

Physiological Health Assessment and Hazard Monitoring Patch for Firefighters

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NORA Relevance

- The project's device is most relevant to Public Safety Sector Program
- Device aims to help improve the safety of firefighters on active duty.
 - Detecting the hazards that firefighters can encounter.
 - Warning when conditions are leading to injuries
 - Detecting an incident
 - Alert a monitoring personnel to provide immediate assistance.

Project Motivation

- Firefighters are exposed to a multitude of hazards when on active duty including:
 - Overexertion
 - Low oxygen environments
 - Falls
 - Contact with objects
 - Impact from objects
 - Burns
 - Hyperthermia
 - Carbon monoxide poisoning
 - Dehydration
- 61 Deaths in 2011 and 71,875 injuries in 2010
- The leading source of the moderate and severe injuries were from falls, slips, or trips (28%)
 - Strains or sprains (34%), thermal burns (10%), and pain (9%)

[1] R. F. Fahy, P. R. LeBlanc and J. L. Molis, Firefighter Fatalities in the United States-2011, NFPA, 2012.

[2] M. J. Karter and M. L. Joseph, US firefighter injuries-2010, National Fire Protection Association, Fire Analysis and Research Division, 2011.

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Firefighter Targeted Devices

- Wearable Advanced Sensor Platform (WASP)
 - heart rate
 - heart rate variability
 - respiration rate
 - activity levels
 - posture,
 - other physiological factors.



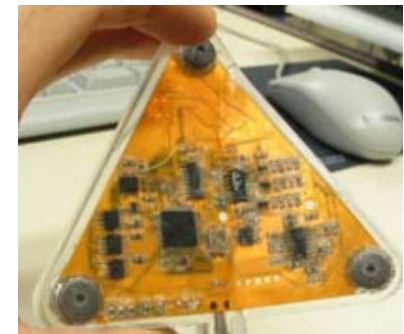
Firefighter Targeted Devices

- Integrated firefighter location and physiological monitor
 - 3-D location
 - Heart Rate
 - Respiration Rate
 - Oxygen Saturation Level
 - Skin and Environment Temperature
 - Posture and activity Level



Similar Wearable Devices

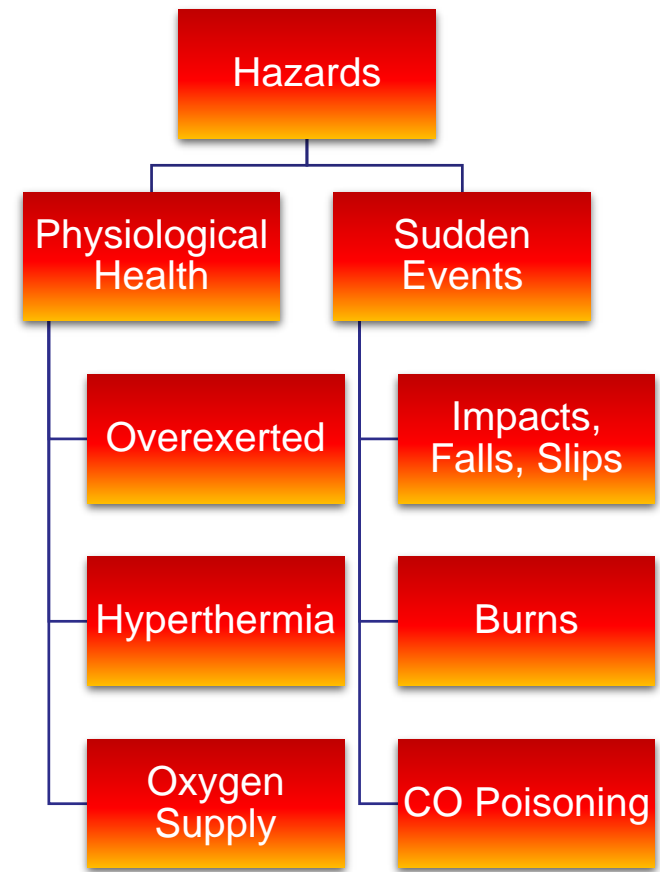
- SenseWear Pro Armband
 - Heartbeat
 - Skin temperature
 - Acceleration
 - Galvanic skin response
 - Heat flux
 - Ambient temperature
- Patch for heat stress monitoring
 - Electrocardiogram
 - Skin temperature
 - Humidity
 - 2-axis accelerometer



- [7] D. Andre, R. Pelletier, J. Farrington, S. Safier, W. Talbott, R. Stone, N. Vyas, J. Trimble, D. Wolf, S. Vishnubhatla, S. Boehmke, J. Stivoric and A. Teller, "The Development of the SenseWear® armband, a Revolutionary Energy Assessment Device to Assess Physical Activity and Lifestyle," BodyMedia Inc, 2006.
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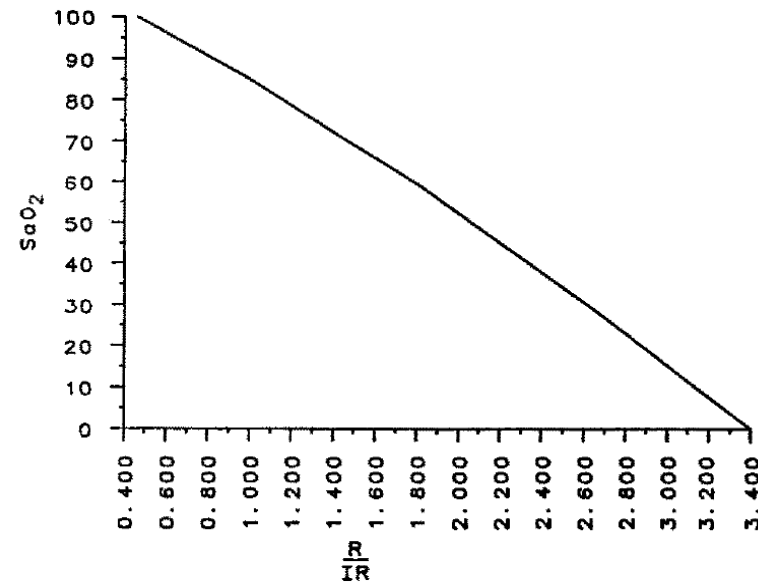
Proposed Device Sensors

- Pulse oximetry
 - Overexertion
 - Oxygen Supply
- Pulse CO oximetry
 - CO Poisoning
- Accelerometers
 - Impacts, Falls, Slips
- Suit humidity and temperature
 - Burns
- Skin temperature
 - Hyperthermia



Pulse Oximeter

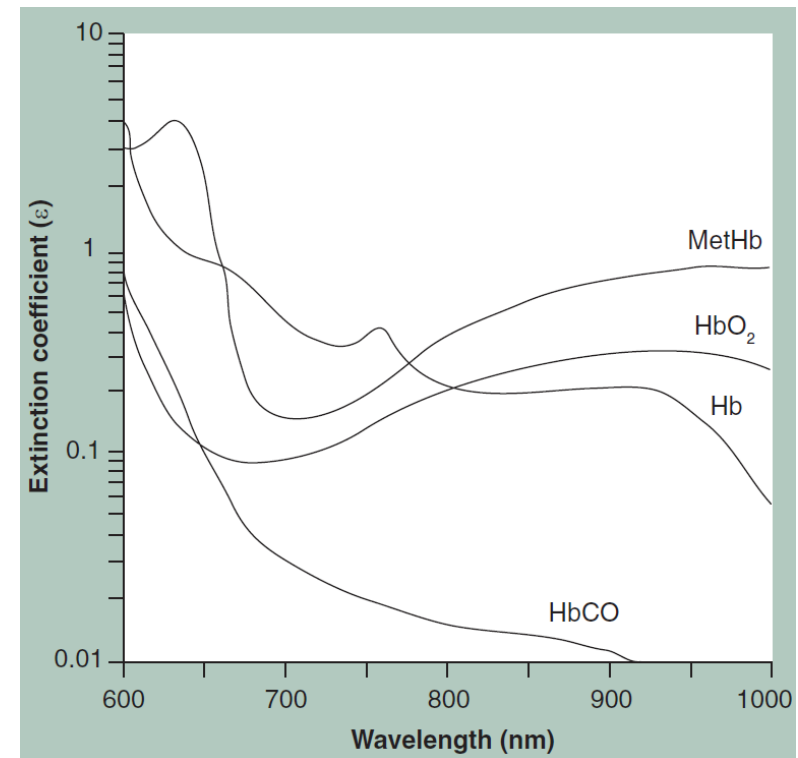
- Uses two different light sources red (645nm) and infrared (940nm)
- Light detected has an AC and DC component
 - AC component represents the blood as it pulses
 - DC component represents the tissue and other unchanging factors
- Heart rate can be derived from the AC portion
- Blood oxygen level can be derived from a ration of the AC and DC of both the red and infrared LEDs



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- [22] Texas Instruments Incorporated, "SpO Pulse Ox Wrist Oximeter Reference Design," 16 March 2014. [Online]. Available: <http://www.ti.com/lit/ug/tidu124/tidu124.pdf> .

Pulse CO-Oximeter

- Similar principles of operation as pulse oximeter to measure carboxyhemoglobin
- Rad-57 Pulse CO-Oximeter is a FDA approved device using this method to measure SpCO



Accelerometer

- Three axis accelerometers are common sensors used in devices to measure acceleration in x, y, and z axes.
- Used for measuring linear acceleration force from impacts.
- Through analyzing the acceleration, time, and duration of the impact can discover if the personal has suffered an injury and needs immediate attention.

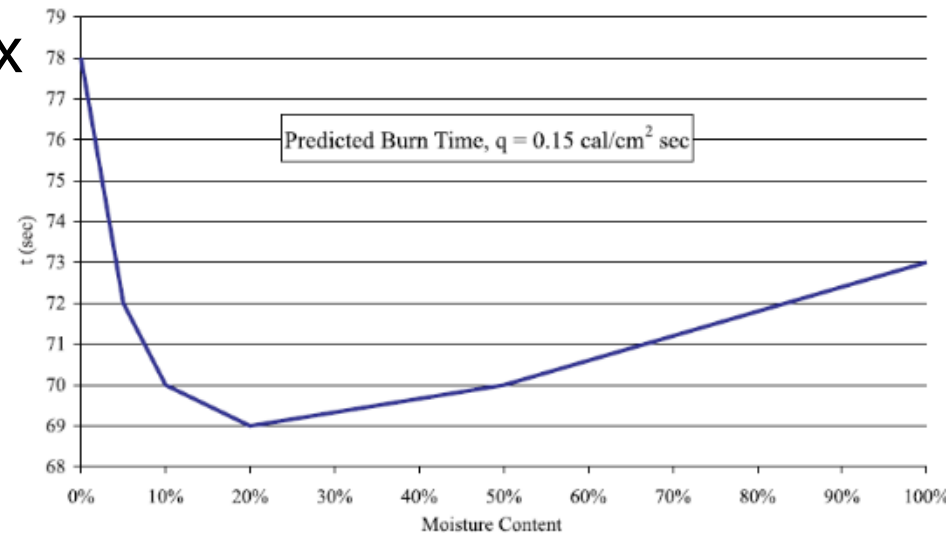
- [18] D. Ambekar, Z. Al-Deneh, T. Dao, A. L. Dziech, V. Subbian and F. R. Beyette, "Development of a Point-of-Care Medical Device to Measure Head Impact in Contact Sports," in 35th Annual International Conference of the IEEE EMBS, Osaka, 2013.
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Skin Temperature

- Temperature sensor applied to the skin allows for real time measurement of the subjects body temperature
- Firefighters regularly expose themselves to environments that can easily lead to heat strain including high physical demands, exposure to high temperatures, and radiative heat.
- Firefighters also wear a partially or fully encapsulating protective clothing leading to core temperature values of 102 to 105 °F

Humidity and Suit Temperature Sensor

- Moisture plays a complex role in heat transmission for firefighter turnout systems and effects the potential of burn injuries to the skin

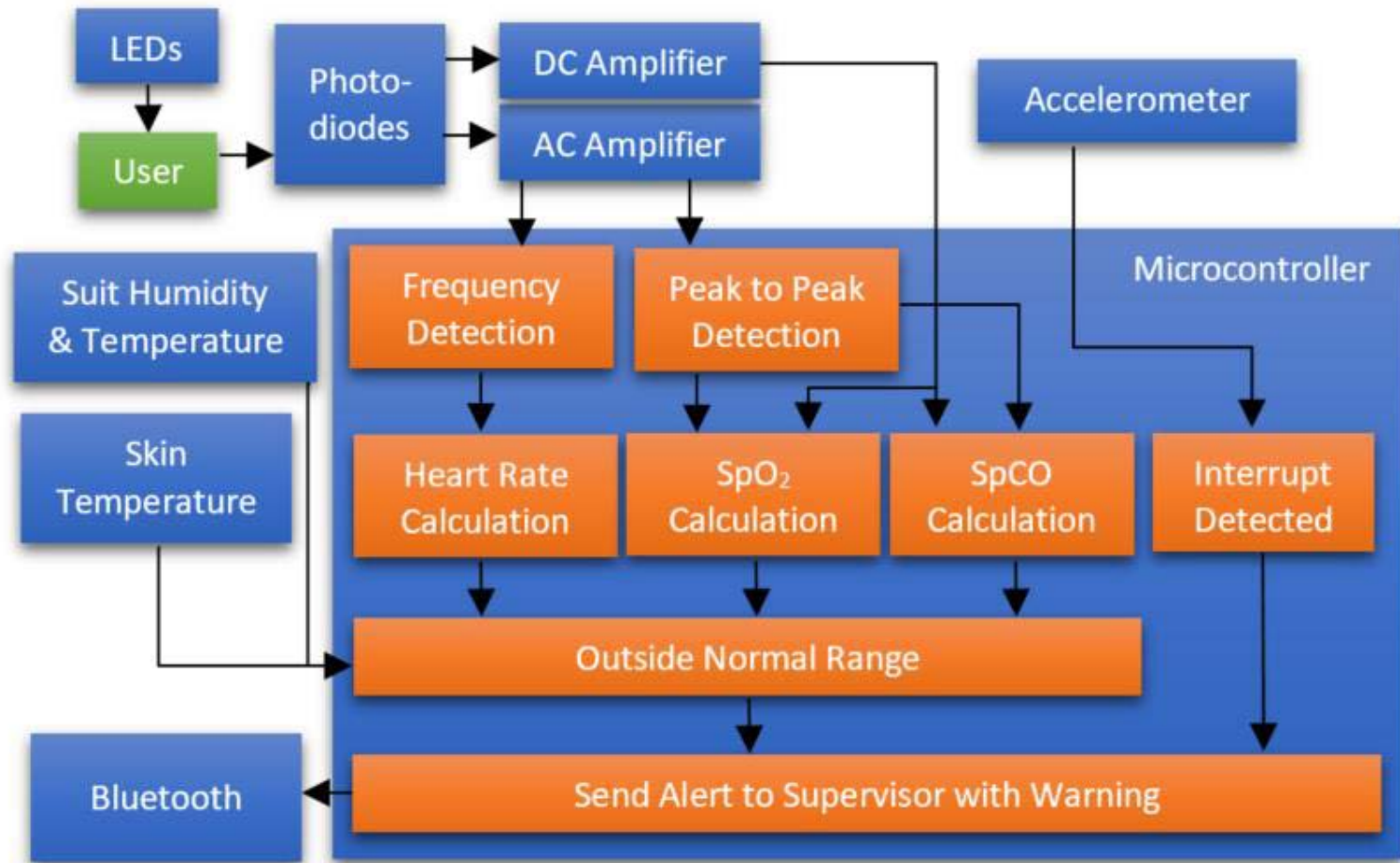


- The environmental conditions also cause heat strain
- Different levels of environmental conditions allow different amounts of time allowed in the environment

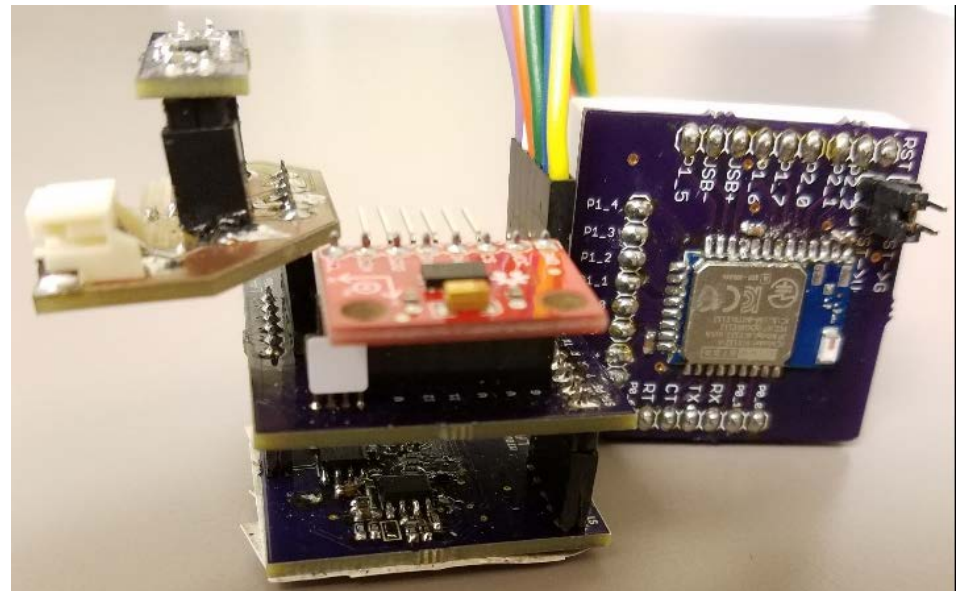
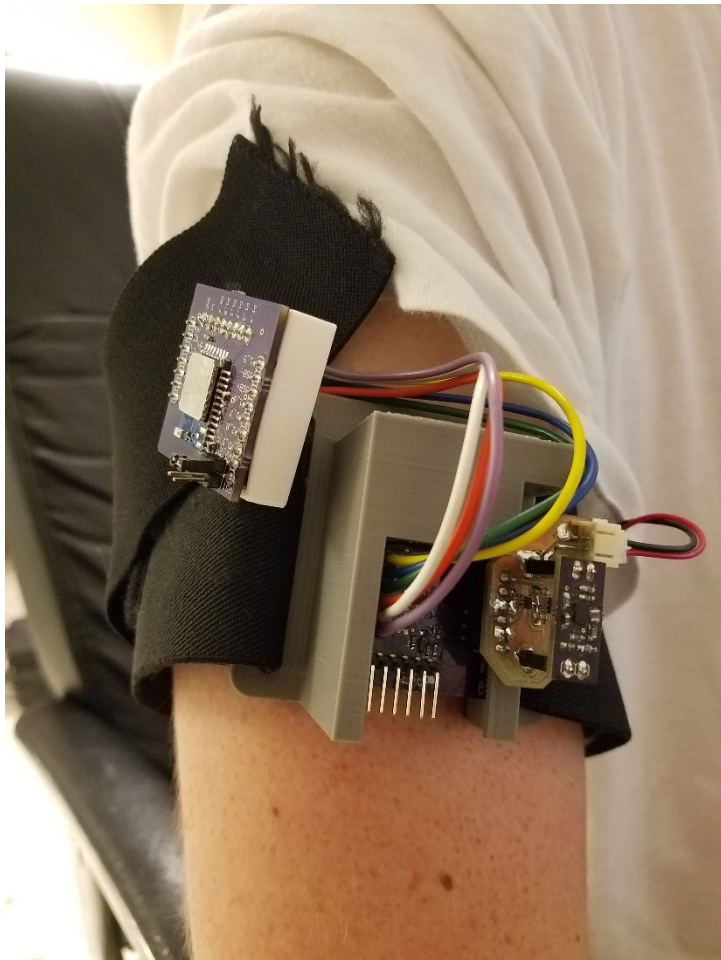
[3] D. Barr, W. Gregson and T. Reilly, "The thermal ergonomics of firefighting reviewed," Applied ergonomics, vol. 41, no. 1, pp. 161-172, 2010.

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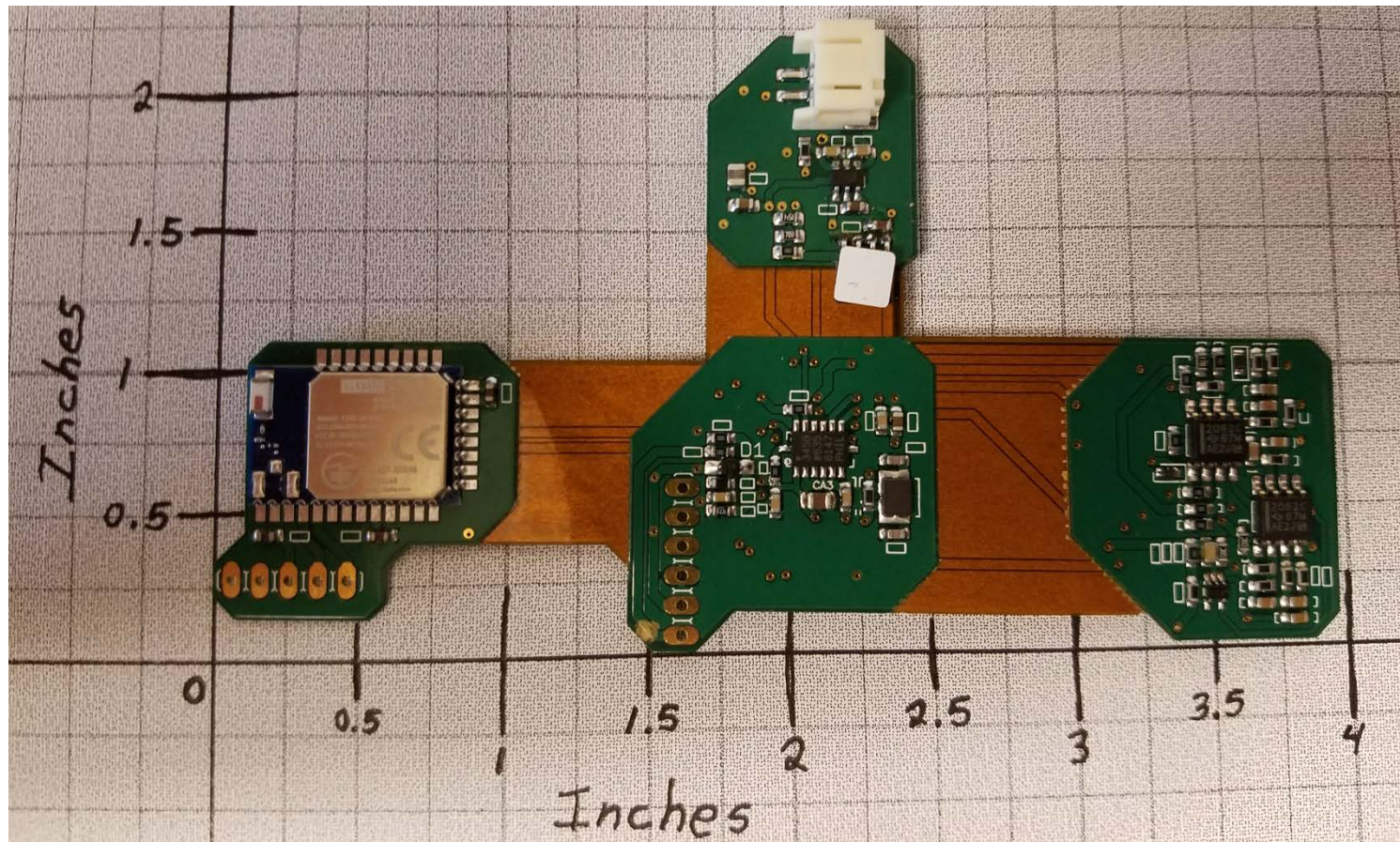
Block Diagram



Proof of Concept with Rigid PCB

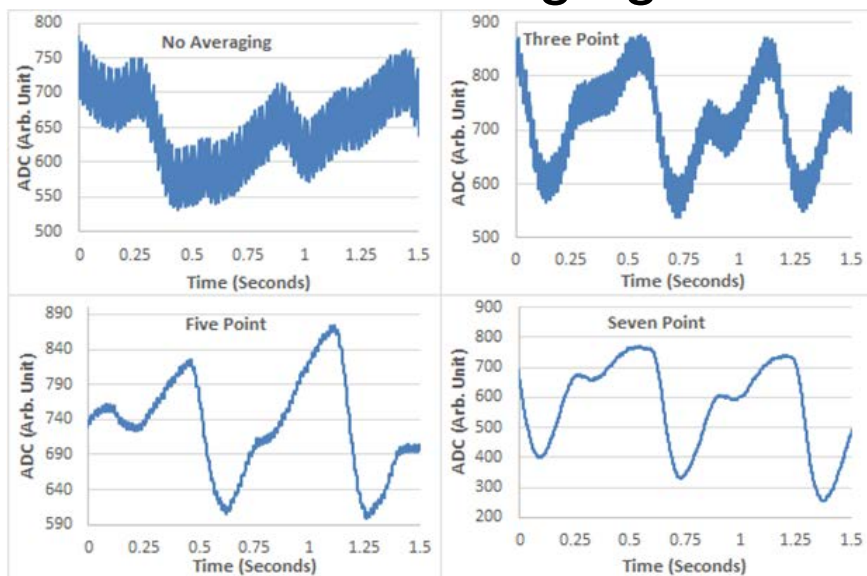


Functional Prototype with Flexible PCB

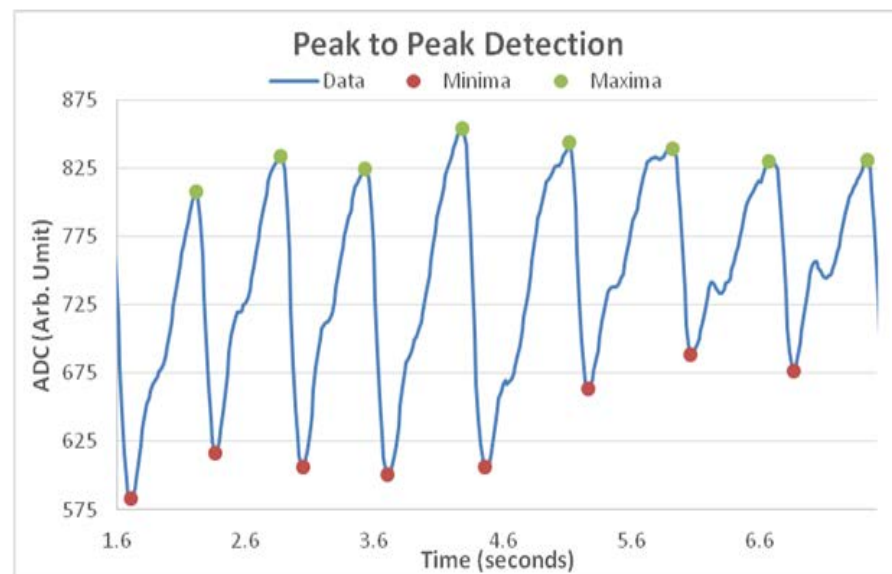


Preliminary Pulse Oximeter Software

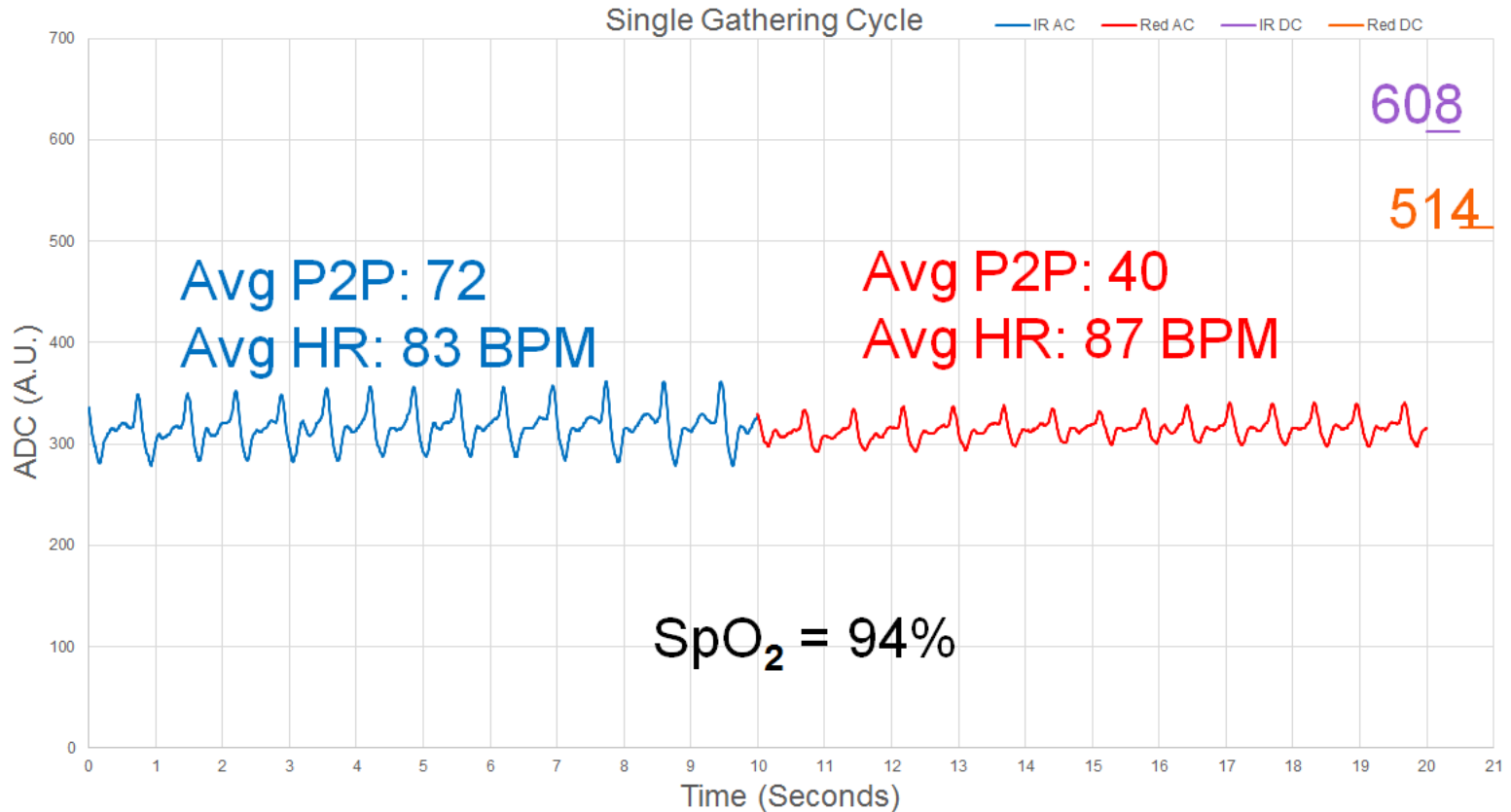
- Boxcar averaging:



- Peak Detection:

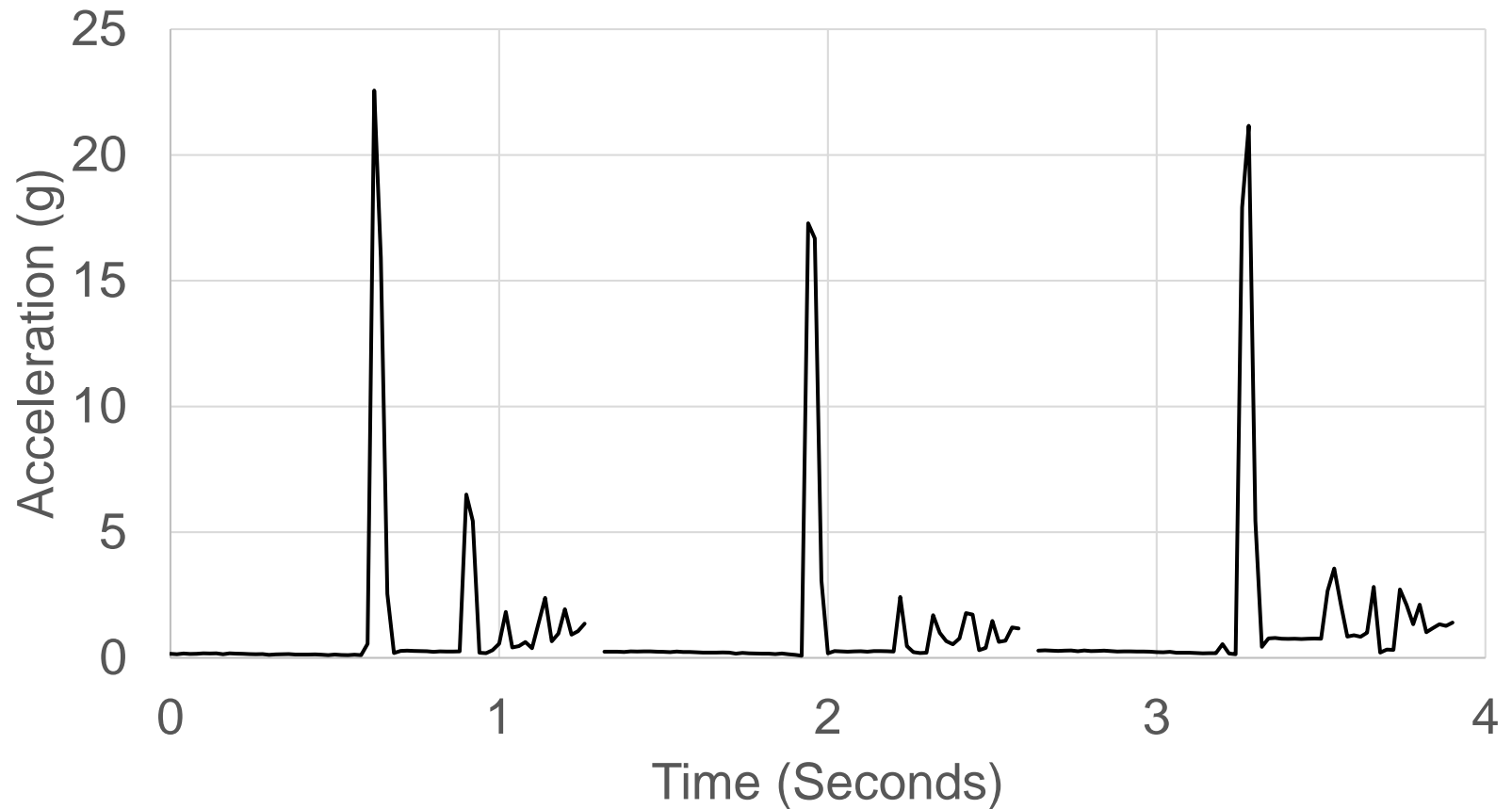


Preliminary Pulse Oximeter Results

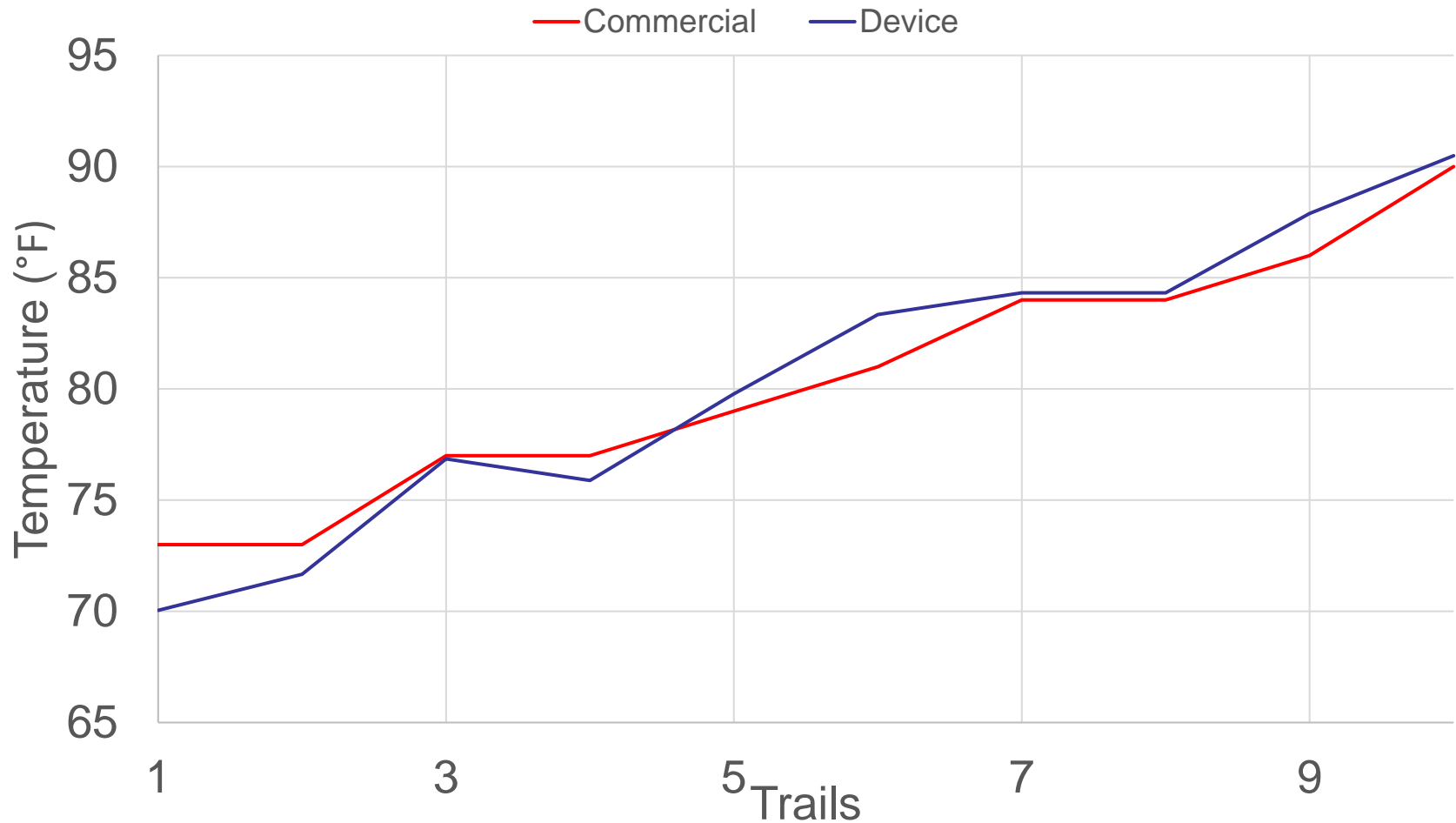


Accelerometer Results

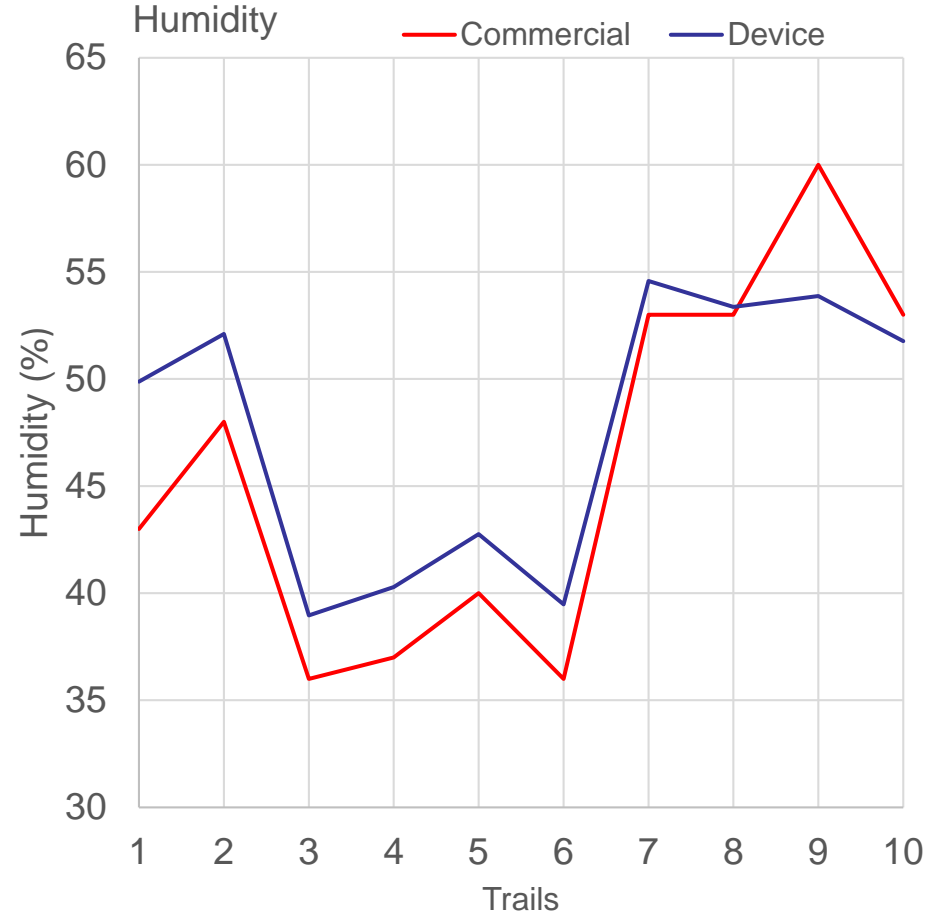
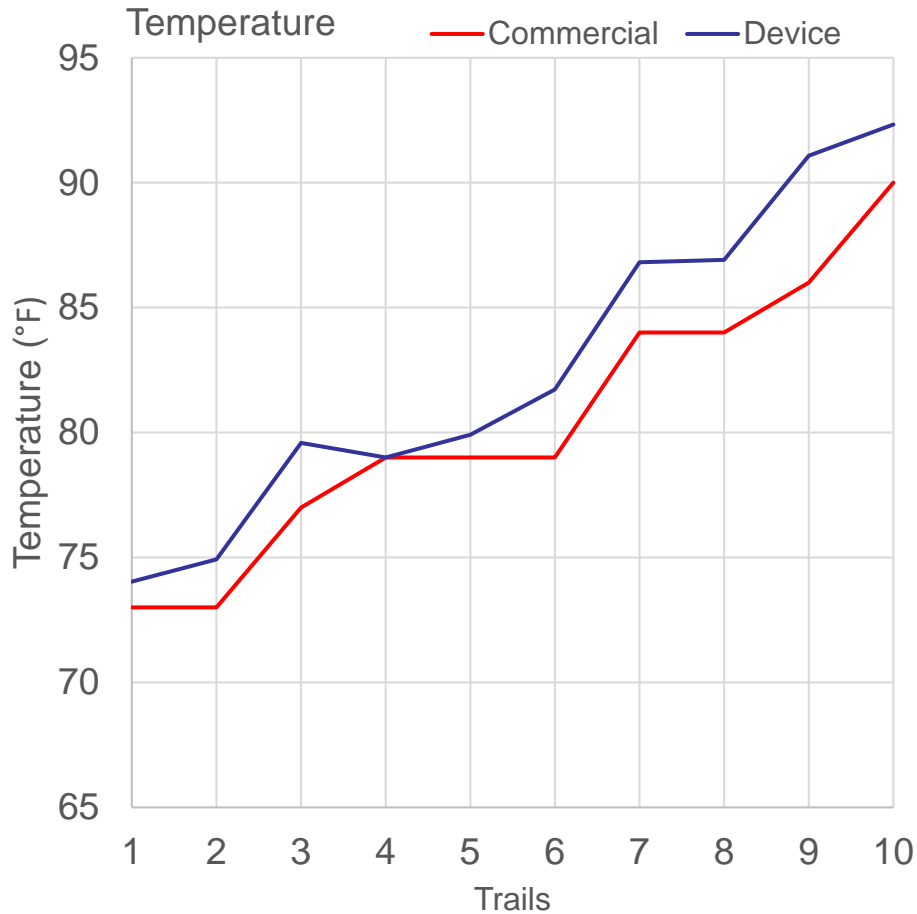
Drop Test



Skin Temperature Results



Accelerometer Results



Pulse CO Oximeter

- Currently the hardware for the pulse CO oximeter is completed and integrated into the patch
- Development of the algorithm for measuring SpCO is under development
- Testing of the pulse CO oximeter is needed.

Potential Research Funding

- Find a new wireless method which can transmit past the fire wall.
- Human testing of the device undergoing physical activity

Conclusion

- The occupation of firefighting is dangerous and full of hazards.
- The proposed device has been designed to monitor firefighters while on active duty
- Ideally every firefighter would have a device to monitor them when in the field allowing for reduced injuries and deaths.

Acknowledgements

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Questions?

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