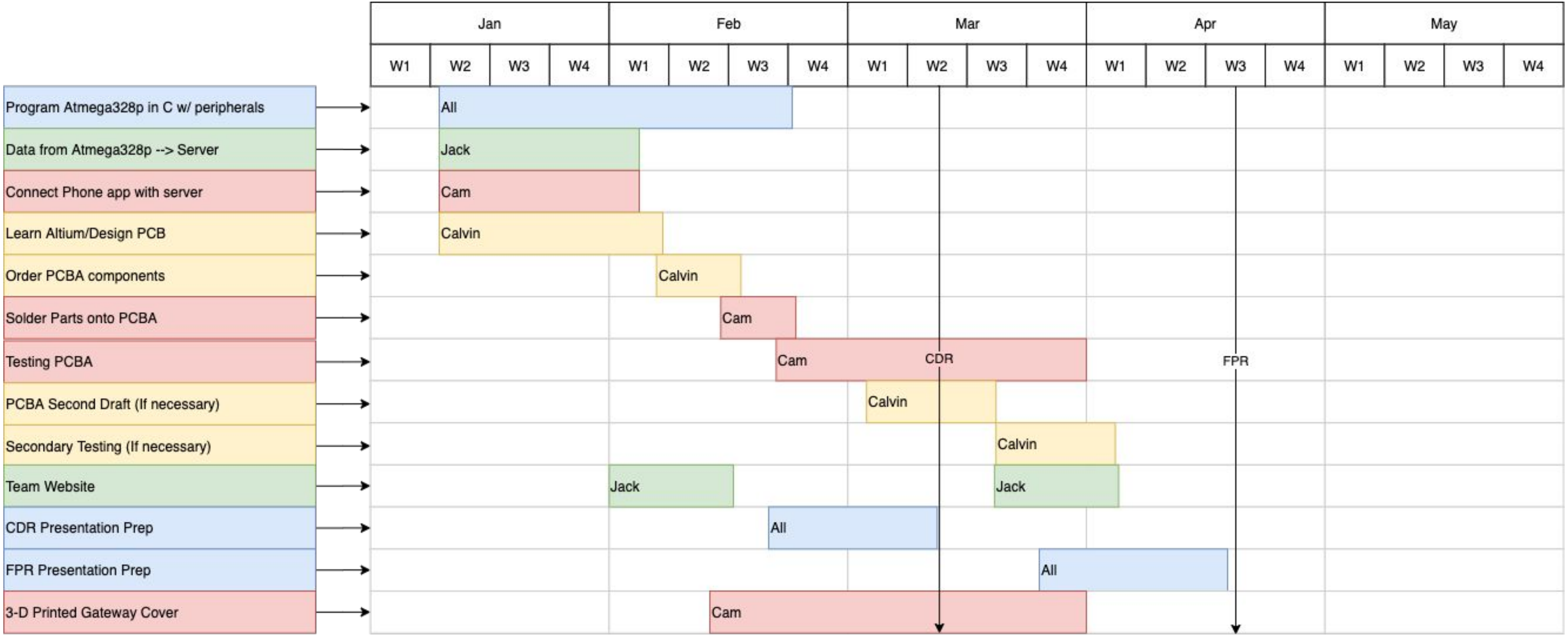


*For prototyping only

Projected Expenditures	
Component/Material	Price
Cellular Board*	$80
GPS Board*	$40
Microcontroller	$3
GPS Module SMD	$16
Cellular Module SMD	$42
PCB(s)	~$40
Temperature Sensor	~$1
Crystal	~$2
Sim Card Reader	$4
u.FL connector	$1
Voltage Regulators	$2
Antenna	$5
Total:	~$240

Responsibilities

Calvin Lee	Jack Newton	Cam Harvey
Hardware Design, Altium lead	Budget management lead, Web service lead	Team coordinator, Peripheral communication lead, App lead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Feb
Mar
Apr
May
W1
W2
W3
W4
Program Atmega328p in C w/ peripherals
All
Data from Atmega328p --> Server
Jack
Connect Phone app with server
Cam
Learn Altium/Design PCB
Calvin
Order PCBA components
Calvin
Solder Parts onto PCBA
Cam
Testing PCBA
Cam
CDR
FPR
PCBA Second Draft (If necessary)
Calvin
Secondary Testing (If necessary)
Calvin
Team Website
Jack
Jack
CDR Presentation Prep
All
FPR Presentation Prep
All
3-D Printed Gateway Cover
Cam

Questions?