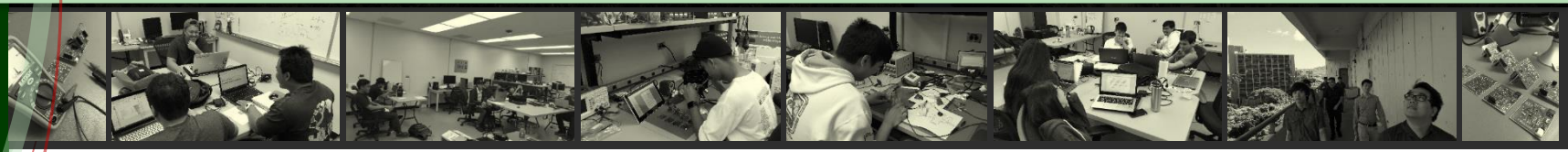
Cranberry Team

Experimental Weatherbox Platform – Generation 3



Smart Campus Energy Lab (SCEL)
Renewable Energy & Island Sustainability (REIS)
University of Hawai´i at Mānoa
Department of Electrical Engineering

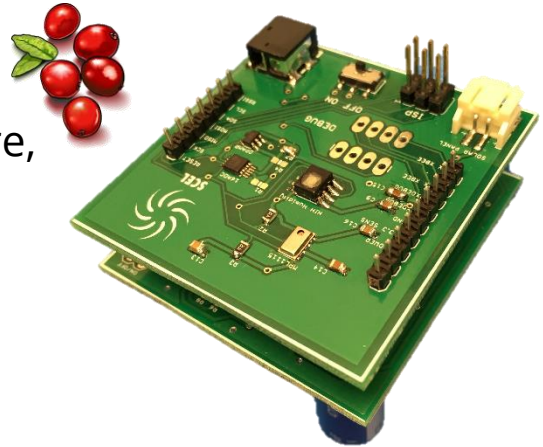
EE496 Final Presentation
December 5th, 2015
Advisor: Dr. Anthony Kuh

Brandon S. Amano
Kim Pee P. Castro

Presentation Overview

Cranberry - Weatherbox Platform

Weather Sensor Module - Measures barometric pressure, humidity, temperature, and luminosity.



- Motivation and Goals
- Overall Hardware Block Diagram
- Team Approach and Procedure
- Hardware Module and EAGLE Design Status
- Bill of Materials (BOM) and Power Budget
- Remaining Tasks and End-Goals

Motivation and Goals

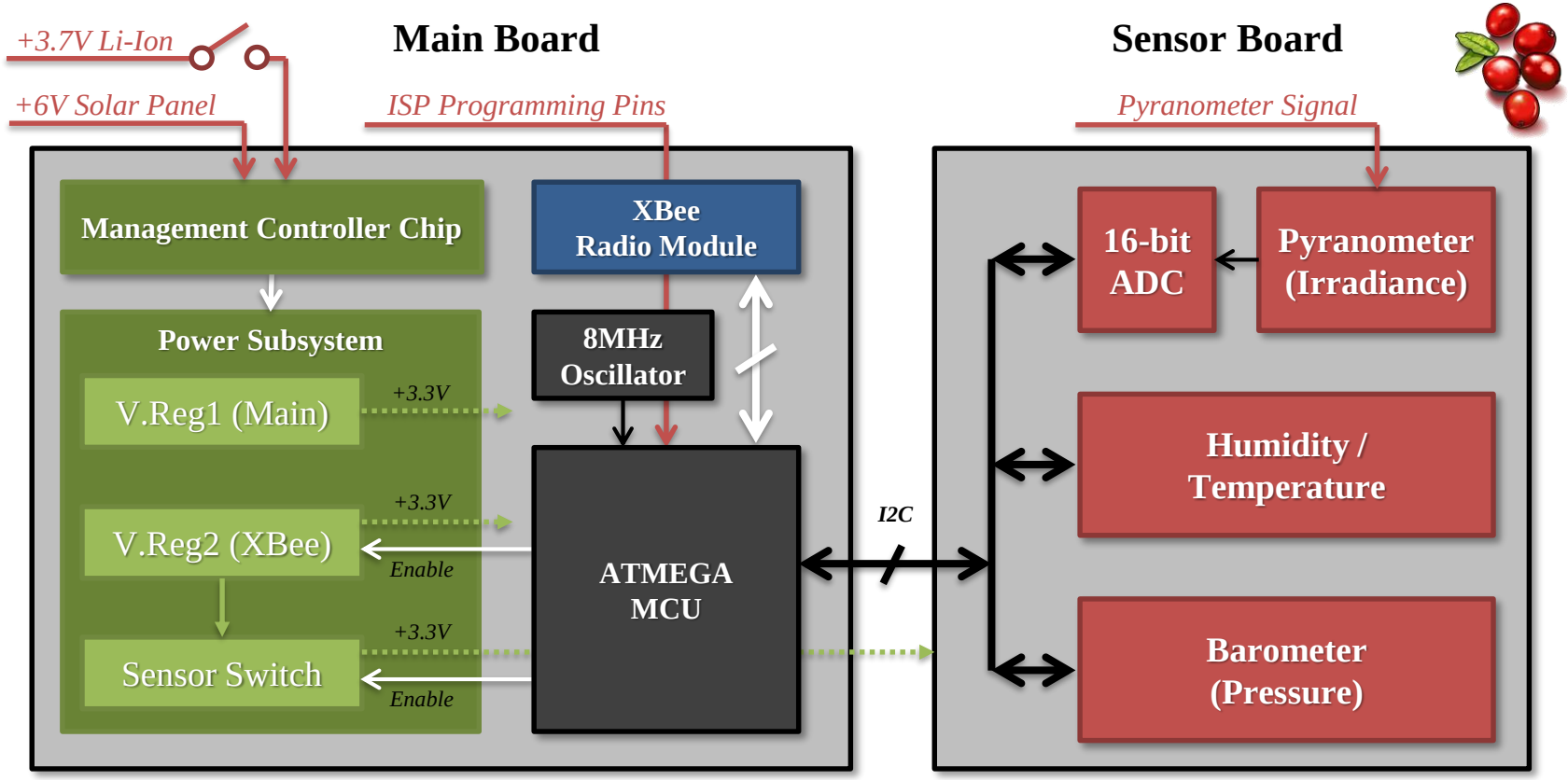
Motivation

- Understand more about renewable energy related fields
- Apply engineering and design skills and use of relevant tools

Goals

- Update *Cranberry* Documentation
- *Version 1*: Troubleshoot problems with original design to produce an operational board
- *Version 2*: Improve upon *Cranberry* board layout and implement personal design preferences

Hardware Block Diagram

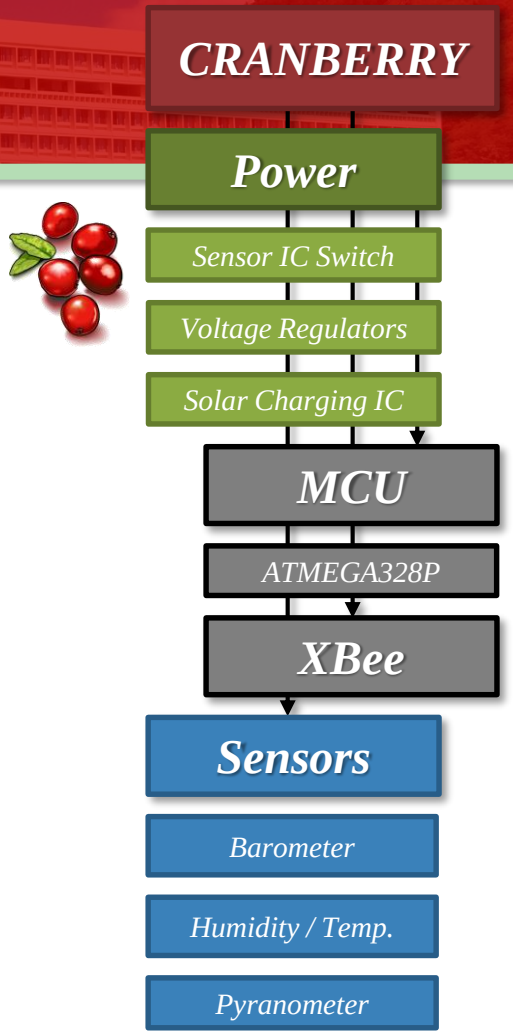


Testing Procedure

Incremental Approach – For each module:

- Verify schematics from datasheet to EAGLE layout.
- Solder on appropriate components.
- Perform continuity checks.
- Ensure proper PWR and GND connections.
- Test the validity of I/O values.

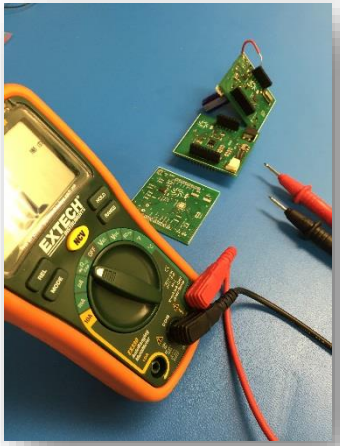
Add next module and repeat testing / debugging steps.



Cranberry Board V1.0 Updates

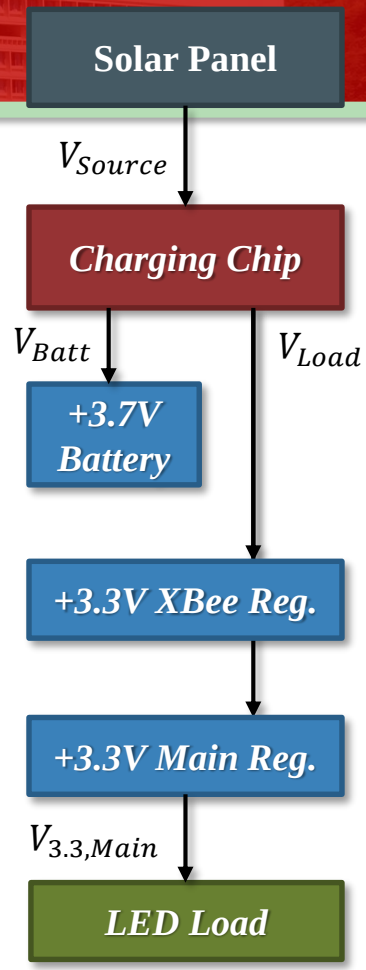
Power Module – Charging Chip and V. Regs

- **Mixture of discrete component packages *(0805 vs. 0603)***
  - ✓ Standardized all to 0805 packages
- **Incorrect sensor switch pin connections**
  - ✓ Bypassed IC so sensor board is constantly powered
- **Incorrect resistors for *Battery Temp. Monitor* THERM pin**
  - ✓ Recalculated correct values using datasheet
- **Discrepancy between charging rate and PROG1 resistor**
  - ✓ Compared boards with 500mA charging rate (PROG1 = $2k\Omega$)



Verification of Power Module

	Parameter	Cranberry #1	Cranberry #2	Dragon Fruit	Adafruit Breakout
Without Battery Without Load	V_{Source}	6.00V	6.00V	6.00V	6.00V
	V_{Batt}	4.06V	4.32V	4.34V	4.30V
	V_{Load}	3.98V	5.88V	5.88V	6.01V
	$V_{3.3,Main}$	3.569V	3.292V	3.304V	
	$V_{3.3,Xbee}$	3.569V			
With Battery Without Load	V_{Source}	6.00V	5.68V	5.67V	5.69V
	I_{Source}	0.01A	0.49A	0.49A	0.50A
	V_{Batt}	3.74V	3.82V	3.837V	3.81V
	V_{Load}	4.16V	5.37V	5.36V	5.68V
	$V_{3.3,Main}$	3.298V	3.294V	3.310V	
	$V_{3.3,Xbee}$	3.290V			
With Battery With LED Load	V_{Source}	6.01V	5.69V	5.66V	
	I_{Source}	0.00A	0.49A	0.49A	
	V_{Batt}	3.74V	3.83V	3.83V	
	V_{Load}	5.84V	5.37V	5.35V	
	$V_{3.3,Main}$	3.299V	3.294V	3.307V	
	$I_{3.3,Main,LED}$	1.51mA	1.50mA	1.51mA	
	$V_{3.3,Xbee}$	3.293V			



Cranberry Board V1.0 Updates

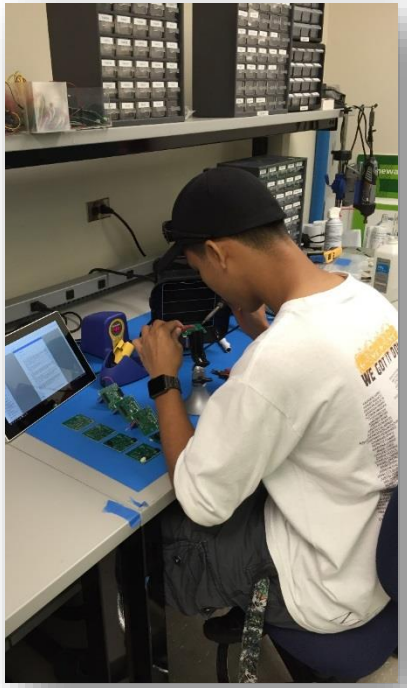
CRANBERRY

MCU

ATMEGA328P

MCU Module – ATMEGA328P

- **Difficulty soldering MCU due to bottom GND pad**
  - ✓ Solder Paste and Hot-Air Rework Station
- **Incorrect use of coupling capacitor for RESET signal**
  - ✓ Bridged with wire and removed from schematic
- **Unused Jumper/Header for MCU Switch**
  - ✓ Bridged so MCU is constantly powered



Cranberry Board V1.0 Updates

CRANBERRY

Sensors

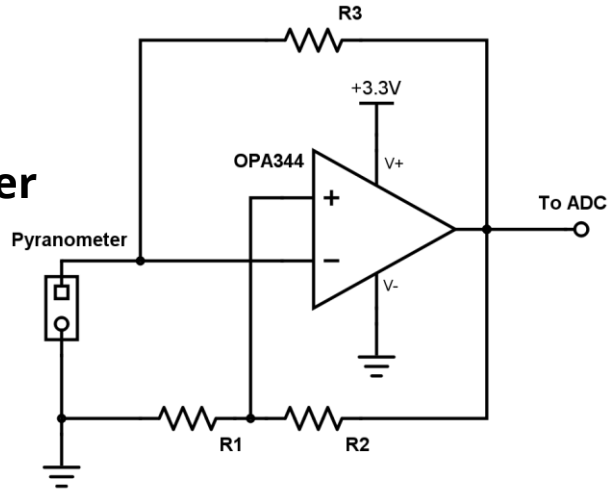
Barometer

Humidity / Temp.

Pyranometer

Sensor Module – Barometer, Humidity, Pyranometer

- **Incorrect decoupling capacitor values**
  - ✓ Changed to match datasheet suggested values
- **Incorrect non-inverting op-amp for Pyranometer**
  - ✓ Bypassed using jumper pin
  - ✓ Uses Apogee SP-215 instead of Apogee SP-110



EAGLE Library and Schematic

EAGLE Part Library

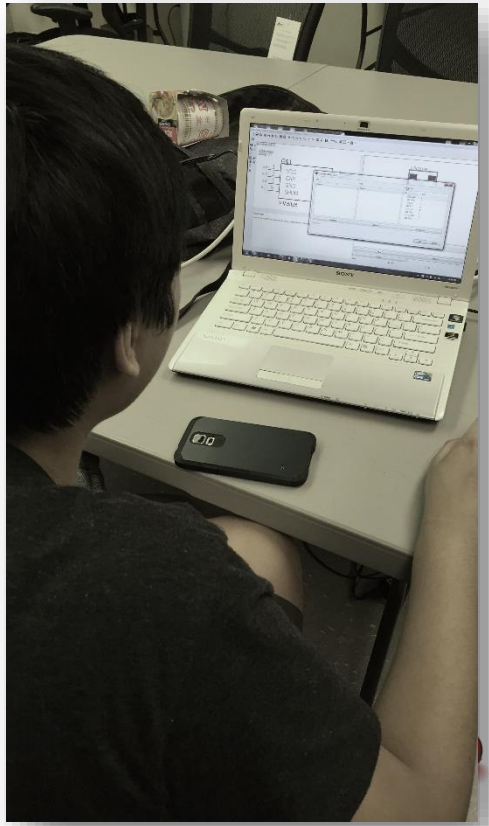
- All main components completed

EAGLE Schematic

- Incrementally implemented each module
- Schematic redone with standard conventions, including proper labeling and documentation
- Corrections made to mirror changes to V1.0 board

EAGLE Design Obstacles

- Missing land patterns on datasheets



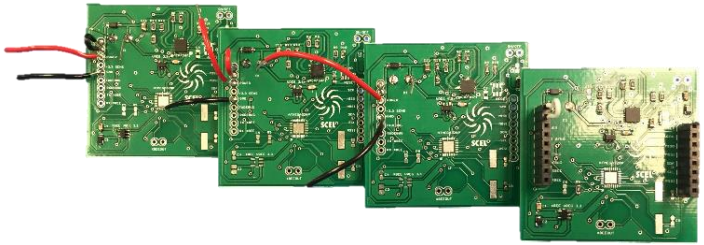
Bill of Materials (BOM)

Resembles SCEL Inventory Sheet

- Contains quantity, part description, package, mounting type, part value, manufacturer, distributor, and unit cost.
- References the EAGLE name and description.

Cranberry Cost: ~$303

(Excluding PCB, Housing, Xbee, and Batteries)



Includes:

- **IC Components**
  (V.Regs, MCU, Sensors)
- **Passive Components**
  (Resistors, Capacitors, Diodes)
- **Misc. Components**
  (Solar Panel, Battery, Switches)
- **Connectors**
  (JST, Pin Headers, Barrel)

Cranberry V1.0 - Power Budget R1.0

Average Component Statistics

- **XBee:** 49.57 mW
  - Idle: 99.9891%
  - Transmit: 0.0109%
- **Barometer:** 0.02 mW
- **Humidity:** 1.07 mW
- **3.3V V. Reg. (2x):** 0.58 mW
- **ATMEGA MCU:** 3.96 mW
- **Irradiance ADC:** 0.26 mW
- **Irradiance Op-Amp:** 1.32 mW

Total System Consumption

- Average Power: 57.36 mW
- Max Power: 75.99 mW

Li-Po Battery Statistics

- 6600 mAh, 3.7V, 19536 mWh
- 15,600 mAh, 3.7V, 46176 mWh
- Useable Energy: 80.0%

Run-Time Statistics

- **6600 mAh:**

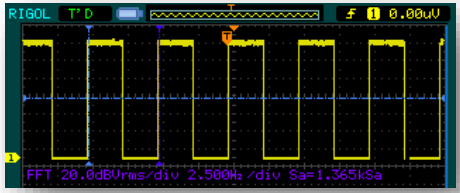
  (257.1 Hrs) 8 Days, 13.67 Hours
- **15,600 mAh:**

  (486.14 Hrs) 20 Days, 6.14 Hours

Final Status of Project

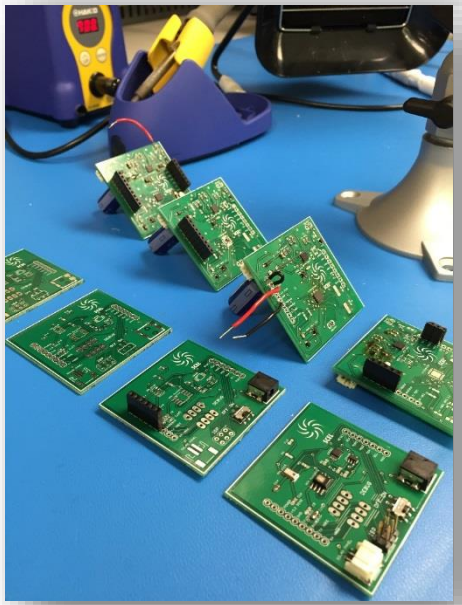
Power Module

- Proper voltages and currents obtained
- Board is powered and Li-Po battery charges



MCU Module

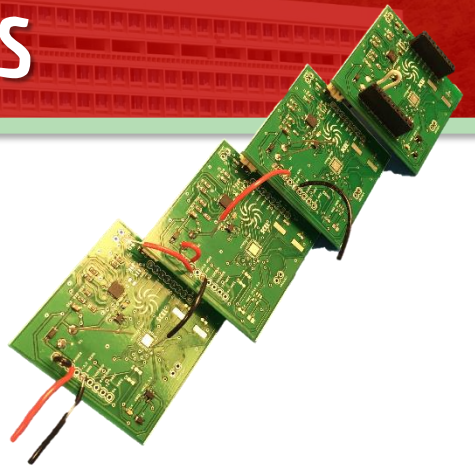
- ATMEGA can be detected and programmed
- Tested for 1 Hz Square Wave output



Sensor and XBee Modules

- Components fully soldered and ready to verify

Outstanding Tasks and Problems

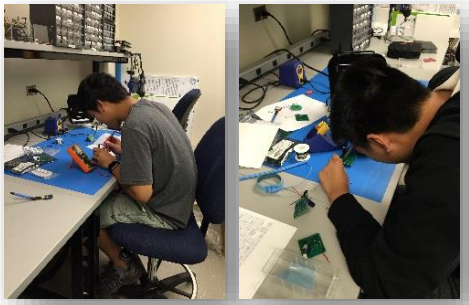


Cranberry Board (V1.0)

- Program MCU to verify proper sensor values.
- Verify proper XBee signals and TX/RX capabilities.

EAGLE and PCB Design (V2.0)

- Redesign new board with updated schematic/board changes and design preferences.



Main Deliverables (Work In Progress):

A working *Cranberry Board (V1.0)* with proper documentation and a redesign for *Cranberry Board (V2.0).*

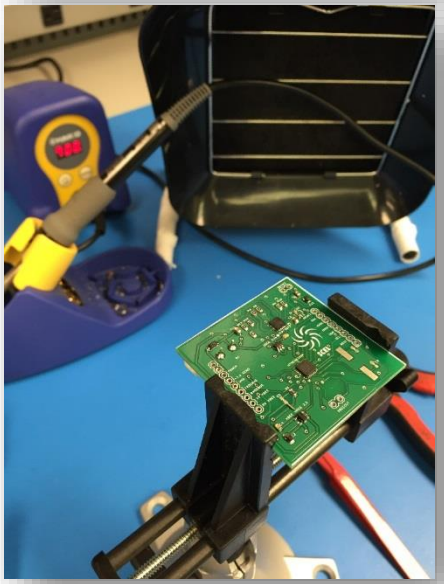
Future Improvements (EE499)

Cranberry Board

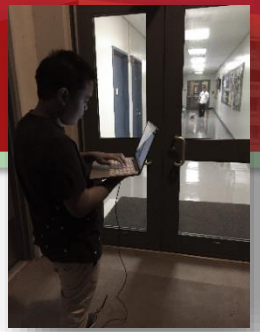
- More accurate / measured power budget
- Universal / standardized housing for all generations

EAGLE and PCB Design (V2.0)

- Additional functionality, status signals, and sensors
- More efficient layout and easily solderable packages
- Correct MCU controlled / mechanical power switches
- Programming and debugging ports for firmware / verification teams



Inter-Team Collaboration




Apple Team

- Power Budget Comparisons
- Changes to circuit schematic / layout

XBee Team

- XBee transmit/receive signals/testing
- Pin connections and soldering practice

Dragon Fruit Team

- Power Budget and EAGLE Layout
- Component selection, debugging, and soldering

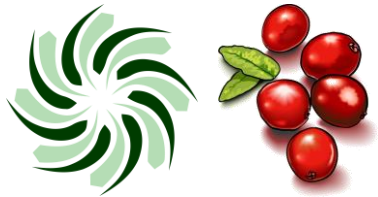
Firmware and Verification Team

- Sensor readings and power budget comparison
- Pin-out connections for programming and debugging

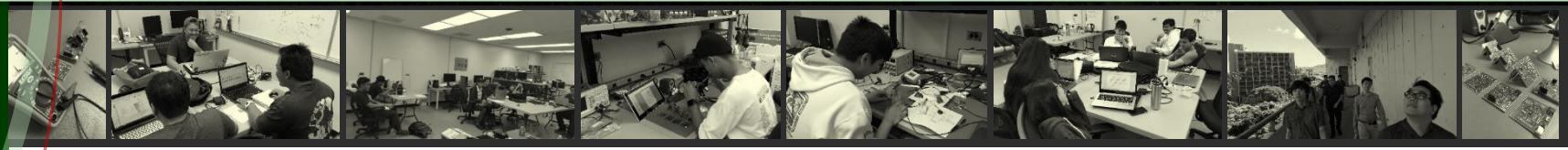
Acknowledgements

Thank you to the following…

- ***Advisor:*** Dr. Anthony Kuh
- ***Leadership Team:*** Christie Obatake, Kenny Luong, Zachary Dorman
- ***Mentors:*** Jon Liang, Jason Tanabe
- ***REIS Team Members:*** Apple, Dragonfruit, Firmware, Verification, Networking and Server, Forecasting, and Wind Sensor



Any Questions?



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College of ENGINEERING
UNIVERSITY OF HAWAI'I AT MĀNOA

Bill of Materials (BOM)

Cranberry Bill of Materials (V1) (BOM)

Part #	Quantity	EAGLE Name	EAGLE Description	Part Type	Part Description	Mounting Type	Part Package	Part Value	Manufacturer	Manufacturer P/N	Distributor	Distributor P/N	Unit Cost	Sub-Cost
1	2	VREG3.3_MAIN; VREG3.3_XBEE	Main Board and XBEE V.Regs	V. Regulator	IC REG LDO 3.3V 0.5A SOT23-5	SMD	SOT23-5	3.3V	Microchip Tech.	MIC5219-3.3YM5-TR	Digi-Key	576-1281-1-ND	$ 0.89	$ 1.78
2														$ -
3	1	C5	ATMEGA RESET Cap	Capacitor	CAP CER 10000PF 50V X7R 0805	SMD	0805	10nF	Yageo	CC0805KRX7R9BB103	Digi-Key	311-1136-1-ND	$ 0.10	$ 0.10
4	1	C3	IC Switch Decoupling Cap	Capacitor	CAP CER 1UF 10V X7R 0805	SMD	0805	1uF	Yageo	CC0805KKX7R6BB105	Digi-Key	311-1458-1-ND	$ 0.10	$ 0.10
5	2	C4, C6	V. Reg Decoupling Caps	Capacitor	CAP CER 470PF 100V X7R 0805	SMD	0805	470pF	Samsung Electro-Mech.	CL21B471KCANNNC	Digi-Key	1276-2516-1-ND	$ 0.12	$ 0.24
6	2	C2, C12	V.Reg Polarized Decoupling Caps	Capacitor	CAP TANT 2.2UF 6.3V 20% 0805	SMD	0805	2.2uF	Rohm Semiconductor	TCP0J225M8R	Digi-Key	511-1439-6-ND	$ 0.69	$ 1.38
7	1	C1	ATMEGA Decoupling Cap	Capacitor	CAP CER 0.1UF 50V Y5V 0805	SMD	0805	100nF	Yageo	CC0805ZRY5V9BB104	Digi-Key	311-1361-1-ND	$ 0.10	$ 0.10
8	2	C7, C8	Crystal Oscillator Decoupling Caps	Capacitor	CAP CER 18PF 50V NP0 0805	SMD	0805	18pF	Johanson Dielectrics	500R15N180JV4T	Digi-Key	709-1171-1-ND	$ 0.10	$ 0.20
9	1	C10	Solar Charger Decoupling Cap	Capacitor	CAP ALUM 4700UF 20% 10V RADIAL	PTH	0.197" (5.00mm)	4700uF	Panasonic Electo-Comp.	ECA-1AM472	Digi-Key	P5130-ND	$ 0.90	$ 0.90
10	1	C11	Solar Charger Decoupling Cap	Capacitor	CAP CER 10UF 20V X6S 0805	SMD	0805	10uF	Murata Electronics NA	GRM21BC81D106KE51L	Digi-Key	490-10500-6-ND	$ 0.24	$ 0.24
11	1	C1	ATMEGA Decoupling Cap	Capacitor	CAP CER 0.1UF 50V Y5V 0805	SMD	0805	0.1uF	Yageo	CC0805ZRY5V9BB104	Digi-Key	311-1361-1-ND	$ 0.10	$ 0.10
	1	C9	Humidity Sensor Decoupling Cap	Capacitor	CAP CER 0.1UF 50V Y5V 0805	SMD	0805	0.1uF					$ 0.10	$ 0.10
	2	C14, C15	Pressure Sensor Decoupling Cap	Capacitor	CAP CER 0.1UF 50V Y5V 0805	SMD	0805	0.1uF					$ 0.10	$ 0.20
	1	C16	Solar Irradiance Decoupling Cap	Capacitor	CAP CER 0.1UF 50V Y5V 0805	SMD	0805	0.1uF					$ 0.10	$ 0.10
12	1	C13	Humidity Sensor Decoupling Cap	Capacitor	CAP CER 0.22UF 50V X7R 0805	SMD	0805	0.22uF	Yemet	C0805C224K5RACTU	Digi-Key	399-3491-1-ND	$ 0.14	$ 0.14
13														
14	1	IC1	Solar Panel / Battery Charging Chip	IC Chip	IC USB/AC BATT CHRGR W/PPM 20QFN	SMD	20-VFQFN		Microchip Tech.	MCP73871-2CAI/ML	Digi-Key	MCP73871-2CAI/ML-ND	$ 1.79	$ 1.79
15	1	ADS1115_ADC	Solar Irradiance ADC	IC Chip	IC ADC 16-BIT I2C PROGBL 10-MSOP	SMD	10-VSSOP		Texas Instruments	ADS1115IDGST	Digi-Key	296-24934-1-ND	$ 6.51	$ 6.51
16	1	MIC7300_OPAMP	Solar Irradiance Op-Amp	IC Chip	IC OPAMP GP 370KHZ RRO SOT23-5	SMD	SOT23-5		Microchip Tech.	MIC7300YM5-TR	Digi-Key	576-1319-1-ND	$ 0.28	$ 0.28
17														
18	1	BAROMETER	Barometer / Pressure Sensor	IC Sensor	IC BAROMETER I2C DGTL MINI 8-LGA	SMD	8-TLGA		Freescale Semiconductor	MPL115A2T1	Digi-Key	MPL115A2T1CT-ND	$ 5.10	$ 5.10
19	0	HUMIDITY	Humidity Sensor (Old)	IC Sensor	SENSOR HUMIDITY SPI 4.5% SMD	SMD	SOIC-8		Honeywell Sensing	HIH6031-000-001	Digi-Key	HIH6031-000-001TR-ND		$ -
20	1	HUMIDITY	Humidity Sensor (New)	IC Sensor	SENSOR HUMIDITY/TEMP I2C 4% SMD	SMD	SOIC-8		Honeywell Sensing	HIH6131-021-001	Digi-Key	480-3652-1-ND	$ 15.13	$ 15.13
21	1	IRRADIANCE_110	Solar Irradiance (Old)	IC Sensor	SELF-POWERED PYRANOMETER		3-Pin Wire		Apogee Instruments	SP-110	Apogee	SP-110	$ 195.00	$ 195.00
22	0	IRRADIANCE_215	Solar Irradiance (New)	IC Sensor	SELF-POWERED PYRANOMETER		3-Pin Wire		Apogee Instruments	SP-215	Apogee	SP-215	$ 235.00	$ -
23														
24	1	Q2	Crystal Oscillator	Crystal	Crystal 8.00MHz 10ppm 18pF 80 Ohm Through Hole HC49/US	PTH	HC49/US	8.00MHz	TXC Corp.	9B-8.000MEEJ-B	Digi-Key	887-1233-ND	$ 0.48	$ 0.48
25	1	U2	ATMEGA MCU	MCU	IC MCU 8BIT 32KB FLASH 32QFN	SMD	32-VQFN		Atmel	ATMEGA328P-MU	Digi-Key	ATMEGA328P-MU-ND	$ 3.58	$ 3.58
26														$ -
27	2	R1, R4	Solar Irradiance Op-Amp Feedback	Resistor	RES SMD 4.7K OHM 5% 1/8W 0805	SMD	0805	4.7k	Stackpole Electronics Inc.	RMCF0805JT4K70	Digi-Key	RMCF0805JT4K70CT-ND	$ 0.10	$ 0.20
27	2	R2, R3	Humidity Pull-Up	Resistor	RES SMD 4.7K OHM 5% 1/8W 0805	SMD	0805	4.7k					$ 0.10	$ 0.20
28	2	R5, R12	MCU Pull-Up; Solar Charger Resistor	Resistor	RES SMD 10K OHM 5% 1/8W 0805	SMD	0805	10k	Stackpole Electronics Inc.	RMCF0805JT10K0	Digi-Key	RMCF0805JT10K0CT-ND	$ 0.10	$ 0.20
29	1	R6	Solar Charger Resistor	Resistor	RES SMD 270K OHM 5% 1/8W 0805	SMD	0805	270k	Panasonic Electo-Comp.	ERJ-6GEYJ274V	Digi-Key	P270KACT-ND	$ 0.10	$ 0.10
30	2	R8, R10	Solar Charger Resistors	Resistor	RES SMD 100K OHM 5% 1/8W 0805	SMD	0805	100k	Panasonic Electo-Comp.	ERJ-6GEYJ104V	Digi-Key	P100KACT-ND	$ 0.10	$ 0.20
31	1	R9	Solar Charger Resistor	Resistor	RES SMD 2K OHM 5% 1/8W 0805	SMD	0805	2k	Panasonic Electo-Comp.	ERJ-6GEYJ202V	Digi-Key	P2.0KACT-ND	$ 0.10	$ 0.10
32	1	R11	Solar Charger Resistor	Resistor	RES SMD 1K OHM 5% 1/8W 0805	SMD	0805	1k	Panasonic Electo-Comp.	ERJ-6GEYJ102V	Digi-Key	P1.0KACT-ND	$ 0.10	$ 0.10
33	1	R13	Solar Charger Resistor	Resistor	RES SMD 150K OHM 5% 1/8W 0805	SMD	0805	150k	Panasonic Electo-Comp.	ERJ-6GEYJ154V	Digi-Key	P150KACT-ND	$ 0.10	$ 0.10
34														
35	1	PANEL	Solar Panel 6V 5.6W	Solar Panel	HUGE 6V 5.6W SOLAR PANEL	DC JACK	3.8mm OD		Adafruit	1525	Adafruit	1525	$ 59.00	$ 59.00
36	1	D1	Solar Charger Zener Diode	Diode	DIODE SCHOTTKY 20V 500MA SOD123	SMD	SOD-123		ON Semiconductor	MBR0520LT3G	Digi-Key	MBR0520LT3GOSCT-ND	$ 0.33	$ 0.33
37														
38	1	BATT	Li-Po Battery JST Cable Connector	Connector	CONN HEADER PH SIDE 2POS 2MM SMD	SMD	0.079" (2.00mm)	2-Pin	JST Sales America Inc.	S2B-PH-SM4-TB(LF)(SN)	Digi-Key	455-1749-1-ND	$ 0.56	$ 0.56

Cranberry's (V1.0) Power Budget

$$P = V * I$$

Cranberry Board (V1.0) Power Budget

3.3 Volt Module	Datasheet Values			Calculated Values			XBee Characteristics	
Device Name	Idle (mA)	Typical Current Draw (mA)	Max Current Draw (mA)	Avg. Current Draw (mA)	Avg. Power Consumed (mW)	Max Power Consumed (mW)	Transmit Time	Idle Time
XBee Transmit	15.00	205.00	220.00	15.02	49.57	49.57	0.0109%	99.9891%
XBee Recieve				0.00	0.00	0.00		
Barometer	0.01	0.01	0.01	0.01	0.02	0.02		
Humidity (HIH6031)	0.00	0.65	1.00	0.33	1.07	3.30		
V. Reg 3.3V (Main)		0.35	0.90	0.18	0.58	2.97		
V. Reg 3.3V (Xbee)		0.35	0.90	0.18	0.58	2.97		
Atmega 328P MCU	0.70	1.70	2.70	1.20	3.96	8.91		
Irradiance ADC	0.01	0.15	0.30	0.08	0.26	0.99		
Irradiance Op Amp		0.80	2.20	0.40	1.32	7.26		
Total Current Draw (mA)	15.72	209.01	228.01	17.38	57.36	75.99		
Supply Voltage (V)	3.30	3.30	3.30	3.30	3.30	3.30		
Total Power Consumption (mW)	**51.86**	**689.72**	**752.42**	**57.36**	**57.36**	**75.99**		

Rechargeable Li-Po Batteries (3.7V)			
Battery	Voltage (V)	Current (mAH)	Useable Energy (%)
6600 mAH Li-ion 3.7V	3.7	6600	80.0%
15600 mAH Li-ion 3.7V	3.7	15600	80.0%

Estimated Battery Running Time						
Battery	Energy (mWH)	V. Reg Efficiency (%)	Max Power Consuption (mW)	Max (Hrs)	Max w/ V. Reg Efficiency (Hrs)	Max w/ V. Reg Efficiency (Days, Hrs)
6600 mAH Li-ion 3.7V	19536	80.0%	75.99	257.1	205.67	8 Days, 13.67 Hours
15600 mAH Li-ion 3.7V	46176	80.0%	75.99	607.7	486.14	20 Days, 6.14 Hours

Cranberry Notes and Documentation

Revision: R1.0

* Current Draw (mA) and Avg. Power (mW) calculations assume sensors (barometer, etc.) are polling 1/2 of time.
* V. Reg current values are taken from datasheet values for loads of Iout = 50mA, because total average system current draw is approximately 57mA for the 3.3V regulator.
* Assume XBee leakage currents are negligible (µA << mA).
* Assume XBee only operates in transmit/idle mode (i.e. does not receive data from the server).
* For XBee Transmit/Idle Time, use given parameters: 82bytes (Transmit Rate = 250 kbps), sent to the server every 3 seconds.