Department of Computer Science and Engineering

Seattle Pacific University

U-Catalyst: Senior Design Project

Mission and Vision Statement

Project – The Second Wind

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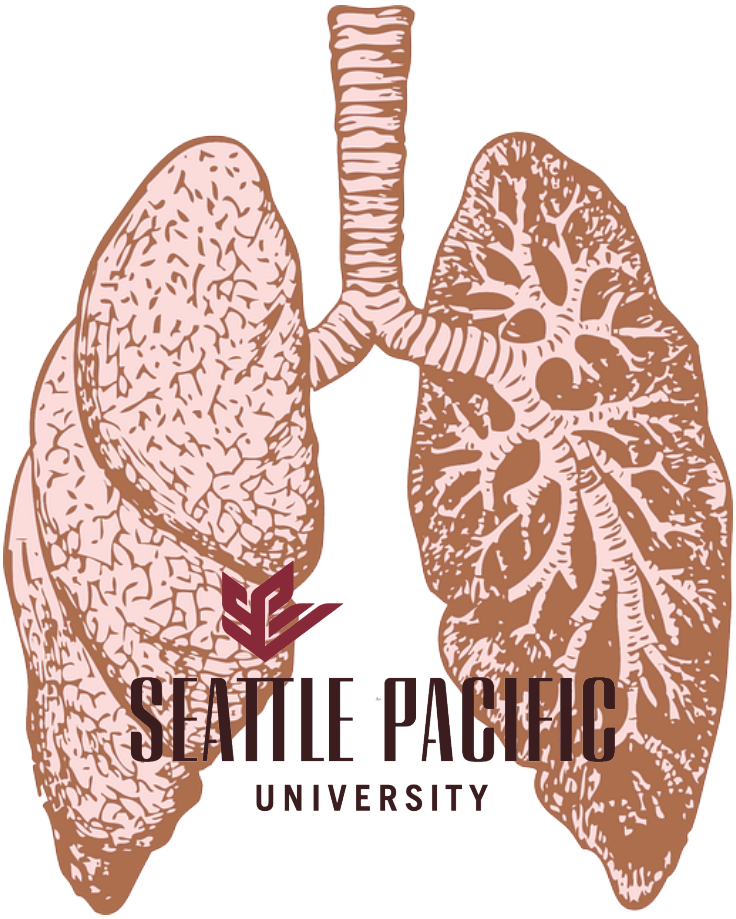

Supervisors:

Dr. James Walker

Dr. Lin Liu

Customer:

Kerry M. Curran

Lung Technologies, LLC,

September 27th 2021

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Quad Chart

Second Wind – Incentive Spirometer

Team Raven: Saihou Jobe (CPE), Makana Dang (EE), Jason Smith(ME), Nate Geller (ME), Omar Garibay (ME)

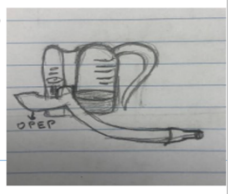
Objective:

- Spirometer will record patient inhalation/exhalation exercises according to doctor's prescription.
- Improve spirometer to increase accuracy of data provided by the device
- Improve patient interaction with the device
- Spirometer has not seen much improvement since it was invented
- To provide Lung Technologies (a medical device company) with an improved spirometer

Concept:

An Incentive Spirometer capable of recording and communicating how many times a patient used the spirometer, as well as having an OPEP (Oscillating Positive Expiratory Pressure) therapy device attached to it.

- Cost Does Not Exceed Existing Products By More Than 20%
- The Aesthetic of the Device Will Be Modernized and Updated



Approach:

Modify existing incentive spirometers to enhance performance by:

1. Adding an electrical component to keep track of patient performance
2. Achieving accurate measurements of inhalation volume through proximity sensors or light sensor.
3. Designing a detachable electrical component that can be connected to different spirometers

Analyses and RRP:

Analyses:

- SOLIDWORKS Flow Simulation of spirometer
- SOLIDWORKS Flow Simulation of Integrated OPEP

RRP

- SOLIDWORKS Simulation Study
- Functional, imprecise, 3D-printed model with functional, accurate, and removeable electronics

Problem Statement

Patients are prescribed therapy that requires them to use an incentive spirometer, but either out of laziness or forgetfulness, the patient does not follow their doctors' orders. The doctor needs to confirm that the patient can perform these exercises before they are discharged from the hospital and take the device home with them for gradual unmonitored improvement and recovery. Currently, there is no way for doctors to verify that their patient has completed the therapy that they were prescribed. The cost needs to be comparable to current models.

Every year 3.4 billion dollars is spent by the United States Heathcare System for post-surgical complications. One area that costs can be reduced is respiratory therapy. Incentive spirometers have been in use for the past forty years and they have been successful in reopening the lung and increasing the capacity of patients. A shortcoming in the device is the lack of hard data delivered to the attending doctor or nurse. The patient, through forgetfulness or lack of energy, will forgo the prescribed inhalation therapy and may end up staying in the hospital longer. This issue has been unaddressed with no major improvement or innovation. Looking into patents that relate to incentive spirometers, several universities students have built units that record data, but the final device is large, expensive, and not a bother to use.

In junction to the inhalation therapy that the incentive spirometer provides, there is also exhalation therapy. Oscillatory Positive Expiratory Pressure (OPEP) device provides an oscillating back pressure against the patient’s lungs as they exhale into the device. This pressure helps loosen up phlegm and fluid buildup in the lungs. The patient is now more able to cough of the buildup and restore lung function. There are six major types of OPEP devices, four are gravity dependent and two are gravity independent. The National Institute of Health performed a study on the performance of these distinct types of OPEP devices. They found that not all performed equally, so there is a need to be particular in the mechanisms of the final design.

Initial Project Statement:

Current spirometers in the market do not store data to let the Pulmonologists know whether patients are conducting lung exercises according to the doctor's prescription. Spirometers do not help in reducing gas trapping and improving ventilation of the lungs. The Incentive Spirometer 2.0 will record patient inhalation/exhalation exercises according to doctor's prescription. It will be designed to have a detachable electrical component that can be connected to different spirometers.

Critical Features:

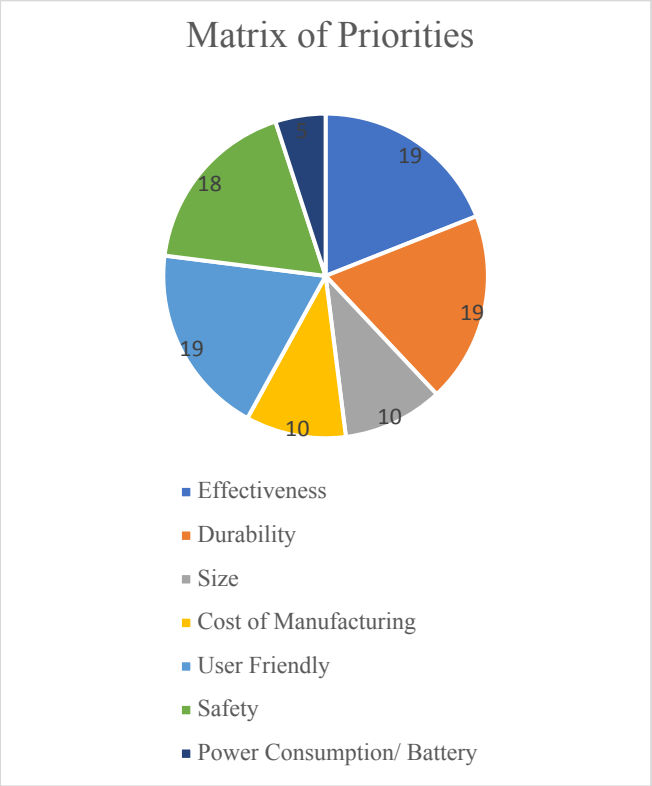
1. Record inhalation exercise results
2. Remind patient to do exercises
3. Exhale

Record: Keep track of patients progress with inhalation therapies

Remind: Engage the patient to continue doing the breathing exercises

Exhale: Ability to perform exhalation therapies

Matrix of Priorities:	
	Max Points:
Effectiveness	19
Durability	19
Size	10
Cost of Manufacturing	10
User Friendly	19
Safety	18
Power consumption/battery	5
Total Points	100



The top-weighted priorities for the Incentive Spirometer 2.0 are Effectiveness, Durability, and User Friendliness. Effectiveness was rated as one of the top priorities because it is crucial that this spirometer is as effective as current iterations, for it to be able to compete on the market. Another top rate priority was the durability of the spirometer because the electrical component spirometer needs to be able to withstand being pulled off multiple spirometers throughout its lifetime. The last of the top-rated priorities is User-Friendliness because the entire point of redesigning the spirometer is to incentivize patients to use it. The next priority is safety. This was rated slightly lower than the previous three because the safety of the patient is crucial, but with this redesign, there is very that we could do to make the product unsafe. The next two priorities are size and cost of manufacturing, these were rated in the middle because our client wants the size and cost of manufacturing to remain close to the current market value of incentive spirometers. The lowest rated priority is power consumption/battery because while ensuring that the device can work with a reasonably sized battery is important, there is room for variability in how long our client wants the device to run between battery changes.

Customer Visualization/Description

1st Customer: Kerry Curran and Lung Technologies

Clearly define a real, sample person, not an ambiguous entity

The main customer that we are making the new incentive spirometer for is Mr. Kerry Curran from the medical company Lung Technologies.

Clearly describe who they are

Kerry Curran and his company Lung Technologies are a post-surgical rehabilitation device company who has challenged us with the production of this new spirometer

Fully describe how the problem you've identified impact them?

Kerry and some of his colleagues have seen this device on the market unchanged the past 40 years and want to make an improvement.

Fully describe an understanding of how they deal with it now and how it impacts their daily life?

They would advertise the new spirometer to different hospital and medical companies and try to have them implement them in their respective places.

Describe your ideal scenario of how would you like them to deal with it?

We would love to see Lung Technologies advertise the product and eventually see the incentive spirometer in hospitals everywhere.

What is their problem?

Hospitals have patients who are prescribed therapy requiring an incentive spirometer but do not follow their doctors' orders.

Where are they?

They are working in collaboration right now with Northwest Orthopedic in Spokane. This can also be shown to companies and hospitals all over the world.

When do they want or need the solution (how time pressing is it)?

The Hospitals and Doctors need upgraded incentive spirometers so that their patients can fully recover after surgery without complications caused the patient not using the incentive Spirometer.

What price is the customer willing to pay?

Kerry Curran and Lung Technologies would like to keep the cost of the spirometer fairly close to the existing model. They are also willing to sell the product at a 10-15% increase of the existing product so around $30-40.

2nd Customer: Hospitals

Clearly define a real, sample person, not an ambiguous entity

Another customer of the spirometer would be the hospitals that would use the new spirometer such as UW Medicine and Fred Hutch.

Clearly describe who they are

Hospital workers concerned with giving patients proper care.

Fully describe how the problem you've identified impact them?

The revised spirometer will improve doctor's or nurse's ability to diagnose and keep track of patient spirometer usage result.

Fully describe an understanding of how they deal with it now and how it impacts their daily life?

The revised spirometer will provide the hospital workers with more accurate data from the patients breathing therapies leading to an increased ability to provide proper care to the patients

Describe your ideal scenario of how would you like them to deal with it?

The hospital worker assigns breathing therapies to a patient, the patient then completes those exercise to the best of their ability. After, the hospital worker would have an accurate record of successful maximum inhalations.

Who is the customer?

The customers would be Hospital suppliers and medical practitioners

What is their problem?

Hospitals have patients who are prescribed therapy requiring an incentive spirometer but do not follow their doctors' orders.

Where are they?

Hospitals across the world.

When do they want or need the solution (how time pressing is it)?

The Hospitals and Doctors need upgraded incentive spirometers so that their patients can fully recover after surgery without complications caused the patient not using the incentive Spirometer.

What price is the customer willing to pay?

The Customer is willing to pay $30-40.

3rd Customer: Patients in need of lung rehab

Clearly define a real, sample person, not an ambiguous entity

The patients that need lung rehabilitation post-surgery. Also patients who just need lung rehabilitation.

Clearly describe who they are

These patients come out of surgery with stressed lungs due to the known effects of anesthesia. Also patients or people rehabbing from lung problems from COVID or other medical issues.

Fully describe how the problem you've identified impact them?

The current spirometer doesn't keep the patient properly engaged in their rehabilitation and also doesn't fully quantify their successful rehabilitation.

Fully describe an understanding of how they deal with it now and how it impacts their daily life?

Currently there is no way to tell if a patient fully completes the rehabilitation of SMIs prescribed by the doctors. In doing so, they might not be fully healed lungs that may further complicate things later.

Describe your ideal scenario of how would you like them to deal with it?

We would love for the patients to feel invited by our new spirometer and want to use it.

Who is the customer?

The customers would be Hospital suppliers and medical practitioners

What is their problem?

Lung problems.

Where are they?

Hospitals across the world.

When do they want or need the solution (how time pressing is it)?

While the spirometer on the market now works, it is not engaging. The sooner we are able to provide this new spirometer, the better.

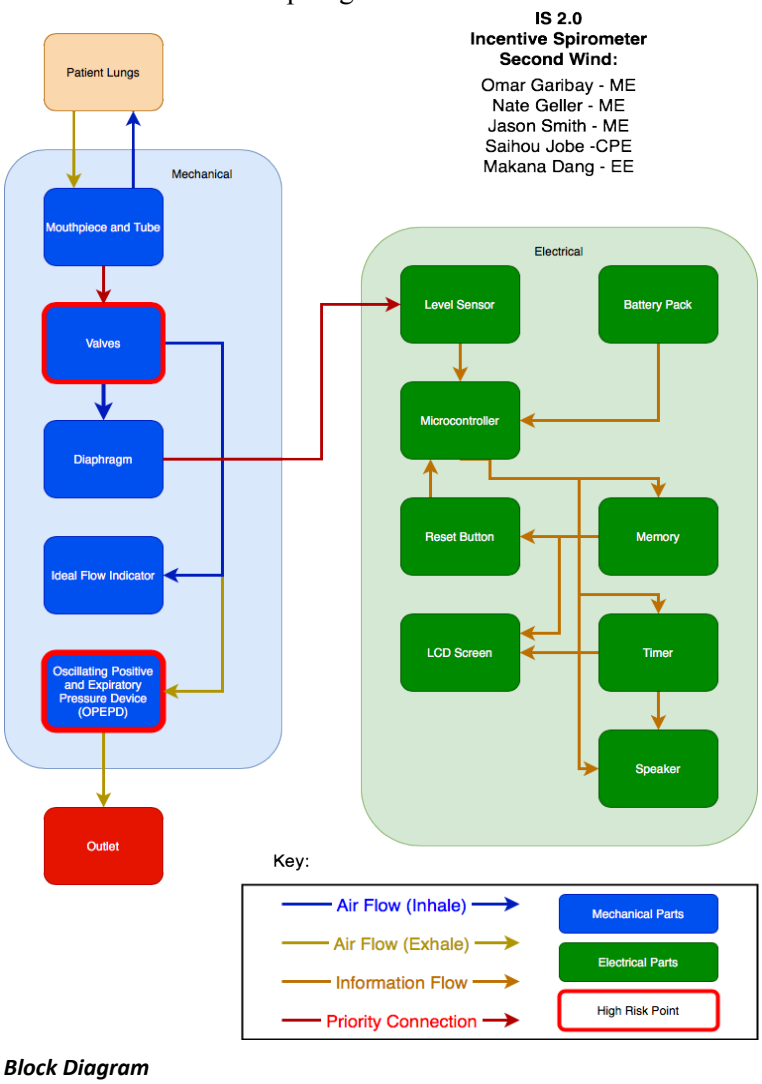
What price is the customer willing to pay?

The Customer is willing to pay $30-40.

Team Final Design

The Incentive Spirometer 2.0 will consist of five mechanical subsystems and eight electrical components. The mechanical subsystems consist of; the mouthpiece and tube, the valves, the diaphragm, the OPEP device. The mouthpiece and tube lead into frame of the spirometer, and it is what the air from the patients' lungs will travel through. The valve subsystem is what the air is traveling through from once it enters the Spirometer shell and leads into the diaphragm. The diaphragm subsystem is what measures the volume of air being blown into the spirometer. The final Mechanical subsystem, the OPEP device, connects to the mouthpiece and tubing. The OPEP will only be used when the patient is exhaling. The electrical subsystems consist of the battery pack, level sensor, microcontroller, memory, LCD screen, timer, and a speaker. The battery pack subsystem is what powers all electrical components in the incentive spirometer 2.0. The level sensor is what will detect the diaphragms volume and will be powered by the battery pack.

The microcontroller is what will receive the information from sensor and send information to the memory and LCD subsystems. The memory subsystem records the number of successful inhalations. The timer subsystem connects to the speaker subsystem and alerts the patient after a certain amount of time passes. These mechanical and electrical subsystems and how they relate to one another are demonstrated in the block diagram below.



Block Diagram

Engineering Analysis List

Data Acquisition – Capturing the level at which the diaphragm reaches the recommended level and stores the number of times this recommended level was achieved by patient.

Piston Accuracy- Ability for the spirometer to accurately measure patient's inhalation volume.

Cost - Keeping cost to within 20% above current market price. Need to know the bill of materials.

Durability – ability for electrical components to last 6+ months without maintenance. Investigate life cycles of electrical components

OPEP – System must oscillate and reach an increased resistance of standard exhalation by 30%. This requires an air tight valve

Patient reminder – ability to remind patient to complete lung exercises according to pulmonologist prescription every 5 to 10 minutes

Flow Rates - Using a SOLIDWORKS flow simulation, we shall achieve the appropriate flow rate to move the piston in a controlled manner.

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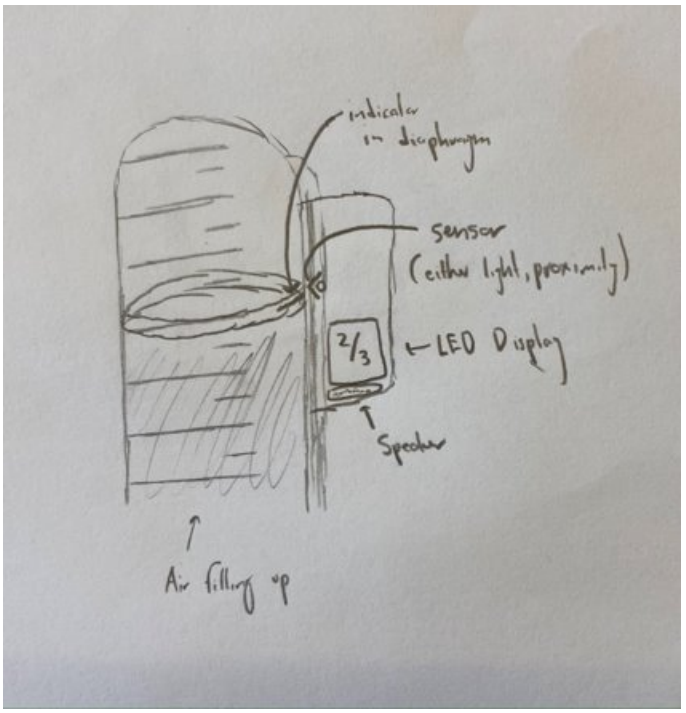
Bills of Materials

Product	Supplier	Link
Incentive Spirometer	Amazon	https://www.amazon.com/Voldyne-5000-Volumetric-Exerciser-
OPEP	Amazon	https://www.amazon.com/Tilcare-Breathing-Expander-Removal
OPEP	Amazon	https://www.amazon.com/Breather-Fit-Inspiratory-Expiratory-F
Plastic 1-way valves	Amazon	https://www.amazon.com/plastic-one-way-valve/s?k=plastic+or
Various Prints and Plastics	Amazon	https://www.amazon.com/clear-3d-printer-filament/s?k=clear+
IR Sensor	Elprocus	https://www.elprocus.com/infrared-ir-sensor-circuit-and-worki
LCD Screen	Amazon	https://www.amazon.com/s?k=lcd+display&i=electronics&ref=r
Battery Holder	Amazon	https://www.amazon.com/s?k=button+battery+holder+with+sw
Electronic Parts		

Risk Reduction Prototype Description

Electrical: Microcontroller and Proximity Sensor Integration and Piston Identification: To succeed we must be able to identify whether the user achieved the targeted SMI prescribed by physician and display these results on a high-quality LED display with the use of a microcontroller. We have not previously worked with proximity sensors or worked with circuits integrated with LED display boards. For the RRP, we propose to build this proximity sensor system including its microcontroller and demonstrate we can record, capture, and display successful SMIs.



Mechanical: There are few devices that deal with OPEP, but there are existing medical papers that have observed the positive effects of the device. The valve system that will allow the device to be used for both purposes will be a challenge since we need good seals that will neither allow for leakages that interfere with the measurement of volume or create a weaker resistance for the OPEP. While we are innovating and adding a new feature to the instrument, we need to make sure that the added feature will not interfere with the existing features of the ideal flow indicator and the main moving diaphragm that measures the volume of inhalation. The device must be compatible with and without the electrical components, but also give readable information to the electrical components.

RRP Specifications

Critical Feature List:

1. Record patient's progress with inhalation therapies

2. Remind the patient to continue their breathing exercises

3. Exhale: Ability to perform exhalation therapies

Spec ID	Requirement	Threshold (Shall)	Objective (Should)	Validation Method	Why this threshold value	Relates to critical feature(s)
RRP001	Proximity Sensor	N/A	Accurately record successful inhalation	Code output	Demonstrates ability to record when diaphragm crosses the target	1
RRP002	OPEP valve	N/A	Simple transition from spirometer to OPEP	Simulation and Experimentation	Demonstrates ability to switch direction air flow within the device	3
RRP003	Alarm system	Adjustable audio reminder to perform inhalation therapies	Adjustable audio and visual reminder on the LCD screen to perform inhalation therapies	Code Output and Testing	Demonstrates that the electronics can keep an internal timer on when the patient needs to perform their exercise.	2

Customer Specifications

Product Specifications
• Incentive Spirometer 2.0 shall remain below 10 inches in height
• Incentive Spirometer 2.0 shall weigh no more than 2lbs
• Incentive Spirometer 2.0 shall have an updated, aesthetic design
• Incentive Spirometer 2.0 shall cost no more than a 20% cost increase of regular spirometers

Feature Specifications
• Incentive Spirometer 2.0 shall be capable of both inhalation and exhalation therapies
• Incentive Spirometer 2.0 shall be user-friendly
• Incentive Spirometer 2.0 shall be capable of being operated by a single patient
• Incentive Spirometer 2.0 shall be able to communicate audibly to the patient when they reach their target volume
• Incentive Spirometer 2.0 shall have a high-quality LCD user interface capable of indicating pass fail
• Incentive Spirometer 2.0 will accurately measure, record, and display the number of successful prescribed SMI
• The electrical component of the Incentive Spirometer 2.0 shall be detachable and reusable for other single-use spirometers
• Incentive Spirometer 2.0 shall remind/alert the patient with a sound notification every 5-10 minutes as dictated by doctors' prescription

Performance Specifications
• Incentive Spirometer 2.0's electrical component shall have a battery life of at least three months

• Incentive Spirometer 2.0 will measure volume as accurately as current models within ±1% margin of error
• Incentive Spirometer 2.0 shall be able to retain data from up to 3000 SMI's

References

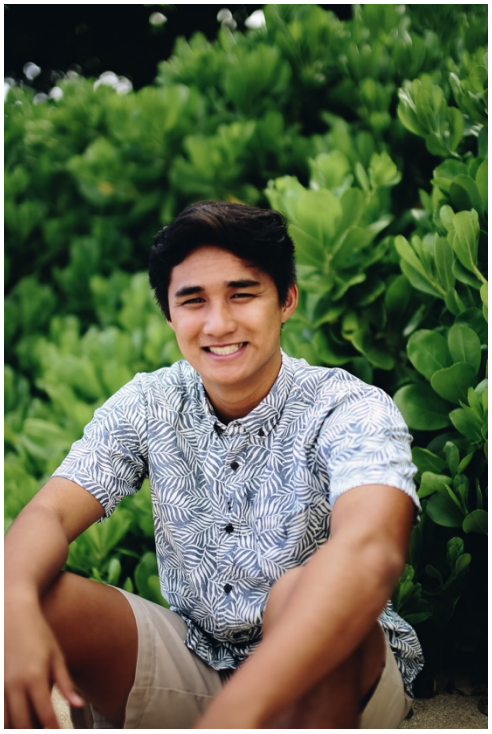
Interview with Kerry Curran, CEO of lung Technologies, LLC

https://drburtonhpi.com/wp-content/uploads/2019/06/Analysis-of-Tidal-Volume-and-Expiratory_Respiratory-Therapy_Spring-2016.pdf

Poncin, William et al. "Comparison of 6 Oscillatory Positive Expiratory Pressure Devices During Active Expiratory Flow." *Respiratory care* vol. 65,4 (2020): 492-499. doi:10.4187/respcare.07271

Svenningsen, Sarah et al. "Oscillatory Positive Expiratory Pressure in Chronic Obstructive Pulmonary Disease." *COPD* vol. 13,1 (2016): 66-74. doi:10.3109/15412555.2015.1043523

Team Bios



Makana Dang

Ever since I can remember my love for math and science has been just as strong as my love for the beach. Growing up in Hawai'i and through attending Kamehameha Kapalama High School, this passion not only grew over time. Now during my final year of pursuing a Bachelor's of Science in Electrical Engineering at Seattle Pacific University, this dream and goal is even closer to becoming reality. I have also been given the amazing opportunity to grow and gain more electrical experience in the form of Power Systems and Utilities at Sea Tac International Airport this past summer with the Port of Seattle. Not only was I able to gain AUTOCAD and technical experience, but I was able to learn how to communicate efficiently with a team successfully. I am very excited to put this experience to use with our Incentive Spirometer 2.0 along with my team for Lung Technologies.

Omar Garibay

I am a first-generation college student studying mechanical engineering. Coming from a family where most work in some form of construction, I was able to bring some of my family's experiences to grow myself as an engineer. Before deciding on mechanical engineering, I transferred from Western Washington University where I was previously studying environmental science. My passion for taking care of the environment remains but the switch to engineering allowed me to be more hands on towards problem solving. I feel as if my experience gives me a unique perspective on problem solving and I hope to bring this perspective to Second Wind.

Nate Geller

Growing up with a civil engineer for a father, I was always encouraged to explore the different types of engineering, but the mechanical aspects of projects always interested me the most. At Seattle Pacific University, I have continued to focus on my passion for mechanical engineering and am excited to be graduating in 2022 with a mechanical engineering degree. In the future I would like to use my engineering talents to work on and develop new projects in the medical device community. I am excited to be working on the incentive Spirometer 2.0 with Team Second Wind and am thankful for the opportunity to work with a costumer in the medical device industry. I believe that my experience with Solid Works, machining and fabricating, and fluid mechanics will be helpful in developing this project.

Saihou Jobe

As a former technician of 17 years, troubleshooting and repairing electronic, pneumatic, and hydraulic systems, I became intrigued by how these systems were made. I did not know, prior to enrolling in an Engineering major, what it took and the different aspects in designing and manufacturing or implementing the plethora of the different tools, equipment, and services inspired by the advancement of technology. I understand there are so many applications to Engineering but SPU Engineering faculty has provided me with the tools I'll need, with the guidance of Allah, to be part of an organization that seeks to improve the general well-being of humanity and to be better custodians of Allah's world.

Jason Smith

I am a student pursuing an ABET accredited Mechanical Engineering degree. Coming from the small town of Oak Harbor and doing Running Start at the local community college, I found myself having to take an extra step to match my peers. Being a whole year younger than them, I could see the difference in life experience between us, but my competitive nature drives me to match my peers and stand on equal terms with them. My passion for working on cars and on computers has caused me to move outside of my comfort, but the expertise I picked up in SOLIDWORKS and researching via forums and research papers will allow me to be on the competitive edge that my classmates are on.

Team Mission and Vision

Our mission is to help doctors and patients have better communication and build devices so that better, cheaper, more effective healthcare can be delivered. The vision for our team is to redesign the inceptive spirometer to include an OPEP feature and give the doctors a more reliable source of patient information.

Team Contract and Team Assessment System Team Name: Second Wind

	Mid Qrtr Assessment					Mid Qrtr Comments	End of Qrtr Assessment					End Qrtr Comments
	FEE	EE	ME	MSE	DNME		FEE	EE	ME	MSE	DNME	
Commitment												
See tasks through to completion by the due date. With a maximum extension of 4 days with communication with the rest of the team.												
Ask a member or a professor for help before giving up on a task.												
Communication												
Be open to new approaches and listen to new ideas.												
Avoid placing blame instead discuss the process improvements												
Any communication that is urgent will be conducted through text, email, and Microsoft Teams												
Any work accomplished will be sent into the Microsoft Teams chat for the whole team's reference												
Problem Solving												
Ensure everyone participates by showing what they worked on.												

Get input from the entire team before a decision is made.												
Address concerns in a public and healthy manner												
Have at least one member act as QA for all tasks/submissions that they did not do themselves.												
Handling Conflict												
Choose an appropriate time and place to discuss and explore the conflict.												
Listen openly to other points of view.												
State points of view in a non-judgmental and non-attacking manner.												
Ask a member or a professor for help before giving up on a task.												
When a conflict arises, take a vote as a team in order to resolve the issue.												
Conducting meetings												
Regular meetings will be held out of class at least once a week 30 minutes before class on Tuesdays unless stated otherwise in advanced												
Meetings will begin and end on time. Extensions will be allowed based on												

time estimates for assignments.												
Team members will come to meetings prepared with updates on progress and plans for next week's progress goals.												
Additional Items												
YOUR INPUTS HERE												

Agreed to:

NAME: Jason Smith DATE:10/10/2021	NAME: Saihou Jobe DATE:10/10/2021	NAME: Makana Dang DATE:10/10/2021	NAME: Nate Geller DATE:10/10/2021	NAME: Omar Garibay DATE:10/10/2021

FEE: Far Exceeds Expectations EE: Exceeds Expectations ME: Meets Expectations MSE: Meets Some Expectations DNME: Does Not Meet Exp.