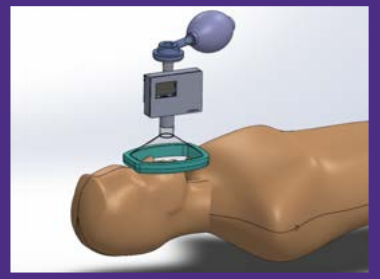
EIH ENGINEERING INNOVATION IN HEALTH

C-O-YOU



Brian Do[1], Liban Hussein[2] , Grant Larocca[3], Emily Rhodes[4], Trevor Tran[3], Andrew Latimer[5], Cathlene Buchanan[6], Carrie Smith[6]

[1] Human Centered Design and Engineering, [2] Electrical Engineering, [3] Mechanical Engineering, [4] Chemical Engineering, [5] Harborview Medical Center, Seattle, WA
[6] Stryker, Redmond, WA

Background

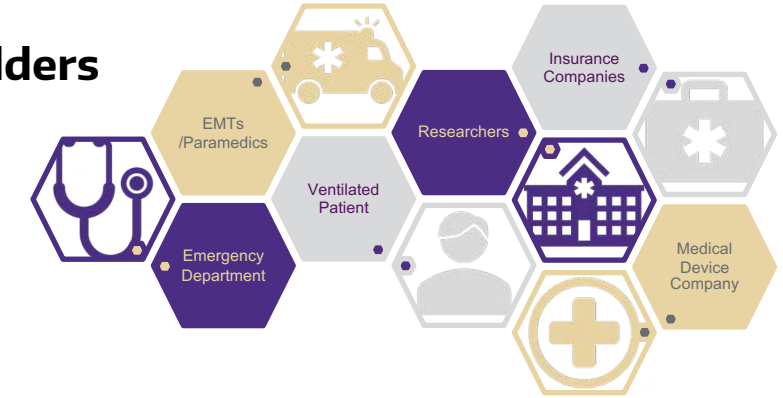
Challenge

Capnography tells first responders vital information about patients (perfusion & ventilation) and helps with intubation but can be obstructive.

Problem

Improper ventilation results in increased stays in the ICU, costing about $790M/Year

Stakeholders:



Patients monitored with ETCO2 = 790,000 in 2016
Market = $500M

Existing Solutions

Mainstream Capnography (Masimo EMMA) 	No wiring Minimal profile	No pressure/flow rate measurement No data transmission
Side stream Capnography (Medtronic Capnostream 35) 	Multifunctionality/ comprehensive data display	No pressure/flow rate measurement Obstructive components
Comprehensive Monitoring Unit (Stryker LIFEPAK 15) 	Multifunctionality/ comprehensive data display Compatible with other technology	No pressure/flow rate measurement Obstructive components

Unmet Need

A way to eliminate wiring of current capnography technology ($EtCO_2$), and provide more information to EMTs in the pre-hospital setting to optimize patient care and reduce complications in transport.

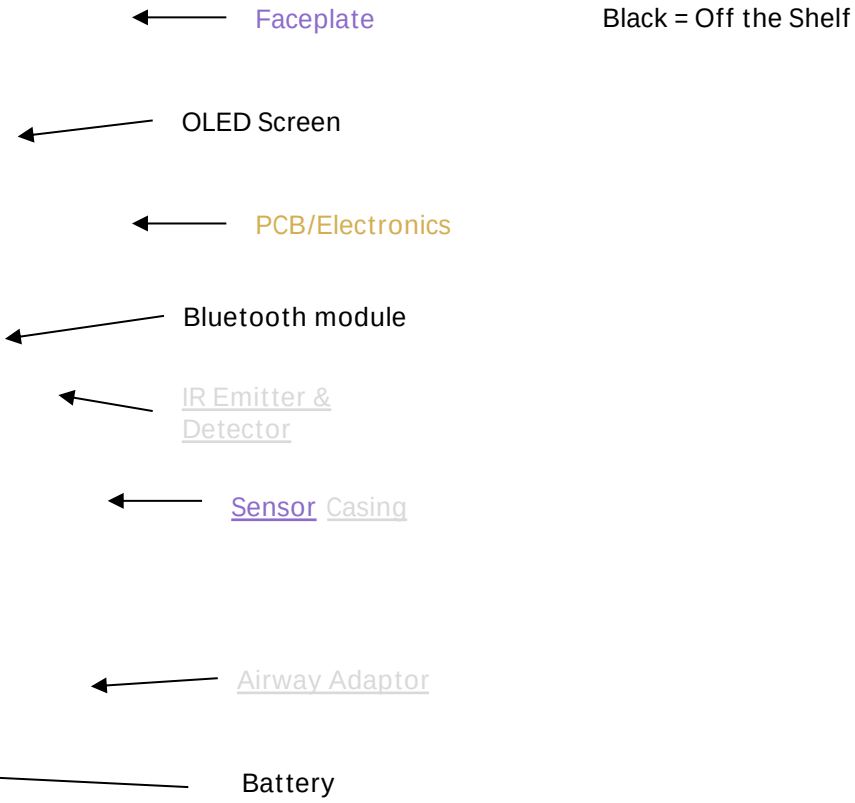
Solution must:
1. Monitor EtCO2
2. Monitor pressure and volumetric flow rate
3. Wirelessly transmit data
4. Have minimally obtrusive components

Design Specifications
1. Be compatible with the pre-hospital environment
2. Provide accurate feedback on ventilation quality
3. Display data intuitively

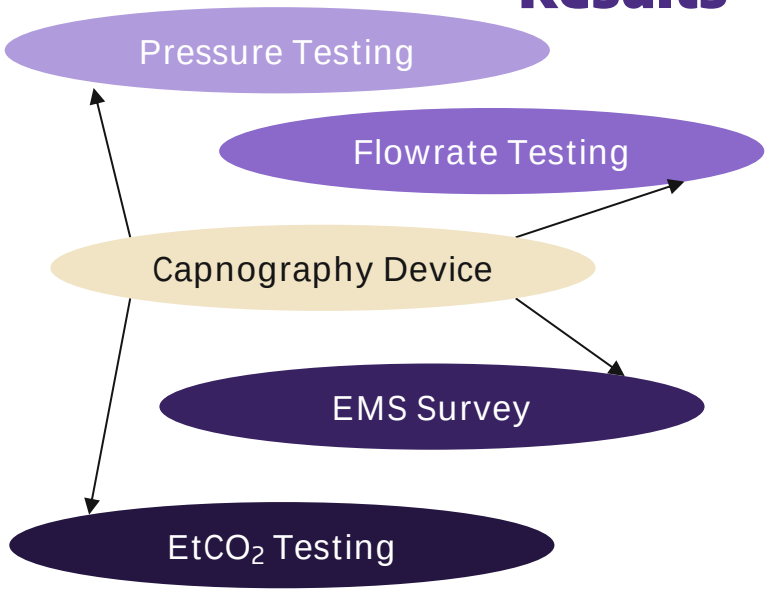
Design Concept

Prototype

Purple = 3D Printed
Gold = Custom
Black = Off the Shelf



Results



Future testing

Combined testing: all components integrated

Bluetooth Testing

Compare EtCO2 values to measurements

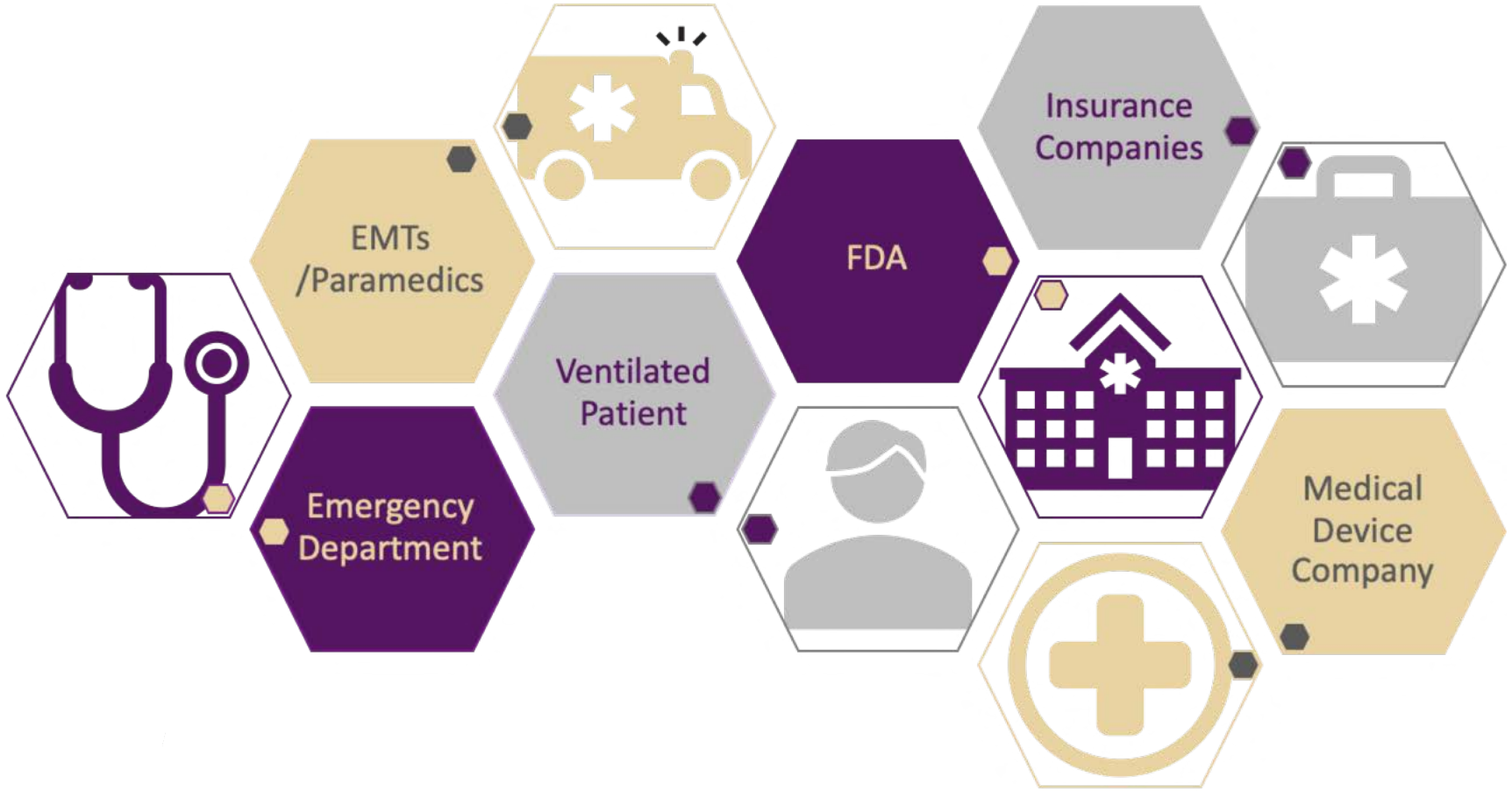
Summary

Incorporated pressure and flowrate readings into a mainstream capnography device that can wirelessly transmit data

Future

- Incorporate device into the clinical setting
- Verify the pressure, flow rate and CO_2 concentration readings

Many thanks to UW/Harborview Emergency Department, Stryker, and to the EIH teaching



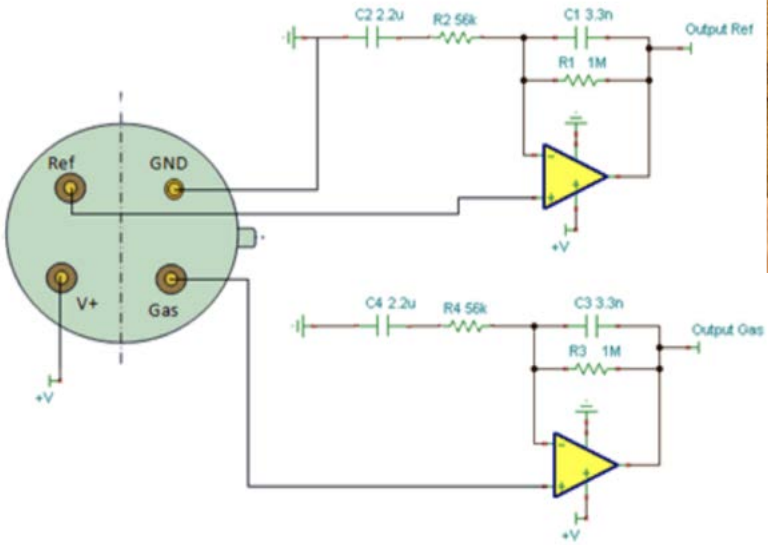
BE BOUNDLESS

Prototype-IR Sensor

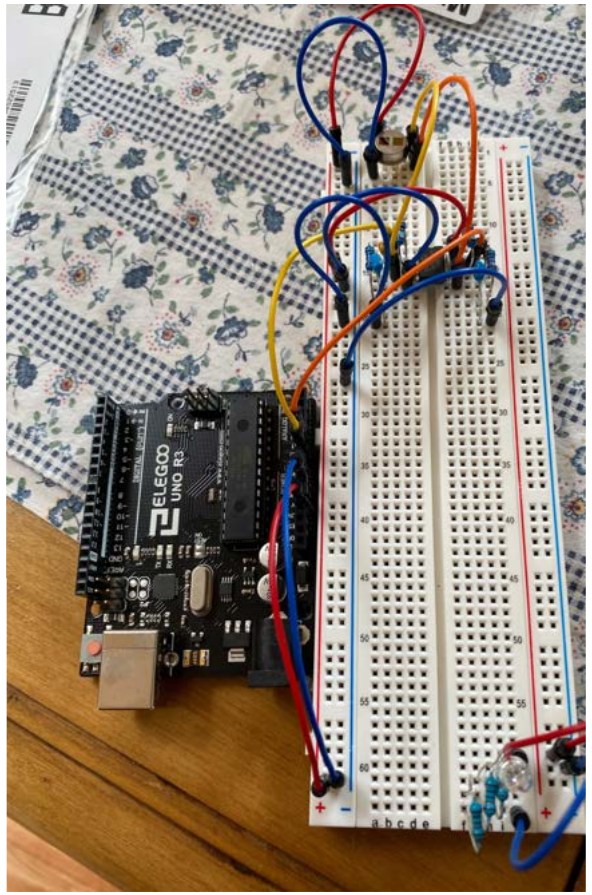
Software and circuit for IR sensor:

- Software/code for plotting IR sensor data completed
- Circuit to input data

Plotted EtCO2 Data: Concentration of EtCO2 [mmHg] vs. Time [seconds]



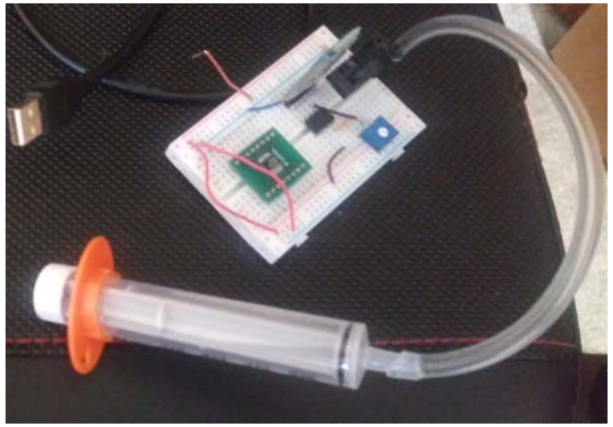
IR Detector Circuit Diagram [1]



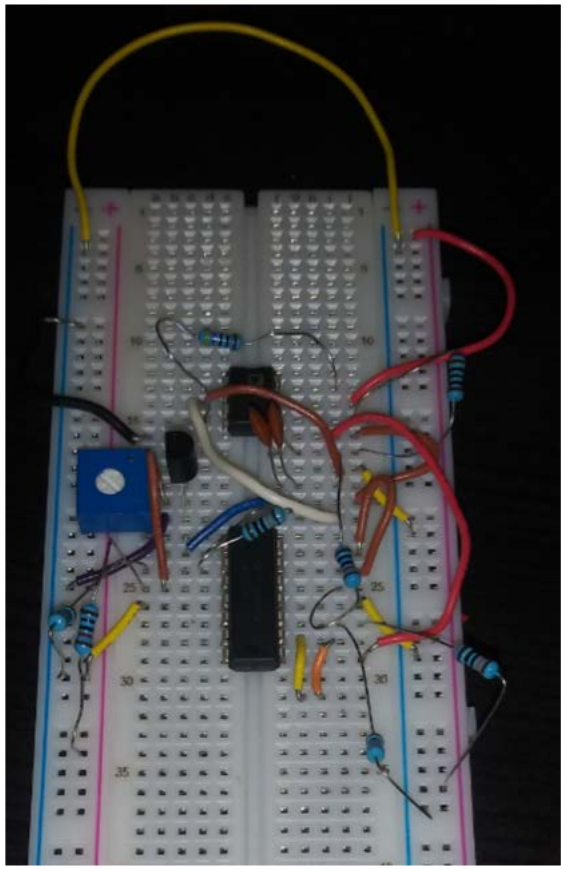
IR Detector Circuit

[1] https://pyreos.com/capnography

Prototype-Pressure/Flow Rate Sensor



Differential Pressure Pneumotachometer Circuit (Winter Qtr.)



Differential Pressure Pneumotachometer Circuit (Spring Qtr.)

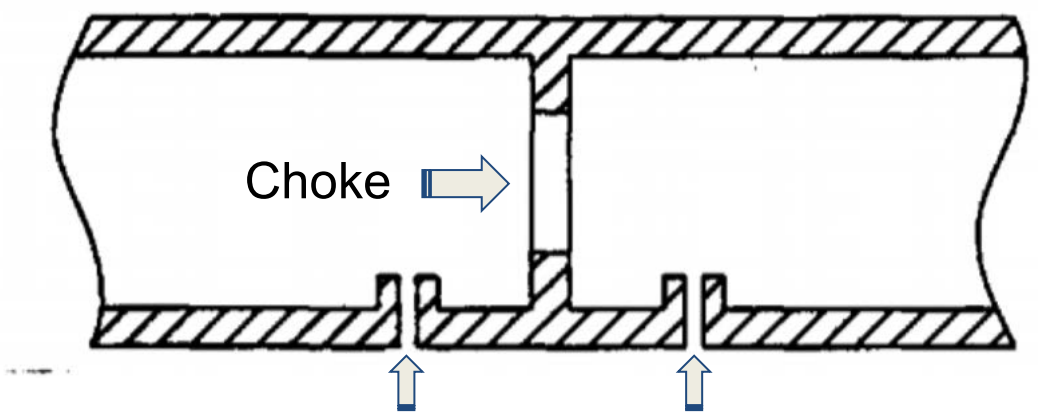
LabView Data Acquisition Unit

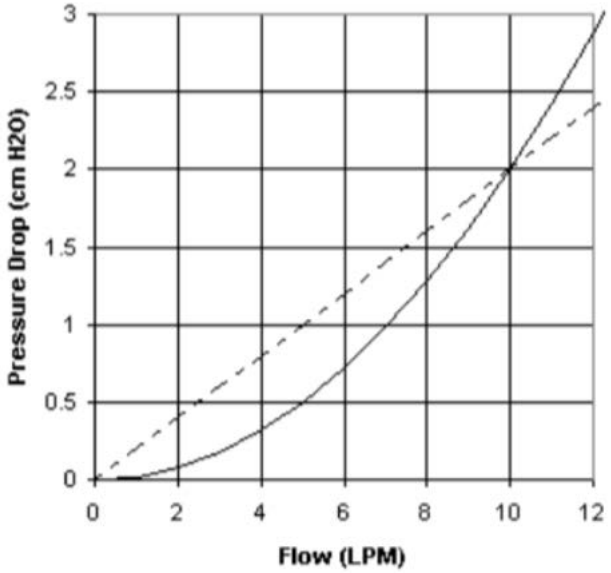
“Airway adapter” and sensor for pressure/flow rate

Flow Rate Tests

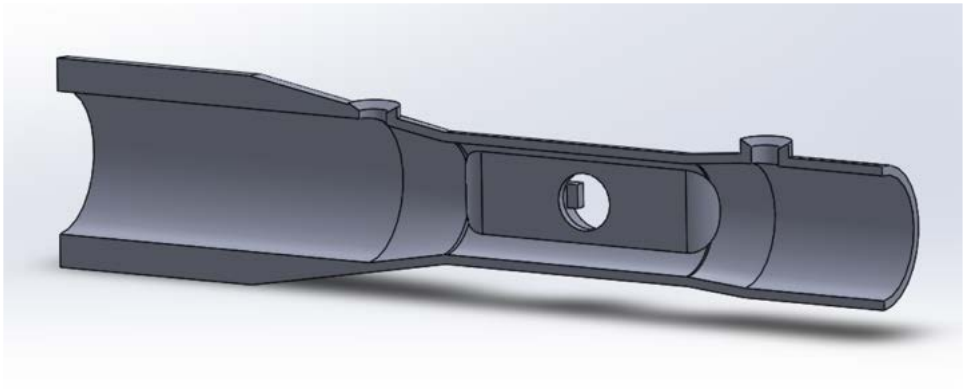
UNIVERSITY of WASHINGTON

- **Minimize flow resistance**
- **Maximize differential pressure drop**
- **Determine necessity of entrance length**
  - **Laminar flow**

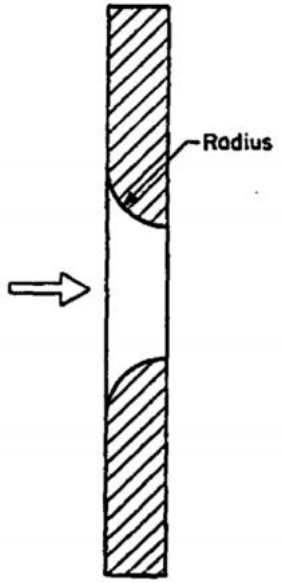




Flow vs. Pressure drop



Cutaway of Airway Adapter Design

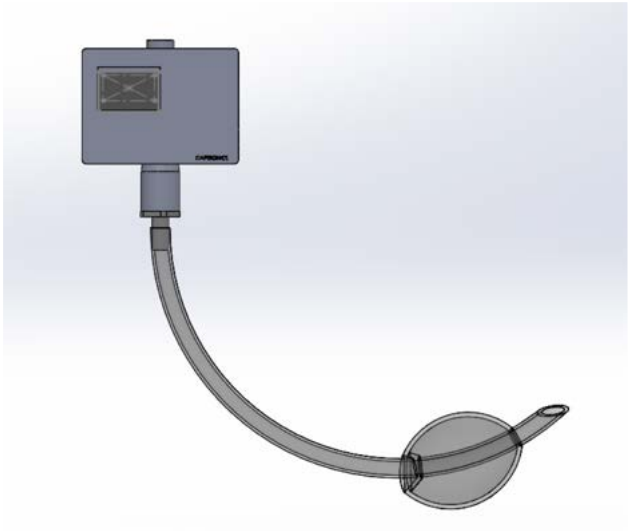


Prototype-Mechanical Aspects

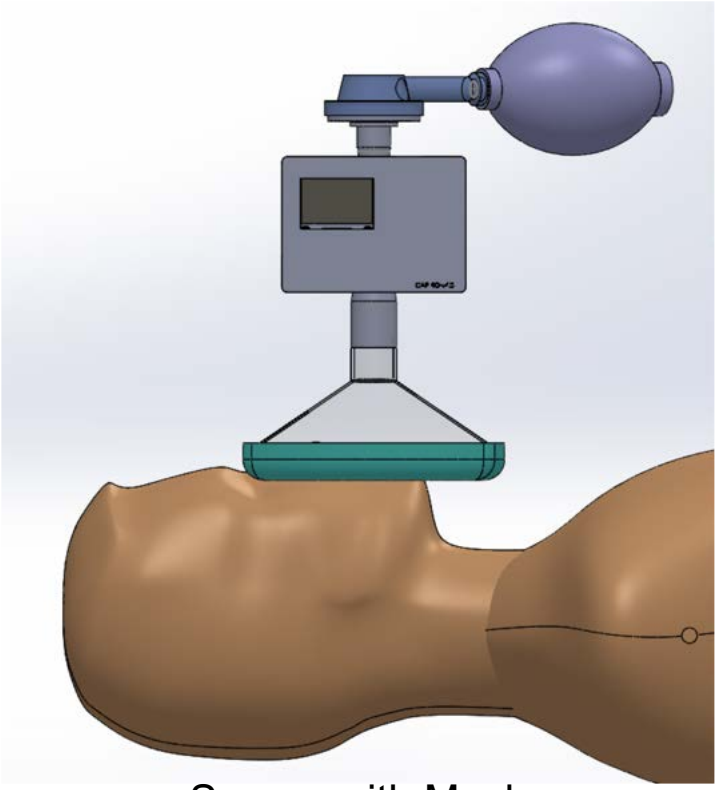
UNIVERSITY of WASHINGTON

Sensor Casing:

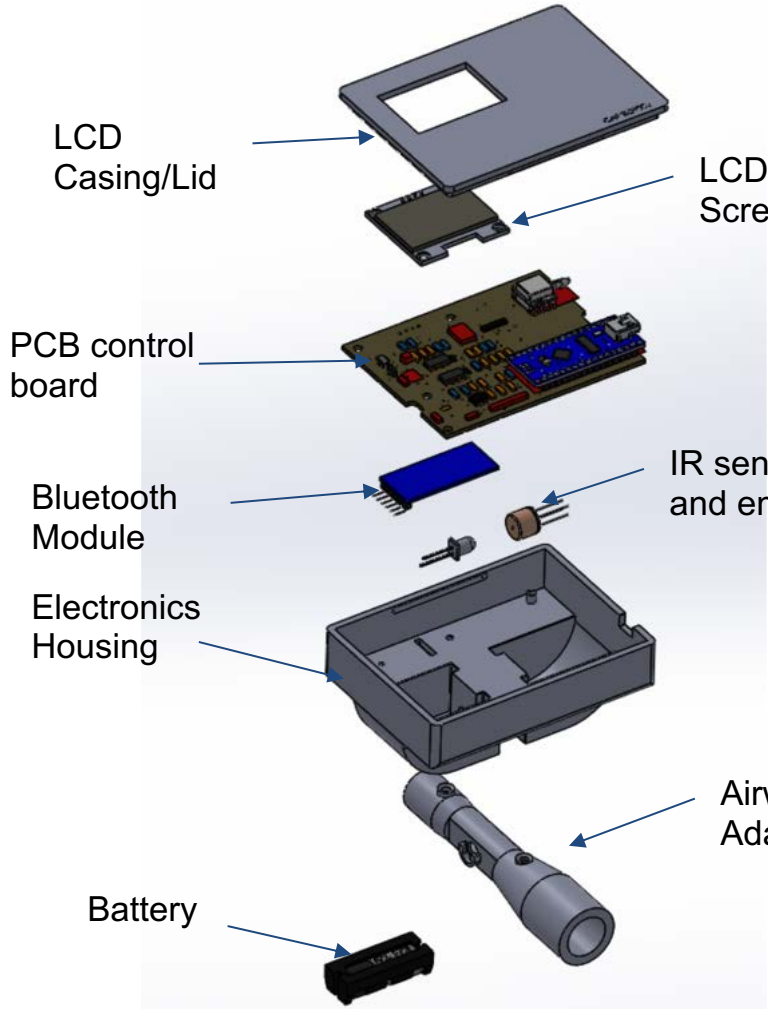
- Houses all electronic components
- LCD screen for vital information
- Connects onto endotracheal tube via airway adapter
- Fully integrated device



Sensor with Intubation Tube



Sensor with Mask



Full Sensor Casing Assembly

UNIVERSITY of WASHINGTON

C-O-You: End-Tidal CO_2 Monitoring

Emily Rhodes [1], Grant LaRocca [2], Trevor Tran [2], Liban Hussein [3]
Brian Do [4], Andrew Latimer [5], Nathan White [5], and Cathlene Buchanan [6], Carrie Smith [6]

[1] Chemical Engineering, University of Washington, Seattle, WA
[2] Mechanical Engineering, University of Washington, Seattle, WA
[3] Electrical and Computer Engineering, University of Washington, Seattle, WA
[4] Human Centered Design and Engineering, University of Washington, Seattle WA
[5] Harborview Medical Center, Seattle, WA
[6] Stryker, Redmond, WA

March 16th, 2020
Winter Design Review
ME/EE 498/514/498

Background: End Tidal CO_2

UNIVERSITY of WASHINGTON

Patients monitored with $ETCO_2$ = 790,000 in 2016

Global Capnography Market = $500M in 2018

Motivation

UNIVERSITY of WASHINGTON

Problem 1:

Inconvenient, bulky and messy

Stryker LIFEPAK 15

Problem 2:

No real time feedback during manual ventilation

Manual ventilation of a patient

Cost of these problems = $790M/Year

Current Solutions

UNIVERSITY of WASHINGTON

Solutions \ Core Functions	Measures CO_2 in Patients' Exhaled Breath	Monitors Pressure and Flow Rate	Wirelessly Transmits Data	Minimally Obtrusive Components	Collects/Stores Measurements
Masimo EMMA 	✓	✗	✗	✓	✗
Medtronic Capnostream 35 	✓	✗	✓	✗	✓
Stryker LIFEPAK 15 	✓	✗	✓	✗	✓

UNIVERSITY of WASHINGTON

Need Statement

A way to eliminate wiring of current capnography technology (EtCO2), and provide more information to EMTs in the pre-hospital setting to optimize patient care and reduce complications in transport.

Core Functions

UNIVERSITY of WASHINGTON

Monitors EtCO2 Accurately to Within Industry Standards

Monitors Pressure and Volumetric Flow Rate

Minimally Obtrusive Components

Wireless Transmits Data

Collects/Stores Measurements

Design Concept

UNIVERSITY of WASHINGTON

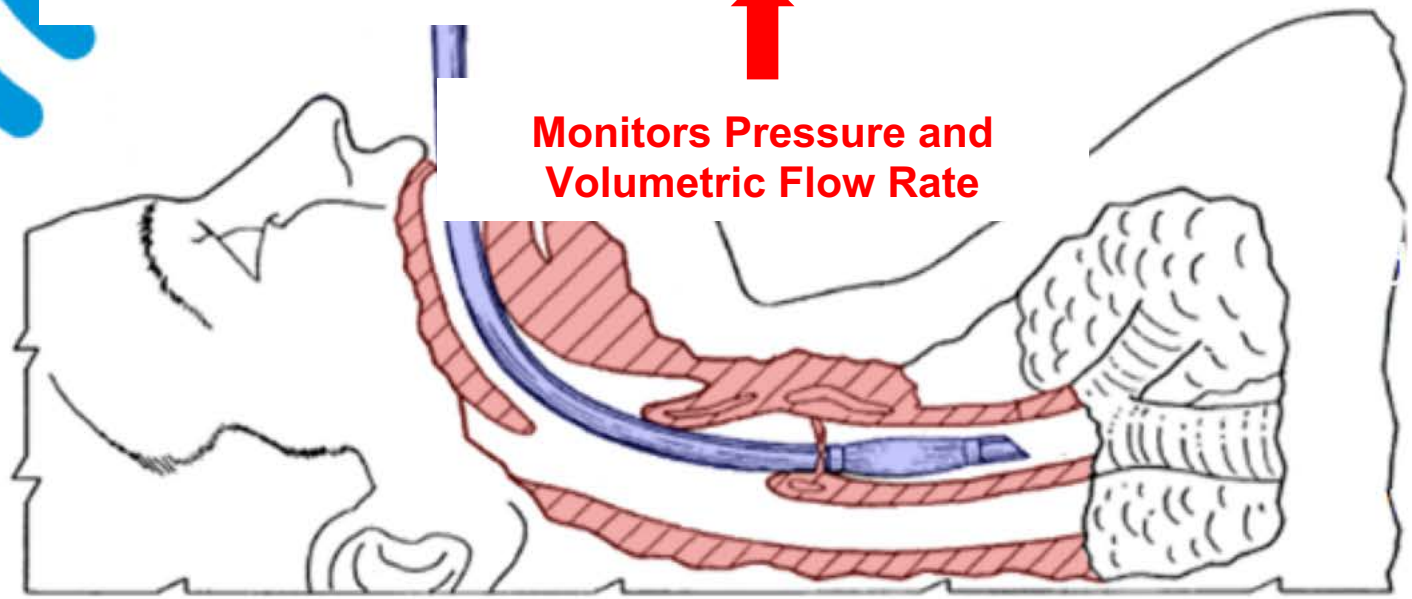
Monitors EtCO2 Accurately to Within Industry Standards

Minimally Obtrusive Components

Wireless Transmits Data

1. Mainstream $EtCO_2$ Monitoring
   IR Spectroscopy of Breath
2. Real Time Bluetooth Data Transmission
   Bluetooth component integration
3. Pressure and Flowrate Measurements
   Novel incorporation of sensors

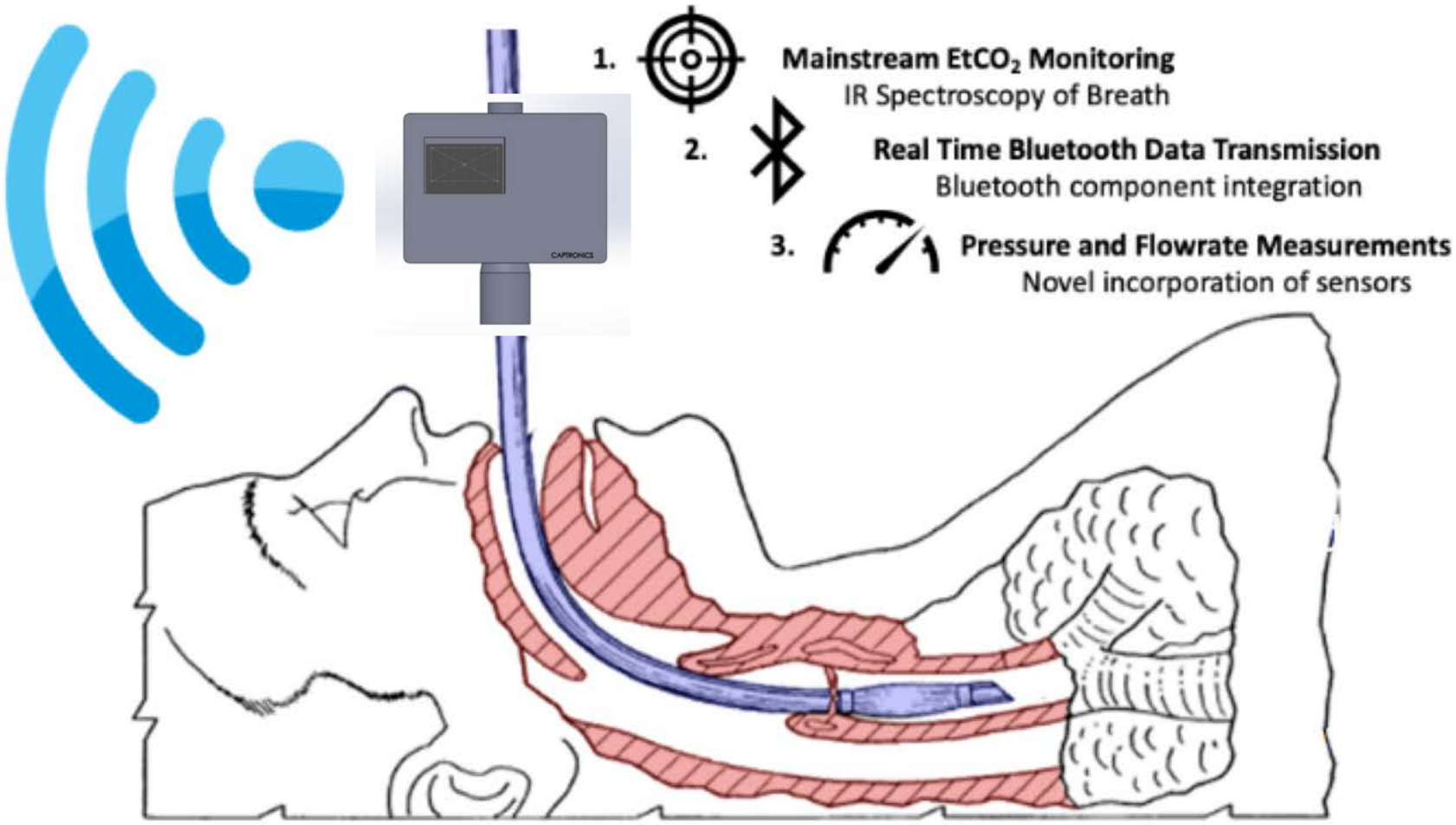
Collects/Stores Measurements



Monitors Pressure and Volumetric Flow Rate

UNIVERSITY of WASHINGTON

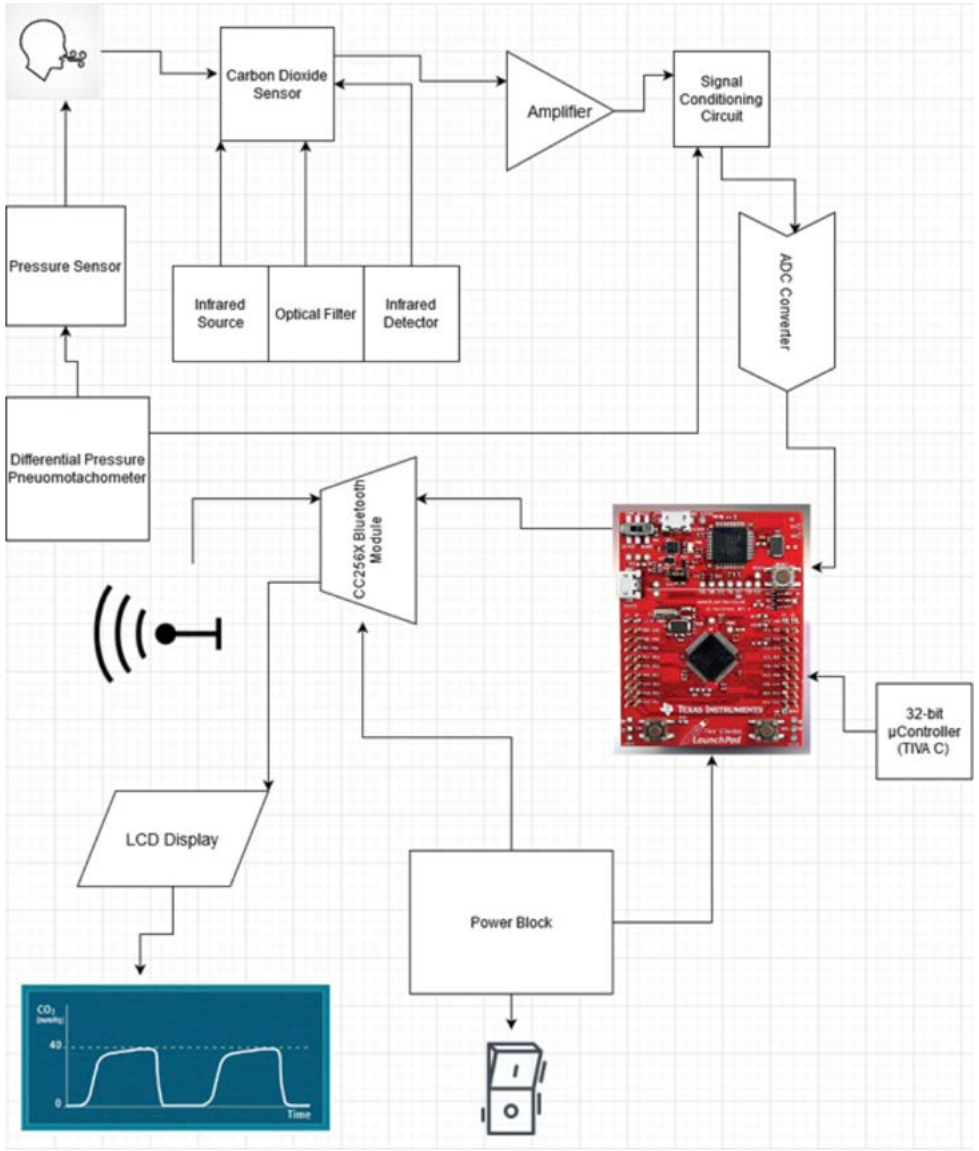
Design Concept

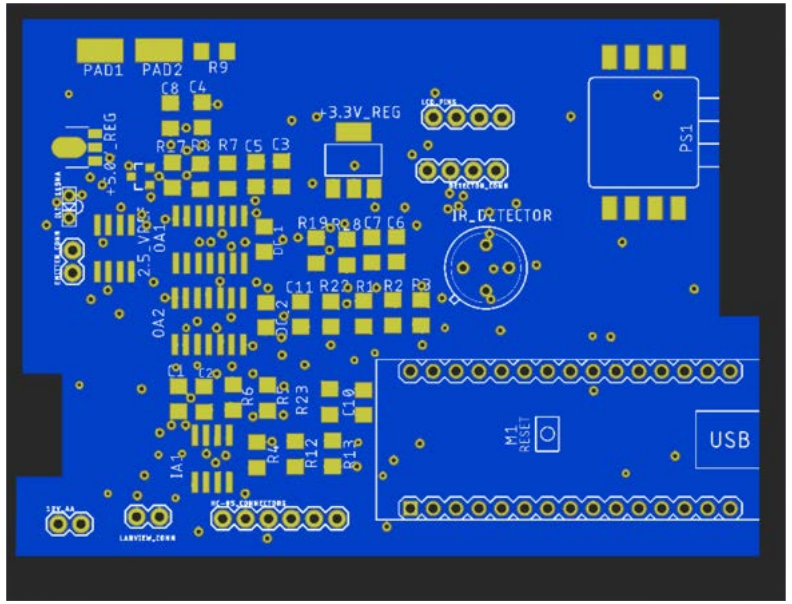


UNIVERSITY of WASHINGTON

System Block Diagram

End-Tidal Carbon Dioxide Monitoring Device





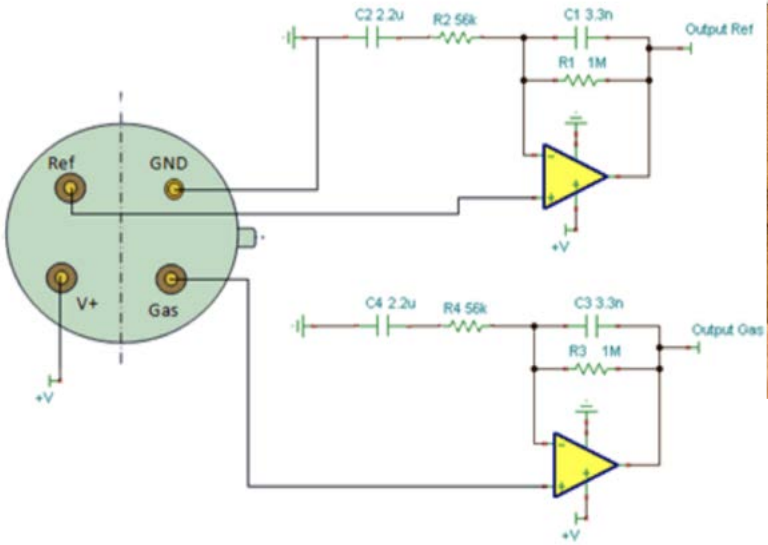
Prototype-IR Sensor

UNIVERSITY of WASHINGTON

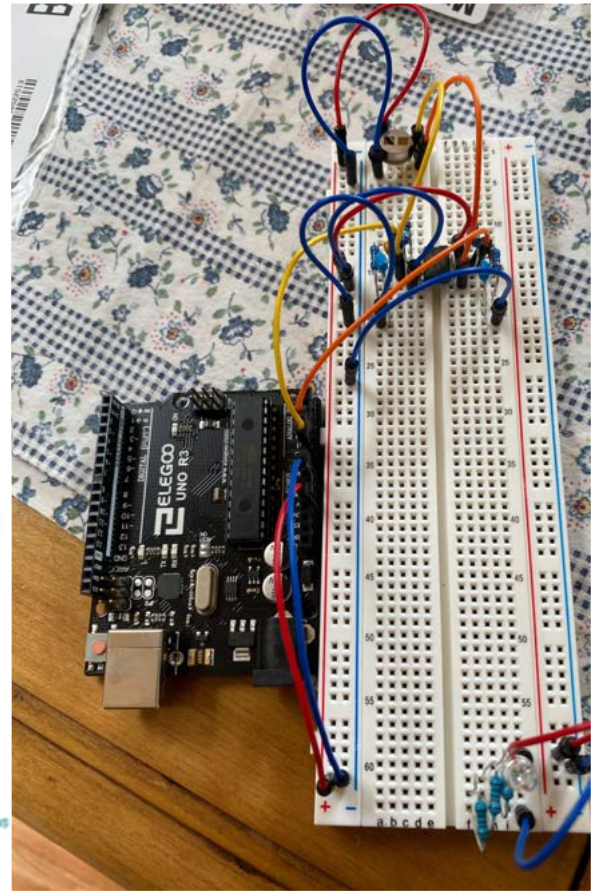
Software and circuit for IR sensor:

- Software/code for plotting IR sensor data completed
- Circuit to input data

Plotted EtCO2 Data: Concentration of EtCO2 [mmHg] vs. Time [seconds]



IR Detector Circuit Diagram [1]



IR Detector Circuit

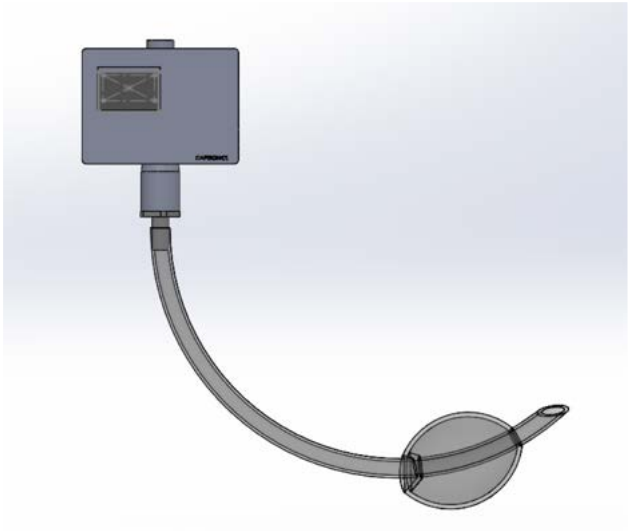
[1] https://pyreos.com/capnography

Prototype-Mechanical Aspects

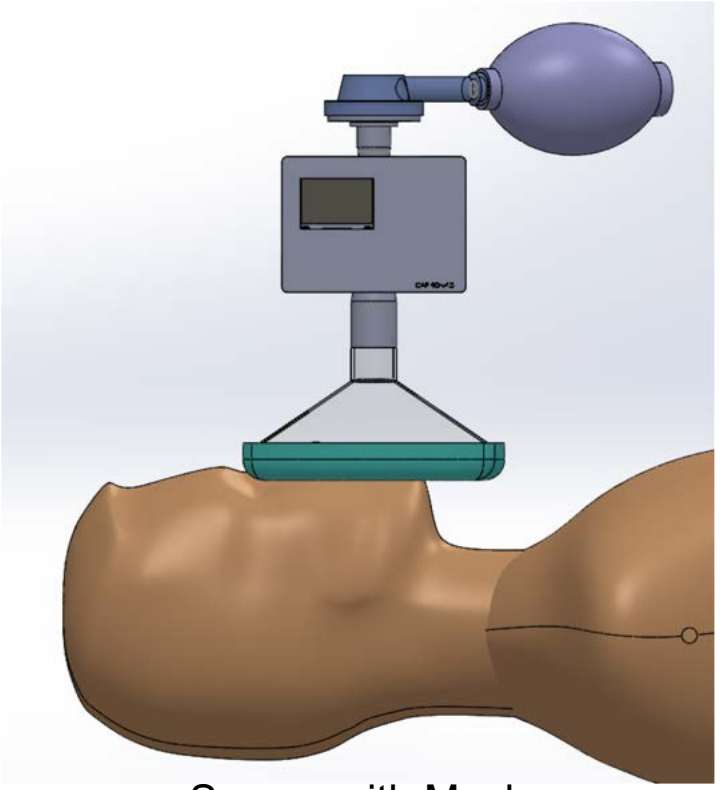
UNIVERSITY of WASHINGTON

Sensor Casing:

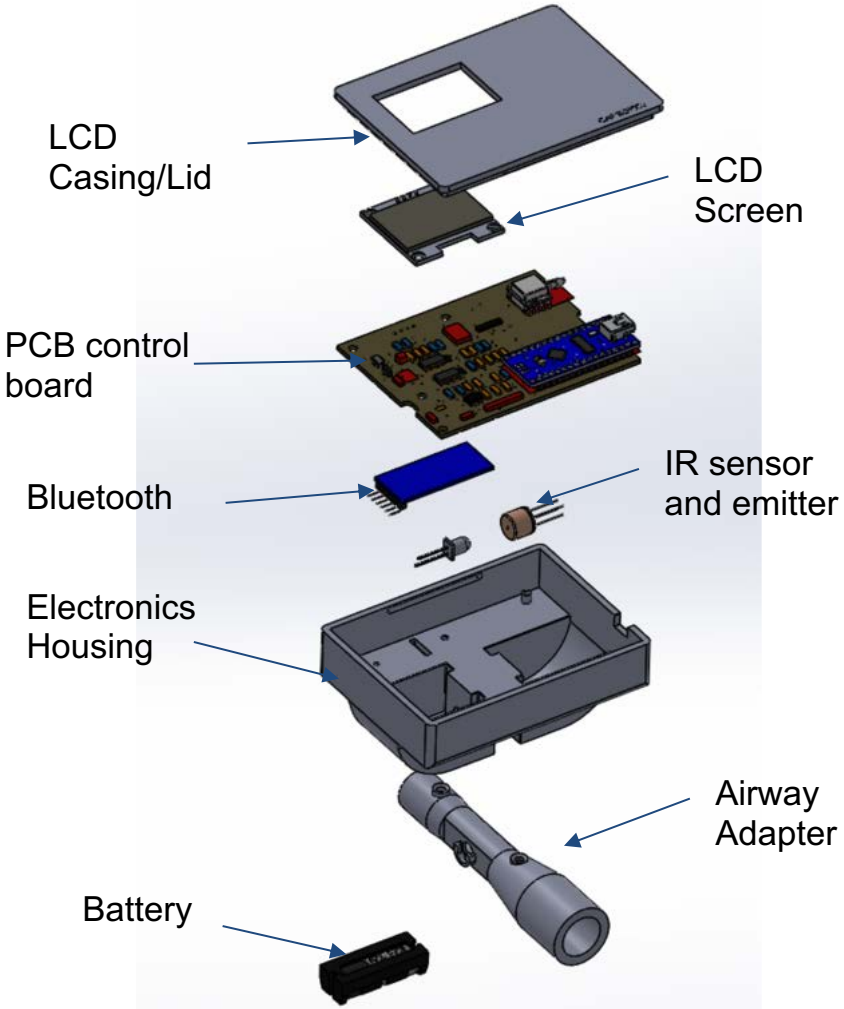
- Houses all electronic components
- LCD screen for vital information
- Connects onto endotracheal tube via airway adapter
- Fully integrated device



Sensor with Intubation Tube



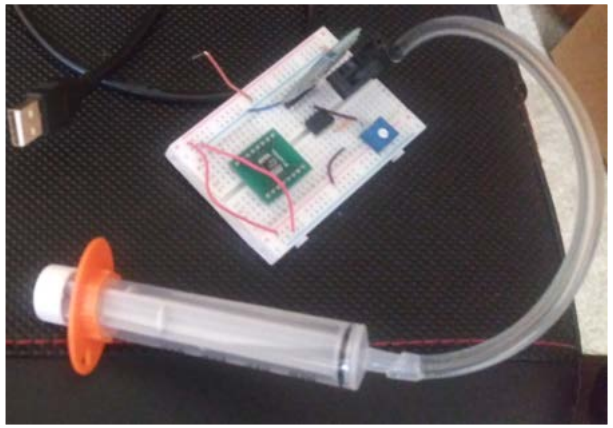
Sensor with Mask



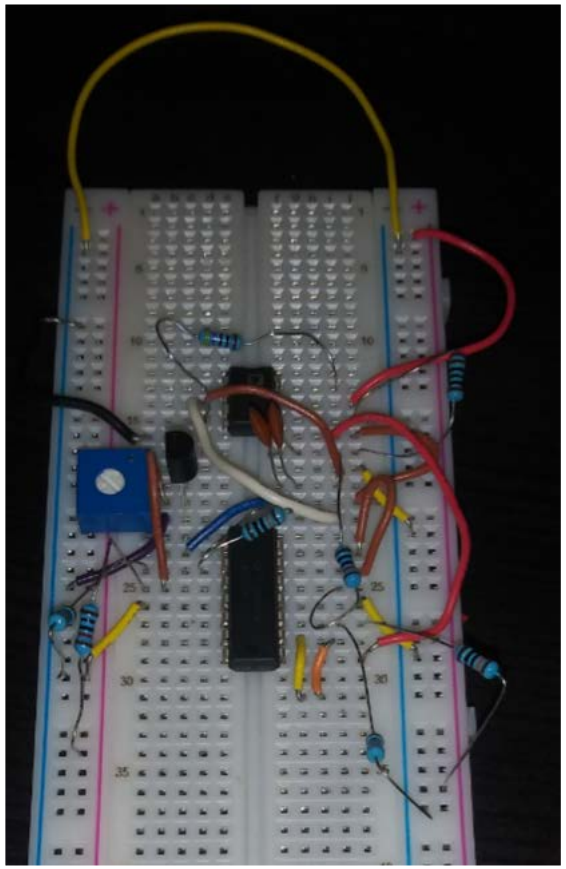
Full Sensor Casing Assembly

Prototype-Pressure/Flow Rate Sensor

UNIVERSITY of WASHINGTON



Differential Pressure Pneumotachometer Circuit (Winter Qtr.)



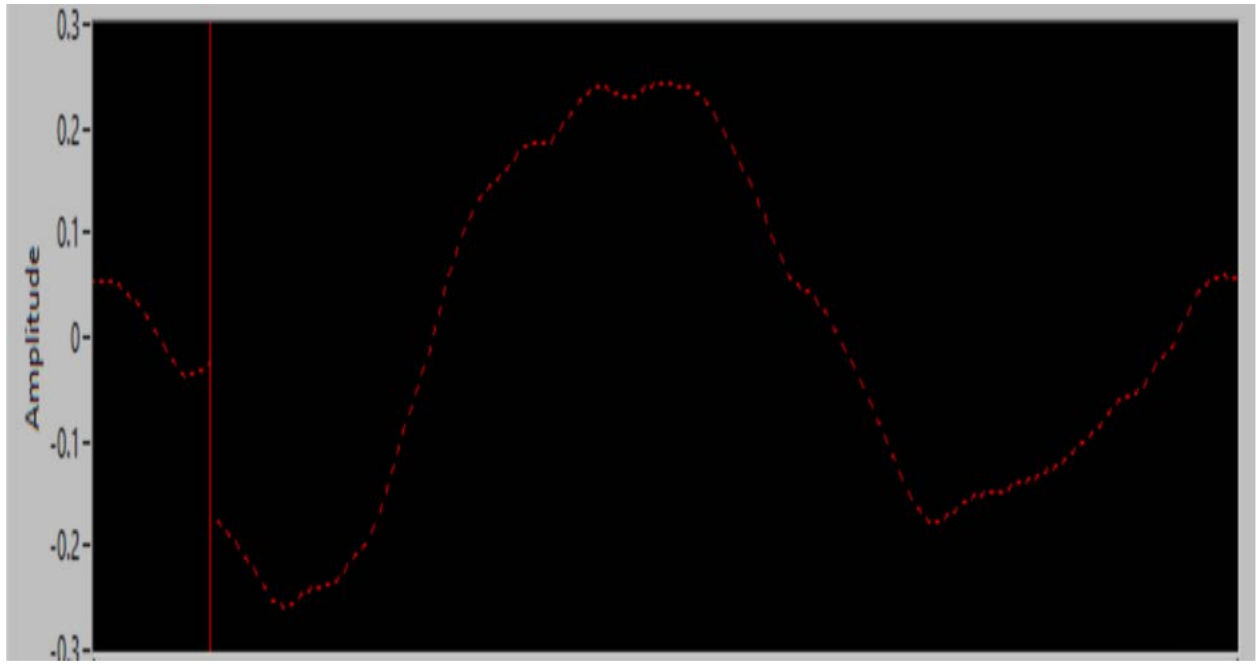
Differential Pressure Pneumotachometer Circuit (Spring Qtr.)

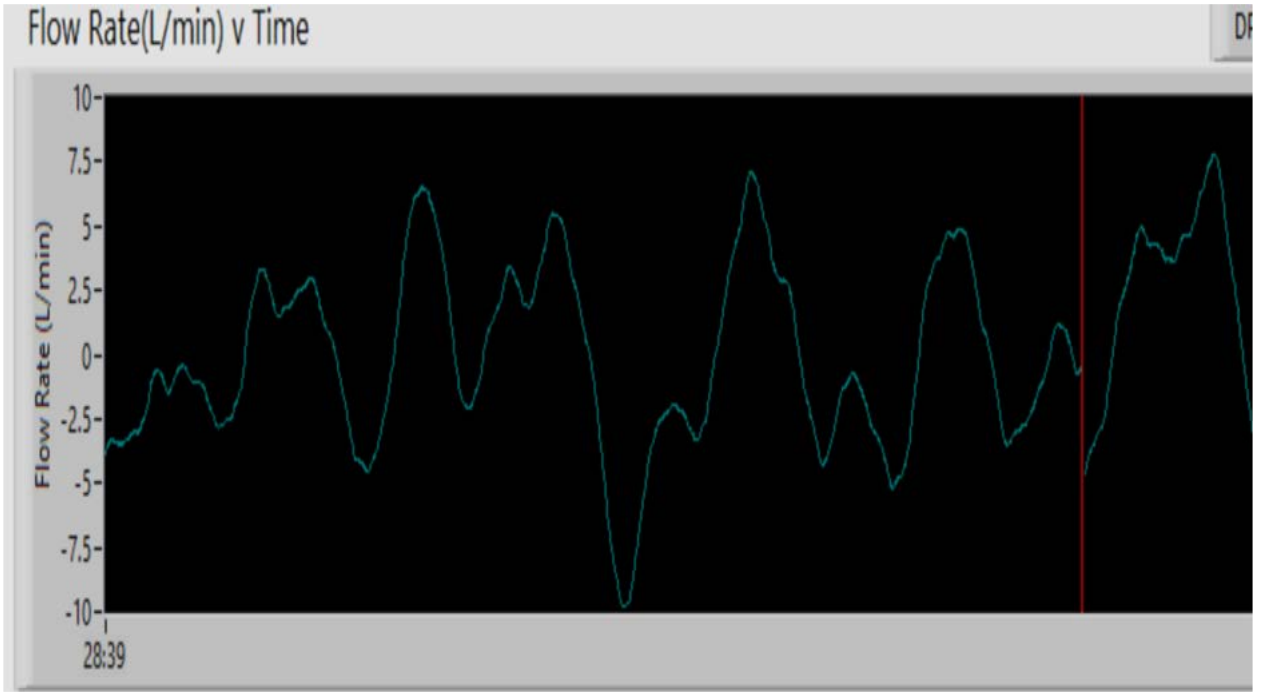
LabView Data Acquisition Unit

"Airway adapter" and sensor for pressure/flow rate

Testing: LabView Pressure/Flow Rate

UNIVERSITY of WASHINGTON





Pressure vs Time (Exhaled)

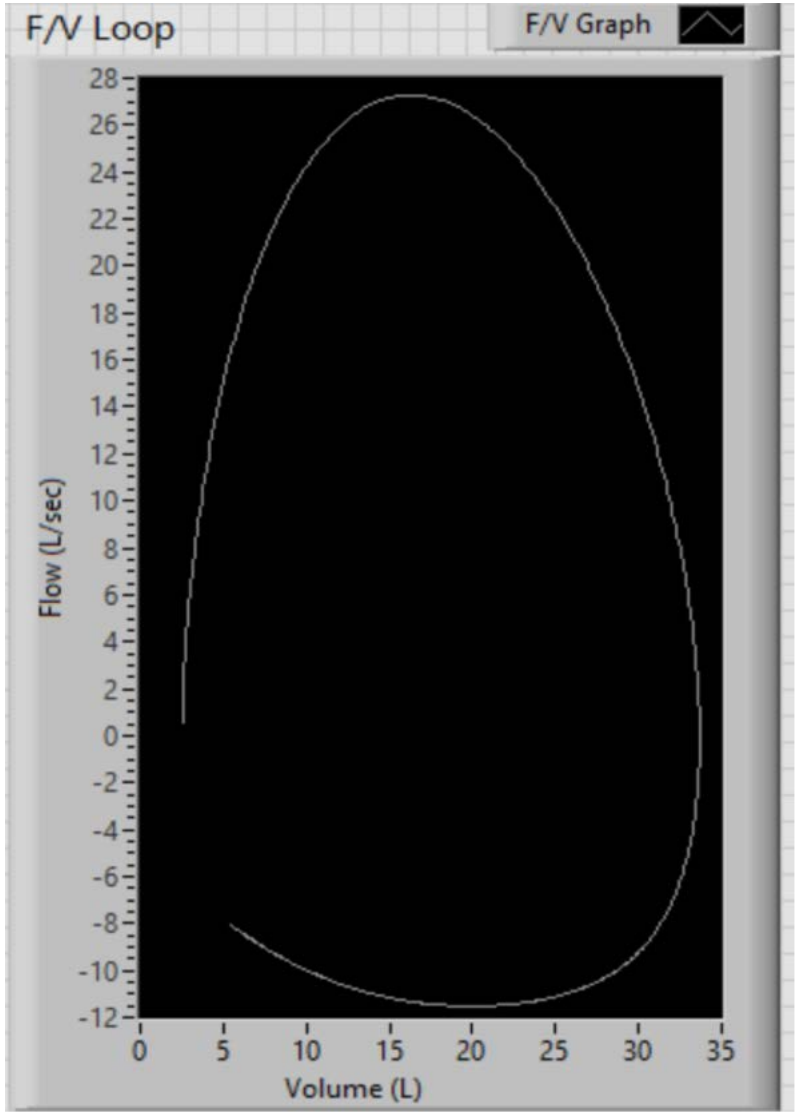
Ideal Range: 0-15 psi
Our Results: 0-4 Psi

Flow Rate vs Time
(several breaths)

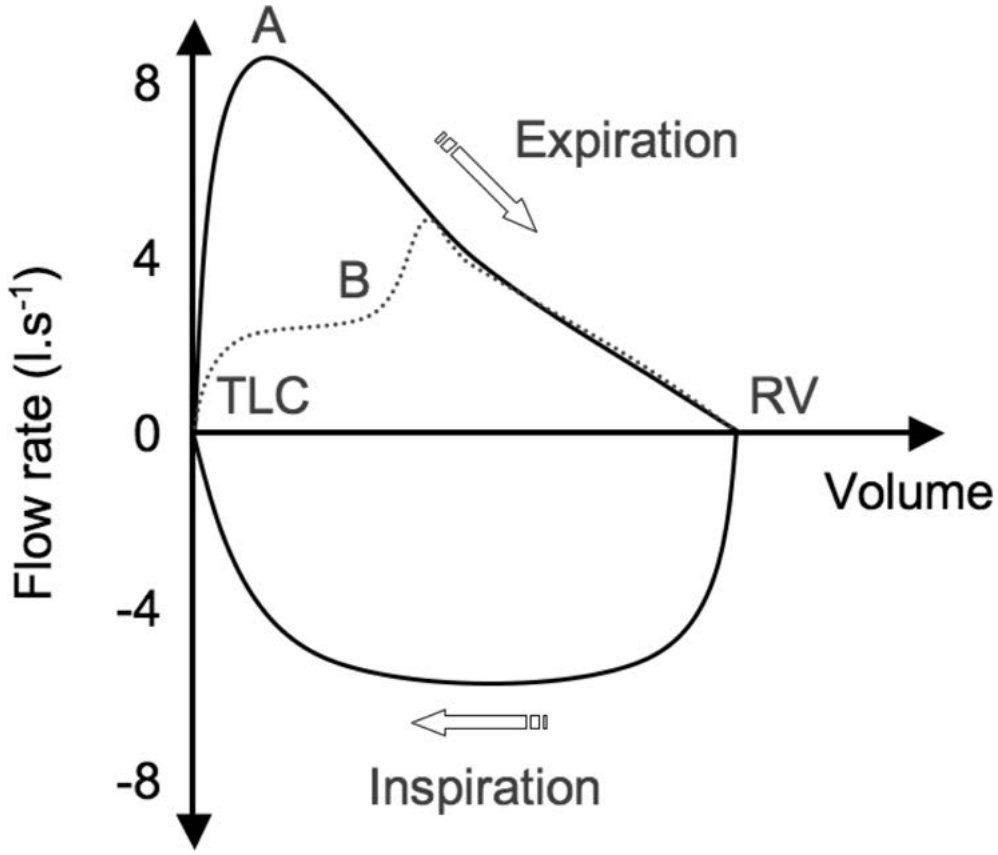
Ideal Range: 400-700 L/min
Our Results: 0-10 L/min

LabView (cont.)

UNIVERSITY of WASHINGTON



(Uncalibrated) Flow vs Volume Loop

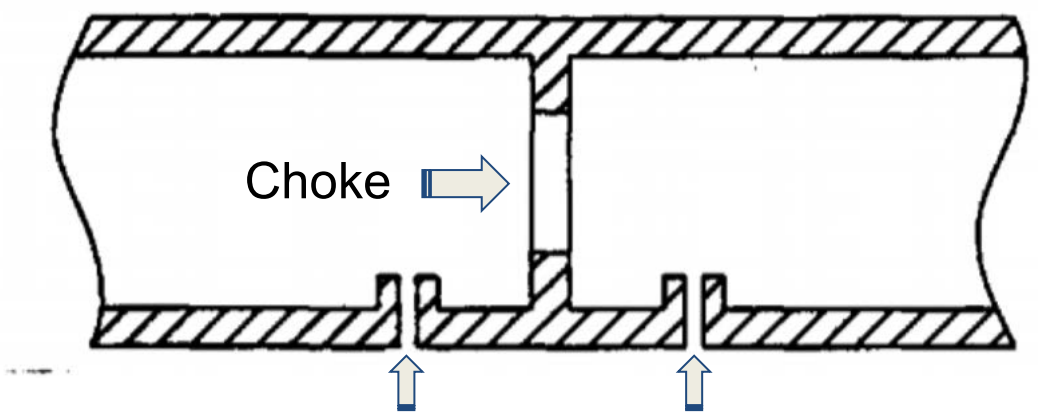


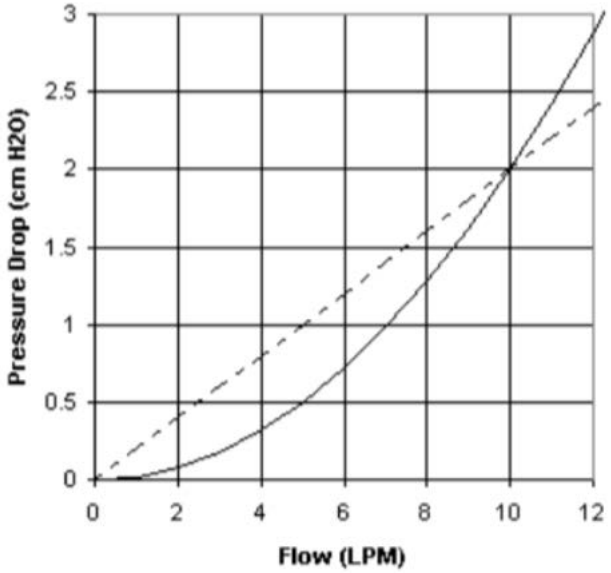
Ideal Flow vs Volume loop

Flow Rate Tests

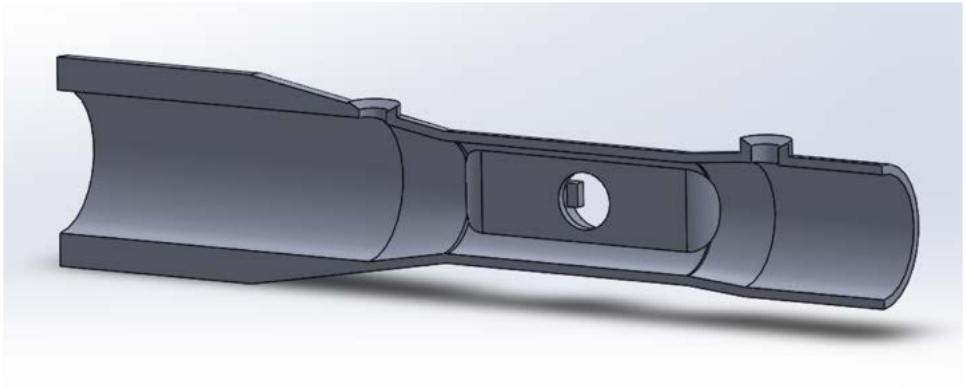
UNIVERSITY of WASHINGTON

- **Minimize flow resistance**
- **Maximize differential pressure drop**
- **Determine necessity of entrance length**
  - **Laminar flow**

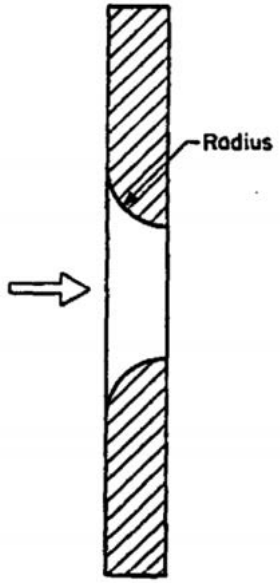




Flow vs. Pressure drop



Cutaway of Airway Adapter Design

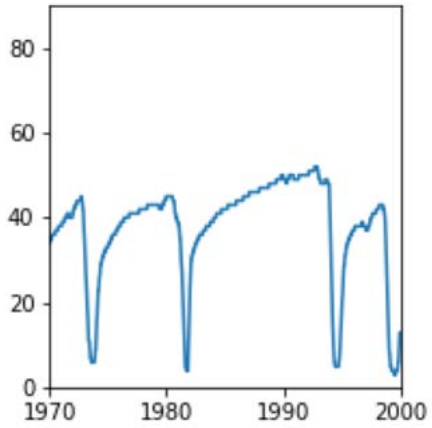


Other/Future Testing

UNIVERSITY of WASHINGTON

Other completed Testing:

- IR detector data and plotting
  - Q: Can our code plot data from the CO_2 sensor?
  - T: Input data into code and see if it can plot the proper waveforms
- Sensor casing shape/size
  - Q: Is the form factor too big to be mounted mainstream?
  - T: 3D printed preliminary design and tested fit on airway adapter



Plot: CO_2 (concentration) [mmHg] vs Time [seconds]

Testing in the near future:

- Bluetooth
  - Q: Can the data from all the sensors be integrated into the TI/Arduino microcontrollers and be transmitted to an LCD/Laptop wirelessly?
  - T: Use microcontroller serial data reader to plot refined data and use HC-05 to transmit to laptop/phone/LCD
- Integrated weight and form factor
  - Q: Does the integrated device weigh less than 150 grams?
  - Q: Does the form factor obstruct EMS personnel in the working environment?
  - T: After integrating, check in with clinical partners and get a qualitative gauge for size and shape
- Airway Adapter Design
  - Q: Does the design allow for accurate pressure/flow rate measurements?
  - T: Run FEA simulations to check for fully developed and laminar flow

Updated Milestones

UNIVERSITY of WASHINGTON

PARTS LIST:

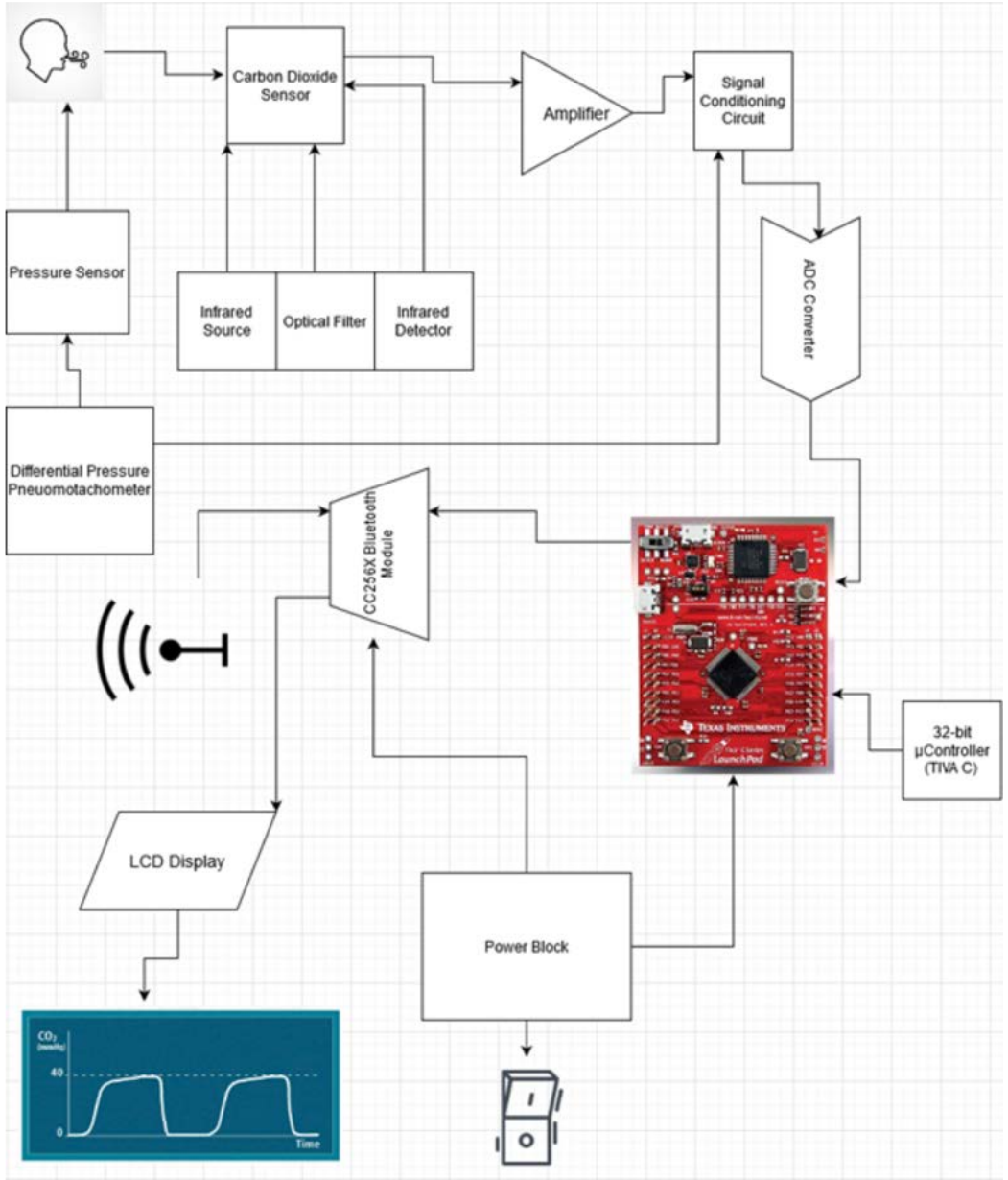
1. Sensor Casing
2. Airway adaptor
3. LCD Screen
4. CO_2 Capnography Sensor
    a. Infrared Detectors Dual CO2 Sensor
    b. IR Emitter
5. Differential Pressure Sensor
6. Flow rate sensor
7. A23 battery
8. PCB control board
9. Bluetooth module
10. Wiring

MILESTONES:

1. Test the individual components **6/2** (continuous)
2. Validate our design with clinicians **6/10**
    a. Incorporate device into the clinical setting
    b. Verify the pressure, flow rate and CO2 concentration readings

Summary and Future Work

UNIVERSITY of WASHINGTON



Questions

Acknowledgements

UW Medicine
HARBORVIEW MEDICAL CENTER

Clinical Partners:

Andrew Latimer, M.D.
Nathan White, M.D. M.S.
Clinton T. Siedenburg, M.S.
Rob Walker, Ph. D.
Cathlene Buchanan, Senior Manager, Stryker
Carrie Smith, Senior Engineer, Stryker

stryker

COLLEGE OF ENGINEERING
UNIVERSITY of WASHINGTON

Professors:

Jonathan Posner, Ph.D.
Eric Seibel, Ph.D.
Soyoung Kang, Ph.D.
TA: Shawn Swanson

Advisors:

Thomas R. Clary
Bill Crone

UW Medicine
UW SCHOOL OF MEDICINE
DEPARTMENT OF RADIOLOGY