Plan Bee

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Group 3

MOTIVATION

- Bees are struggling to survive with each passing day
- The world needs environmental support of bees
- Apiarists are facing extreme colony loss
- Most colony loss issues could be prevented with more knowledge and data
- The apiary industry is not technologically up to date
- Streamlining an industry such as this benefits everyone

GOALS AND OBJECTIVES

- Creating a data gathering system that is capable of transmitting data over a long-range communication network.
- Create a board that mainly monitors temperature, humidity, pressure, and light sensitivity.
- A low power System is important for this project.
- The board needs to be small so that it can be streamlined into the Apiary Industry.

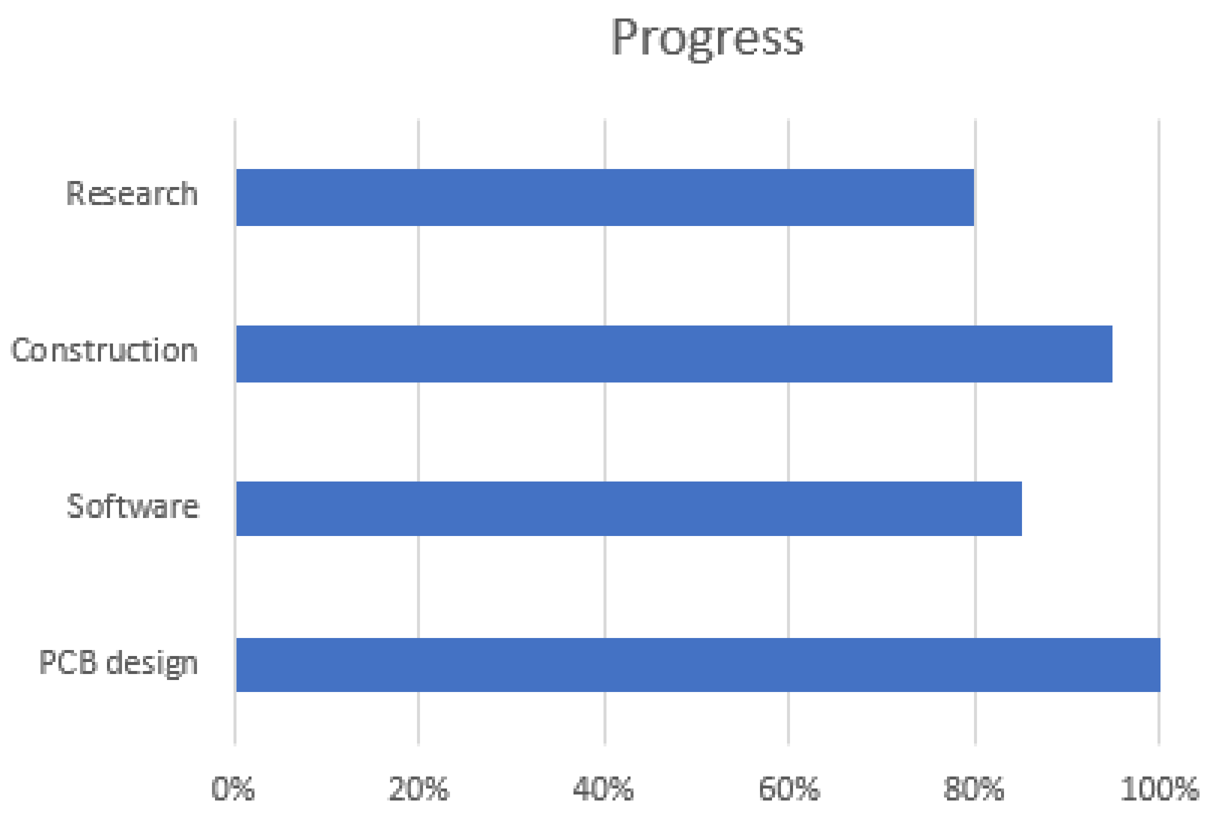
ENGINEERING SPECIFICATIONS

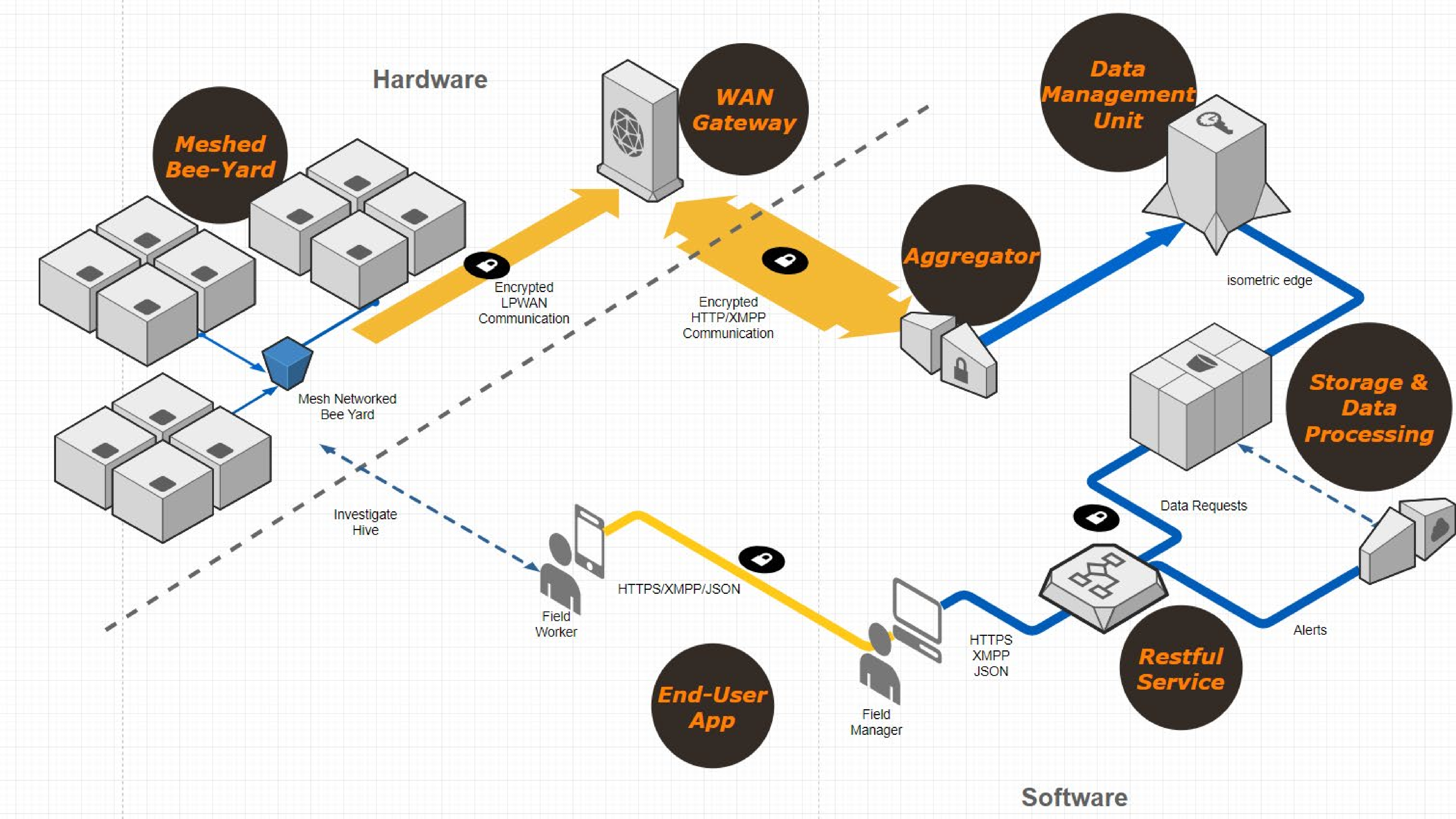
Specification	Description
Range of Communications	Reach of 10 mi. at Sub-1 GHz bands. Inversely correlated to response time and cost.
Product Dimension	Able to fit the space between hives.
Power Consumption	Supply only the minimal amount of power through solar panels for efficiency and cost.
Weather Resistance	Exposed to the elements. The product should last and hold its own.
Easy to Assemble/Install	Easy to set by anyone with zero experience.

MEMBERSHIP RESPONSIBILITIES

	PCB Design	Software	Construction	Research
Primary	Tariq Ausaf	Yannick Roberts	Katelyn Winters	Giovanny Reyes
Secondary	Katelyn Winters	Tariq Ausaf	Giovanny Reyes	Yannick Roberts

PROGRESS


Progress
Research
Construction
Software
PCB design
0%
20%
40%
60%
80%
100%


Hardware
Meshed Bee-Yard
WAN Gateway
Data Management Unit
Encrypted LPWAN Communication
Encrypted HTTP/XMPP Communication
Aggregator
isometric edge
Mesh Networked Bee Yard
Storage & Data Processing
Investigate Hive
Data Requests
HTTPS/XMPP/JSON
Field Worker
Alerts
HTTPS XMPP JSON
Restful Service
End-User App
Field Manager
Software

HARDWARE

HARDWARE ORGANIZATION

Sensor Transponder

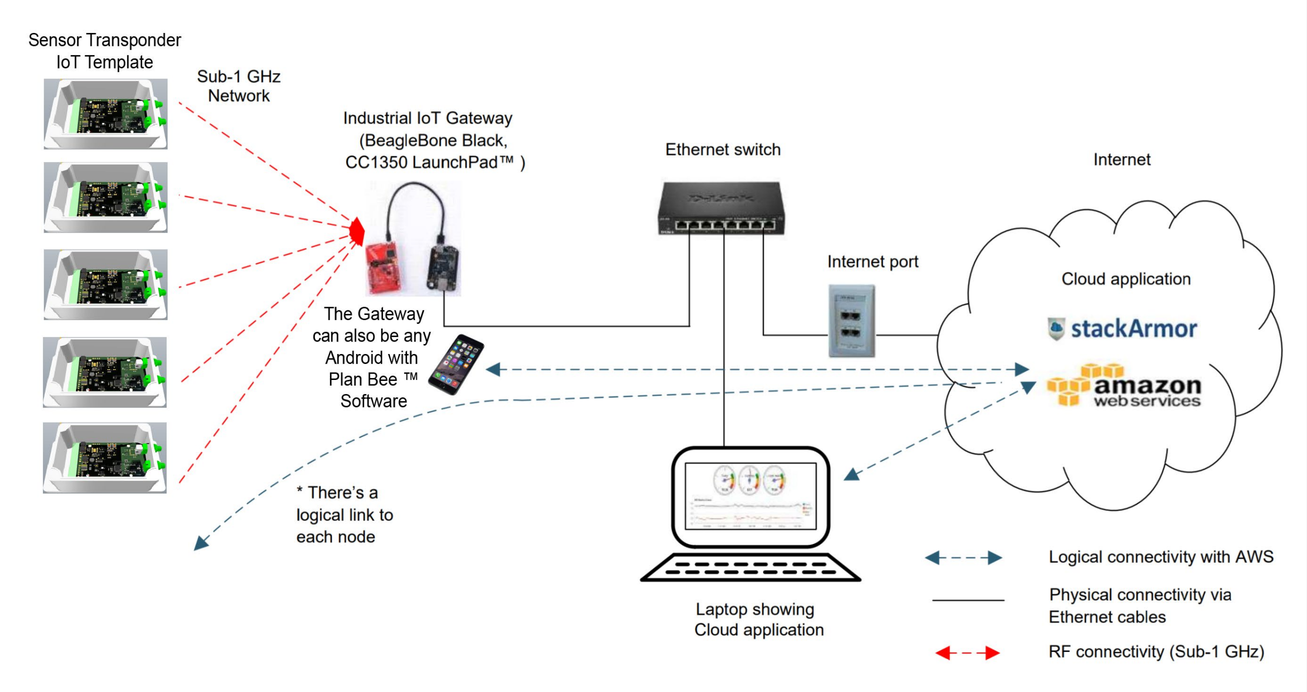
- Long-range communication (10m+) RF Communication Capability (968 MHz)
- Bluetooth 4.0 Capability (2.4 GHz) latches via Zigbee onto Gateway
- GPS Real-time tracking
- Onboard Sensors for General Spatial Monitoring
- Attachable Sensors Interface

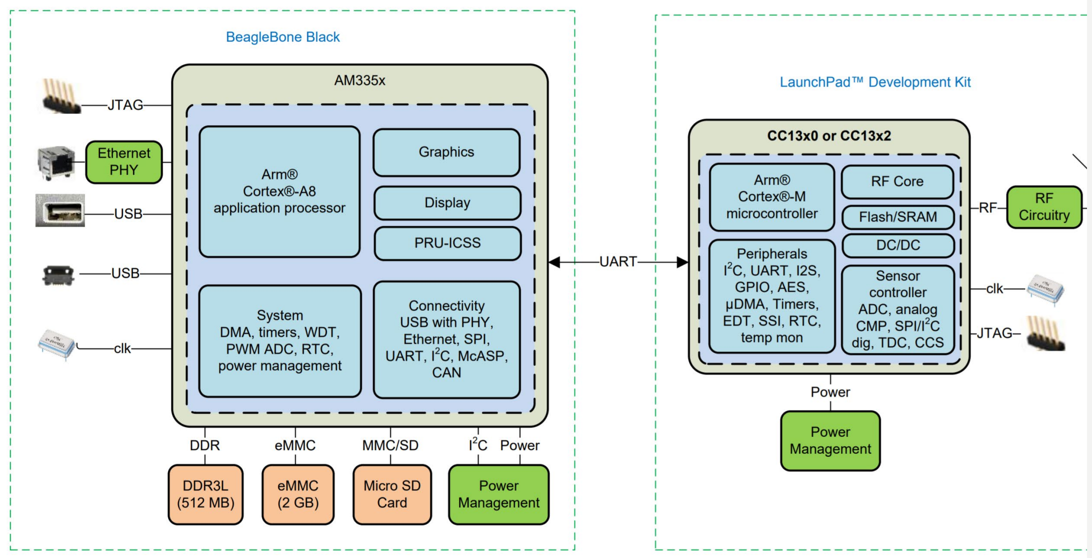
GATEWAY ILLUSTRATION

- Maximum of 112 per Sensors Transponder (SPI / I2C Limitations) – artificially limited at 30

- Maximum of 60 Sensors Transponders attached to each Gateway

Linux ▶ Beagle





THIS ISN'T UCF ANYMORE…

TI CC1352R WMCU – WHY?

Three Processors embedded at different levels:

- ARM Cortex M4F Processor
- RF Core Processor
  - ARM Cortex M0 Embedded Processor

Supports several interfacing protocols and sensors:

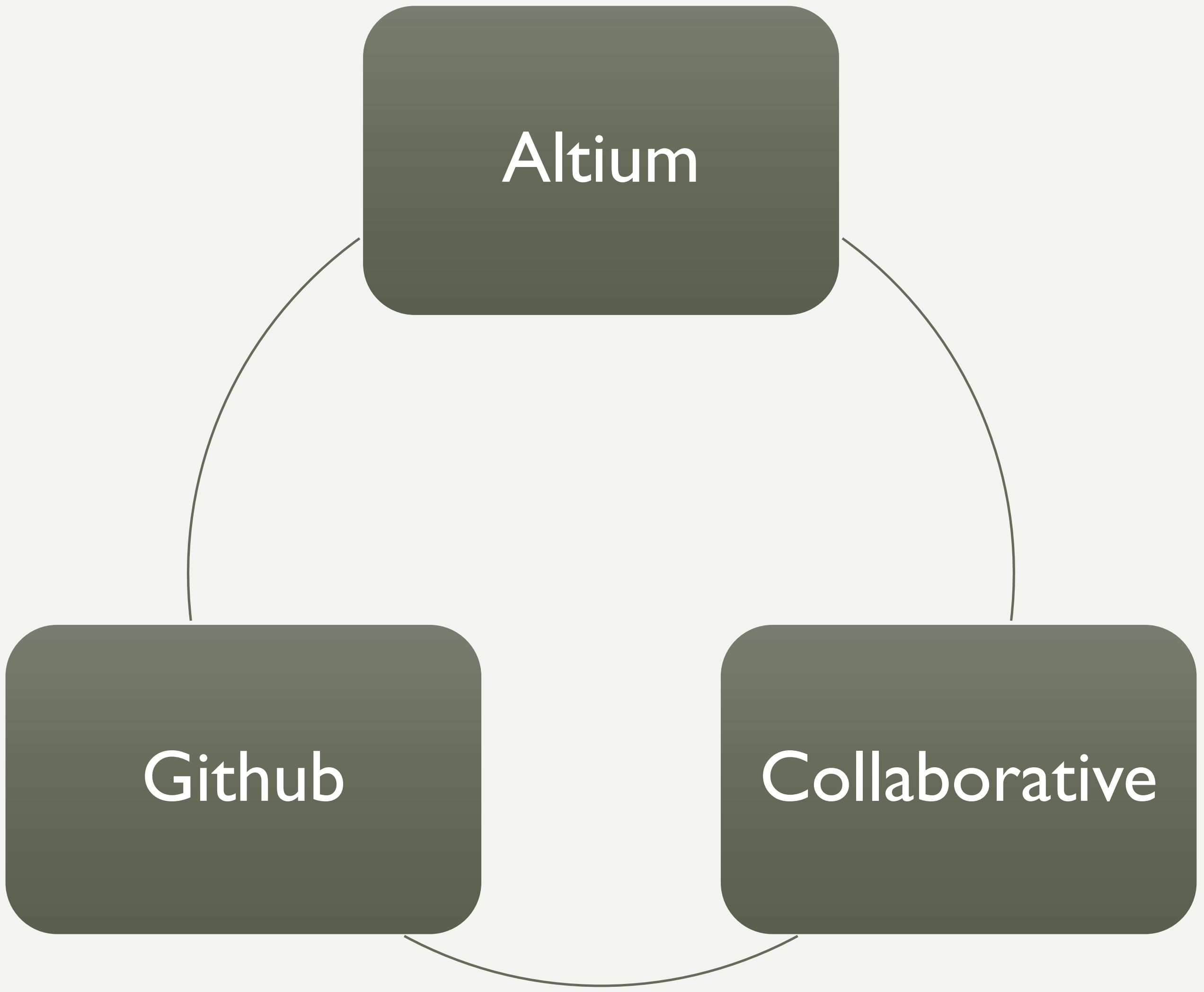
- 2X UART
- I2C and SPI
- 28 additional GPIO (Analog Or Digital)

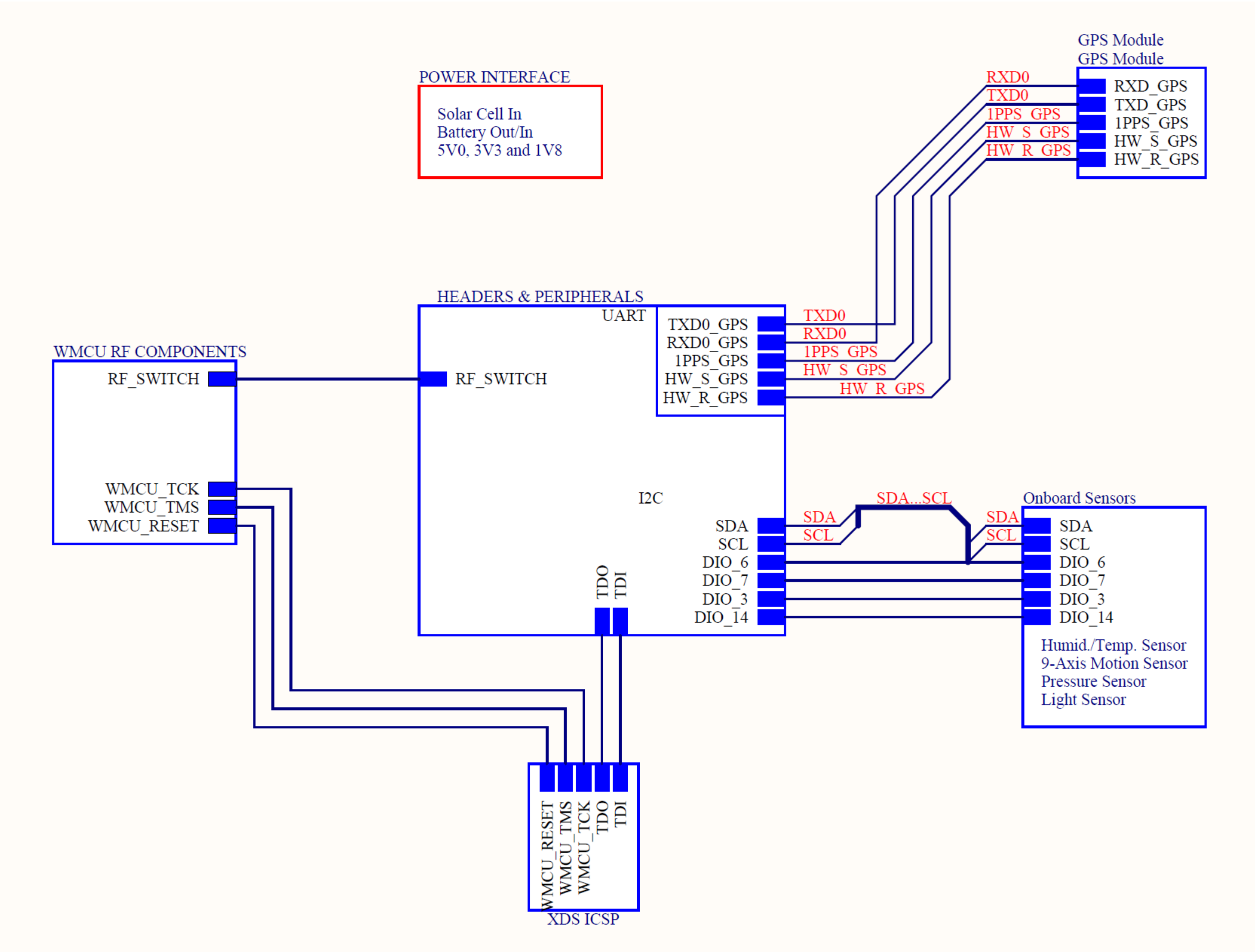
High-Power WMCU supporting both Long-Range and Short-Range Communications:

- BLE 4.0 low-energy
- Zigbee
- Thread
- LPWAN
- 10+ miles possible at 14 dBi (antenna gain)

SENSOR TRANSPONDER

HARDWARE DEVELOPMENT





SCHEMATIC OVERVIEW

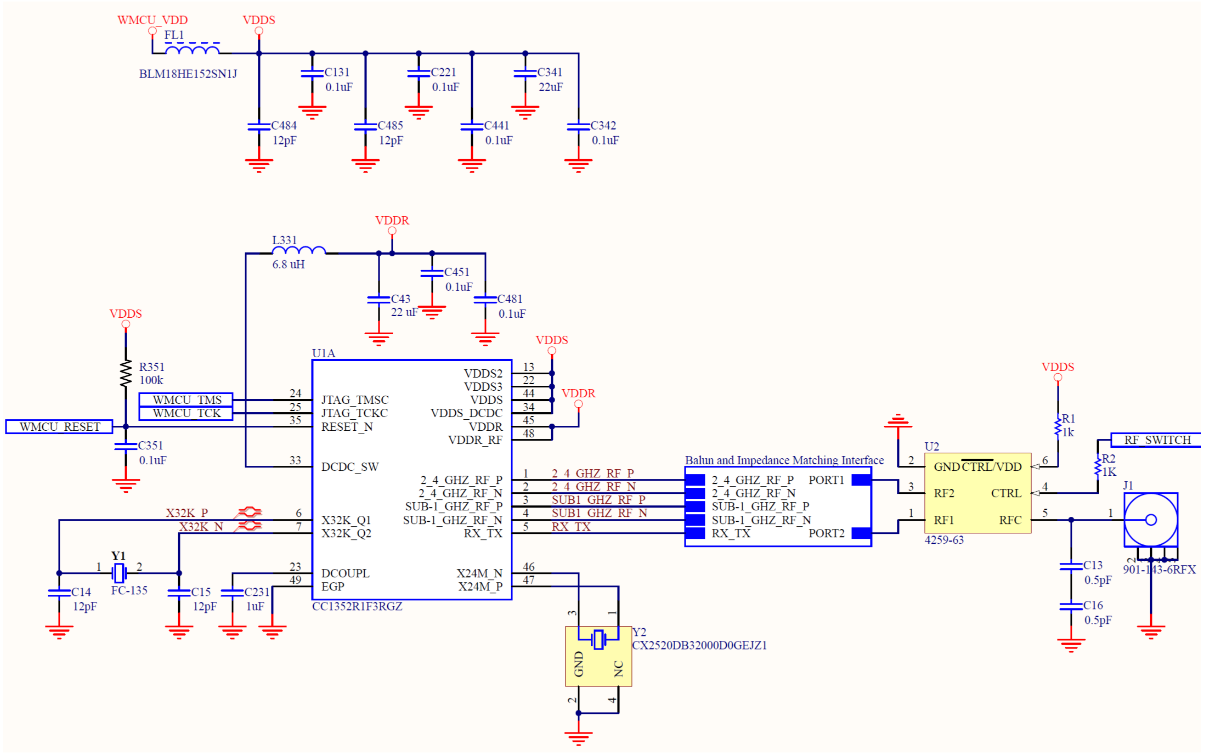
Power Interface supplies power – PWR and GND planes on PCB – connected using vias

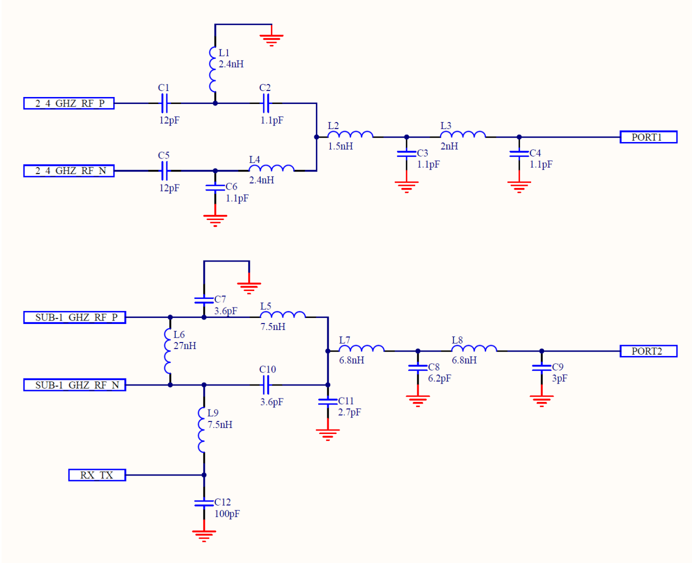
WMCU RF Components acts like the "brain"

Headers & Peripherals connect everything together like the "heart"

XDS is like the "parent"

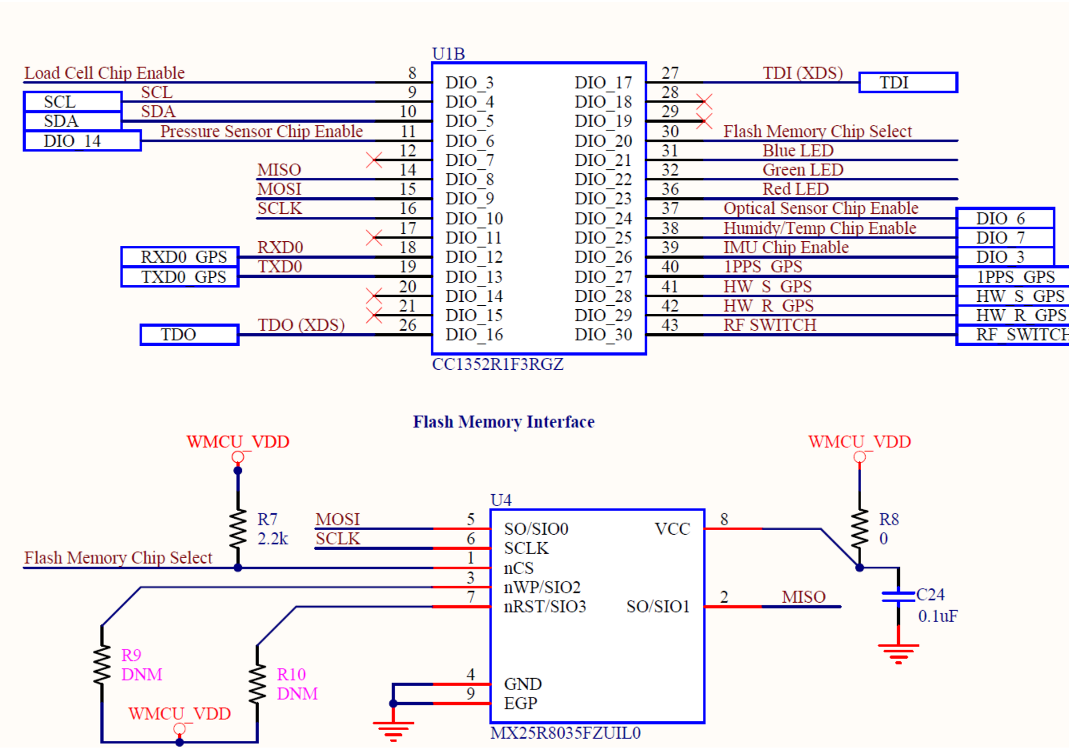
UX, GPS and Onboard Sensors like the "eyes and ears"

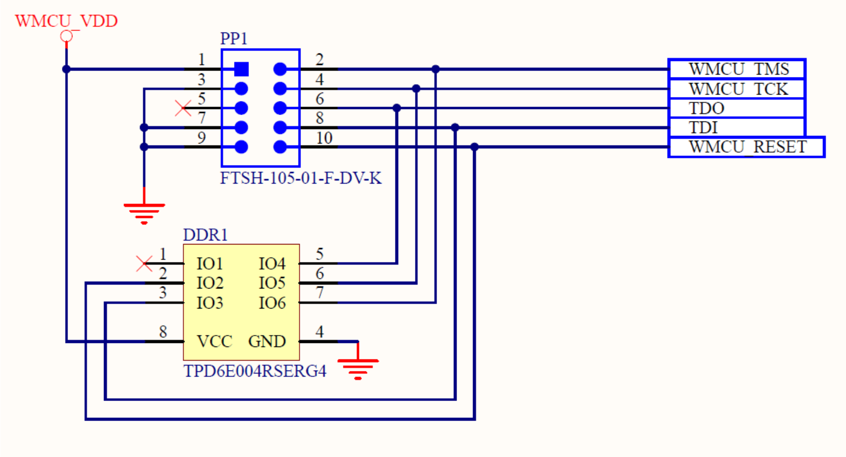




WIRELESS MCU + RF COMPONENTS

- BLM18HE GHz Noise Suppression Chip Ferrite Bead + Filtering Capacitors for power
- CC1352R1 is the workhorse – AMR-based MCU + High-Power Wireless Transmission
- 32 kHz (aux timing) and 48 MHz XTALs (MCU CLK)
- PE4259 solid-state RF Switch
- 2.4 GHz Duck Antenna
- Balun "merges" and "splits" differential signal
- Impedance matching for maximum power transfer, minimizing data loss / noise
  - 50 Ohm everywhere…

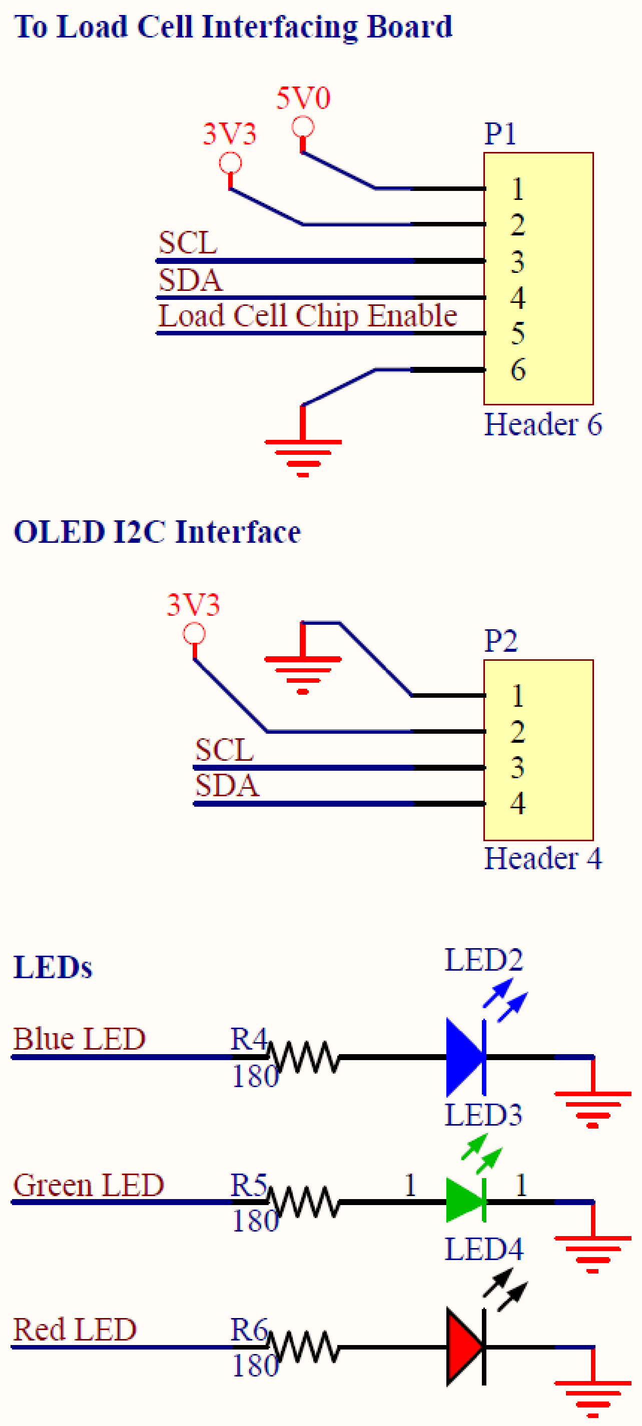


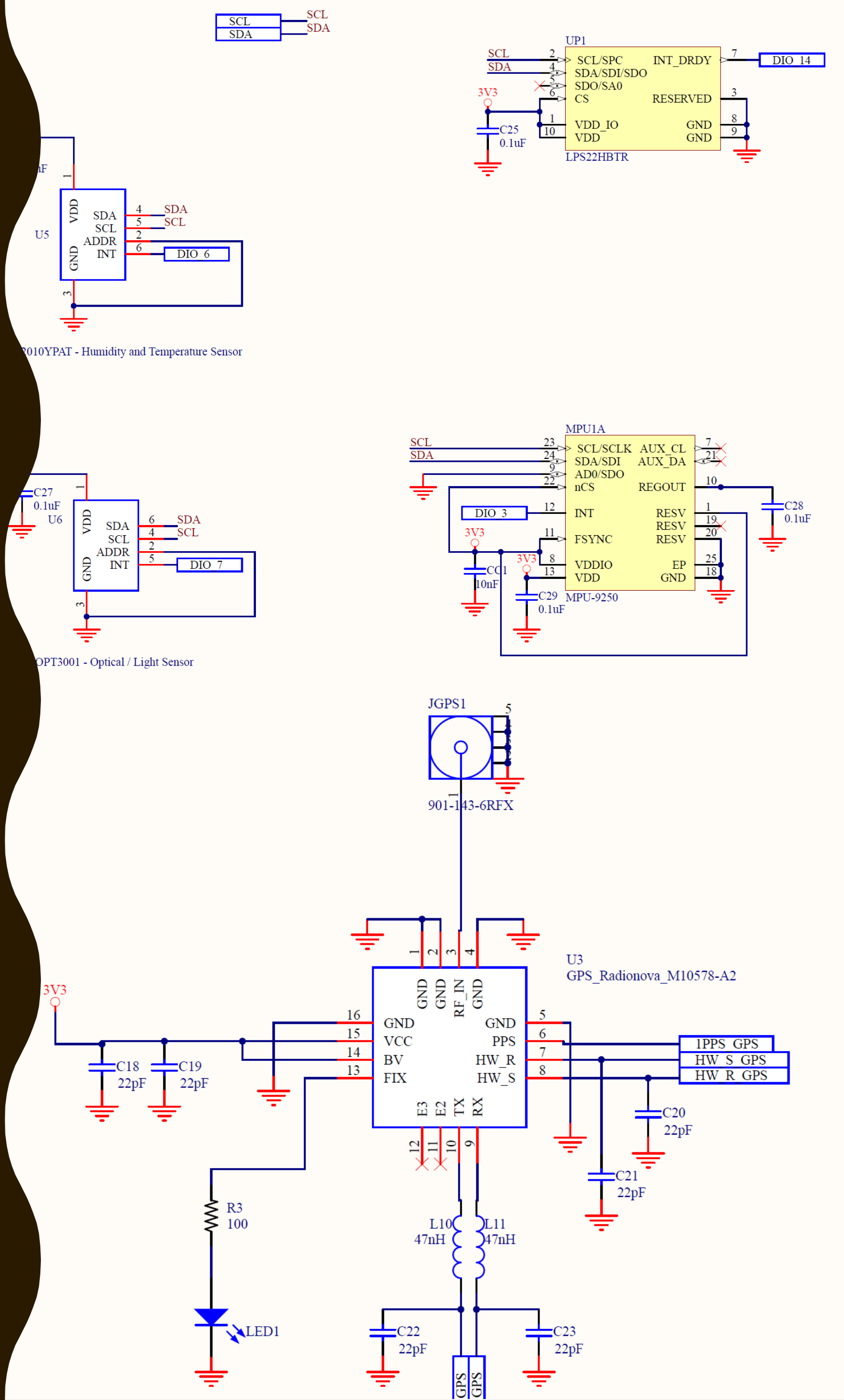


HEADERS & PERIPHERALS + PROGRAMMING INTERFACE

- "Heart" of our Sensors Transponder
- XDS – X-Window Direct Save Protocol – the programming interface we're using to flash the WMCU
- Headers & Peripherals interfaces all onboard and external devices
  - I2C to communicate with onboard sensors
  - UART to communicate with GPS chip
  - SPI to communicate with external sensors interface (MSP432-G)
  - Management of the User Interface (UX)

USER INTERFACE

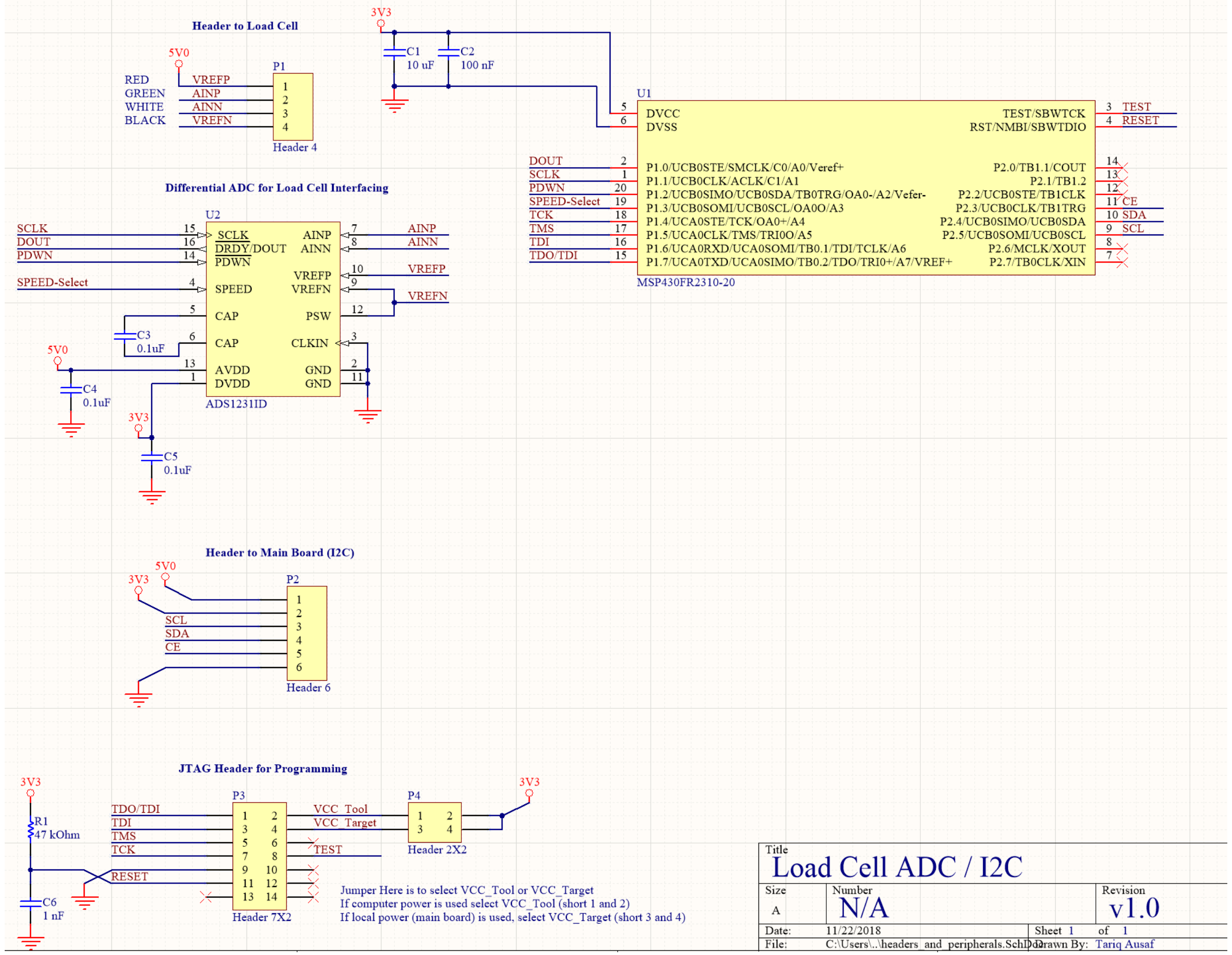




GPS MODULE + ONBOARD SENSORS

- GPS Similar to WMCU
  - Communicates at 1.582 GHz
  - 50 Ohm everywhere in communication routing lines
  - Frontend + Backend (entire ARM 3 processor)
  - 1PPS more precise than CC1352 – used to calibrate
  - NMEA GPS data output through UART – precise clock local time, location data…
- Humidity and Temperature
- Light Sensor (light level)
- Pressure Sensor
- 9-Axis Motion Sensor (IMU)

OFFBOARD SENSORS

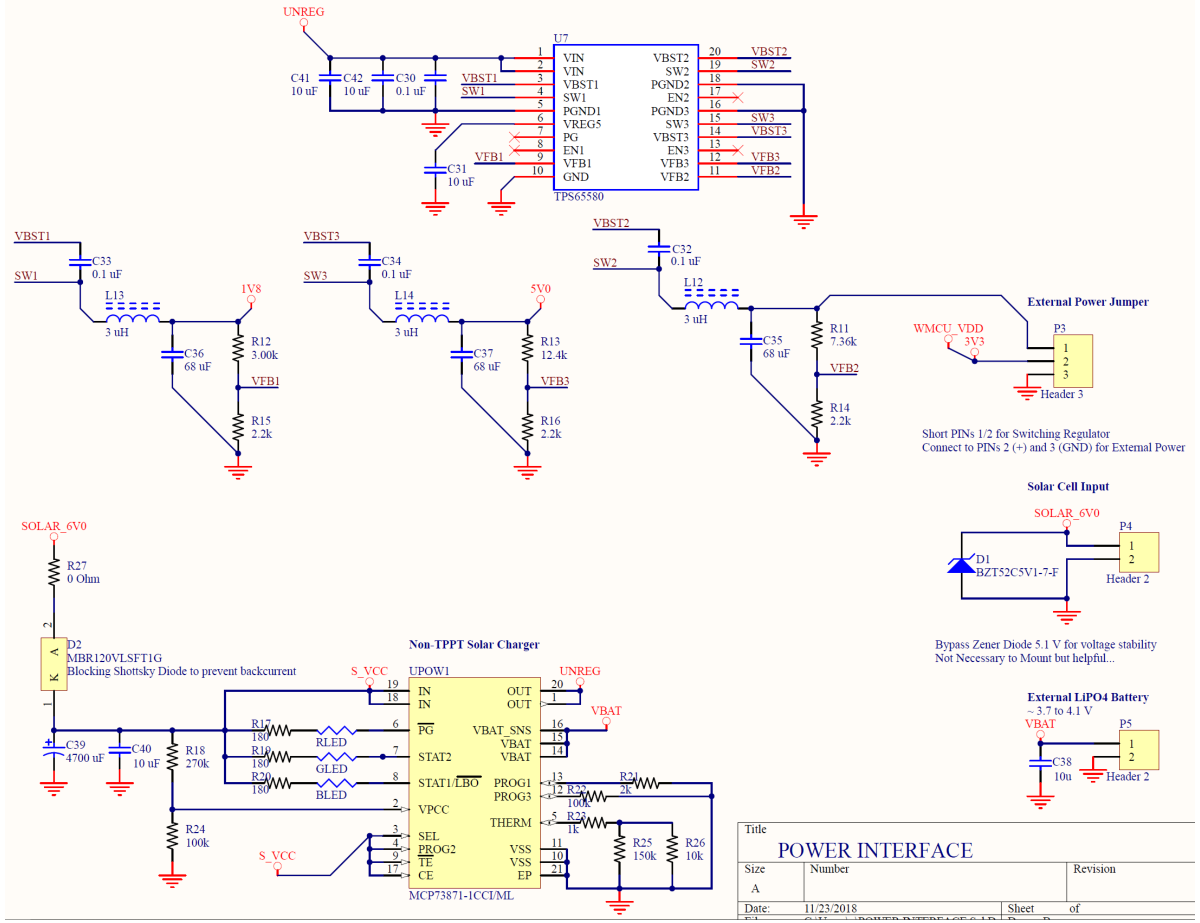


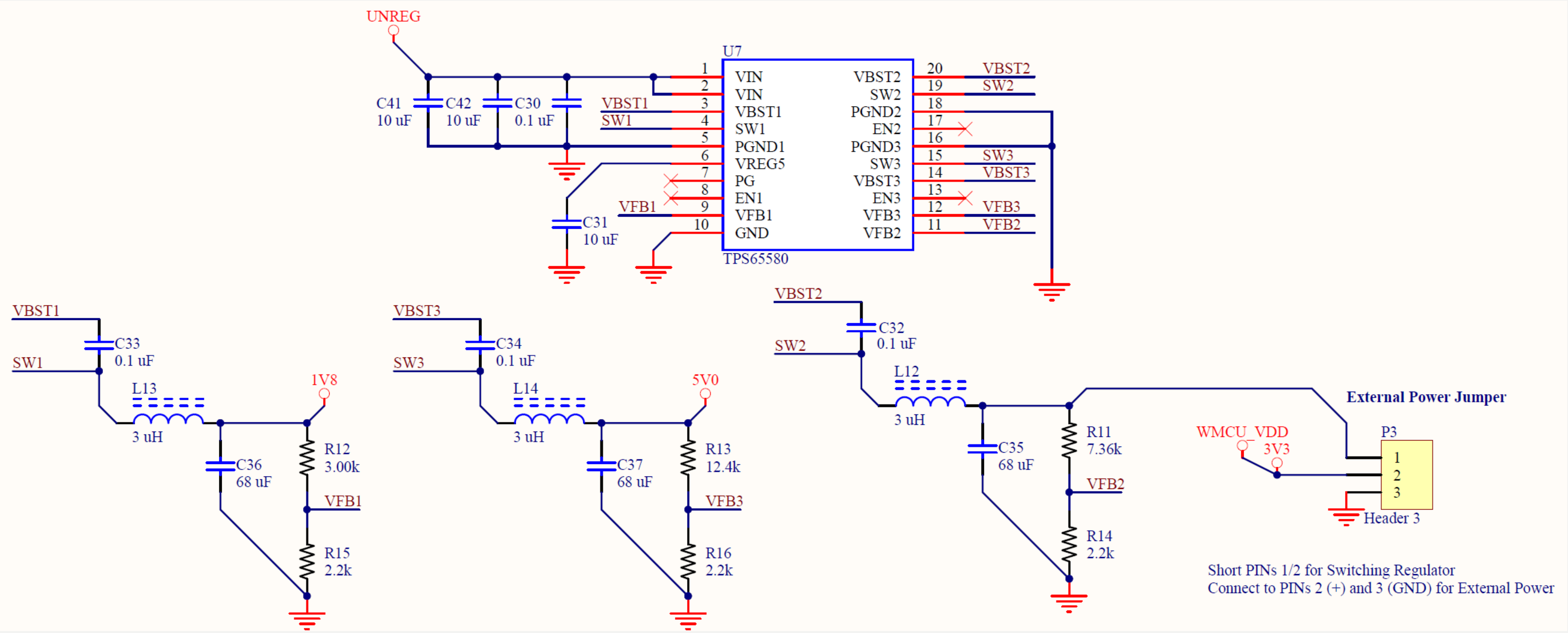
ONBOARD SENSORS

Sensor	Sensor Type	Price	Protocol	Operating Voltage	Temperature Range
MPU 9250	3-Axis Gyroscope, Acelerometer	$9.32/chip	I^2C and SPI	2.4 V to 3.6 V	-40°C to 85°C
LPS22HBTR	Pressure Sensor	$3.28/chip	I^2C and SPI	1.7 V to 3.6 V	-40°C to 85°C
OPT3001	Ambient Light Sensor	$3.35/chip	I^2C	1.6 v to 3.6 V	-40°C to 85°C
HDC2010	Humidity and Moisture Sensor	$3.35/chip	I^2C	1.62 V to 3.6 V	-40°C to 85°C

POWER

- Header P3 for 6V Solar Panel Input
- Solar LiPo Charger
  - Routes power from best power source available – always going to pull from solar before the battery
- Header P5 for external LiPo Battery
- Jumper Header to turn power on/off





TPS6580 VOLTAGE REGULATOR

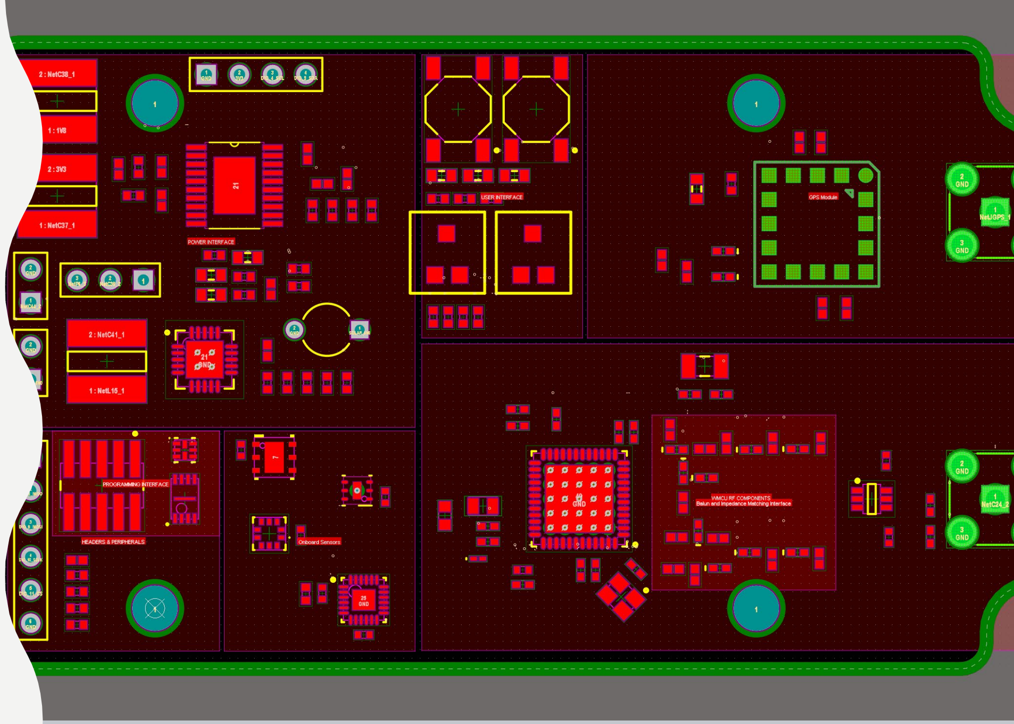
- Switching Voltage Regulator
  - Only Step-down needed
  - 30% or more efficient than comparable linear regulator w/ lower heat generation.
  - 3V3 for most everything
  - 1V8 and 5V0 are also available
  - No expensive DC/DC
  - Increased noise

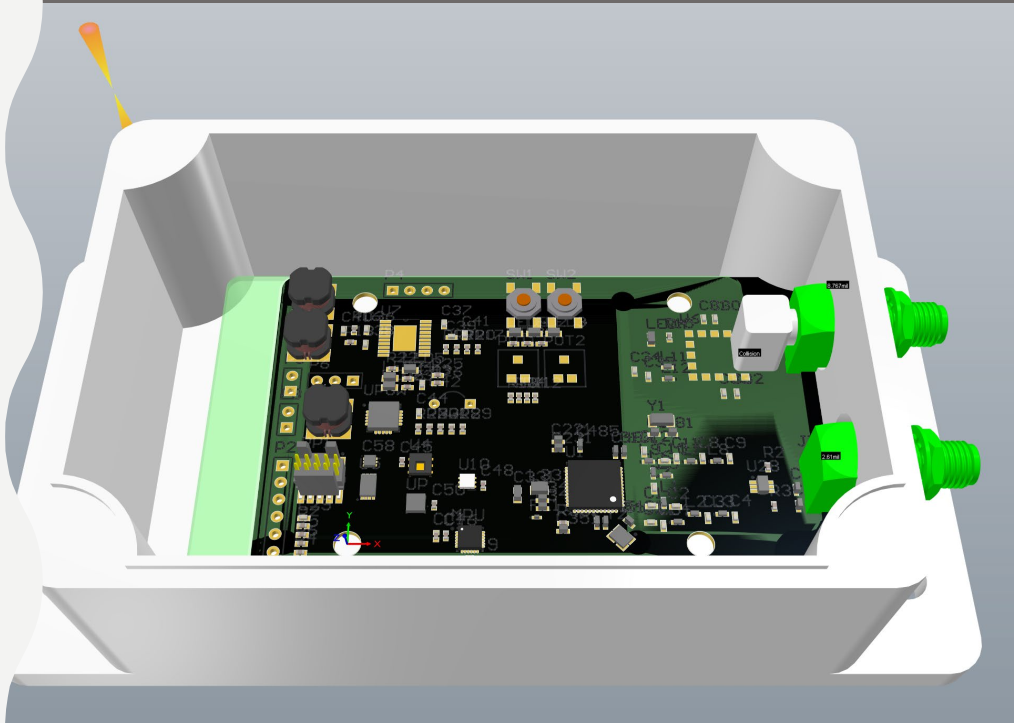
BATTERY

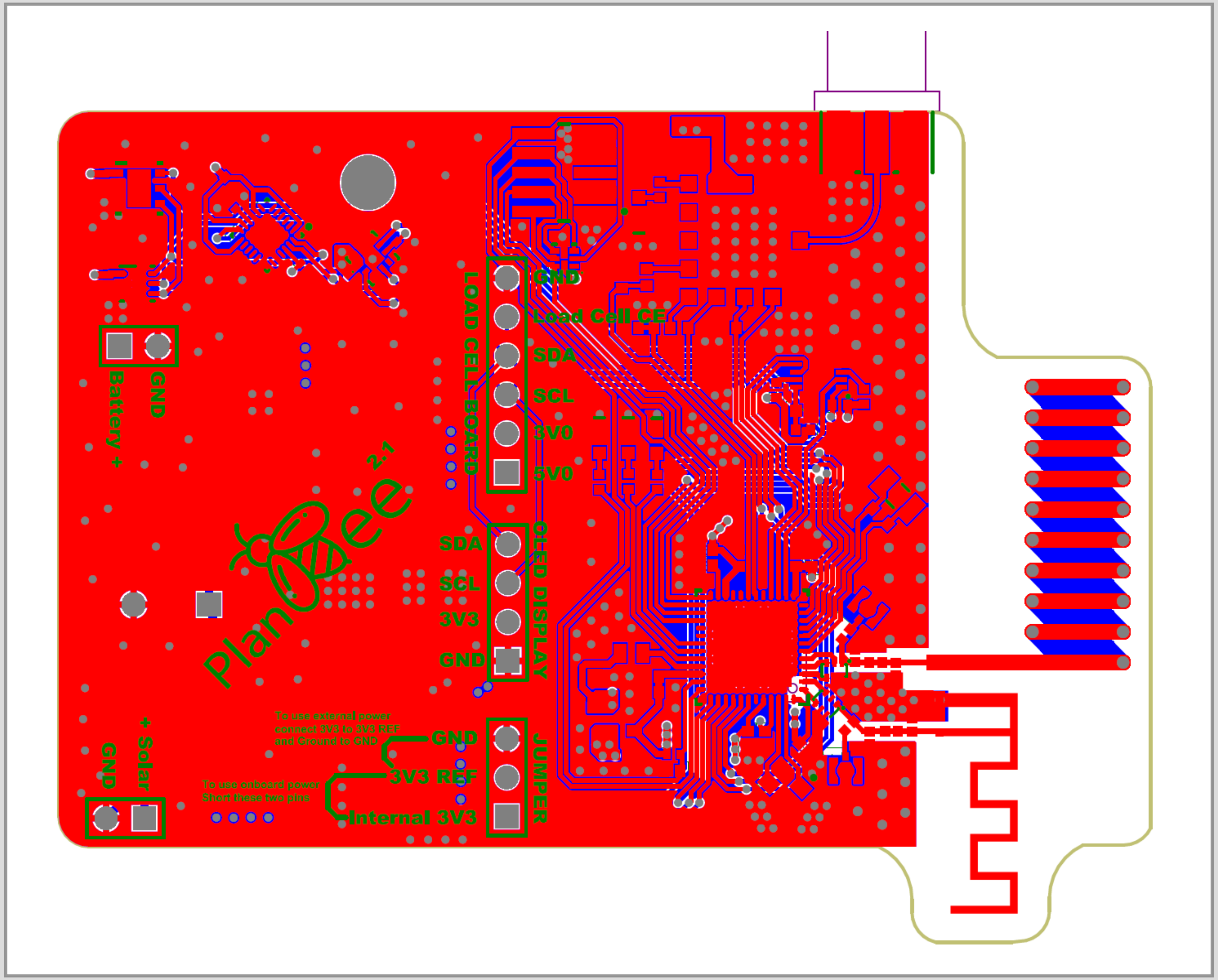
- Lithium polymer battery (LiPo).
- Four times the energy of density of nickel batteries.
- Higher current first for charge.
- More malleable and higher specific energy than regular Li Ion.
- Can be more expensive per volume.

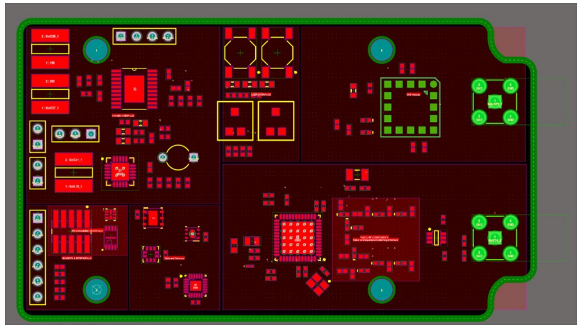
PCB LAYOUT

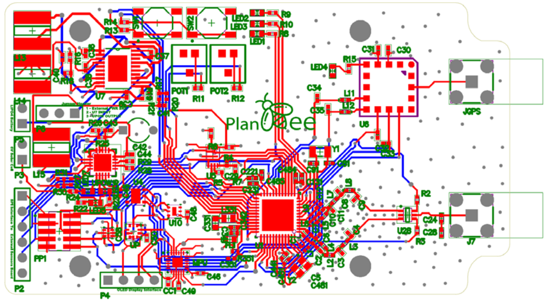
- GPS on the top-right, about 20 mm away from CC1352R1 below it – Balun and Imped. Match embedded
  - Routing to-and-from RF components is 12 mils thick Copper (50 Ohm trace Impedance, Max Power)
- Normal routing is 7 mils thick throughout the board
- User Interface Top-Center
- Onboard Sensors Bottom-Center
- Headers and Peripherals + XDS Debugging + Power all on far left (bottom-to-top)
  - Minimum 50 mm away from RF components
- 4 layer board
  - RF Component Routing (GPS and CC1352)
    - 15 mil thick dielectric
  - GND Plane
    - 50 mil thick dielectric between ground and power plane
  - Power Plane (vias from power components)
    - 15 mil thick dielectric
  - Routing for everything else
- Board is ready to manufacture!

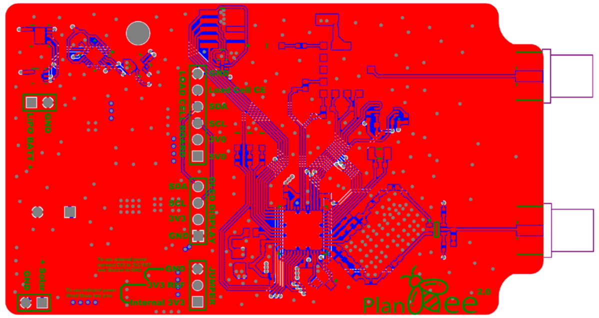





GND
Load Cell CE
SDA
SCL
5V0
5V0
LOAD CELL BOARD
SDA
SCL
3V3
GND
OLED DISPLAY
GND
3V3 REF
Internal 3V3
JUMPER
To use external power
connect 3V3 to 3V3 REF
and Ground to GND
To use onboard power
Short these two pins
GND
Battery +
GND
+ Solar
PlanBee
2.1







PCB MANUFACTURING EXECUTION

- PCB Manufactured:
  - Advanced PCB * ☹
    - 1.8V not connected on power plane
  - JLCPCB – Shenzhen, China
- We have purchased a Solder Dispenser and PCB Oven (Infrared IC Heater) for soldering
  - We have a PCB oven at UCF, but unusable
  - Soldering Gun + Solder Flux for any touchups
- Placement we have done ourselves
  - 138 components in total on the PCB
  - Diode array short
    - Pads were spaced only 20 microns apart

SOFTWARE

Transponder Firmware

Samples Sensor Data

Stores Sensor Data

Transmits Data to Gateway

Manage Device Parameters

SOFTWARE ORGANIZATION

Additional Resources Utilizes:

Texas Instruments RTOS

Language :

Assembly, C, C++

Gateway Firmware

- Stores Data to local Database
- Transmits Data to an online server
- Manages Transponder Devices
- Transmits Data to local user.

SOFTWARE ORGANIZATION

Additional Resources Utilizes:

Linux

SQLite

TI's 15-4 network Stack

XMPP, HTTPS

Language :

C, C++, Python(Automate)

Web Service

- Authenticates and Communicate with Gateway Device
- Stores Data on Online Database
- Provides is RESTful api for accessing Data

SOFTWARE ORGANIZATION

Additional Resources Utilizes:

Amazon AWS

MySQL

Bootstrap

XMPP/HTTPs

Language :

Golang, Json, JavaScript,

User Application

- Present Data to End User
- Alert User of Events
- Synchronizes Data with Gateway and Cloud Service

SOFTWARE ORGANIZATION

Additional Resources Utilizes:

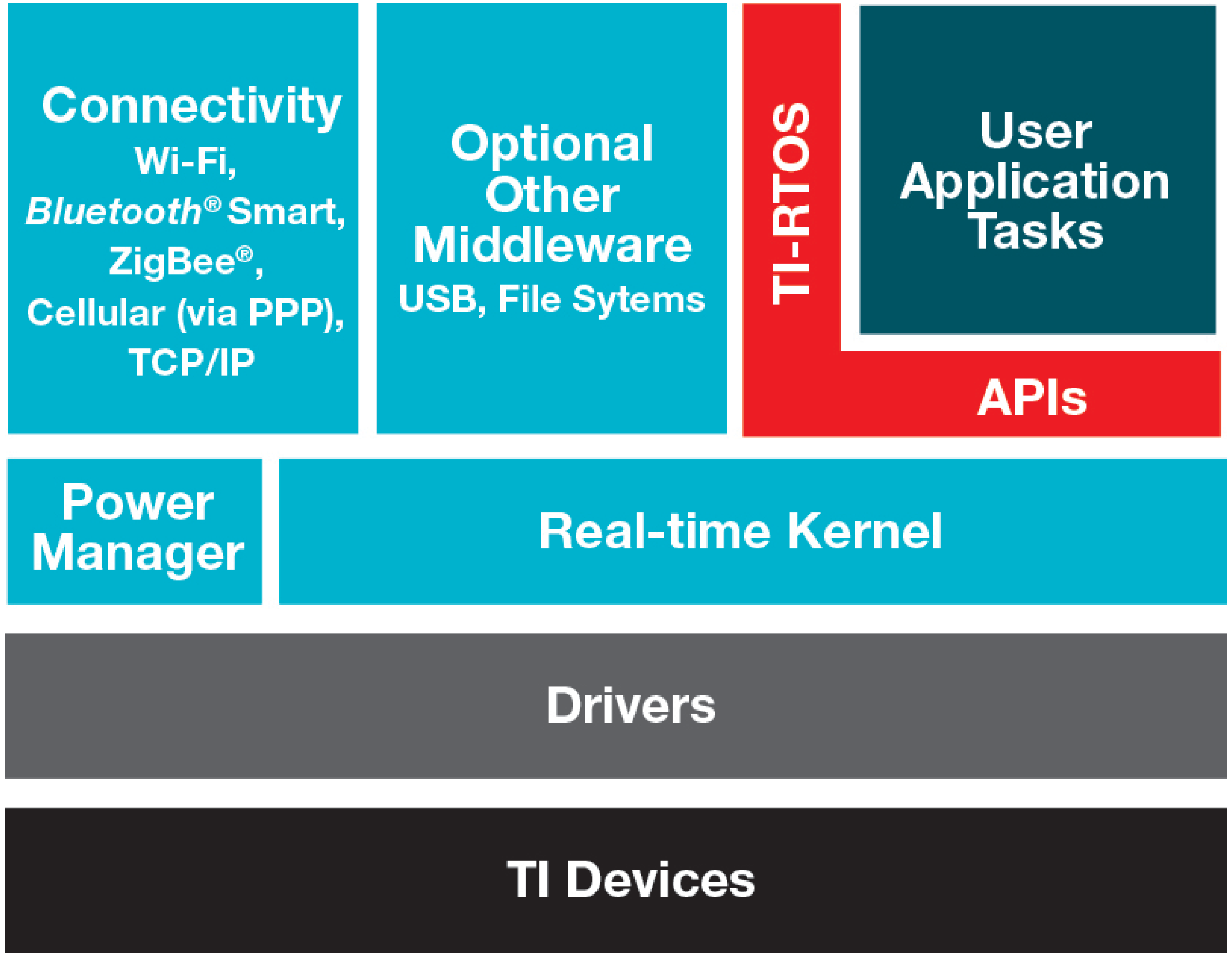
Android

SQLite

Language :

Java

TRANSPONDER FIRMWARE



TI-RTOS

Multi-Tasks OS

Task Preemption

Hardware Interrupts

Software Interrupts

Task Preemption

Concurrency Control

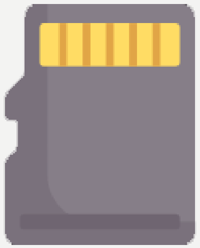
FIRMWARE ORGANIZATION

The 3 D's

Data Sampler

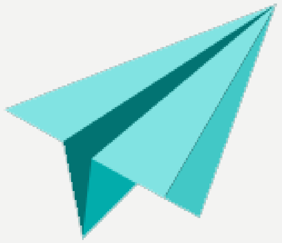
Temperature
Gyroscope
Accelerometer
Compass
Ambient Light
Humidity
Pressure

Data Aggregator



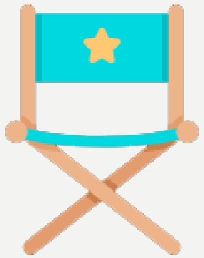
Processing
Timestamp
Identifier
Storage
Maintain

Data Dispatcher



Connects
Encrypts
Transmits
Validates

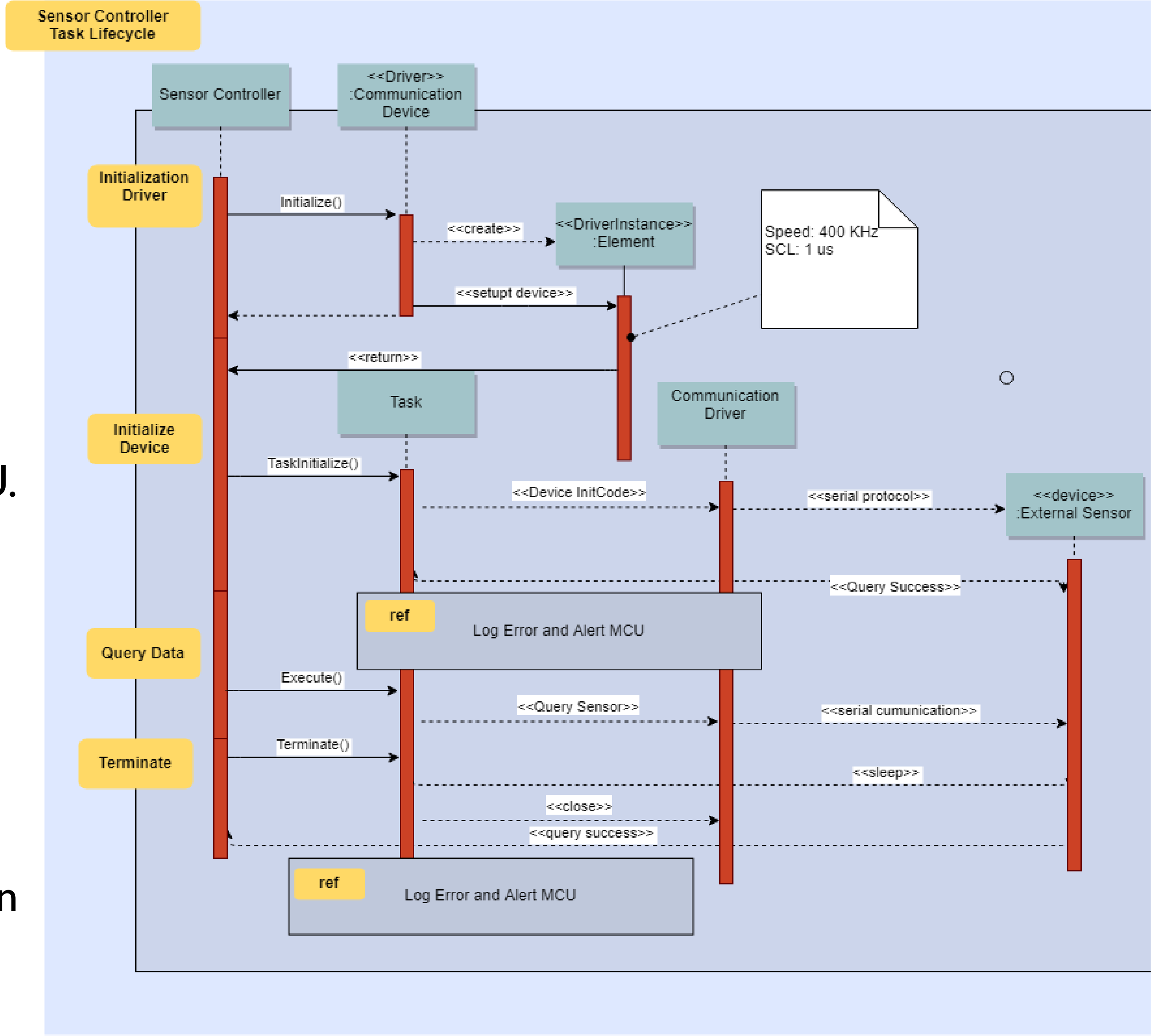
System Director



Configures
Delegates
Authenticates
Synchronizes
Alerts

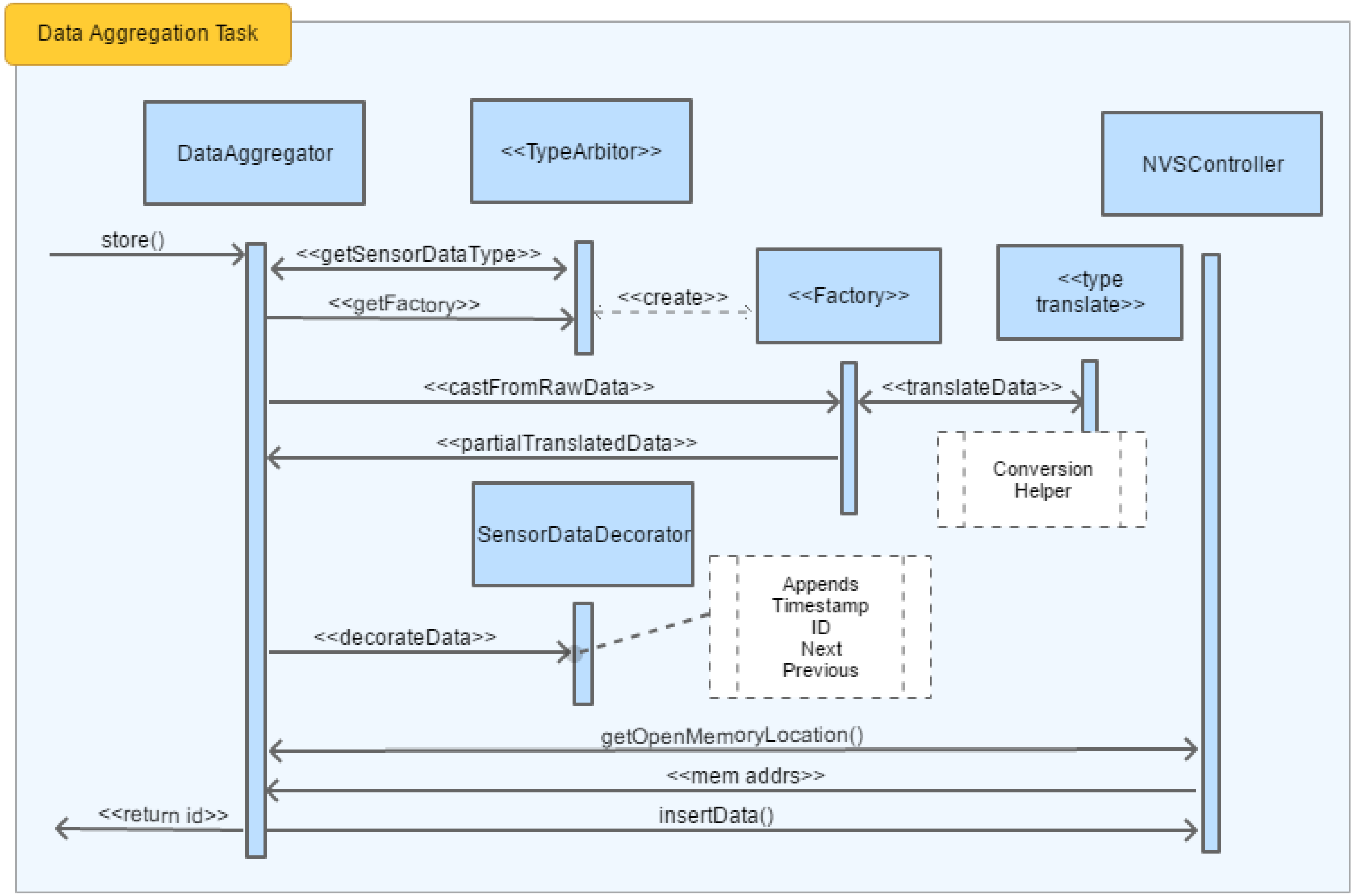
DATA SAMPLER SEQUENCING DIAGRAM

- Executed using the on-bard low-powered ARM thumb processor, SCU.
- Triggered periodically using the onboard Real-Time-Clock.
- Utilizes standard I2C messaging protocol.
- Pushes data to a shared buffer and triggers a hardware interrupt for main processing unit.



Data Aggregation Sequence Diagram

- Executed on main processor.
- Triggered from hardware interrupt.
- Stores Data to Non-Volatile memory.
- Thread Safe (Semaphores).
- Blocking.



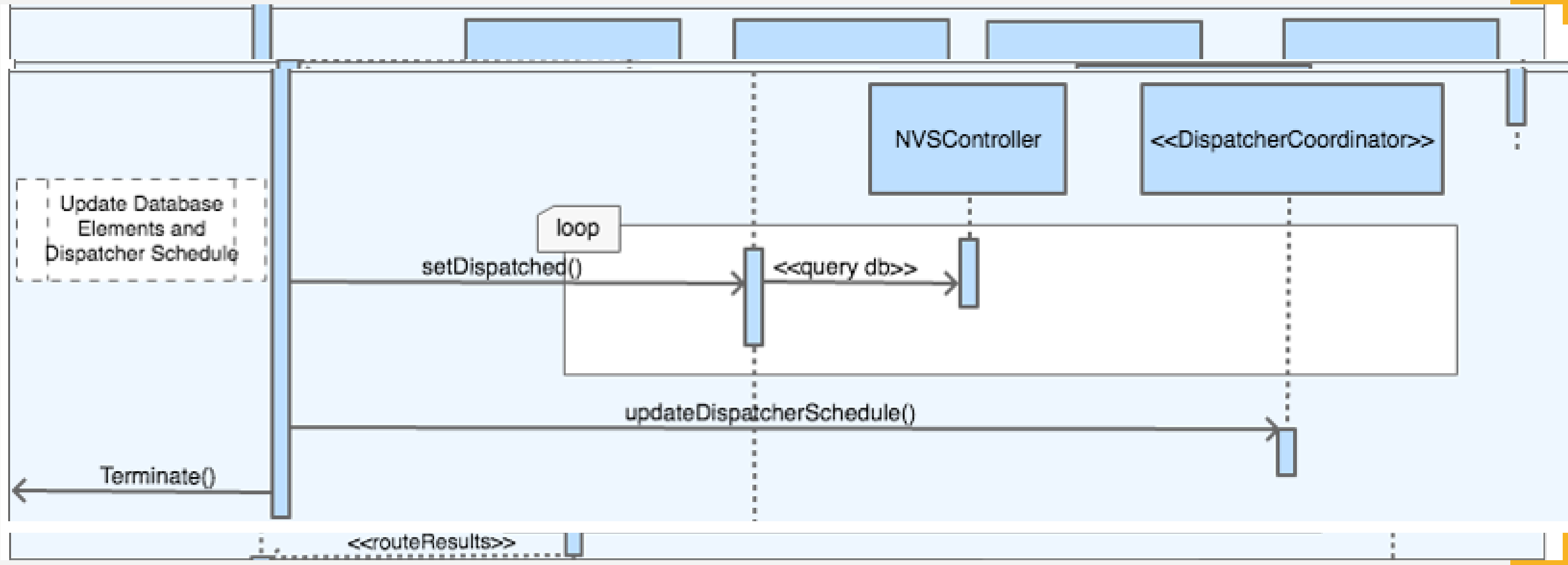
NVSCONTROLLER STRUCTURE

- Data is stored in of chip Non-volatile storage
- Each Sensor Data Type is assigned a 32 KB Block
- Pages Elements are written and read to local memory using 256 byte buffers (page).
- Entire Datastore utilizes round buffers for storage.

<table>
<tr><th>Block (64KB)</th><th>Block (32KB)</th><th>Sector (4KB)</th><th colspan="2">Address Range</th></tr>
<tr><td rowspan="3">15</td><td rowspan="3">31
|
30</td><td>255</td><td>0FF000h</td><td>0FFFFFh</td></tr>
<tr><td>:</td><td>:</td><td>:</td></tr>
<tr><td>240</td><td>0F0000h</td><td>0F0FFFh</td></tr>
<tr><td rowspan="3">14</td><td rowspan="3">29
|
28</td><td>239</td><td>0EF000h</td><td>0EFFFFh</td></tr>
<tr><td>:</td><td>:</td><td>:</td></tr>
<tr><td>224</td><td>0E0000h</td><td>0E0FFFh</td></tr>
<tr><td rowspan="3">4</td><td rowspan="3">9
|
8</td><td>79</td><td>04F000h</td><td>04FFFFh</td></tr>
<tr><td>:</td><td>:</td><td>:</td></tr>
<tr><td>64</td><td>040000h</td><td>040FFFh</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">7
|
6</td><td>63</td><td>03F000h</td><td>03FFFFh</td></tr>
<tr><td>:</td><td>:</td><td>:</td></tr>
<tr><td>48</td><td>030000h</td><td>030FFFh</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">5
|
4</td><td>47</td><td>02F000h</td><td>02FFFFh</td></tr>
<tr><td>:</td><td>:</td><td>:</td></tr>
<tr><td>32</td><td>020000h</td><td>020FFFh</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">3
|
2</td><td>31</td><td>01F000h</td><td>01FFFFh</td></tr>
<tr><td>:</td><td>:</td><td>:</td></tr>
<tr><td>16</td><td>010000h</td><td>010FFFh</td></tr>
<tr><td rowspan="5">0</td><td rowspan="5">1
|
0</td><td>15</td><td>00F000h</td><td>00FFFFh</td></tr>
<tr><td>:</td><td>:</td><td>:</td></tr>
<tr><td>2</td><td>002000h</td><td>002FFFh</td></tr>
<tr><td>1</td><td>001000h</td><td>001FFFh</td></tr>
<tr><td>0</td><td>000000h</td><td>000FFFh</td></tr>
</table>

Data Dispatcher Sequence Diagram

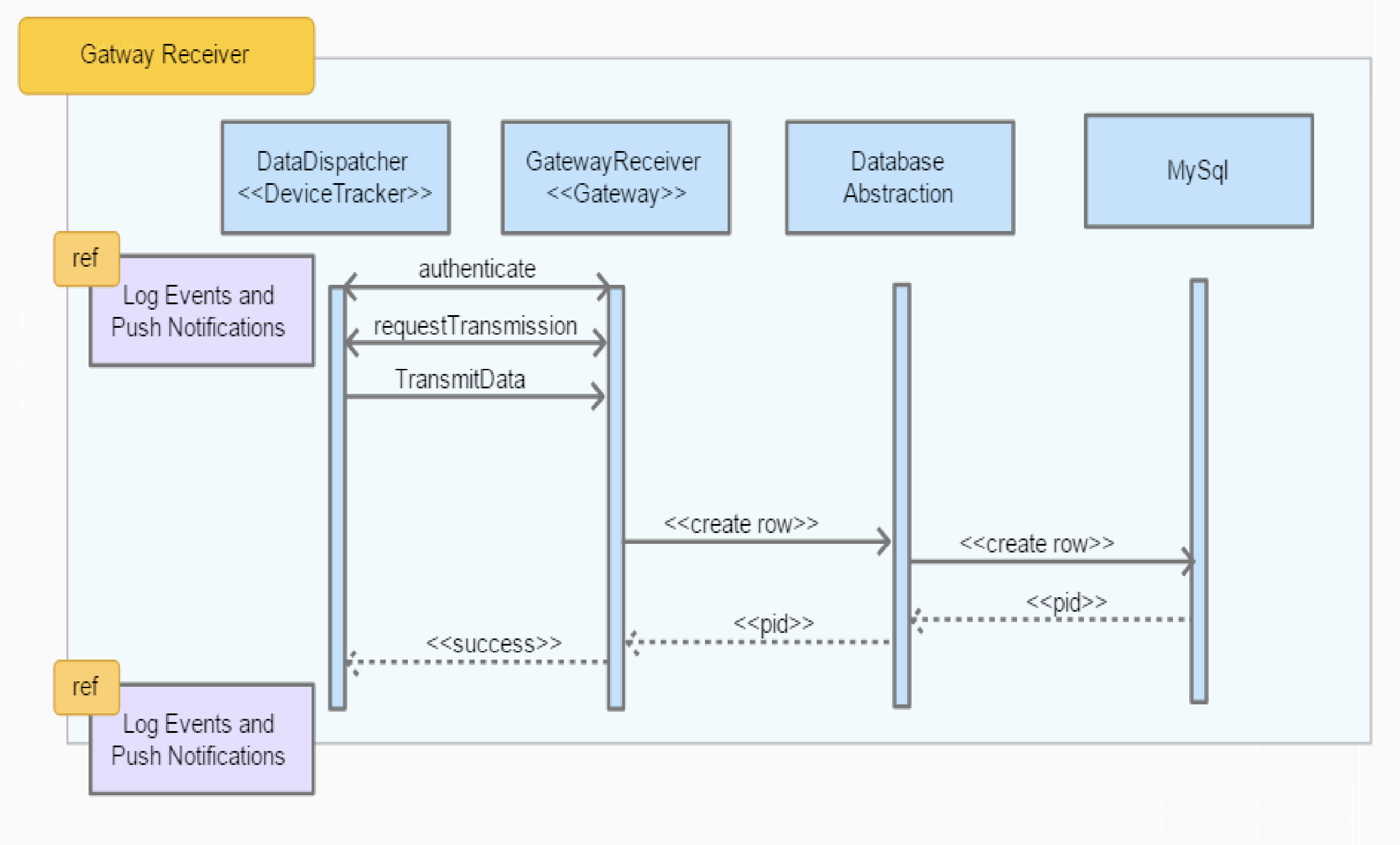
- Periodically Executed on main processor using RTC.
- Transmits data to gateway.
- Thread Safe (Semaphores).



GATEWAY FIRMWARE

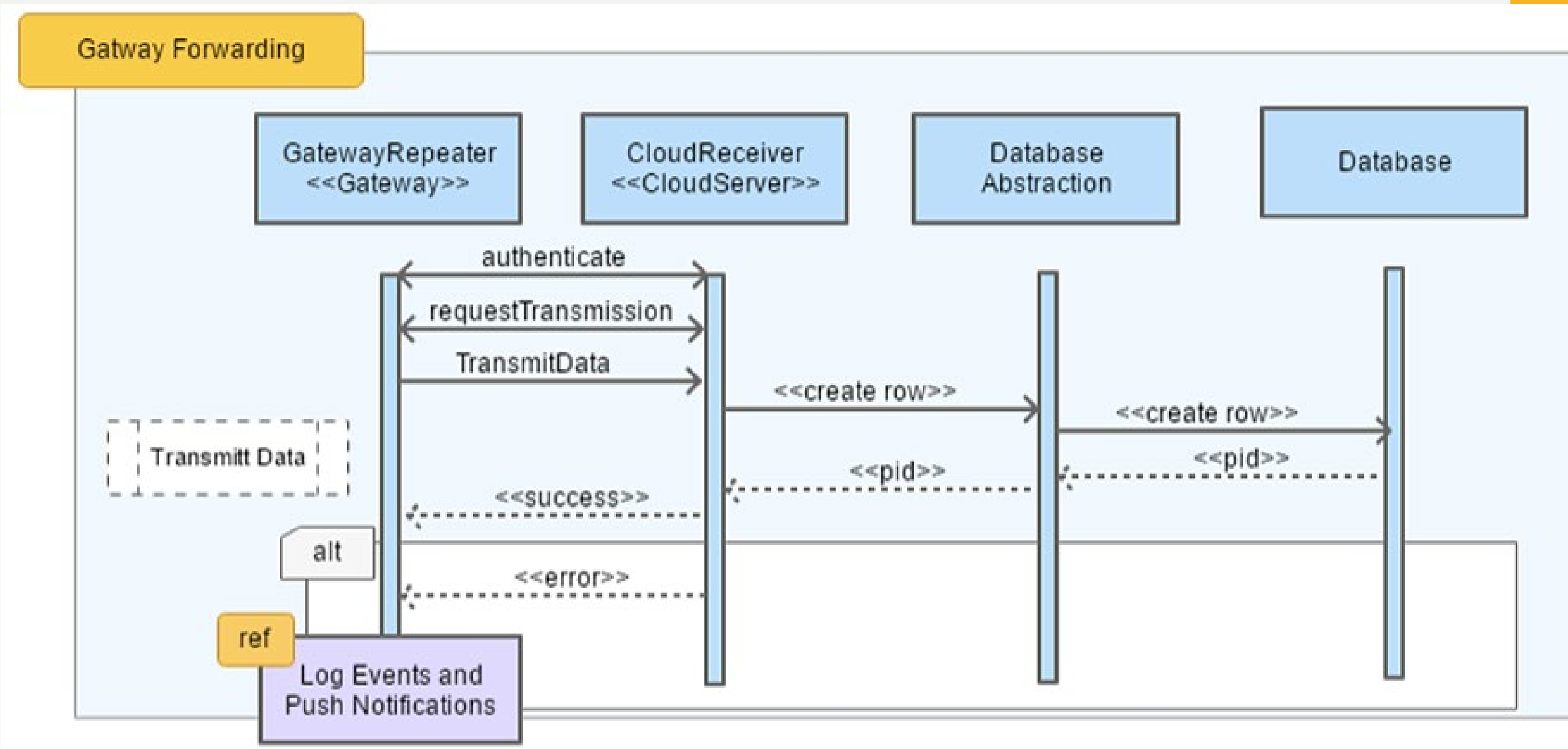
Gateway Receiver Sequence Diagram

- Authenticates transponder device using 256-bit AES encryption key.
- Private key stored on encrypted portion of device.
- Provides primitive network addressing for transponder devices.
- Stores data to local SQLite database.

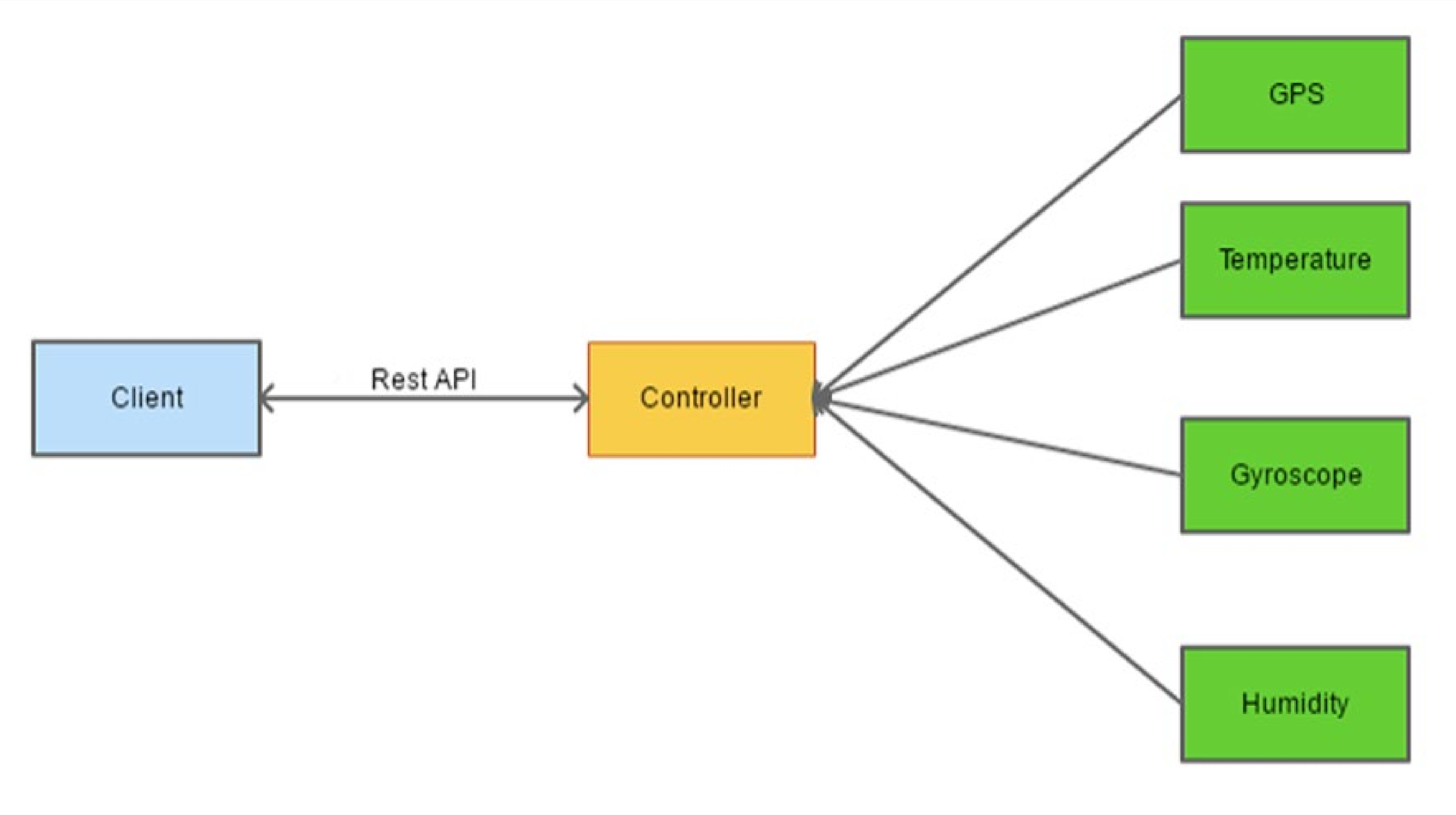


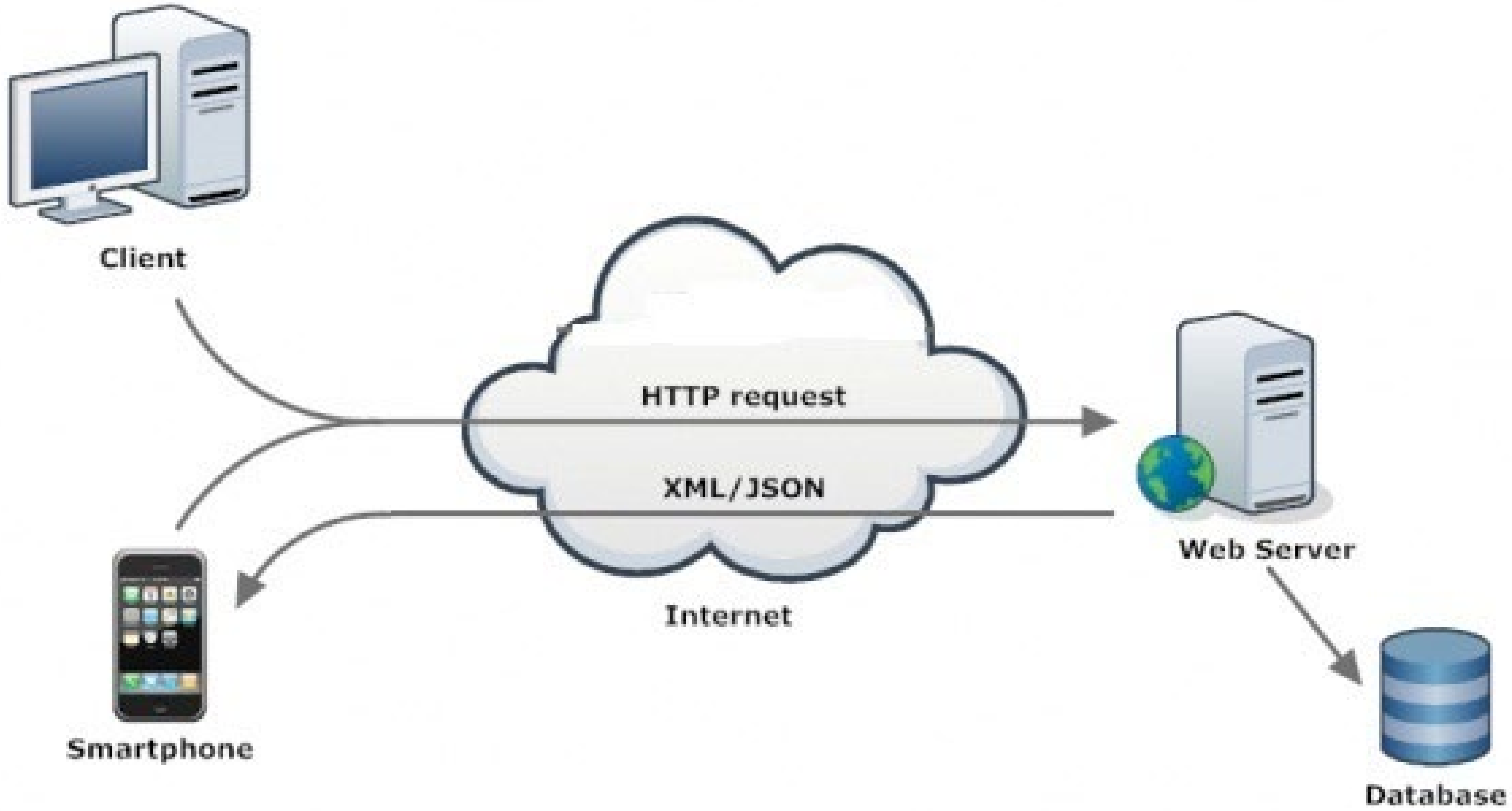
Gateway Forwarding Sequence Diagram

- Authenticates with web service or a nearby mobile device.
- Pushes data using GCM/XMPP protocol.



WEB SERVICE

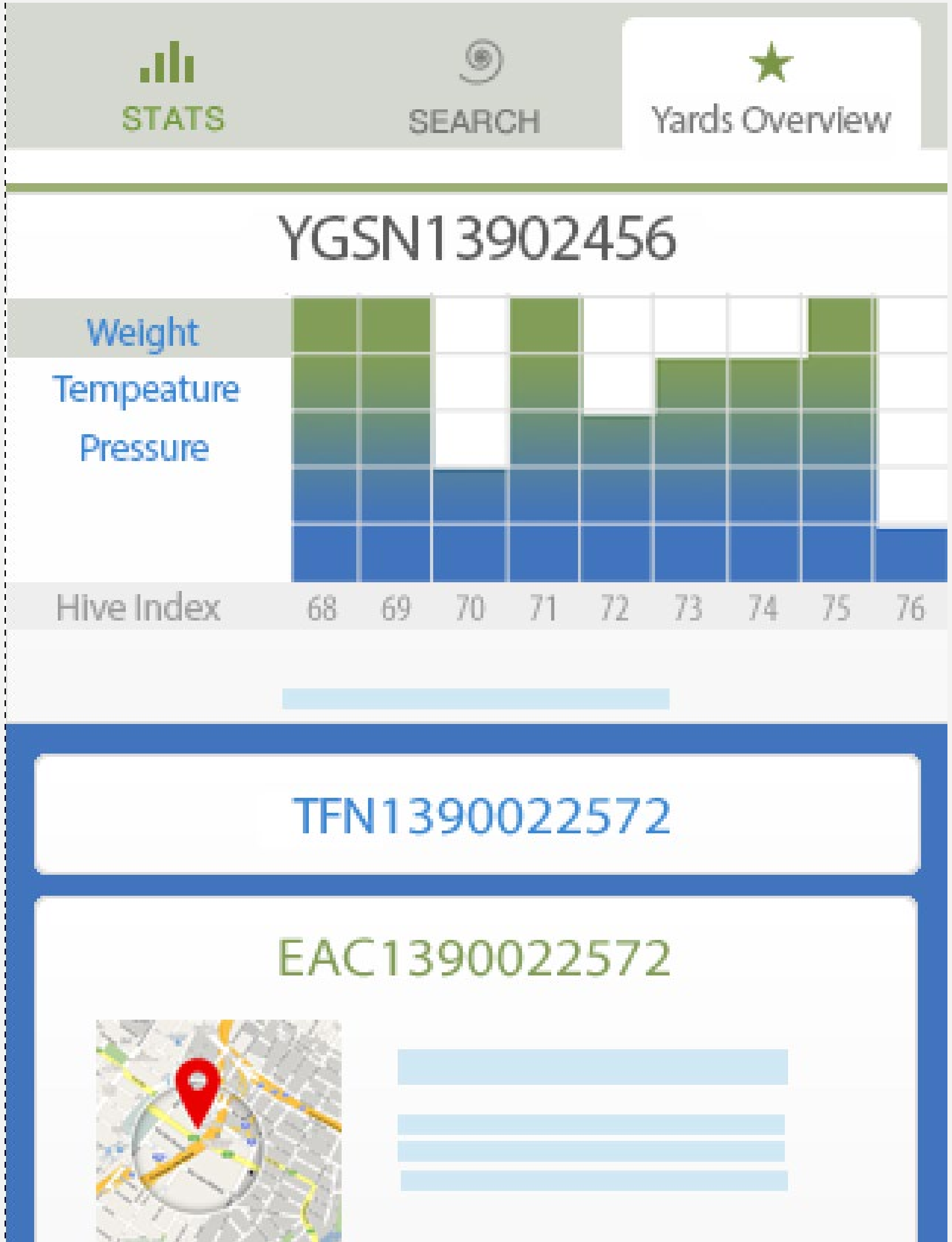

Client
Rest API
Controller
GPS
Temperature
Gyroscope
Humidity



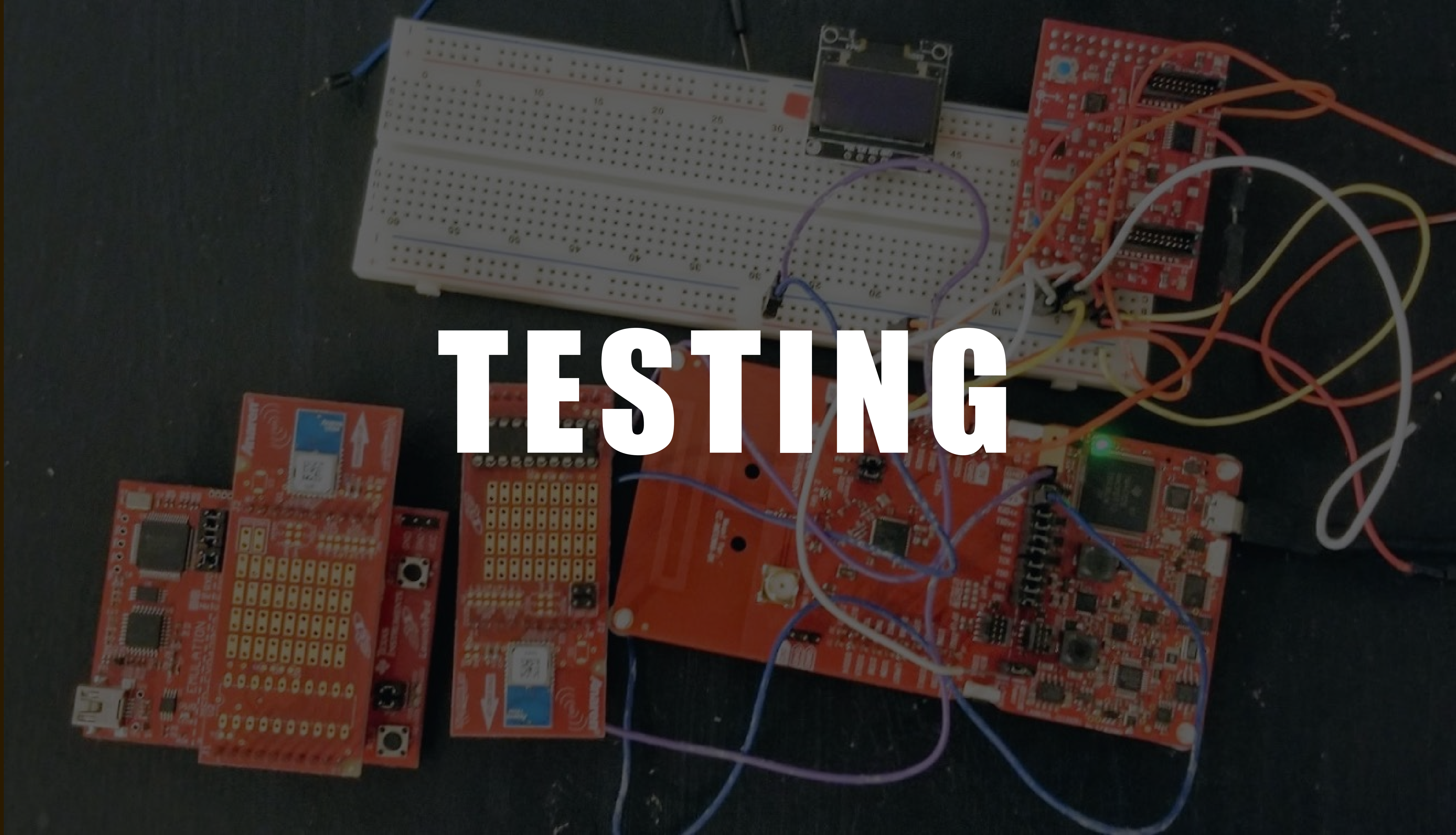
Rest WebService

USER APPLICATION

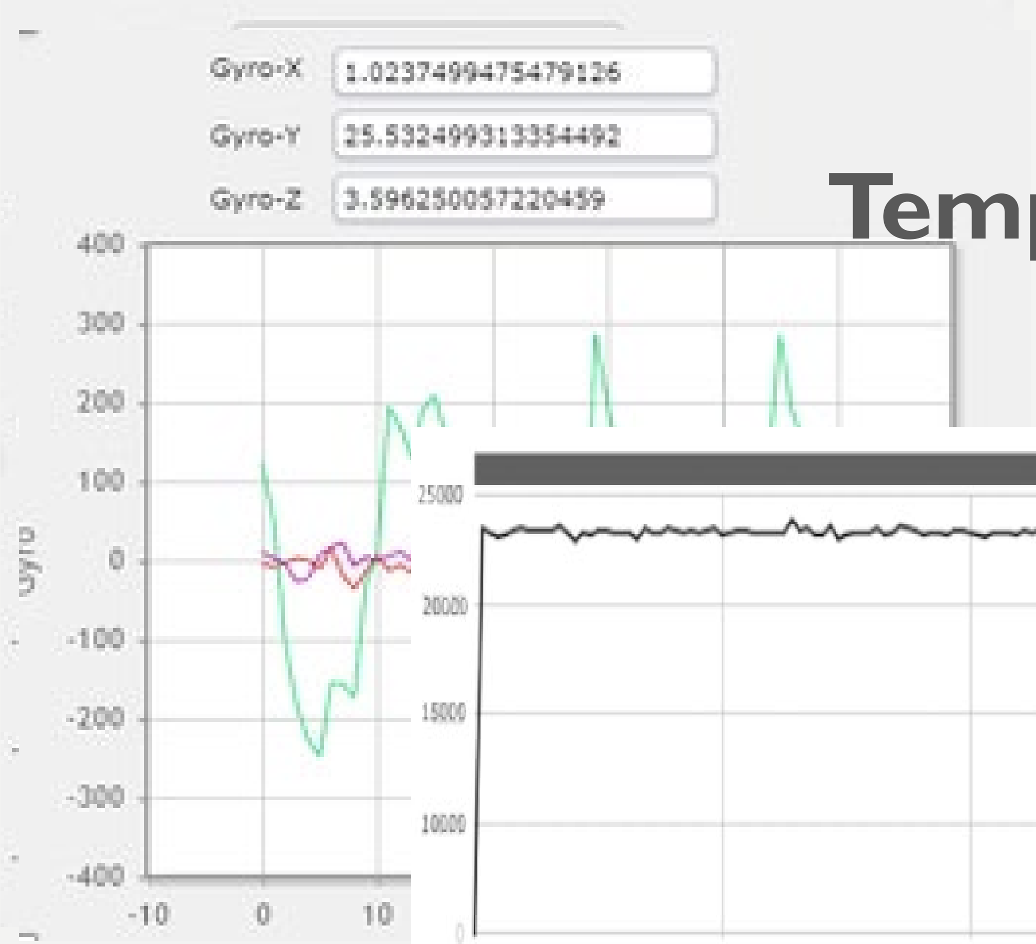
- Read data from gateway and synchronizes with cloud.
- Presents data in an intuitive fashion.



TESTING



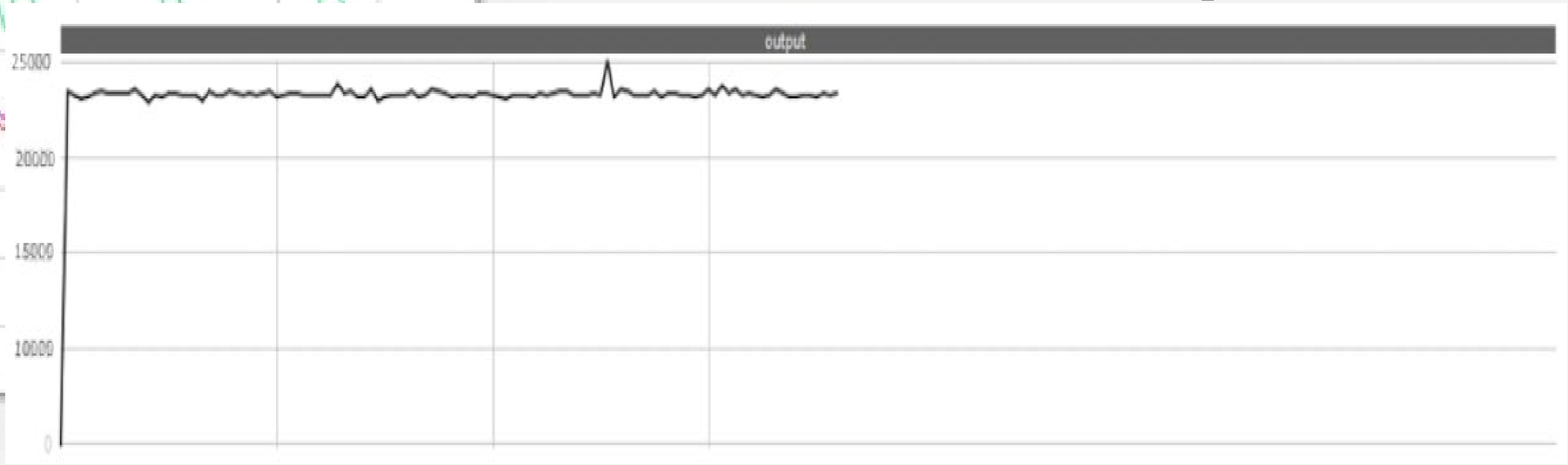
SENSOR TESTING



Temperature

Accelerometer

Gyroscope



START POINT: 2nd Floor of Yannick's House;

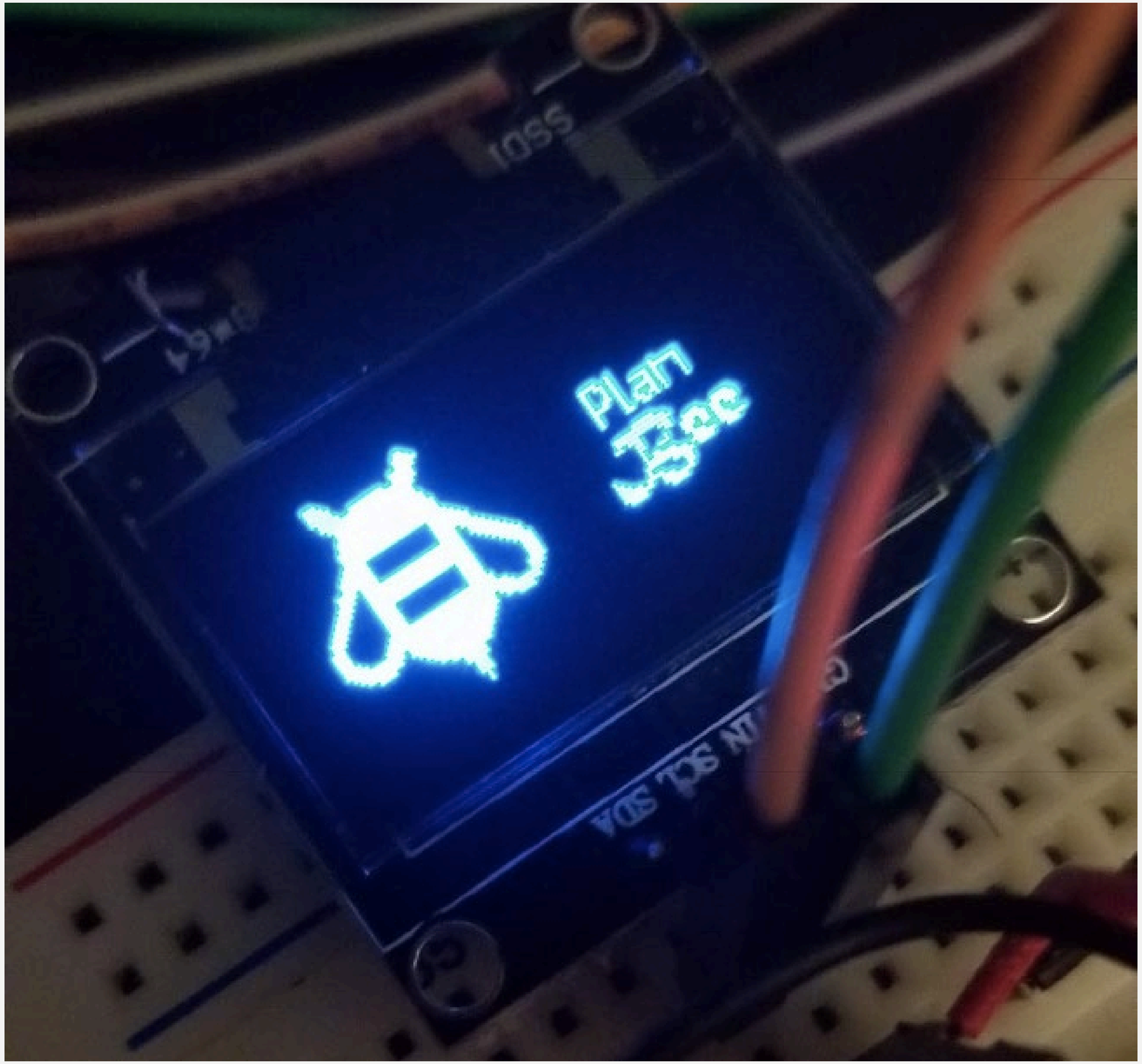
END: **823 m away**

WIRELESS COMMUNICATION TESTING

- Transmit the string "Hello UCF" across sub 1-GHz connection.
- We were able to communicate across approximately 500 meters.
- We're expecting to achieve data transfer rates of approximately 100 bytes per second.
- Hives are expected to transmit, on average, 80 bytes per hour.

FURTHER TESTING

- Driver for display has been developed and working. It is able to output texts and binary images.
- Busses are debugged for accuracy using an oscilloscope and logic analyzer.



SOFTWARE UNIT TESTING

- The firmware code is currently being unit tested using Google Testing suite.
- Attempting a test driven development routine where unit tests are written prior to application code.

BUDGET

INITIALLY PROJECTED BUDGET

We knew we would run into unexpected costs, and we have. Luckily, we planned for all of this:

- Power Components
- Hardware Prototyping
- Hardware Manufacturing / Fabrication Processes in-house
- Software Setup and Application Hosting
- Miscellaneous Costs…

Type	Item/Description	Supplier	Part No.	Unit(s)	Projected EPU ($) *	Projected Exp. ($) *
Power	Solar Cells (6.2 W)	Adafruit	1525	3	75.00	225.00
	High Efficiency Synchronous Switch Mode Charger	TI	BQ24650	3	20.00	60.00
	$LiFePO_4$ Batteries (1000 mAh)	Westinghouse	N/A	3	25.00	75.00
	Solar Panel Mount	Renology	N/A	2	15.00	30.00
	** Miscellaneous Solar Costs					150.00
Hardware Prototyping	Microcontroller including RF Comms Chip	TI	MCU: MSP-EXP430G2 Comm Chip: CC1300x RF	2	120.00	240.00
	Sensors Kit for MSP430 MCUs	TI	Multiple	2	35.00	70.00
	Single-Strand 22 Ga. Copper Wire for ICs	N/A	N/A	100 feet	0.55	55.00
	Varied Basic Electronic Components Kit (Rs, Caps, MOS, Diodes, Op Amps, etc.)	N/A	N/A	4	15.00	60.00
	**Miscellaneous Hardware Prototyping Costs					200.00
Hardware Fabrication	PCB Fabrication Stage 1	Altium	N/A	2	30.00	60.00
	PCB Fabrication Stage 2	Altium	N/A	2	30.00	60.00
	RF Comm. Chips	TI	CC1352R	4	25.00	100.00
	MCU Chips	TI	MSP432	4	12.00	48.00
	**Sensors Costs & Miscellaneous Hardware Fabrication Costs					200.00
Software Setup	Amazon AWS Server	N/A	N/A	1	0.00	0.00
	IBM Watson AI Usage	N/A	N/A	1	0.00	0.00
	Application (Dashboard) Development	N/A	N/A	1	0.00	0.00
	** Software Hosting & Miscellaneous Development Costs					375.00
Miscellaneous	Final PCB Packaging	N/A	N/A	2	20.00	40.00
	Weatherproofing Enclosure	N/A	N/A	2	30.00	60.00
	Total Projected Cost					2158.00

FURTHER NOTES

- We have spent about $1500 (of our original $2200 budget)
- We had a few unaccounted items that we had forgotten to include in the original budget:
  - PCB oven
  - Soldering paste dispenser
  - GPS Modules
  - Several thousand SMD components…

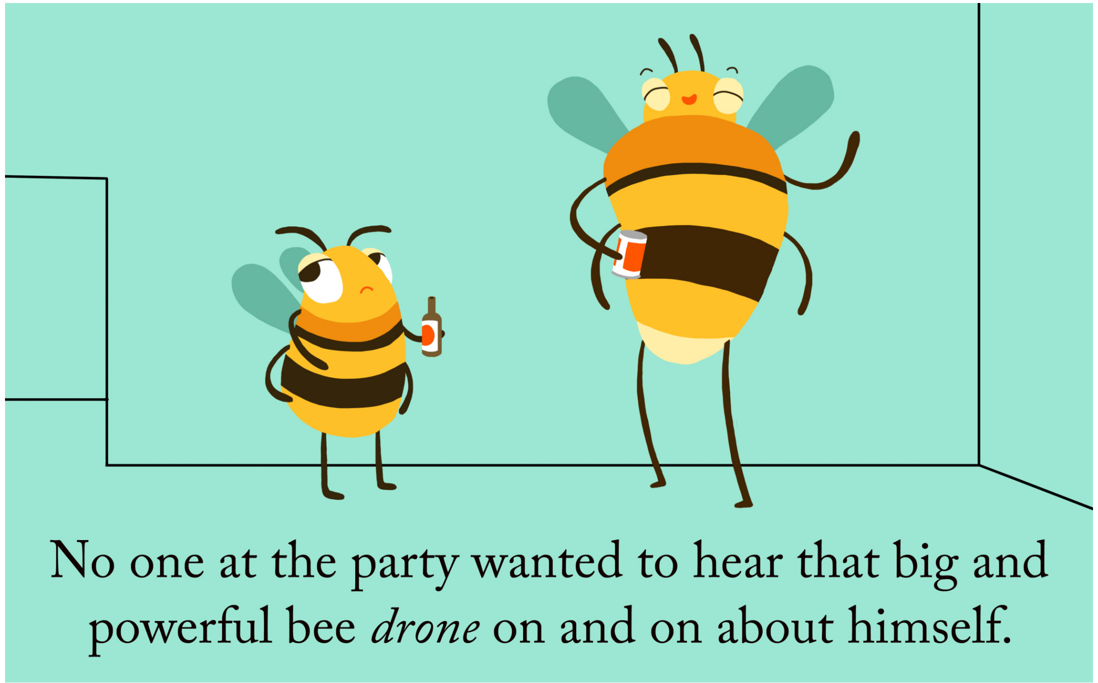
STRETCH GOALS

STRETCH GOALS

- Camera (on Gateway)
- External sensors Interface
  - Placement inside the hive is important
  - Weight sensors (load cells)
  - Vibration sensors – density to replace load cells + machine learning
  - Additional Sensors
    - Temperature sensor inside hive
    - Humidity
    - Rainfall data
    - Medication + Food sensors + Control System (dispenser)
- Meshing Devices
- GSM Radio
- GPS replaced with GPS-frontend-reciever + Software Defined Radio ($3 frontend + software versus $30 module) – make the device as inexpensive as possible

DRONES? BECAUSE WHY NOT!!!

- Autonomous drones for land surveying.
- Camera sensors



THANKS TO OUR SPONSORS

Pollination,Us Inc.

Steven Eisele: Owner

QUESTIONS

IS THIS WHAT ALL THE **BUZZ** IS ABOUT?!