
PULSO

Executive Summary

The future of lung health in urban centres is at risk all over the world. Worsening air quality caused by overcrowding, poor indoor ventilation and rising vehicular transport warrants this concern. As trends surrounding health and bodily autonomy become increasingly popular, the need for monitoring lung health rises. This is where Pulmo comes in. Pulmo is a wearable lung health monitor, comprised of cutting-edge technologies which identify a variety of respiratory data points, such as blood oximetry, diaphragm expansion, breath sound detection and lung shape. Advanced machine learning models analyse the data and provide the user with insights to improve their lung health (available through the app). It also generates a preliminary diagnosis of the different types of respiratory conditions: lung tissue diseases, lung circulation diseases and airway diseases. This report shows the Pulmo development process. Future contextual studies were conducted to determine the problem space and the concept was developed using technology found through extensive literature reviews. A service system was then formed, with the UK healthcare system in mind (although Pulmo can be used worldwide, the UK has been used as a case study). Finally the system was evaluated by experts in each aspect, and against its' original objectives.

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Other Experts

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Contents

Problem Definition

By 2050, 75% of the world's population will live in cities [1], leading to heavy overcrowding in urban centres. Indoor air quality in the UK is poor, and the increase in vehicular transport will damage outdoor air quality further. The combination of these three factors spell a bleak future for lung health, especially for those in urban centres. It will therefore become increasingly important for respiratory problems to be detected early, so that patients have a greater chance of improvement. Effective containment of lung disease is dependent on an early diagnosis, which is often difficult in healthcare systems worldwide.

People living in overcrowded homes are 3 times more likely to have respiratory problems [2]

70% of homes in the UK breach WHO limits on 3 key pollutants [3]

95% of carbon monoxide emissions in cities come from motor vehicle exhaust [4]

USERS & STAKEHOLDERS

User – Professionals in Urban Centres

Professionals between the ages of 30 and 50 often work in areas with poor indoor and outdoor air quality [5], putting them at risk of poor lung health. They are also interested in self-monitoring their health, and maintaining autonomy over it. [6]

Stakeholder – Healthcare Providers

Public healthcare systems, such as the NHS, are failing [7]. This is not a problem limited to the UK – such systems are under threat across Western Europe [8]. This has accelerated interest in private health insurance [9].

People have demonstrated an interest in gaining early diagnoses where possible [10] and insurance companies share this, as it is financially advantageous to have fewer patients requiring advanced care.

Stakeholder – Healthcare Professionals

Healthcare professionals are pivotal to medical systems as diagnoses cannot be given without them. Reducing the time spent on diagnosing illnesses can improve patient experience, as doctors are able to focus on providing treatment, giving the patient a better chance of improvement.

Future Scenario

Future contextual studies were used to generate a credible scenario for the issues that will be faced by the populations of urban centres in 2042. Whilst the problem of worsening air quality will affect urban centres worldwide, the UK has been focussed on and treated as a case study for the purposes of this project.

FUTURE SCENARIO

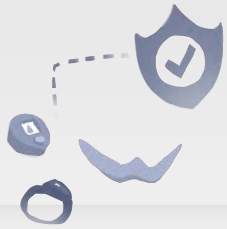
Driver Trend

Respiratory health of population in urban centres worsens [11]

People want to self-monitor their own lung health to detect any problems early

A diagnosis can only be generated by a doctor

Doctors need reliable data in order to diagnose



Insurance companies provide the medical monitoring devices

If the monitoring device detects a problem, a preliminary diagnosis is generated

The user takes the diagnosis and data to their doctor, who can decide the next steps

Indoor and outdoor air quality worsening [3][4]

Trend towards self-monitoring health [6]

Legally, doctors can only rely on data from medical devices

The decline of the NHS means more people require health insurance [7][8]

USER PERSONA

Rick Clark, 35

Rick is an environmental engineer. As his firm are expanding to new offices, he has to constantly travel to different cities around the world. However, he has an inherited risk of COPD and is particular on maintaining his lung health.

User Motivations

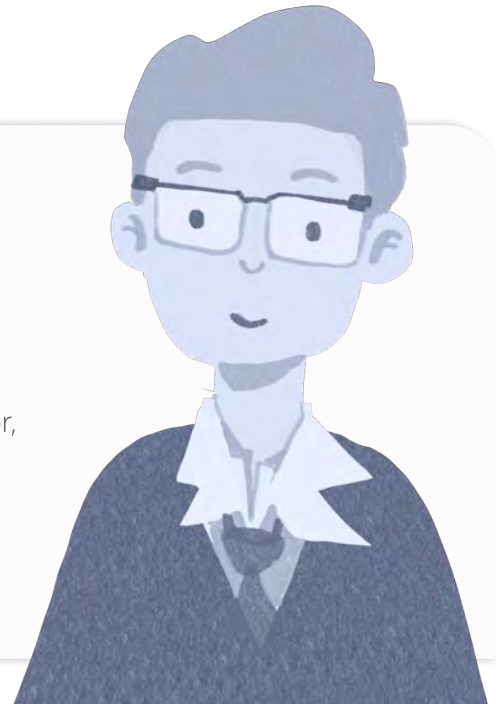
"There are 1.2 million people in the UK who are diagnosed with COPD [and] up to two thirds are undiagnosed"[12]

1. Family history of lung disease
2. Occupational health risk (e.g. long-term exposure to pollutants)
3. Health-conscious data trackers

Pain Points

It is difficult to keep track of his health continuously as he is always travelling for work.

Whenever he goes to a doctor, they are not permitted to use any of the data from his FitBit or personal health apps [13].



Project Development Plan

PROJECT AIM

The aim of this project is to develop a product service system (PSS) that can monitor the respiratory health of the user. As well as providing data, the PSS must be able to detect any emerging problems. It should be able to generate a preliminary diagnosis.

DESIGN DEFINITION

How might we passively **monitor** the **lung health** of professionals in urban centres, in order to detect any problems early and **generate a preliminary diagnosis** from them?

◄ Ideation

CONCEPT OVERVIEW

Design Objectives

Concept Overview

- What are we trying to achieve?
- What are the requirements that our concept must meet?
- What is our concept?
- What is our system?

Portfolio Page

TECHNICAL DEVELOPMENT

Technological Enablers

Technical Development

Sensing Technology

- What will the state of technology be 20 years from now?
- Which data points need to be monitored to generate an accurate picture of lung health?
- What sensing technology can be used to monitor those data points?
- What materials will be used?

USER DEVELOPMENT

Product Interaction

User-Centric Dev

- What requirements will the user have of Pulmo?
- How will Pulmo fit into the user's life?
- How can we keep the users' data safe?

SYSTEM DEVELOPMENT

Data Analysis

Pulmo App

Pulmo and IoT

PSS

Pulmo and Healthcare

- How will users get ahold of Pulmo devices?
- How will users be persuaded to use Pulmo?
- How will users interact with data interpretations?
- How will the Pulmo system be implemented?
- How will Pulmo fit into the user's home?

VALIDATION

Expert Validation

Objectives Evaluation

- Will Pulmo work from a medical perspective?
- Will Pulmo work from a technical perspective?
- Will Pulmo work from a user-centric perspective?
- Will the Pulmo system integrate well with healthcare systems?
- Has Pulmo met its' original objectives?

Design Specification

Exploration of current trends and drivers, and research into the future scenario context were combined with the project aim and design definition in order to generate a set of requirements of the overall product service system. It can be divided into 2 parts: monitoring lung health and generating a diagnosis.

Trends and Drivers > Design Objective > Design Requirements

Monitor Lung Health

The aim of the PSS is to generate a comprehensive picture of the user's lung health, and therefore, a significant component will be the monitoring

- The trend of self-monitoring in different aspects of life shows that people want to have an overall picture of their health [7]
- Passive monitoring has been shown to be more successful than active counterparts [14]
- There is a trend towards non-invasive methods of healthcare [14], specifically for monitoring of long term conditions

Design Requirements:

- The monitoring system must track enough data points to generate an accurate image of the user's health
- The monitoring system must be passive
- Monitoring must be non-invasive

Generate Diagnosis

Simply monitoring the lung health will not be sufficient to make the PSS a success. Should inconsistencies or problems be detected, it must generate a preliminary diagnosis that the user can take to their doctor

- There is a trend towards eroding trust in doctors [15]
- Healthcare systems worldwide are being digitalised [16]
- Trend towards increasing wait times for a diagnosis [17]

Design Requirements:

- The system should use the user's past medical data to generate an accurate diagnosis, in order to ensure trust
- The system should aid the healthcare industry in the transition to digital twins
- The system should help to shorten the diagnosis-treatment pipeline

Concept Overview

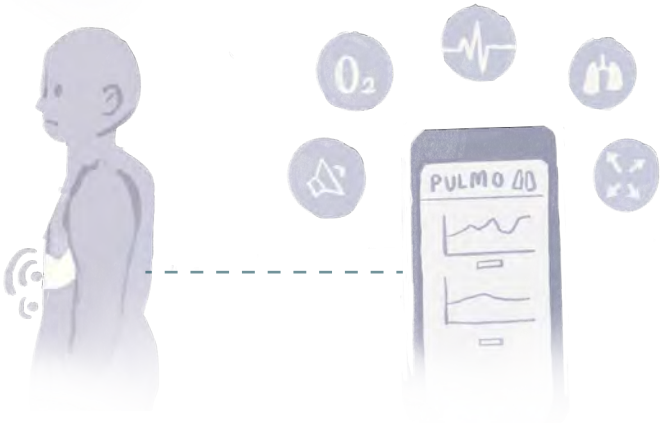
The ideation process in phase 1 led to the final concept of Pulmo – a wearable patch that monitors a variety of data points to generate an overall picture of the wearer's lung health. Using the data collected, Pulmo can generate a preliminary diagnosis of several lung conditions. Respiratory conditions fall into 3 categories: airway diseases, lung circulation diseases and lung tissue diseases [18]. Users can then take the diagnosis and the accompanying data to their doctor for validation.

Cheaper Insurance

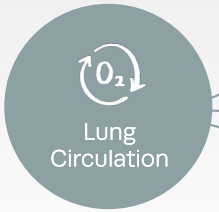
Health insurance companies are offering lung monitoring devices to their policyholders, in exchange for a cheaper insurance rates.

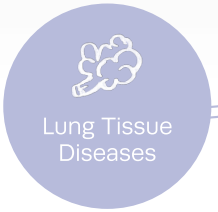
Taking Control of Personal Health

Because people are interested in monitoring their own lung health (due to the general worsening air quality [4]), this is an attractive offer. They obtain Pulmo from their insurance company, and set up an account on the accompanying app.

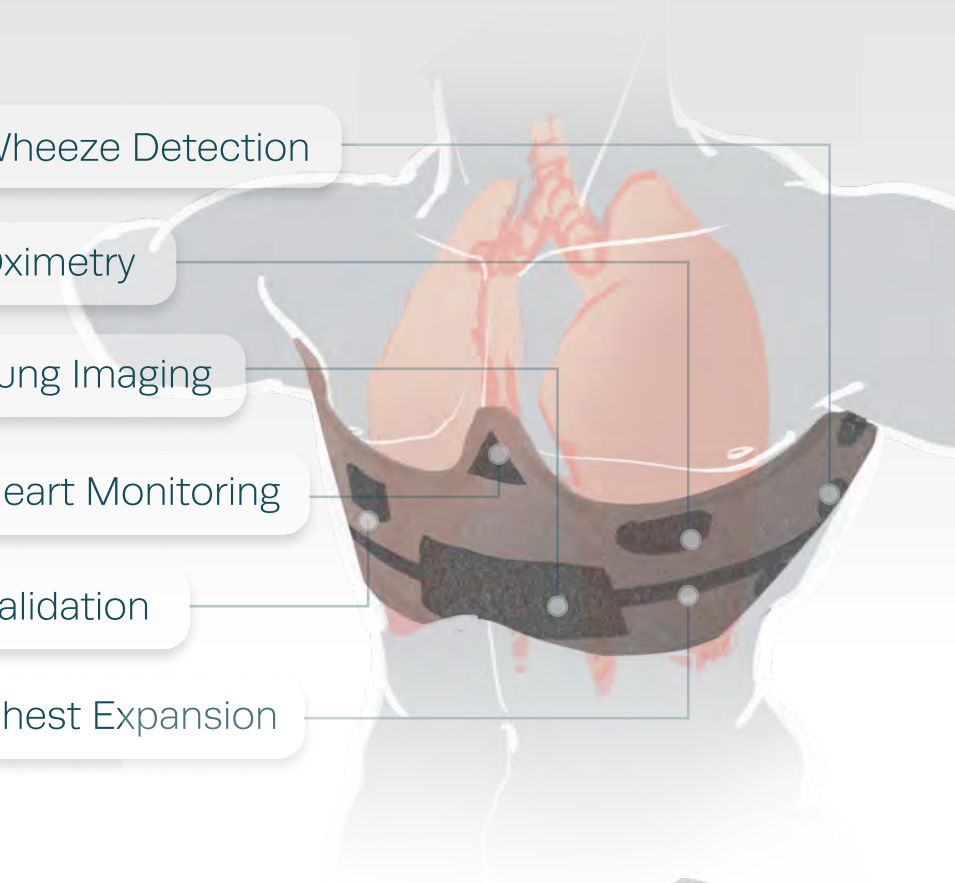


Pulmo collects data on the user's lung health (blood oxygen levels, lung capacity etc.) and uses it to provide tips to the user on how best to improve their lung health.





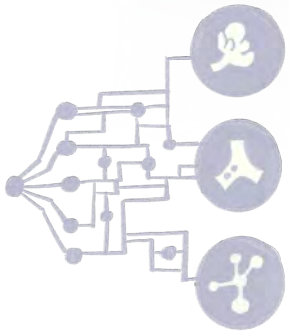
- Wheeze Detection
- Oximetry
- Lung Imaging
- Heart Monitoring
- Validation
- Chest Expansion



Data Analysis and Interpretation

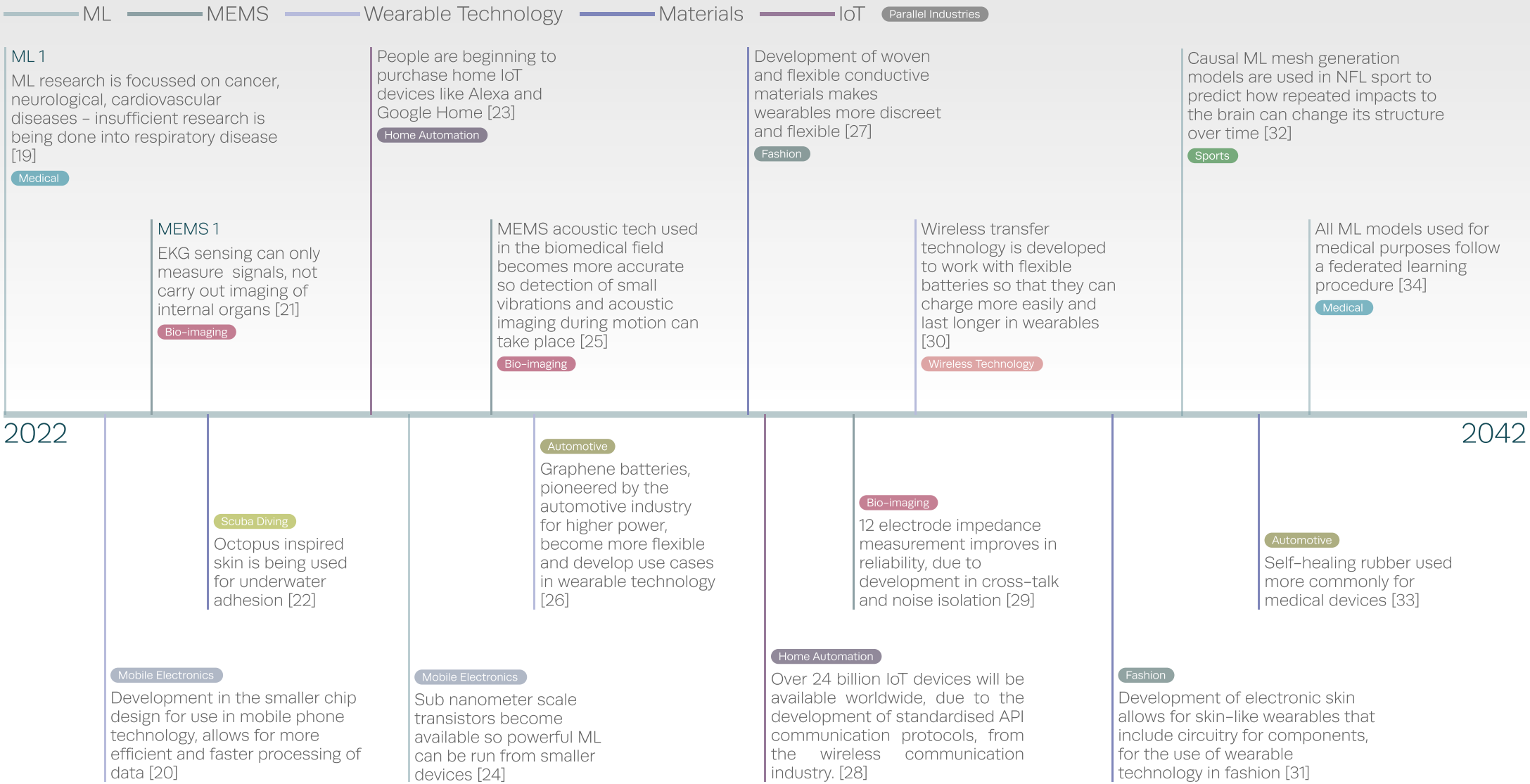
The data collected will be analysed using machine learning algorithms. Any inconsistencies can be detected early and used to suggest potential respiratory conditions.

An alert of the suspected condition will appear on the app. The user can take the diagnosis to their doctors, who can view the data and validate the diagnosis.



Technological Enablers

An extensive literature review was conducted to generate the technological enablers. The main aspects of Pulmo and it's service system were identified to be: machine learning (ML), micro-electromechanical systems (MEMS), wearable technology (WT), materials, and Internet of Things (IoT). A roadmap was created in order to ascertain at what stage of development these enablers would be in by 2042. As development in medical technology is typically slow, inspiration was drawn from several parallel industries as well. These technological enablers were vital for project progression, and have been highlighted throughout the project.



Technical Development

SILICONE PROTECTIVE LAYER Materials

A silicone protective layer over the top will protect the sensors from damage, and make it easier to clean, due to its hydrophobic nature. Its high moisture resistance will protect the sensors from damage. It also has high elasticity, meaning that it will be sufficiently flexible to use [27].

ACOUSTIC SENSORS MEMS

The acoustic sensors will be used for detecting lung sounds, crackles and vibrations. This is a technique known as auscultation, usually a preliminary method of diagnosing lung diseases [25].

PCB ML

The PCB contains the accelerometer and gyroscope for data validation, as well as the main CPU that is able to run the ML models, on locally embedded chips, to analyse the sensor data

BATTERY CASE Materials

The battery case, made out of a self-healing rubber [23], holds the flexible battery, PCB and charging coil, and will align with the centre of the user's chest. The case will protect the electronics from damage, making them last longer

CHARGING COIL WT

The charging coil will allow for wireless charging. Devices will move to wireless charging solutions in the future, as the trend will be towards more portable devices with fewer required components [30].

BATTERY WT

A highly powered, flexible, graphene battery will provide the product with the power to work sufficiently. The bendable and stretchable nature of graphene batteries will mean that they are an appropriate choice for the wearable patch.

RESISTIVE BAND

The resistive band will measure the diaphragm movement of the user, indicating their lung capacity [29].

ELECTRONIC SKIN Materials

The electric skin works as an electronic conductor, but mimics the function of human skin, making it more comfortable for the user [27].

OCTO-SKIN Materials

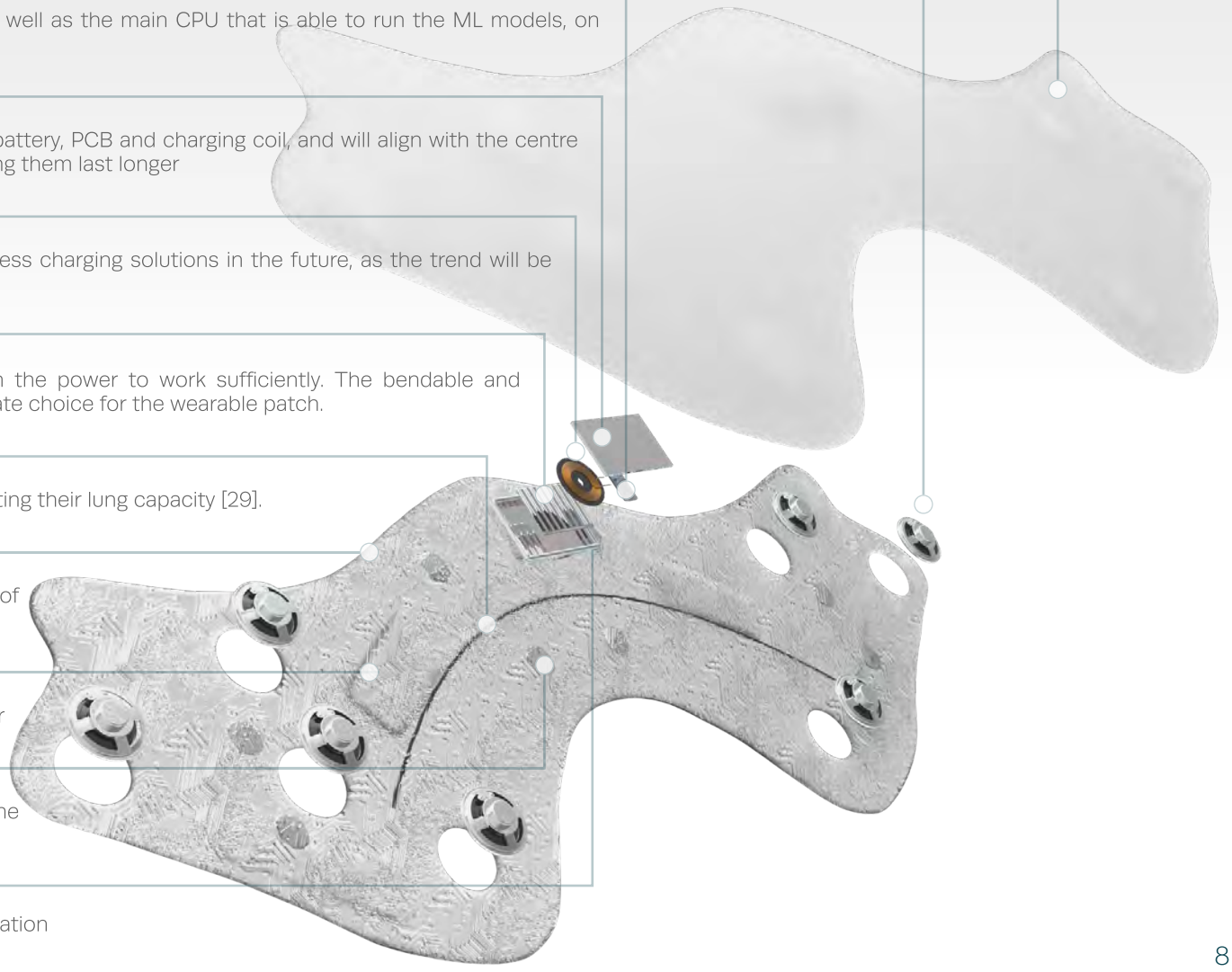
Active membranes inspired by octopus skin [22] will attach Pulmo to the user

EKG SENSORS MEMS

EKG sensors will be used for imaging of the lung shape and for monitoring the heart, and detecting structural inconsistencies.

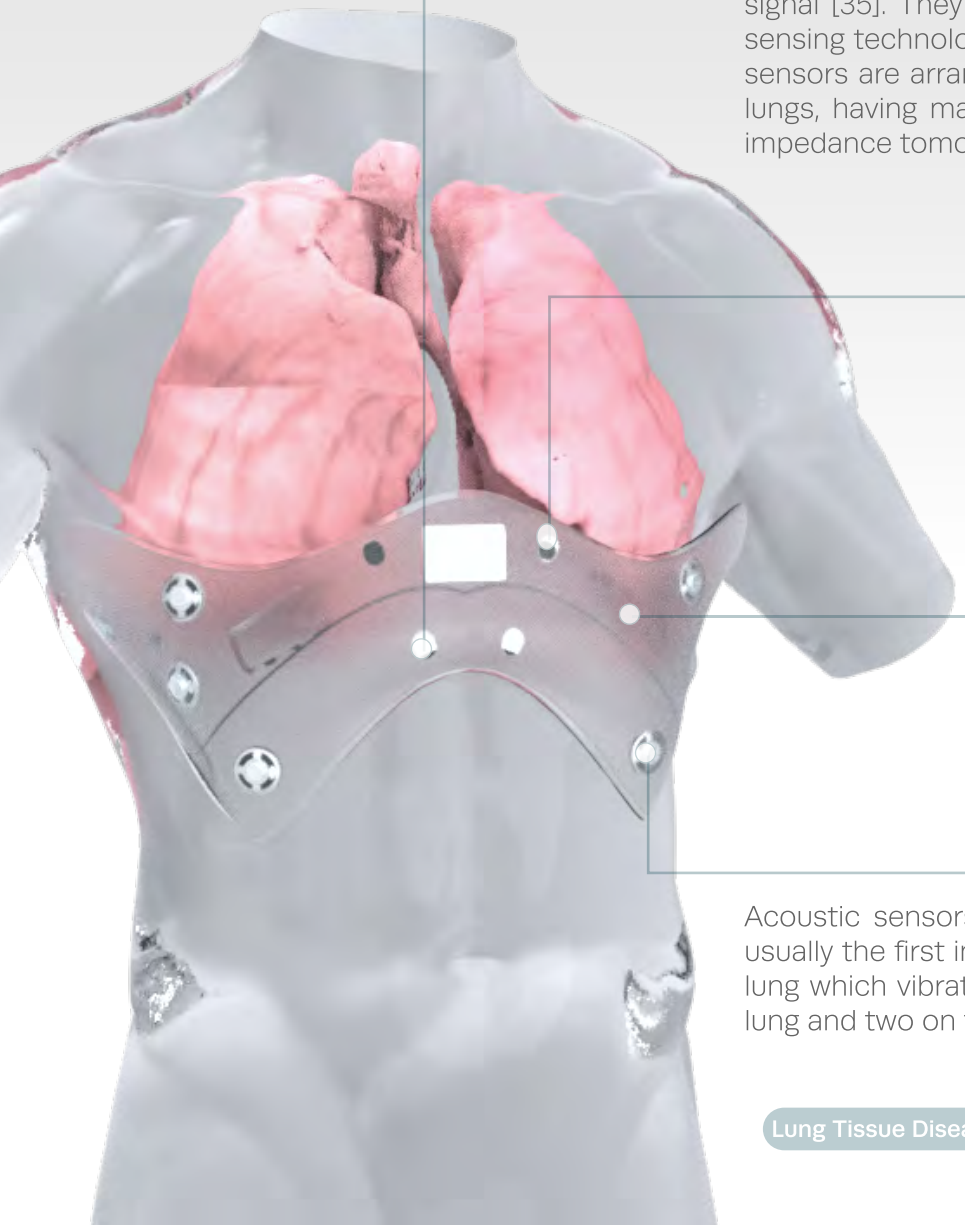
PPG SENSORS MEMS

PPG sensors will be used to detect blood oxygen levels, indicating lung circulation



Sensing Technology

The sensing technologies all come under the category of MEMS enablers. There are 4 types of sensors incorporated into Pulmo, all of which track different data points. Each of the data points is used to diagnose a different category of lung disease: lung circulation, lung tissue and airway diseases.



EKG

EKG (electrocardiogram) sensors interpret simulations of muscles, the output of which is an electrical signal [35]. They are currently used to read the electrical activity of cardiovascular muscles. However, as sensing technology develops further, it will be used to monitor a wider variety of data points. In Pulmo, EKG sensors are arranged in an array. Whilst a singular sensor can be used to monitor blood circulation in the lungs, having many of them in an array can facilitate medical imaging, through the process of electrical impedance tomography (EIT) to detect lung tissue disease [36].

PPG

PPG (photoplethysmogram) sensors are used to detect blood oxygen levels by projecting infrared light onto the skin and measuring volumetric variations of blood circulation [37]. Changes in the reflected light indicate the motion of blood and colour wavelength of the blood vessels, thereby evaluating both heart rate and blood oxygenation. This will be used to detect lung circulation diseases.

Resistive Sensors

Resistive sensors measure chest, and therefore lung, expansion as well as the motion of the diaphragm. These factors can be combined to provide an indication of the users lung capacity.

Acoustic Sensors

Acoustic sensors can be used to monitor lung sounds, such as fine crackles and vibrations which are usually the first indicator of inconsistencies [38]. They can create a 'vibration map', highlighting areas of the lung which vibrate most. One sensor will be positioned on each lobe of the lungs, with three on the right lung and two on the left. They can be used to diagnose both lung tissue and airway diseases

Lung Tissue Disease | Airway Disease | Lung Circulation Disease

User–Product Interaction

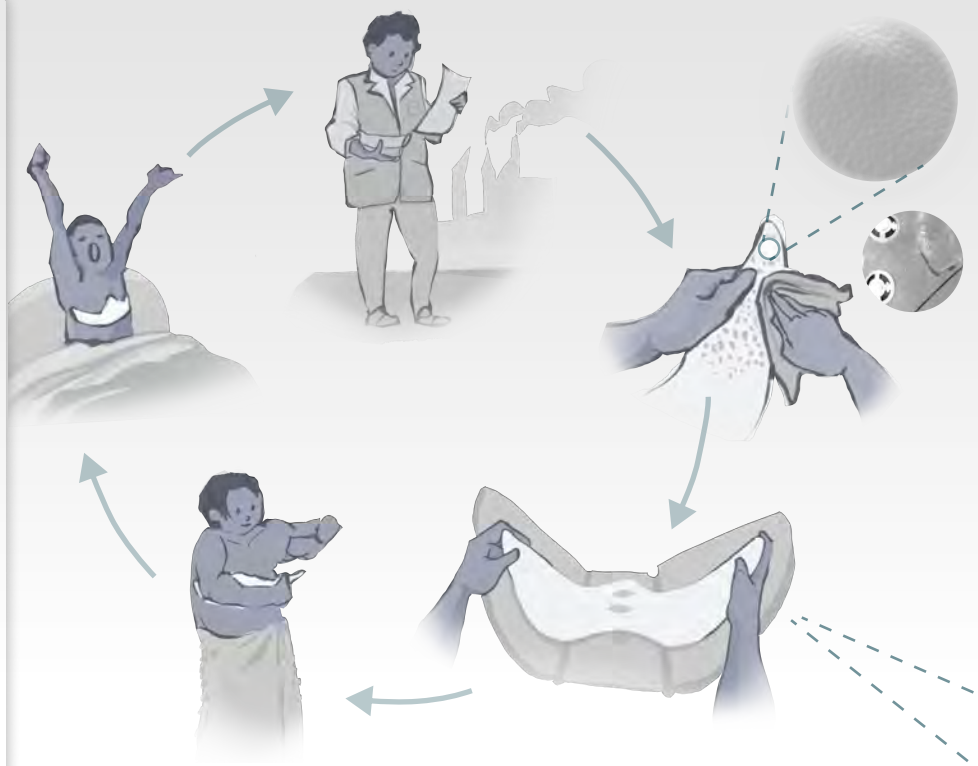
Through evaluation of Rick's daily life, a user-centered specification was created as the basis for user-centric design development of Pulmo.

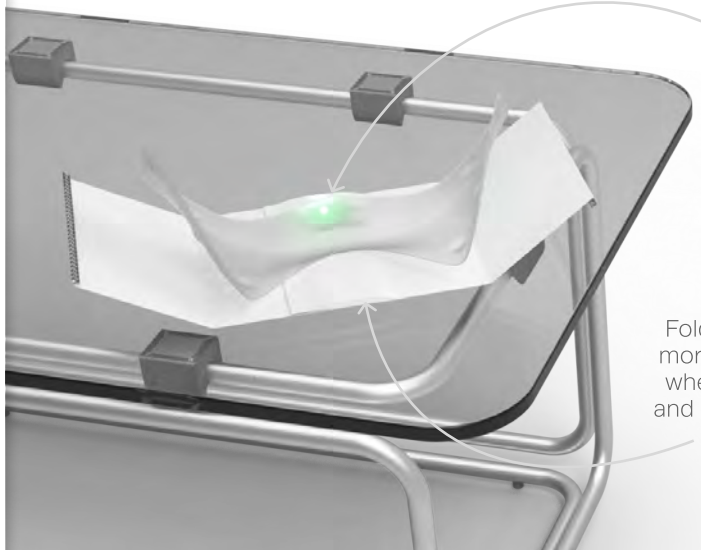
PULMO'S USER REQUIREMENTS

Long-term adoption of Pulmo:

1. Key personalised insights into their respiratory health
2. Convenient monitoring and checkups on potential disease development
3. Seamless IoT integration into homes and personal devices

1. It should not be visible through the user's clothing
2. It should not cause discomfort throughout the day
3. It should be both sweat-resistant and breathable
4. It should not restrict movement and need constant readjustment throughout the day
5. It should not be affected by any external pressure on the device
6. It should be easy to remove
7. It should be easy to clean
8. It should be easy to charge and able to charge in a short period of time
9. It should be easy to put on
10. It should not interfere with Rick's sleep





Lights up green at the top when charging

Foldable design making it more compact for a future where tight urban spaces and hybrid working/travel is more common

CLEANING 3 7

Silicone Layer Materials

The electronic skin (the inner layer that is touches the user) is porous [39], so gas and moisture exchange can take place, making it more breathable and comfortable.

Silicone has antibacterial properties, meaning that it is easy to clean [40]. It is also hydrophobic, so pathogens (typically hydrophilic) are unable to stick to it.

Medical-grade anti-bacterial wipes are used to hygienically wipe down Pulmo as they will be most effective and easily accessible in 2042 [41].

CHARGING 8

Wireless Charging

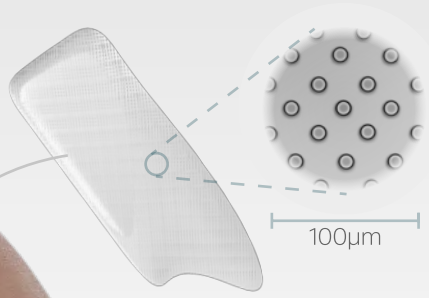
High-speed wireless charging mats for consumer devices will be commonly found in 2042 as charging devices trend towards convenience [42]. This is more sustainable as the durability of ports will no longer be of concern.

The 4 charging coils allows Pulmo to be placed in a variety of positions.

User-Centric Development

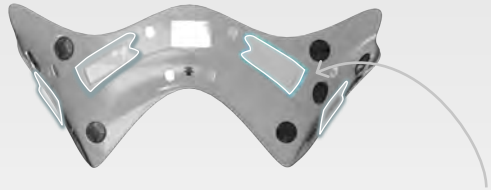
Based on the requirements identified on the previous page, development of form, materials and user experience took place.

SKIN ADHESION 3 4 6



Octo-Skin Materials

Unlike contemporary chemical adhesives such as medical tape or stick-on wearables, 'Octo-skin' [21] retains its adhesive properties even after hundreds of uses. Its microscopic size allows it to adhere to flat and uneven surfaces, so it can be used on skin. Laterally pulling on the device will disengage the active membranes giving a much higher comfort level than contemporary adhesives. Octo-skin is highly robust and ensures suction even in the face of perspiration and unconventional movement.



Octo-skin patches are strategically placed to increase blood circulation to the lungs as they mimic the cups used in cupping therapy. Dry cupping therapy is shown to reduce congestion, phlegm, and fluids [43].

EASE OF USE 9 10

Chest Alignment

The active membranes easily attach to the body, making Pulmo easy to put on.

If there are alignment problems, the user will get an alert on their app.

Sizing

A range of standard sizes will be available to ensure accessibility and inclusivity for all body types.

Sleeping WT

Metrics associated with pulmonary health and sleep have shown to be closely correlated [44], hence wearing Pulmo during sleep plays a crucial part in generating holistic insights.

To accommodate this requirement, Pulmo is designed to be ultra-light, thin, and flexible, so users can sleep in any position without discomfort.

FLEXIBLE AND THIN 1 2 5

Thinness and Visibility MEMS

At its thickest section, Pulmo is 2cm thick. The rest of the patch is less than 1mm, so it can be worn under clothes without it being visible.

Flexibility WT

Pulmo is flexible and can be wrapped around users of different body shapes, whilst maintaining comfort for all. It is only slightly stiffer where necessary – in the centre surrounding the sensors and battery.

Weight MEMS

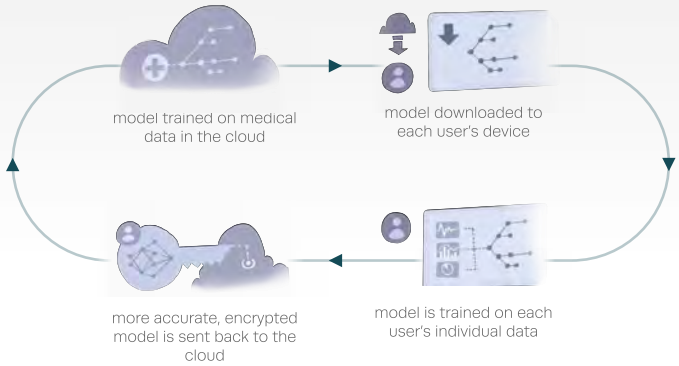
The patch weighs only 400g, meaning that it is extremely lightweight, and the user won't feel that it's too heavy whilst they are wearing it.

Data Analysis

The data collected from Pulmo is analysed, for the following 3 purposes: generating a preliminary diagnosis of any underlying conditions, providing the user with insights and feedback on their lung health, and for working within the home's IoT system. Each of these factors was deconstructed to understand the different aspects of data analytics, and the state of both machine learning and IoT in 2042.

DATA FOR DIAGNOSIS

The primary purpose of data analysis is to generate a preliminary diagnosis, specifically targeting people who have a history of respiratory diseases. The most vital requirement is that it generates an accurate diagnosis, whilst also keeping the user's data safe. For this reason, a federated machine learning model will be used.



Data never leaves the user's device, ensuring maximum privacy protection [45].

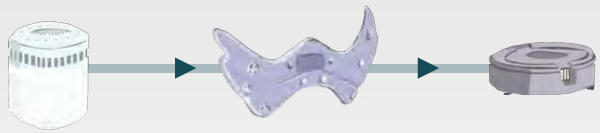
A horizontal federated learning model will be used, with the central model receiving data from similar datasets. While numerical data can be analysed using machine learning techniques, image-based data requires a more complex deep learning model due to its high dimensional nature. By leveraging the power of deep learning, Pulmo ensures that our users receive the most accurate and personalised insights possible, all while safeguarding their privacy and security.

DATA FOR INSIGHTS

Pulmo's revolutionary deep structural causal ML models enable the development of counterfactual meshes that show users how their current lifestyle choices may impact their lungs, as well as the potential benefits of making different choices. This technology allows users to visually explore the effects of their lifestyle on their lung health, empowering them with valuable insights that can help motivate them to make positive changes.

Users are more likely to make long-term life style changes if they can visually observe the impact of their gain or loss [46] on a model of their lungs – as opposed to numerical data, such as charts. By capitalising on this behaviour, Pulmo actively encourages users to change their lifestyle for the better, benefiting them and the insurance company. This process makes understanding lung health intuitive and simple.

DATA FOR ORGANIC HOMES



air purifier sends information on air quality inside the home to Pulmo

Pulmo signals the smart vacuum cleaner to run more frequently

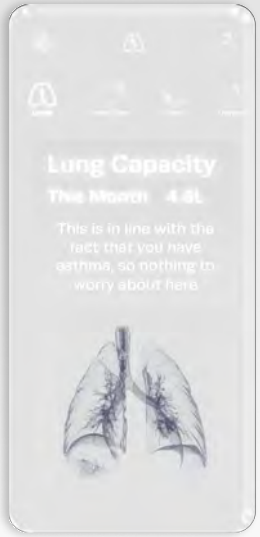
Pulmo's powerful insights and trends can be seamlessly integrated into a system of smart devices chosen by the user, including smart inhalers and air conditioners. By sharing data across all of these devices, Pulmo enables a more comprehensive analysis of the user's respiratory system.

Organic Homes

Organic houses are derived from smart homes, where the smart gadgets in the home interact and communicate with one another. Data is shared to form a dynamic and organic system that responds to the user's needs and desires without any direct human input. Utilising a central smart processor in the house, such as Alexa, enables analysis of data from numerous data-feeds to meet user needs. Output devices can also be monitored to observe impacts on the user. This closed loop technology allows the home to holistically monitor smart gadgets and alter their settings immediately and organically – subsequently making the user's living space more comfortable.

Pulmo App

There are 4 different aspects of the app: tracking health and providing feedback, incentivising the user to keep using Pulmo, ensuring proper usage, and showing the preliminary diagnosis in the event of problem.



Tracks Lung Health

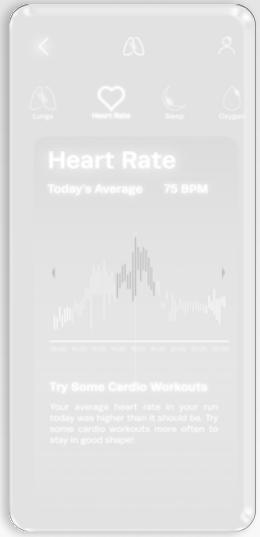
Shows the data in a visual and comprehensive manner to give users the feeling of autonomy over their health

Health App Integration IoT

Connects with any other health apps that the user has, such as Fitbit or Strava, and collates the data to give informed insights

Suggesting Improvements ML

Suggests improvements to the user, as exercise programmes to help improve lung health



Credit Collection

Accumulates 50 credits for every day that Pulmo is properly used

Rewards

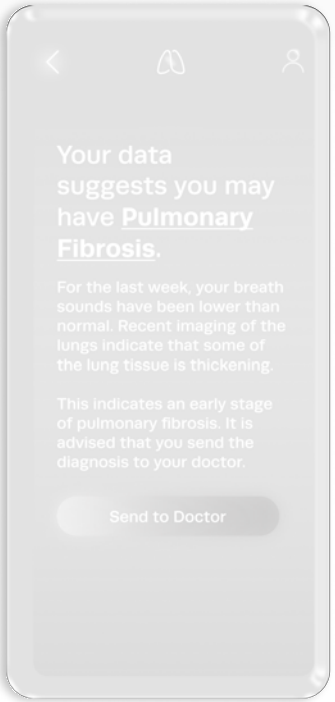
Offers rewards when the user reaches 5000 credits (50 days of usage) to incentivise them to continue

Gamification

Gamifies wearing Pulmo as research suggests that this positively motivates people to take better care of their own health [47]

Wearing and Maintaing Pulmo

Informs the user on how best to use Pulmo, including adjusting it to ensure proper positioning, and reminders to clean and charge it

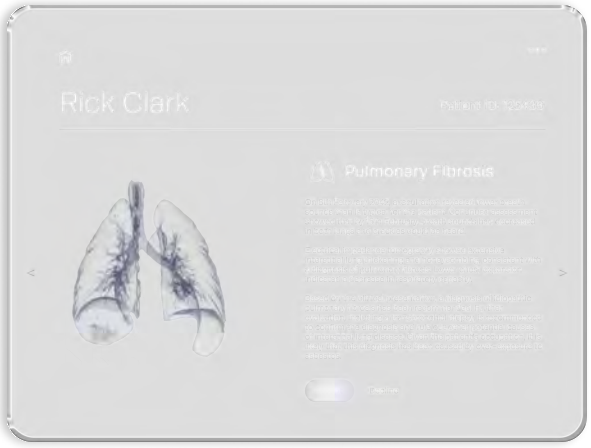


Diagnosis ML

Generates an initial diagnosis for the user, giving reasons in a manner that the user can understand and provides an option to send it to their doctor

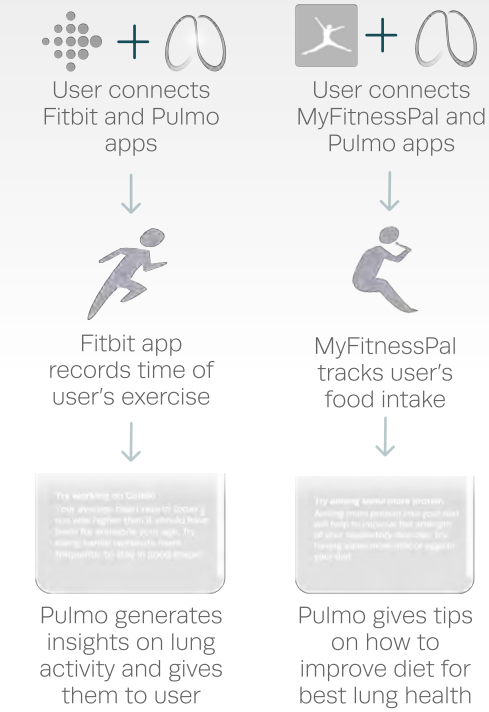
Doctor UI

Provides a more detailed medical report to the doctor, and gives the them the option to accept or decline the diagnosis, so that they have the final say



THE APP IOT

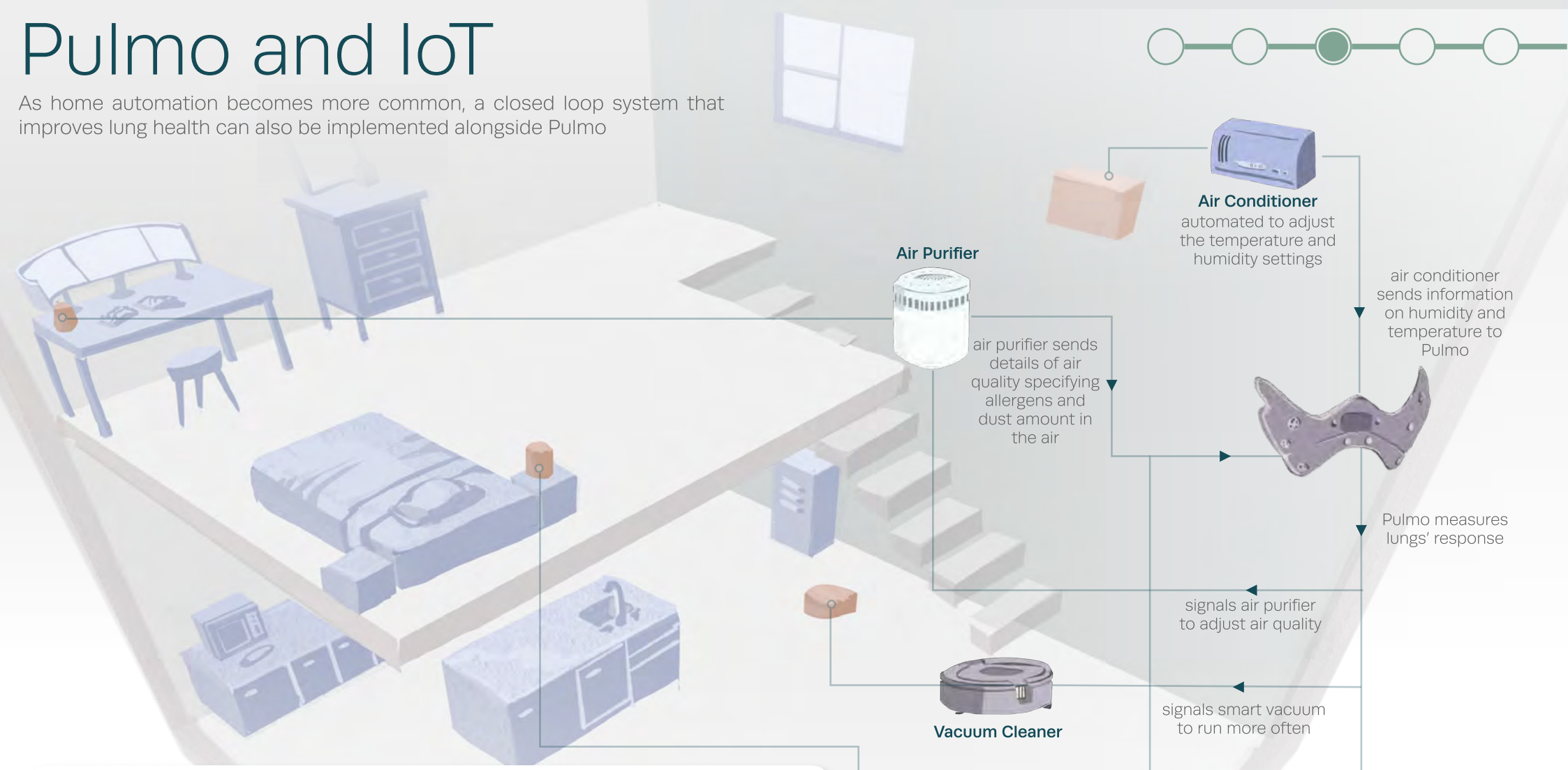
The Pulmo app will integrate with other health apps that have similar privacy policies. No data will be shared with third parties. The app can link data on the user's fitness and eating regime with the lung data from Pulmo, allowing for more informed insights and personalized recommendations.



By integrating with other health and fitness apps, Pulmo can provide a comprehensive and holistic approach to improving lung health.

Pulmo and IoT

As home automation becomes more common, a closed loop system that improves lung health can also be implemented alongside Pulmo

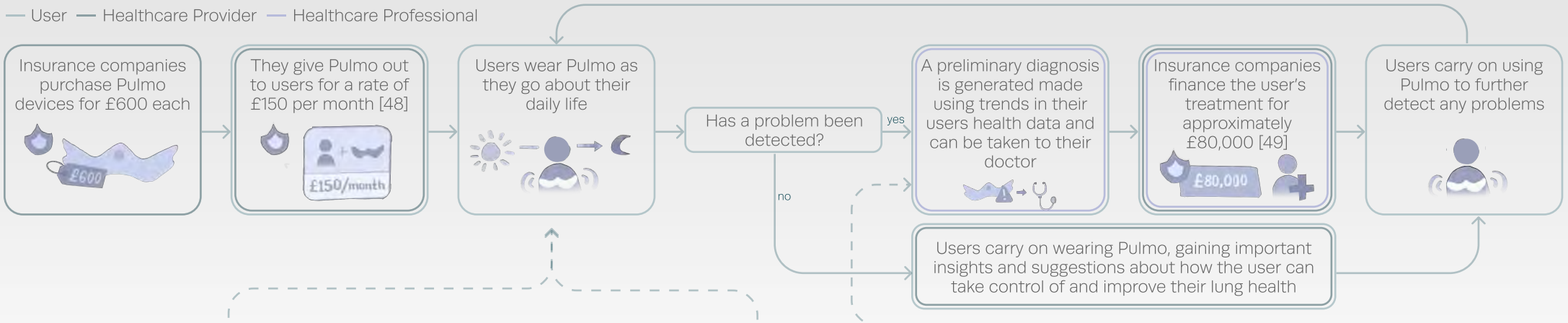


The integration of the Pulmo API into other smart devices, such as smart inhalers, has the potential to create a closed loop system for monitoring and improving lung health. The development of smart automation links between devices allows for Pulmo to fit well into the future home and environment, to aid the development of organically changing rooms based on the user data.

Should Pulmo be successful, it can be made to interact with further devices outside the house. For example, when the user enters the gym, Pulmo will connect with the exercise machines and change settings, depending on the user's breathing patterns. It can also link to their fitness apps, giving them a more comprehensive overview of their workout.

Product Service System

A system diagram was created, looking at various possible scenarios, and at what point users and stakeholders will interact with them. Based on this, possible barriers to implementation were also identified, as well as milestones that must be achieved in order for this system to come to fruition.



BODY SIZING WT

Although Pulmo is designed to be flexible, there is still the possibility that it will not fit every body type in a way that allows for accurate data collection. There will need to be a range of Pulmo sizes available to suit a range of user body types. This will make manufacture more expensive. It may be necessary to give users detailed instructions on how to wear Pulmo at the start, and give them regular guidance.

MISUSE & DAMAGE

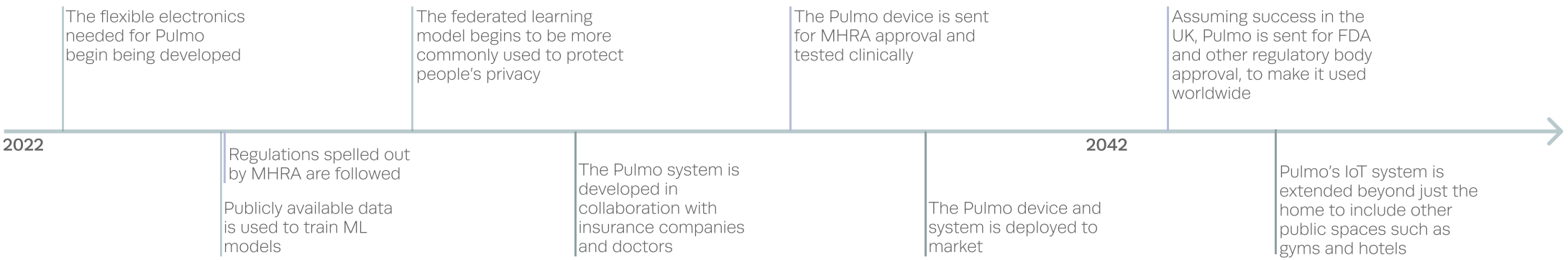
If users do not correctly use Pulmo, or it becomes damaged, repairing it could be more costly for insurance companies, meaning that they actually make a loss. This may make insurance companies less likely to engage with the system. To prevent damage, insurance companies may choose to implement a reward system for appropriate usage, such as offering cheaper premium rates.

MISTAKES IN AI

One of the most significant barriers will be that the algorithms being used are not actually able to accurately identify problems or inconsistencies. This is possible if the model has not been trained on an appropriate amount of data. To mitigate against this, the model will be trained with high-quality data, and given that it will be a federated learning model, it will improve over time.

IMPLEMENTATION ROADMAP

Tech — System — Legal

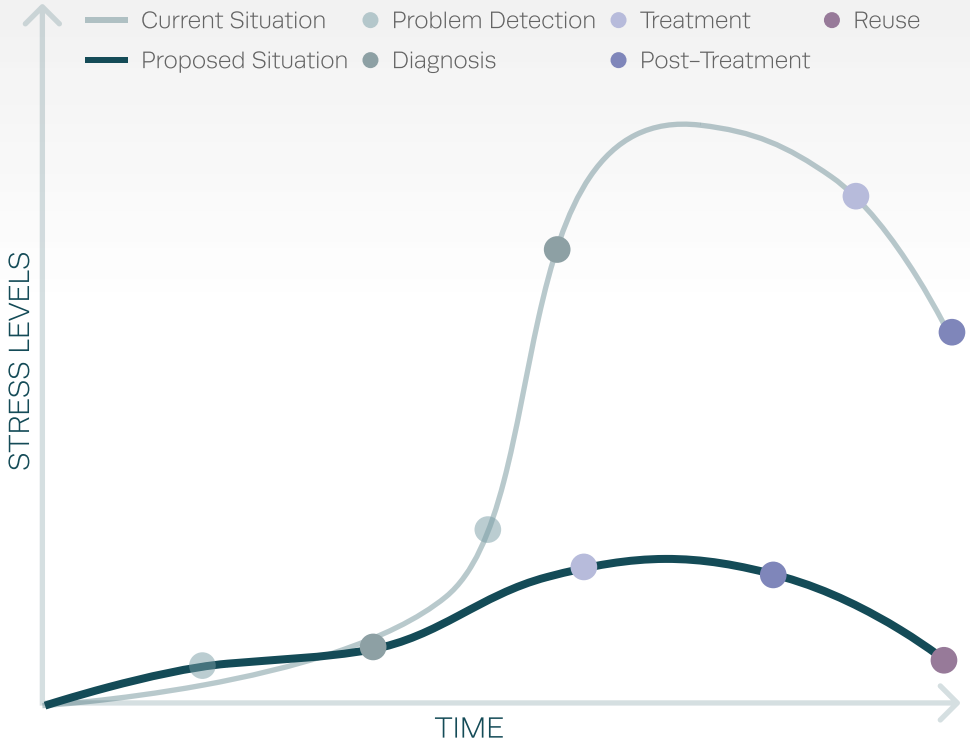


Pulmo and Healthcare

Telemedicine and digital twins are rapidly revolutionising the medical care industry, with a growing number of healthcare providers and patients alike recognising their potential to improve the quality, accessibility, and efficiency of medical care [50]. Pulmo leverages cutting-edge telemedicine technologies and digital twin models to offer users a more personalised and responsive approach to respiratory care.

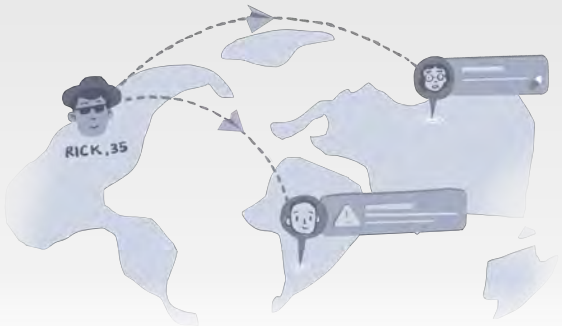
DIAGNOSIS PIPELINE

The healthcare system faces a major challenge of long wait times to obtain a second opinion on medical diagnoses [51], resulting in patients having to visit different hospitals and redo tests, which is a costly and time-consuming process. Pulmo aids in the development of the digital twin which allows the users data to be checked remotely, by multiple doctors ensuring that the diagnosis is correct and the steps of treatment are the most effective.



The Pulmo PSS will ease the user's stress levels considerably, as problems will be detected much earlier, and therefore will be much easier to treat.

DIGITAL NOMADS



It can be challenging for digial nomads to establish a long-term relationship with a doctor in one specific location. With Pulmo's procedure, a patient's medical data is collected and stored in a digital twin that can be accessed and shared with doctors in different locations. This means that they can receive diagnosis and treatment recommendations from a doctor in one location and have them validated by a third-party doctor in a different location without having to physically travel to either location. Pulmo contributes to the idea of a global, versatile healthcare system, where a user can access their healthcare from anywhere in the world.

DIGITAL TWINS

A digital twin is a digital data-driven representation of a physical entity. In the case of healthcare, they are becoming increasingly popular [52]. Pulmo allows for the high-fidelity and holistic capture of data for the respiratory system. This provides all data points necessary to create a digital replica of the lungs that can be analysed. Pulmo easily fits into the medical wearable system, allowing it to share its data across a standard format – enabling data points to be combined with other wearables and form a complete digital twin of the body. This will allow doctors to closely inspect the users body without the patient having to be present in the clinic. This not only makes it easier for a doctor to review a patient but also allows them to have complete data of the users body over a significant time span.

Expert Validation

To validate the Pulmo PSS, a number of different experts were consulted. Each has a different perspective, so all aspects of Pulmo were properly validated: technical, medical, user-centric and systemic.

Professor Thrishantha Nanayakkara
Robotics Professor at Imperial College London

Technical Systemic

> The IoT system in the home is so powerful – it will help to make your idea really successful if it integrates well into the users' lives

We asked Professor Nanayakkara to validate our PSS from a technical standpoint, specifically the technologies and sensors used.

The fact that a majority of the technology being used derives from different industries makes Pulmo more likely to work, as relying on medical technology alone will result in slow progression

Thrish particularly liked the IoT systems in which Pulmo fits in, as it makes the product more usable – if it fits well into the user's existing setup, and helps to tailor their homes towards each user's specific needs.

Dr Ming Hui Ying
General Physician with a Special Interest in Pulmonary Health in Malaysia

Medical

> The idea of a detection device is fantastic, and its uses could actually stretch beyond the realm of simply detection to monitoring and treatment as well

Dr Ming Hui Ying validated our concept from the perspective of medical usage, and how well it can achieve it's function.

The versatility of Pulmo means that it can actually be used for a variety of purposes, including monitoring of chronic conditions, as well as for treatment.

The doctor's UI would be very helpful, as they can easily view and validate the diagnosis, instead of conducting tests again. However, it would be vital to ensure that Pulmo could reach all the necessary parts on the body to take accurate measurements on all patients, regardless of their body shape.

Dr Talya Porat
Senior Lecturer in Human Factors Engineering at Imperial College London

User-Centric Systemic

> The fact that it can be used for early diagnosis and behavioural insights will help the user to take control of their lives

We asked Dr Porat to validate Pulmo from a user-centric perspective. She has extensive experience in designing for healthcare interventions.

The concept will help with decision support, which is a very integral part of personalised medicine, so the early diagnosis part is definitely in the right direction.

It would be important to think about the internal motivations of the users. External incentives do not always work and so it would be good to ensure that users really are empowered by this device, and find it beneficial in taking charge of their own health.

Dr Guang Yang
Advanced Research Fellow in Medical Imaging at Imperial College London

Technical Medical

> This works with the idea of personalised medicine, which is exactly the direction it's going in and similar to the work we're doing now

We asked Dr Guang Yang to validate our measurement methods and ML models used with Pulmo.

The implementation of the ML models would greatly allow for increased use in personalised medicine. Pulmo's IoT system will allow for a holistic data collection method, meaning that the ML models needed would be very powerful.

However, the ML models and insights rely heavily on the accuracy of readings of the sensors. It will therefore be vital to ensure that sensors are able to give noise-free readings.

Evaluation Against Objectives

OBJECTIVES	ACHIEVEMENT	CRITICAL EVALUATION
The monitoring system must use the patient's past medical data from a variety of different data points to generate an accurate diagnosis of any problems	4 different data points are monitored and between them, all aspects of lung health are being measured The machine learning model will be refined over time using patient's data, making it as accurate as possible	Electrical impedance tomography was chosen over ultrasound for imaging, as the former is more likely to work in areas of bone and tissue. However, it is possible that in 20 years, ultrasound has developed to actually be more effective than EI tomography.
The monitoring system must be passive and non-invasive	The user only has to wear Pulmo, not interact with it in any other way Monitoring is all done through biomarker sensing, at no point is the skin perforated	Pulmo was designed to be medically non-invasive, as research indicates that non-invasive technology will be preferred. However, people may still find it to be too obtrusive (as it is sticking to the body), and therefore be unwilling to use the device
The monitoring system should help to shorten the diagnosis pipeline by aiding in the transition to a digital twin	The data is all held digitally, aiding in this transition As the doctor already has the data to use, they do not have to do so many tests, shortening the diagnosis pipeline	The Pulmo diagnosis system was designed with the idea of reducing patient wait times for diagnosis. However, this is assuming that the user will have a reasonable level of trust in the Pulmo diagnosis. People may not trust it however, meaning that the doctor will have to repeat tests, not saving any time.
Pulmo should be comfortable, breathable and discreet	There is no uncomfortable adhesive for the user to deal with The materials are porous so gas exchange can take place Pulmo is ultra-thin meaning that it cannot be seen under the clothes	Octo-skin has replaced adhesives, but users may find it as uncomfortable as gel based adhesives, and will therefore not want to use it. Similarly, battery and sensor technology may not have progressed to a point where the flexible ones we are using are available, so it will be thicker.
Pulmo should be easy to put on & take off	Octo-skin can easily be engaged and disengaged	Users may not find octo-skin so easy to attach, making Pulmo difficult to put on. However, it also may be too strong, meaning that users won't find it easy to take off. The technology may not have progressed enough to be so easy to use in fashion.
Pulmo should be easy to maintain in terms of charging and cleaning	A charging mat will be provided that will allow the user to easily charge Pulmo Anti-bacterial wipes can be used to clean Pulmo	The charging mat uses an array of coils to allow Pulmo to be charged wirelessly. However, in the future, an alternative method of charging may have been developed that is more effective. Furthermore, whilst Pulmo can be cleaned using strong anti-bacterial wipes, a more effective method of UV cleaning may have been developed by then.

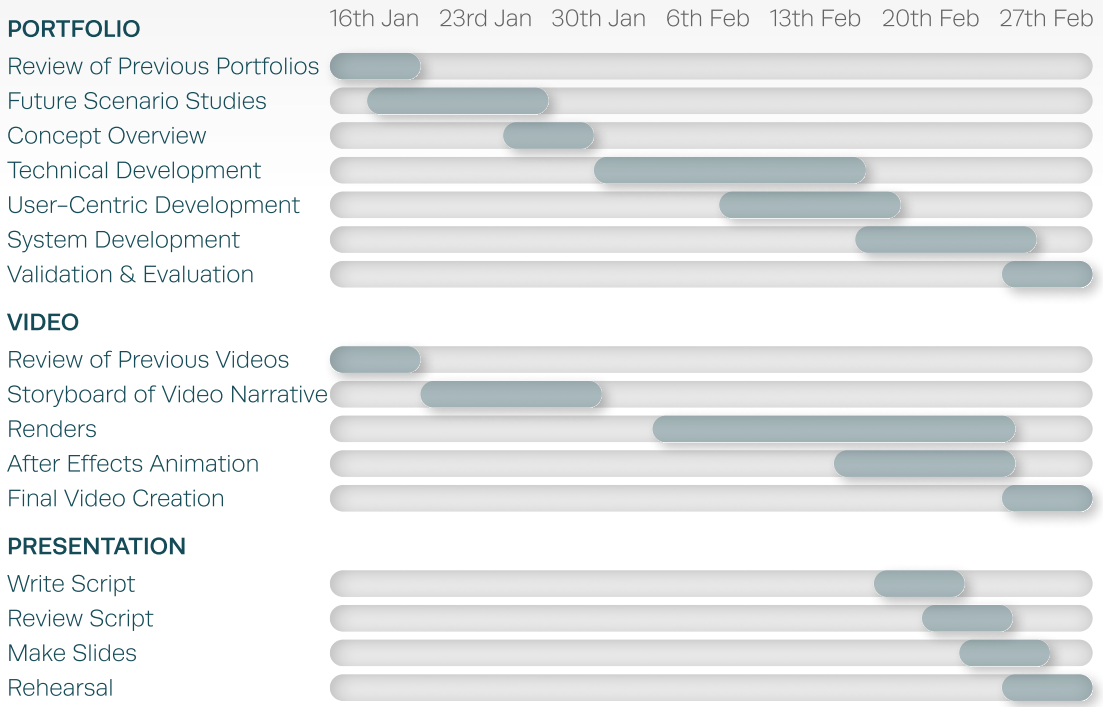
Project Management

COLLABORATIVE PLATFORMS

One of the improvements that needed to be made as a result of the work done in phase 1 was that the record of work needed to be more streamlined. Therefore, Notion was used for meeting minutes, and for keeping track of tasks. A Gantt chart was made of all tasks. Each task had a status field (not started, in progress or done), an assignment field (to assign each task to either one person or to multiple depending on the task), and a due date. This helped to ensure that everybody was aware of the tasks and adequate progress was being made. For the actual portfolio and more design-based tasks, collaborative platforms like Figma and FigJam were used. To share CAD files, the shared folder on Teams was used.

TIME & BUDGET MANAGEMENT

Since there was no physical embodiment that was needed, the allocated of budget of £200 was spent on rendering CAD images and videos in render farms



TEAM REFLECTIONS

The team held bi-weekly meetings on Mondays and Wednesdays to discuss progress, arising issues, and subsequent action points . Fortnightly meetings were conducted with the project supervisor to discuss any specific technological questions. Term 2, required consideration of different timetables due to electives. However, time management enabled a consistent pace of working that led to us finishing the work well in advance to the deadline.

TEAM ROLES

Sarthak

Took on technical aspects such as CAD development, technological enablers and data analysis.

Tanya

Was responsible for the video and visuals of Pulmo, rendering and animating across the project.

Lauren

Managed visual elements by producing graphics and worked on the user-centric development.

Jiayi

Worked on aspects of the CAD and video. Helped with visual elements such as the logo.

Anusha

Managed the progression of the portfolio pages, content such as data analysis and defining the Pulmo system.

INDIVIDUAL REFLECTIONS

During the development of CAD, it was useful to get constant feedback and make iterations on the design.

It was important to clarify issues and seek feedback as a group to enable fast progression in all aspects

I learned that making progress in one section can aid the development of another

I learned how great teamwork could gather the fortes of each member and move more efficiently to our final goal.

Several aspects gave the illusion of being behind - a more detailed map of the work could have been useful.

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