Team 31 Final Presentation

Joydeep Ganguly and Dennis Wong (assistant)

Problems in Workplace Conditions

Background	Modern manufacturing involves the use of high power equipment, and factories typically have very heavy machinery in close quarters to "squishy" workers
The Issue	Poor safety habits – no Personal Protective Equipment (PPE) means more accidents which are expensive and damaging
Key Question	How can we use technology to improve worker safety and workplace conditions?

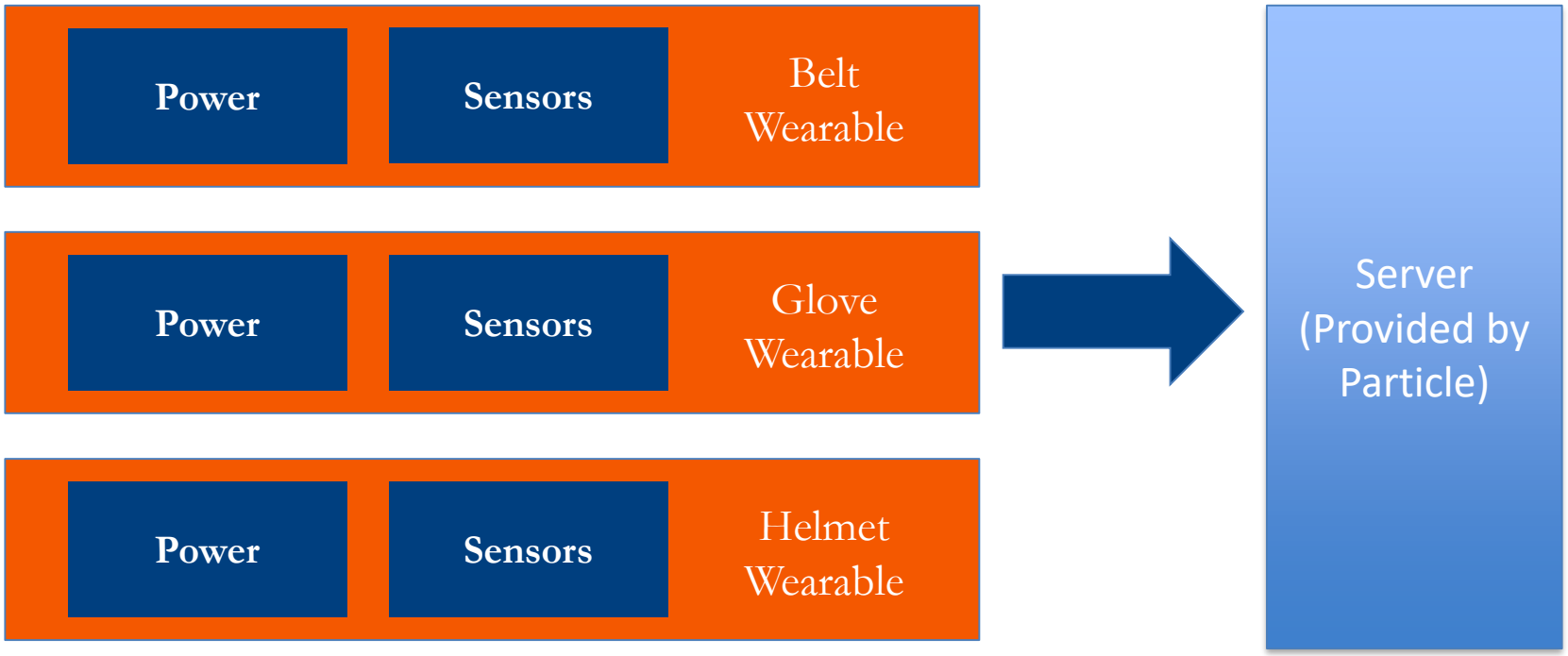
Agenda

Agenda
Overview
Data Collection Blocks
Power Blocks
Localization Blocks
Ethics
Conclusion

Our Solution: Worker Tracking Technology

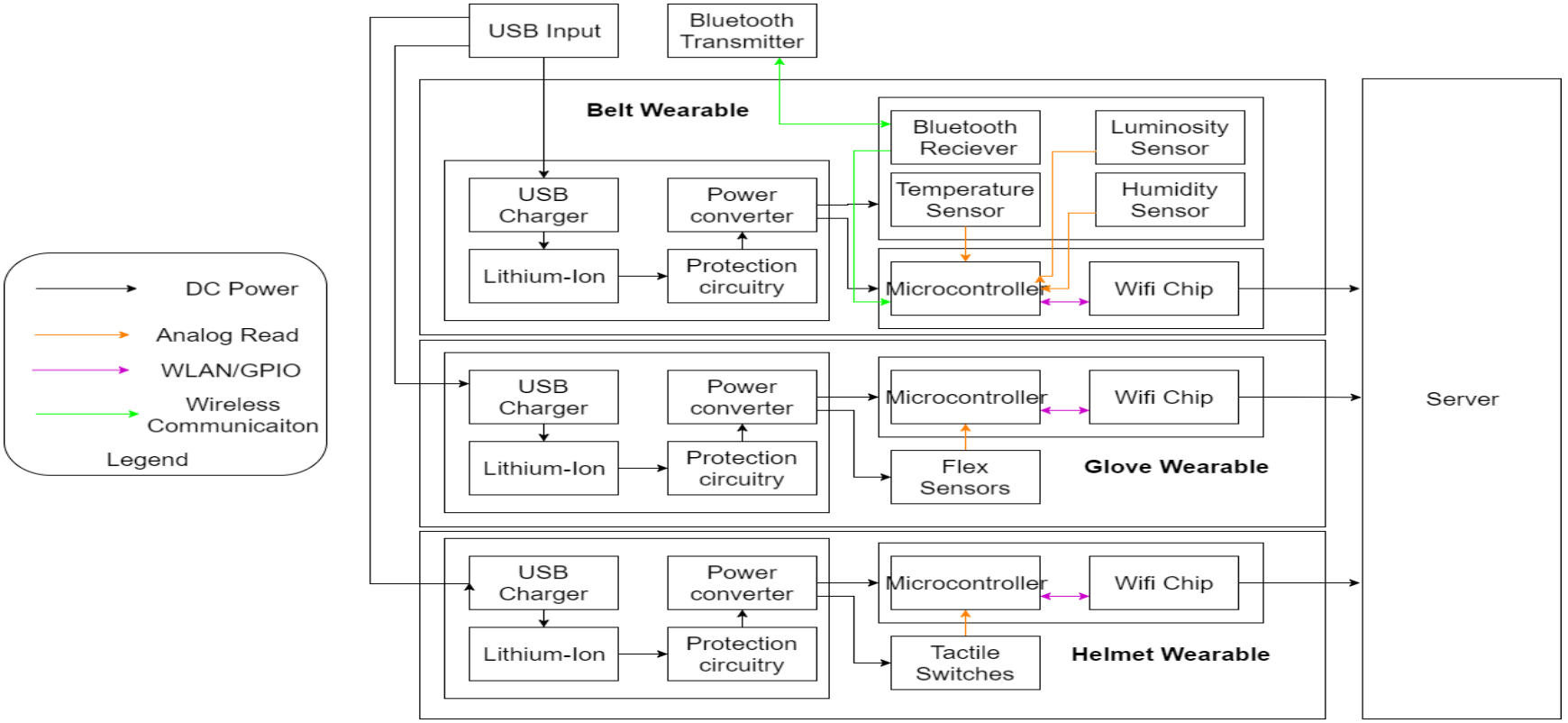
Key Idea

Gather information on workers' PPE habits, position, and conditions, logging all relevant factors



Better data collection enables safer, better workplaces

Final Block Diagram



The final block diagram was a significant design effort

Helmet and Glove Wearables – Approach

Key Idea: Measure "Activity for PPE"

Gloves	People's hands move
Helmet	Helmets press down

Choose Key Metrics → Design/Build Circuit → Test Classification → Physical Implementation

By choosing good metrics to measure, we can detect if workers wear their PPE

Helmet and Glove Wearables – Requirements

Key Idea: Measure "Activity for PPE"

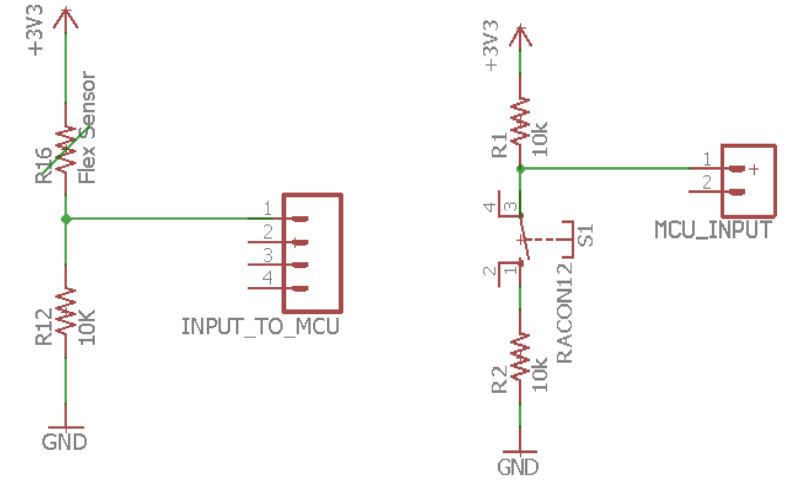
Gloves	People's hands move
Helmet	Helmets press down

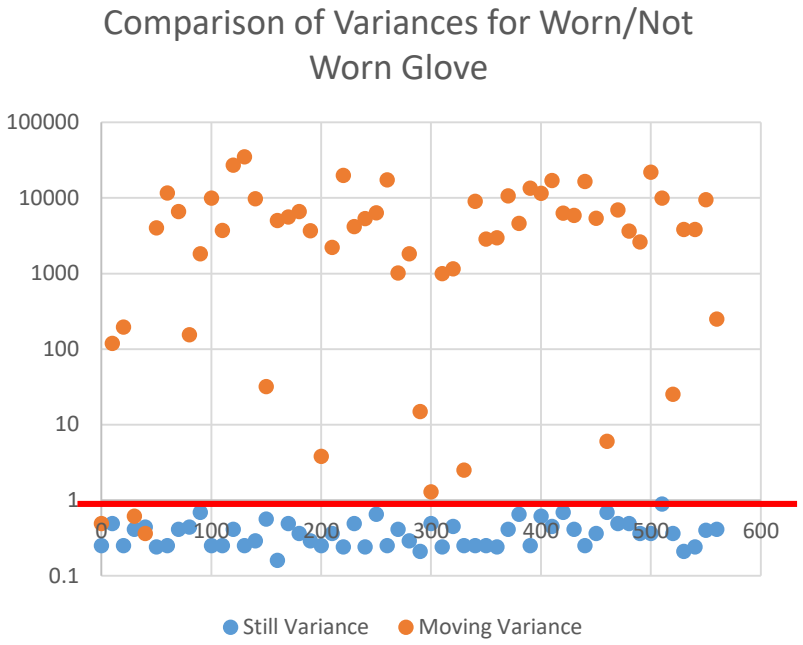
Key Requirement: Accuracy		
Sensor	Requirement	Approach
Glove	75% Accurate	Statistical Measures
Helmet	100% Accurate	Button Switches
Other	Within 5% of reference	Analog Sensor Reads

The data collection blocks had to be accurate, and ergonomic

Helmet and Glove Wearables – Results

Glove and Helmet Circuits





The helmet was always accurate and the glove was 94% accurate

Power System

Key Challenge

How do we power a sensor apparatus safely for the whole workday?

Key Requirement: Usability	
Requirement	Explanation
Lifespan	The battery has to last a full workday
Safety	Battery (and worker) life should be protected
Ease of Use	The device must have a minimal form factor, and recharge quickly

Overall Process

- Select Parts
- Design Circuit
- Design Board
- Integrate
- Test

The power system was the backbone of the entire wearable project

Power System – Component Selection

Power System

MCU

- Native support for communication over WiFi
- Robust development environment and support
- Analog read pins for all necessary inputs
- **Final Decision: Particle Photon**

Battery Chemistry

- Must support 8 to 9 hours of continuous use, for full workday
- Rechargeable, with reasonable charging speeds and charge lifecycle
- 8 hours of draw time
- **Final Decision: Lithium Polymer**

Buck Boost

- All components require at least 3.3V, but lithium batteries discharge from 3.7V to 2.8V
- The buck-boost converter needs to handle at least 650mA
- The buck-boost converter must have the ability to switch modes
- **Final Decision: TPS63001**

Charging Unit

- The battery must be rechargeable, safely so it can be used
- The charging unit must be able to charge the battery between .1 and .5 C
- The charger should shut off the circuit during charging
- **Final Decision: Max 1551 IC**

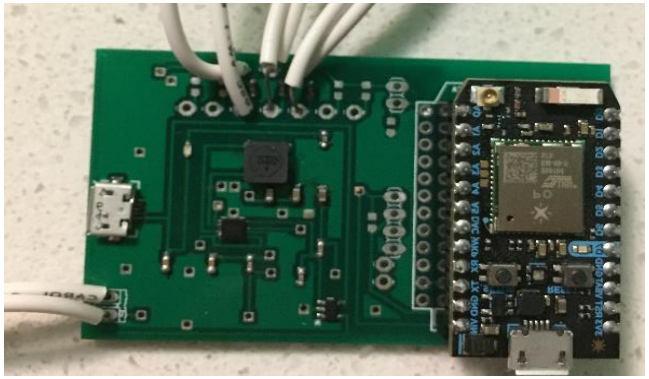
Parts were chosen considering the functionality of the system as a whole

Power System – Design and Build

Key Challenges

Heat	Circuit (briefly) caught fire
Soldering	QFN and DFN packages
Routing	Inefficient autorouting process
Debugging	Murphy's law…

Finished Products



Designing the PCB had electrical and physical constraints to keep in mind

Power System – Requirements and Verification

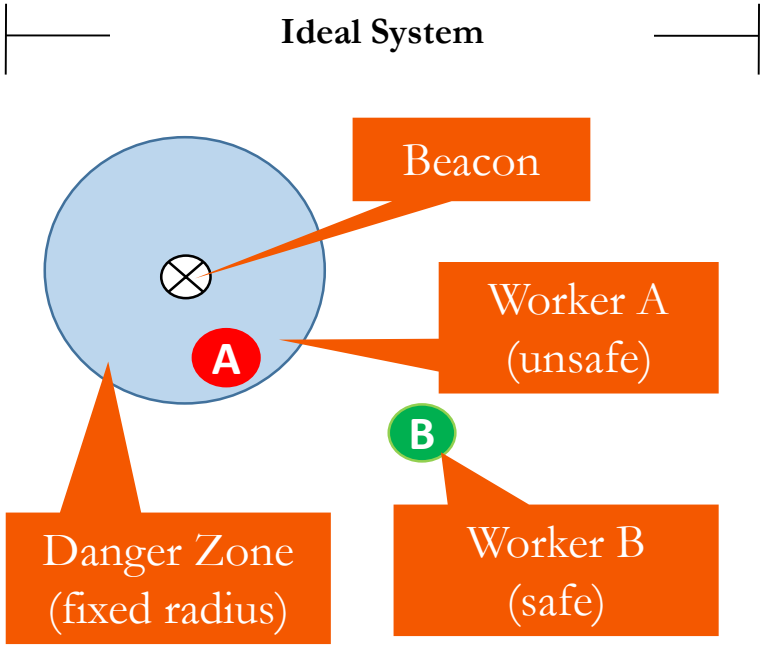
Requirement	Verification	Result	
Lasts longer than 8 hours	Device was run for prolonged amount of time	Battery life was 13 hours	✓
Safely handles 650 mA load	A high current load was used to test power module	• Circuit was still running after an hour • Nothing burned out	✓
Supports charging and operation mode	Over a short period of time, the device was rapidly switched between the two modes	Nothing broke	✓

The PCB met all the technical requirements

Indoor Localization – Approach

Key Challenge

How do we detect if a worker is in an unsafe area?



Indoor localization allows for more granular insights on safety

Indoor Localization – Requirements

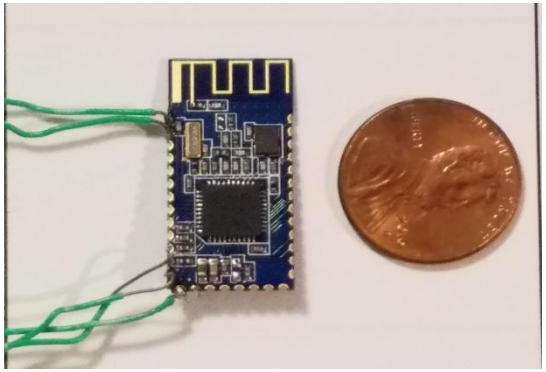
Key Challenge

How do we detect if a worker is in an unsafe area?

Key Requirement: Data Collection	
Requirement	**Explanation**
Accuracy	The positioning system should be accurate to within 2 meters
Communication	The "sensor" must communicate with the MCU
WiFi	The MCU must communicate with a server for data logging

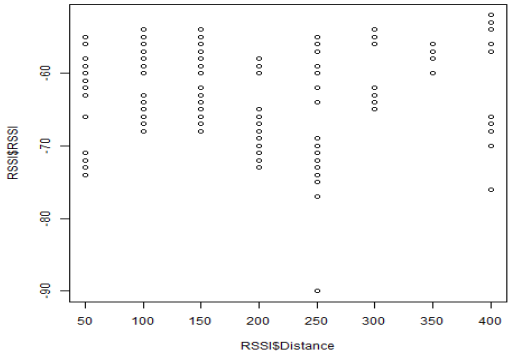
The data collected needed to be accurate, and safely stored

Indoor Localization – Original Plan



```
serialread.ino

44
45  void loop() {
46
47      if((millis() - lastSend > sendDelay) && ack){
48          //Query temperature and humidity
49          //broadcast it out to the particle website
50
51          Serial1.write("AT+DISI?");
52          lastSend = millis();
53          ack = false;
54      }
55
56      while(Serial1.available()){
57          c = Serial1.read();
58          incomingBuffer[idx++] = c;
59          if(sentEoT(c)){
60              incomingBuffer[idx] = '\0';
61              ack = true;
62              idx = 0;
63              processBuffer();
64          }
65      }
66
67
```



1 Design

- Survey indoor localization technologies
- Cost/Scalability tradeoff
- **Bluetooth Low Energy**

2 Build

- Program HM-10 chips to send and receive
- Test with reference apps
- **Integrate with MCU**

3 Predict

- Predict distance from the measured RSSI values
- **Failed Completely (Initially)**

Things did not go according to plan

The (First) Problem – Noise

Survey

Examine filtering techniques and research for successful RSSI Filters, eventually choosing **Kalman Filtering**

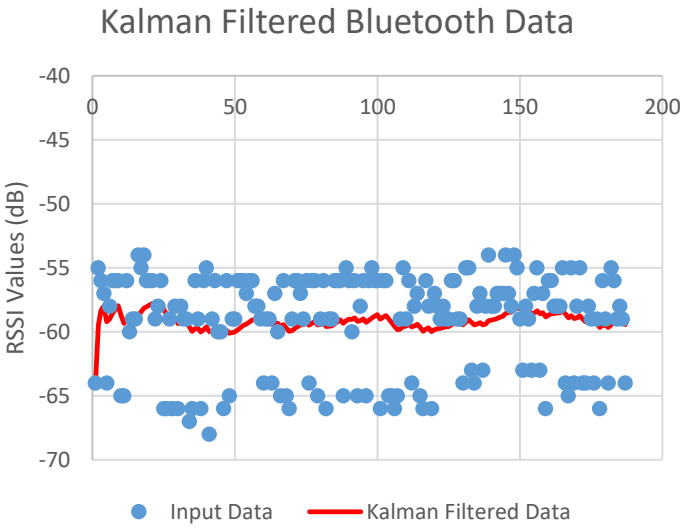
Design

Research Kalman filtering algorithm, and **define system model** and other relevant factors

Build

The software filter was implemented in Java, for ease of use and scalability onto servers

Comparison



Noise is clearly reduced, while preserving signal characteristics

A Kalman Filter was implemented to reduce noise and aid in classification

Two Approaches to Distance Estimation

	Physics Model	Maximum Likelihood
Key Assumption	▪ Bluetooth signal falls off as 1/r2, ▪ Estimated by comparing received signal strength (RSSI) and transmitted	▪ The reflection at certain distances has characteristic patterns ▪ Estimate distance by comparing RSSI patterns to known "fingerprints"
Verification	▪ Gather a large dataset ▪ Estimate the distance ▪ Calculate average absolute value of error	▪ 10-fold cross validation ▪ Track misclassification rate ▪ Calculate average absolute error
Accuracy	▪ Average Error: 2.33m ▪ Unsuitable for application	▪ Misclassification Rate: 11% ▪ Average Error: .6m for misclassified data ▪ **Within requirements**

The maximum likelihood approach was found to be more accurate in practice

Indoor Localization – Results

Key Challenge

How do we detect if a worker is in an unsafe area?

Key Requirement: Data Collection		
Requirement	**Explanation**	
Accuracy	The positioning system should be accurate to within 2 meters	✓
Communication	The "sensor" must communicate with the MCU	✓
WiFi	The MCU must communicate with a server for data logging	✓

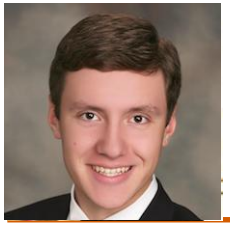
The Particle server and maximum likelihood combination met requirements

Ethics

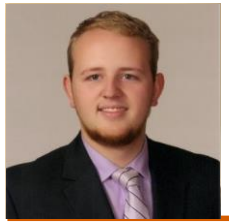
PCB/Circuit Safety	• Thermal runaway • Heat dissipation • Short circuit protection
Worker Privacy	• WiFi Security • Overall Privacy Concerns • Data reporting errors

Acknowledgements

John Capozzo



Michael Fatina



Jackson Lenz

Professor Hutchinson

Questions?