Cocoon.

Wearable airbag technology

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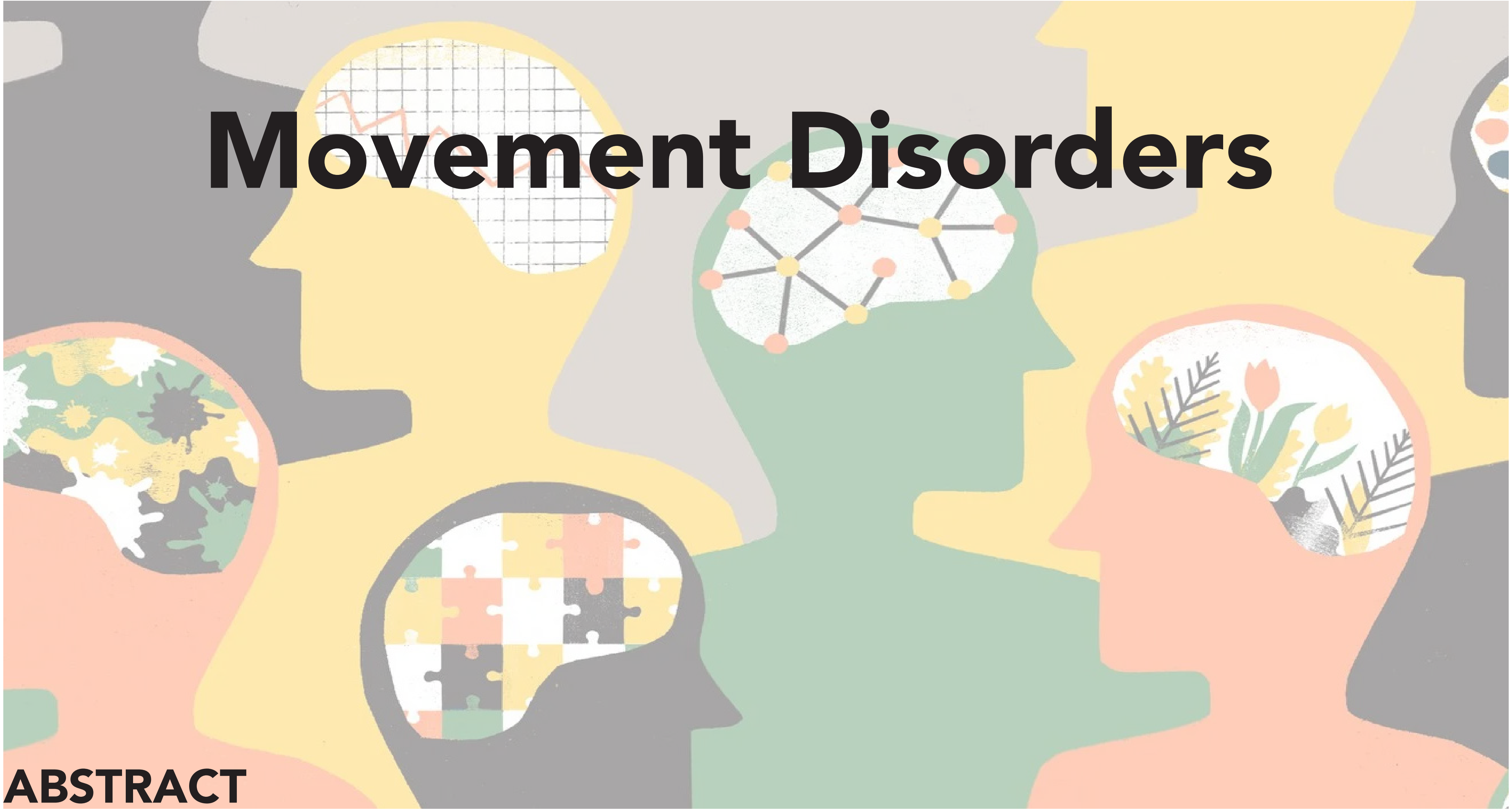
This report is written from the perspective and knowledge gained on my personal journey living with a dystonic movement disorder. It examines one of the key issues faced based on real life experience to highlight a currently unmet need.

Note: At this time, this design proposal focuses on a bespoke market and client base, but it is hoped in time this would expand as it becomes more cost effective to produce.

INDEX

4	ABSTRACT
5-6	INTRODUCTION
7	USER PERSONAS
8	USER JOURNEY MAP
9	MY PERSONAL EXPERIENCE
10	COCOON CORE STAKEHOLDERS
11	COCOON CORE CLIENTS
12	THE ARGUMENT FOR AIRBAG TECHNOLOGY
13	AIRBAG RESEARCH
14-15	CALCULATIONS OF HUMAN MOTION
16-17	CALCULATING FALL ALGORITHMS
18	MARKET FORECAST
19-20	COMPETITOR RESEARCH
21-23	COMPETITOR ANALYSIS
24-25	LEGAL CONSIDERATIONS
26	PATENTS
27	DESIGN CONSIDERATIONS
28-29	PRODUCT DESIGN SPECIFICATION
30-32	INITIAL IDEATIONS
33-34	NORMATIVE EVALUATION
35	DEVELOPMENT
36-38	PRIMARY RESEARCH
39-40	PROTOTYPING
41	DEVELOPMENT
42-46	TECHNICAL BREAKDOWN
47	PRODUCTION
48	PROPOSED SYSTEM
49	PRELIMINARY BIOMETRICS DATA COLLECTION
50-53	COCOON FINAL DESIGN
54	STORYBOARD
55	COCOON HERO IMAGE
56-58	COCOON'S INTERFACE
59-63	COCOON BRANDING
64-65	THE FUTURE OF COCOON
66-67	FINAL EVALUATION AGAINST PDS
67	CONCLUSION
68	APPENDIX I
69	APPENDIX II
70	APPENDIX III
71	APPENDIX IIII
72	APPENDIX V
73	APPENDIX VI
74	APPENDIX VII
75-86	REFERENCES



Individuals with neurological movement disorders are a currently neglected but growing group that are vulnerable to falls and injuries that can cause death, serious long term health issues or require hospitalisation. Quality of life may diminish due to injury or fear of injury and the adoption of avoidance behaviour in a desire to stay safe. This can have an impact on physical activity, social interaction , independence and wellbeing. At the same time, it adds to the increasing societal burden of increasing health service costs.

While there have been many advances in understanding and diagnosing complex neurological conditions through the use of genetic testing and brain imaging.

INTRODUCTION

Movement Disorder is an umbrella term for a spectrum of neurological conditions, characterised by abnormal body movements. These can be aggressive (hyperkinetic) or restrictive (hypokinetic), voluntary or involuntary and can also be accompanied by weakness, spasticity and other motor deficits. The list of movement disorders is broad with many shared symptoms. (refer to Appendix I)

Some are present at birth or have later onset due to external factors such as age, head trauma, stroke, toxin ingestion, medications and infection (Dystonia Ireland), or for reasons unknown. For example: Parkinsons is degenerative and causes loss of control and stability. Age is a known factor (Mejia, N I, 2020) and numbers are expected to rise with an aging population who may also have co-morbid risk factors e.g., sight loss, muscle weakness and poorly controlled blood pressure, which contribute to falls.

Epilepsy, is an interruption in normal brain activity which can cause sudden drop seizures with risk of bone fractures and loss of consciousness from a blow to the head (IEEE, 2018) There are over 40 subtypes effecting around 625, 800 people in the UK or 1:107. Each year around 1,000 people in the UK die from an Epileptic related injury.

Dystonia and its many variants can be genetic, induced, or of unknown cause and exhibit both extreme rigidity of movement where limbs are locked in position (tonic) or extreme repeated movement i.e. uncontrollable flailing. (clonic) It carries both the risks of a fall and further injury particularly to the head and limbs

There have been many advances in the study of complex neurological conditions but wrongly, movement disorders are still misdiagnosed as psychogenic or psychosomatic giving rise to derogatory perceptions. Default treatment remains drug based while other support is generally less available.

(Adobe,n.d)

(Network 13, 2021)

(Network 13, 2021)

SET TO INCREASE

Across all ages 1 : 6 in the UK were diagnosed with some form of neurological condition costing the economy £96 billion as of 2019 and it is said that movement disorders are set to "considerably increase between 2010 and 2050",(Movement Disorder Society, 2011) due in part to increased longevity.

Movement disorders in any form are a major challenge in the lives of patients, their families, carers and the healthcare systems who treat them. Between April 2021 and April 2023, the waiting list for neurology treatment in the NHS had grown 76% to more than 220,000 people.

IMPLICATIONS

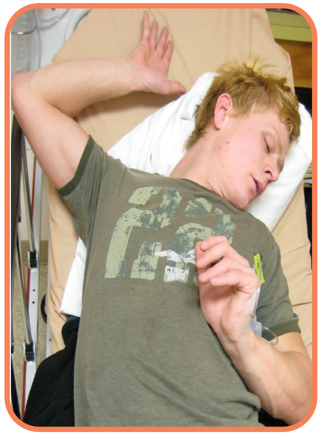
Currently, the UK healthcare system is under immense pressure with a record number of ambulance callouts and hospital admissions. They are at capacity and are unable to meet response time and handover targets (Smith T, 2023), which is vital time in which those who experience a fall and seizure do not have.

Whether a fall is due to age, other illness or a movement disorder there is a real risk of not having timely assistance. Quick assistance reduced hospital admissions by 26% and decreases the chance of death by 80% (IEEE Sens, J, 2016). The treatment and after care cost to the NHS of falls in the elderly alone is more than £2.3 billion per year. The human cost is reduced independence, loss of confidence and strength due to inactivity and increased anxiety.

THE GOAL

- To prevent or mitigate injury and alleviate severity
- To avoid or reduce the level and duration of hospitalisations and their associated cost and that of emergency services
- To restore sense of wellbeing, independence and autonomy to the individual so they remain economically active members of society.

"Parkinson's disease is one of the most diffused neurodegenerative human diseases, with an estimated prevalence of 120–180 cases per 100,000 individuals in industrialized countries and a prevalence increasing with age"



Medication Induced Dystonia. (Wikipedia, 2024)

The wait list for neurology treatment in the NHS grew by 76% between 2021 to 2023 and is getting longer

USER PERSONAS

Three user personas were explored to help gain insight into the lives, limitations and needs of a primary client to help tailor design considerations.

Icon 1

Sophia's Story

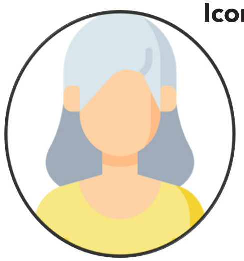
Sophia is 21 and developed Dystonia when she was 4. It has impacted her freedom to pursue solo interests and be independent. Her main worry is falling and not being able to control her movements which result in cuts and bruises and on one occasion a suspected brain injury. She feels vulnerable and hates going to hospital where she has had some bad experiences. Before an episode she feels an 'aura'. This is a sensation linked to an impending episode but it doesn't help to predict when. She knows they can't be stopped but wishes there was something that made her feel safer and reduced her risks, so she could carry on as normal.

Icon 2

Mike's Story

Mike is a 41 year old father of 3 who enjoys climbing. He suffered a concussion climbing and is diagnosed with Epilepsy after experiencing tonic-clonic seizures. He is anxious about the drugs prescribed and side effects at his age. He has found there are alternative therapies which have gained credibility such as a ketogenic diet, but he knows he can't rely on diet alone and has looked at protective devices but these are basically shields and he would feel self-conscious wearing them. He feels depressed because he fears how getting a head injury would impact his family. He needs to get through these episodes and feel normal again.

Icon 3



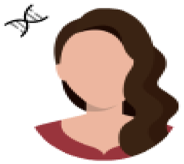
Julie's Story

Julie is 75. What started as a slight tremor has been diagnosed as advancing Parkinson's and she has had a couple of falls which have left her shaken. She lives alone and has the option of care visits but doesn't want to be seen as disabled. She feels lonely because going out seems risky, but she is becoming withdrawn. Her concern if she falls at her age is that bone fractures can kill and dreads the indignity of being found too late. She knows there is no cure but wants to remain self-sufficient as long as possible otherwise she will feel depressed and worthless.

A User journey of one of the Personas is then used as a tool (refer to Index II for a secondary example) to help identify and think about unmet needs in the market and highlight potential barriers or opportunities for improvement or innovation.

User Journey Map

Dystonia, Independence after recovery



Scenario

Sophia has gone out for the day, She had been feeling a bit nauseous earlier and for days has had d phantom nerve pains under her skin an odd sensation under her skin she has felt a and her friends couldn't come, but she didn't want to miss the event. She found it frustrating having to rely on the company of others, but in the past she had been grateful to have people around her who understood her condition and could explain to first responders as she was not always coherent when she had an episode or able to call for help or give consent to treatment.
The day was more crowded than she expected and it was hot. She remembers going to get a bottle of water and feeling strange and disorientated. At some point people were leaning over her and talking but it's all a bit vague.

Her Expectations

- To find alternative support which allows her to leave the house with confidence
- A product that can communicate her condition to first responders and doctors ahead of hospital admission time with recommended advice and patient permission.
- A product that not only saves her life but doesn't give the appearance of a medical aid

Day One — Hospitalisation

1. Sophia has been taken to hospital because the episode won't stop and she is in a lot of pain through hitting her already bruised arms against the bed rails while waiting for the medication to work. As usual she has already lost her earrings because of her violent head movements.
2. The doctors have no idea if/how the episode was triggered. No further diagnosis is offered
3. She is left to make her own way home

First Week — Recovery

4. Most of Sophia's recovery is spent in bed. She is chronically tired, sleeping 12+ hours a day and experiences intense nerve pains across her body.
5. She is not eating properly and her mobility remains poor.
6. By the end of the week, this begins to improve

Week 2-3 — Aura

7. Sophia feels a continual build up of nerve pain but she wants to go out
8. As 'Aura' pain increases, she is too scared to go out in the fear that she will get severely hurt again.
9. Feeling depressed, Sophia laments that she misses her friends, family and the ability to live an unrestricted social life

Week 3 — Research

10. Change has to happen. She begins to research options that may help protect her enough to allow her to go out more often independently.
11. She has been researching fall prevention and has found companies that specialise in self inflating wearable airbags. Sophia is keen to find out more.
12. Some airbag products have very specific applications and are costly so deciding on the right product for her will take time.

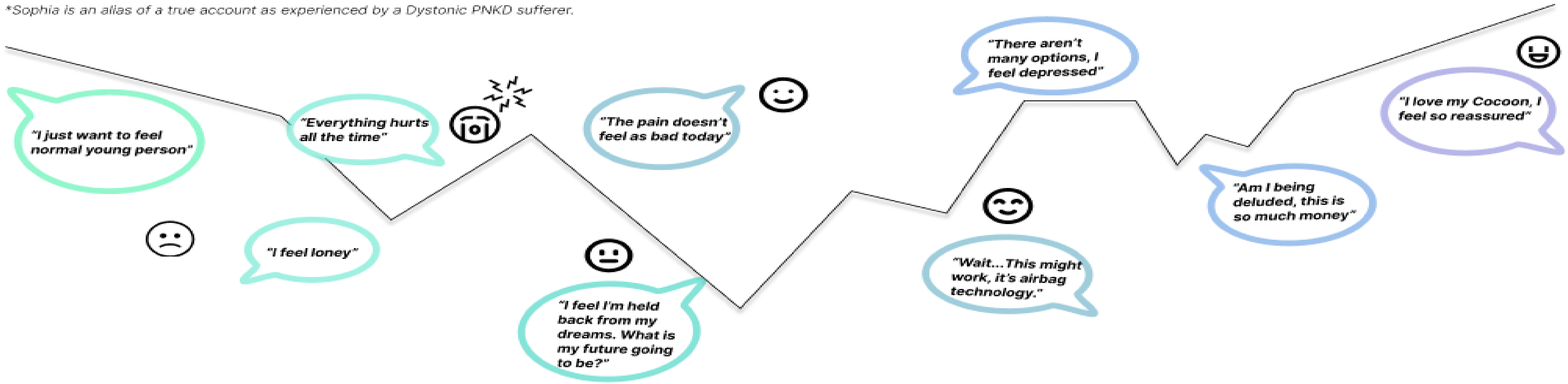
One Month — Compare

13. She whittles down products based on; the level of protection they provide, price, design, customer reviews and the aftercare the company provide.
14. She cross compares rigorously as this is a one time purchase. Some only offer protection for the head or chest region whereas she needs full body protection. Only one product, Cocoon, offers this.
15. She consults with family and friends who know her situation well for advice

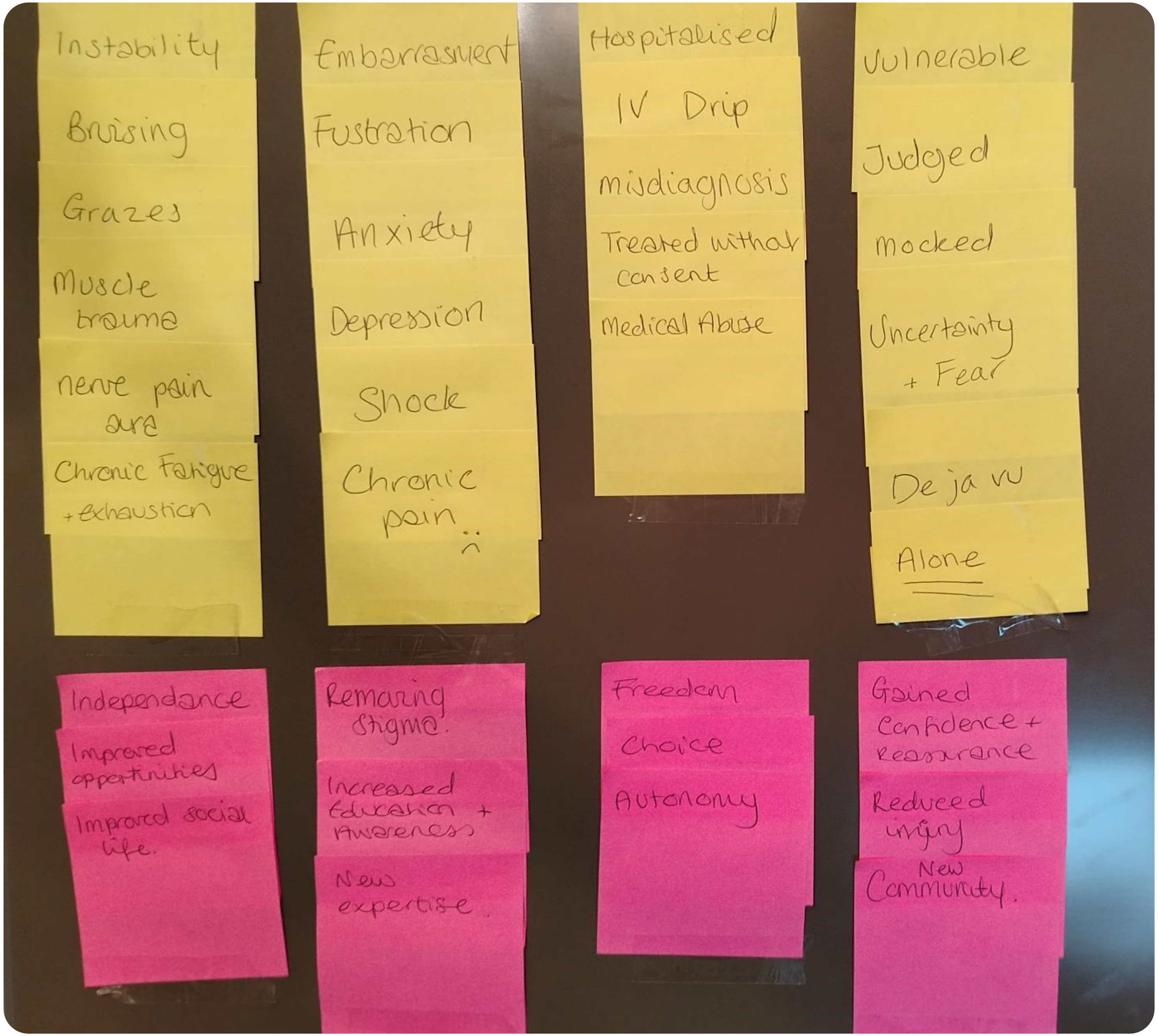
One Week — Decision

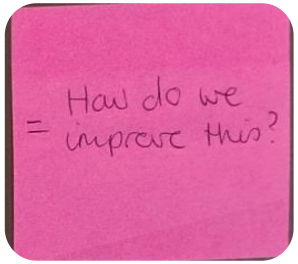
15. Sophia decides on Cocoon and places her order.
16. On arrival of her airbag, she sets up her account with Cocoon, registers her next of kin, her condition and other relevant info.
17. It feels like life and new opportunities have begun! She can leave her home at ease.

*Sophia is an alias of a true account as experienced by a Dystonic PNKD sufferer.



MY PERSONAL EXPERIENCE





PROBLEMS VS NEEDS

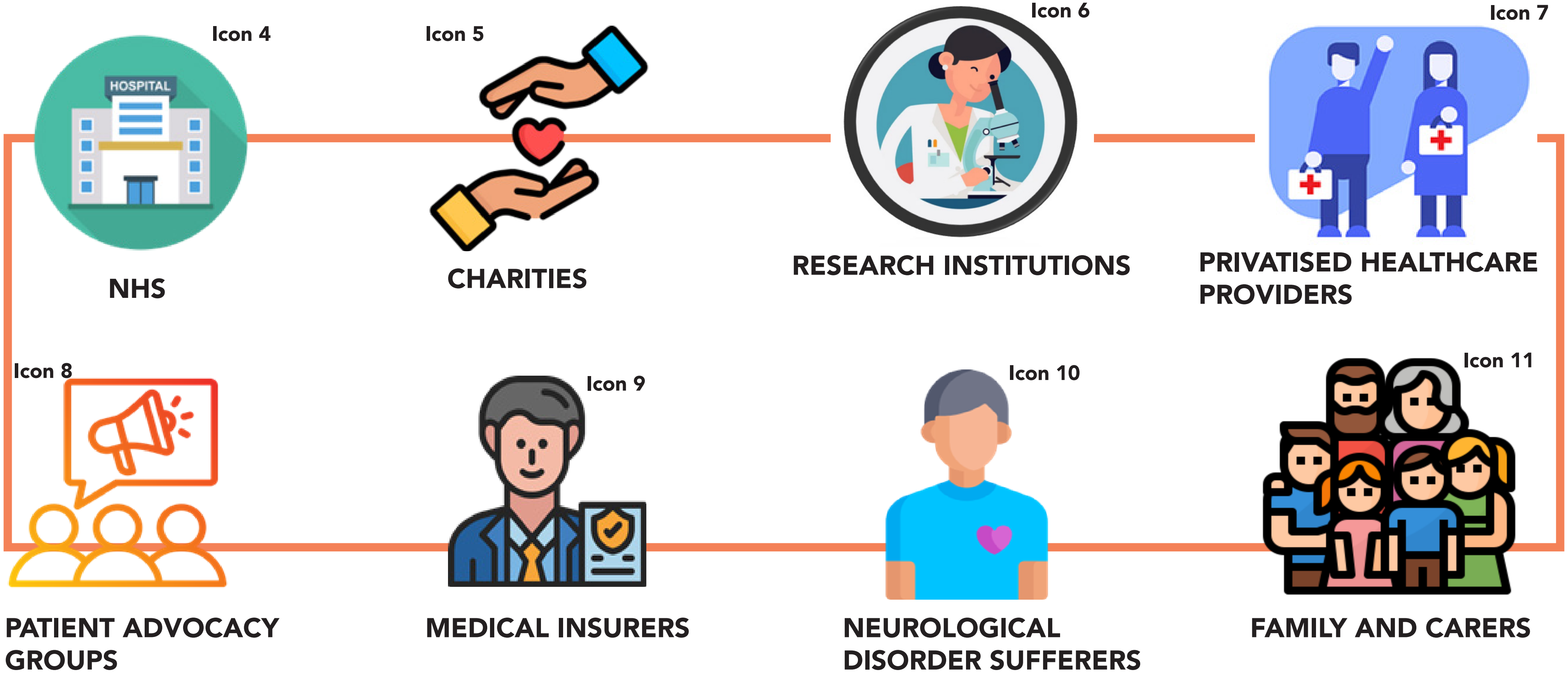
Based on personal experience a quick dynamic thoughts/ reminder board was made to help focus the design intention. This can be revisited and amended as a reminder during the process.

Yellow post-its express negative feelings and experiences

Pink post-its express positive goals and outcomes

Refer also to Appendix III to see an example of a Dystonic (patient) diary

COCOON'S CORE STAKEHOLDERS



Stakeholders were identified as having, as a minimum, some vested interest. The individual remains central to this proposal as both client and stakeholder. A short analysis identified 2 further potential clients on a B to B basis and an opportunity for possible collaboration in research and testing.

COCOON'S CORE CLIENTS

Icon 12

CLIENT

Individual who has the ability to purchase privately or use insurance

Icon 13

B2B

NHS is one of the largest procurers of goods and sevices in the UK and offers huge opportunity for high-quantity sales.

Private medical suppliers who wanto to extend their range of products and take a mark up on the product

Icon 14

R&D

Research institutions like UCHL, charities and other advocacy groups for collaboration in design, testing and feedback, etc.

THE ARGUMENT FOR AIRBAG TECHNOLOGY

The objective is to enable someone, susceptible to falls, with a movement disorder to avoid injury without compromising their day-to-day freedom and activities.

As a starting point 2 key questions were asked:
- Can a fall be prevented and if not, can the consequences be mitigated?
- How can this be done without compromising lifestyle and altering behaviours?

There are already devices in the market or available free from the NHS that aid stability like walking frames, grab rails and wheelchairs, but these have restricted use and don't necessarily prevent a fall or lessen the impact as some people may still fall awkwardly.

The Cochrane review also concluded that up to 65% of stroke victims had a fall while in hospital or 75% in the community and there was no evidence of any intervention that could prevent them. This pointed to mitigation rather than prevention.

TAKING A LOOK AT PROTECTIVE WEAR

Safety certified protective wear have been around for decades in the form of clothing, shields, etc and are used across a wide array of industries from the health sector to construction. Clothing options are mainly limited to hard headwear, boots and gloves. They are not able to control an accident only reduce injury on impact.

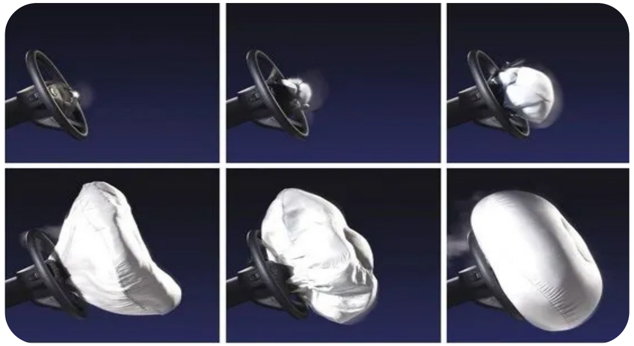
Advocacy groups like epilepsy.org.uk also identify anti-seizure safety products that can be purchased from third parties like Ortho Europe, but they do not endorse them. These are mainly products that protect the head and neck and may come semi-bespoke. Either rigid or soft shell they need to be worn in anticipation of a seizure. Due to the helmet like design and added padding they may be acceptable in a home setting or during a sport but they are not discreet. It is not necessarily possible to get these products free via NHS.

This research drew out further design ideas. It had to detect an unpredictable event, protect, be worn, discreet, lightweight, meet exacting safety standards and in some way be bespoke. This pointed to some sort of apparel that either changed or could include a protective device, like an airbag

AIRBAG RESEARCH

Airbag Technology has been around since the 1950’s in the motor industry as a way of protecting drivers and passengers in a car accident.

In the 1970s and ‘90s this had moved on with increasingly sophisticated technology that enabled a protective cushion to be deployed in milliseconds, Arguably, riders are more vulnerable than car passengers and the concept of airbag protection took traction in MOTO GP. However, as a rider faces numerous unpredictable hazards the software has to anticipate the moment of collision so that the airbags inside the suit fully deploy ‘before’ contact is made to protect back, shoulders and ribcage by absorbing the force.



Airbag Deployment (zigwheels, 2013)

There are numerous variables to be taken into account in order to do this and race suits are fitted with sensors, accelerometers, gyroscopes and a GPS. When sensors detect a fall, it activates the gas canisters inside the suit to fully inflate the bag in 25 milliseconds. The software makes use of information drawn from around 40,000 recorded rider journeys to fine tune algorithms in order to differentiate between a genuine incident and a near miss, so that inflation doesn’t occur at random.

This technology has also been extended into body worn Equestrian safety. It has the benefit of huge investment, a track record in safety and meeting certifiable standards. It is anticipated that R&D in this area will trickle down, making components smarter, more integrated and cheaper.

(shop, 2024)

APPLYING AIRBAG TECHNOLOGY TO MOVEMENT DISORDER

Movement disorders are not generally easy to predict particularly early on. For an airbag to successfully protect a user from a serious fall and all that follows it is estimated it would have to deploy in well under a second. There would also be a number of unpredictable variables such as the surroundings and whether there is any other hazard close by that may be struck while falling.

As this will be a new area for the use of airbag technology there will not be existing data to build on but the components are well understood and demonstrated in other products. It is expected that the data needed for a system to differentiate normal and abnormal movement will have to be collected on an individual basis for a tailored product.

CALCULATIONS OF HUMAN MOTION

Sensors are used to capture a wide range of motion exhibited by a person. This gait data is stored in an algorithm which analyses and compares current motion data with historical records. Such data is subjective as different heights, statures and biological physiologies result in different walking styles, especially for those with movement disorders, therefore individuals should be measured with a Body Sensor Network.

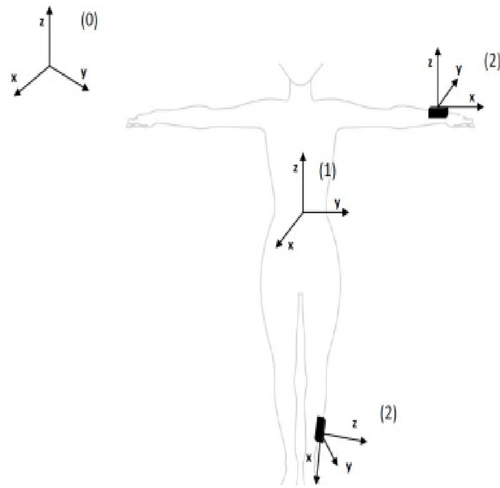
THE BODY SENSOR NETWORK

A body sensor network, involves a group of sensors attached to a user's limbs and chest region, that collect physiological data on Activities of Daily Living (ADL). A number of tests can be conducted to measure a user's range of movement such as the 6 Minute Walk Test and the Get Up and Sit Down Test.

Stretching and light movements (MDPI, 2021)

This ADL data is fundamental for the algorithm's understanding of its user. It serves as the basis for the airbag system to ascertain what is normal or abnormal movement in order to trigger inflation.

The body is considered to have its own static inertia, as represented with Euler Angles XYZ. Rotation around these angles is referred to as, Roll around the X-Axis, Pitch around the Y-Axis and Yaw around the Z-Axis. However, static values do not account for small discrepancies of movement, known as 'compensation' or 'True Positive Movement'.



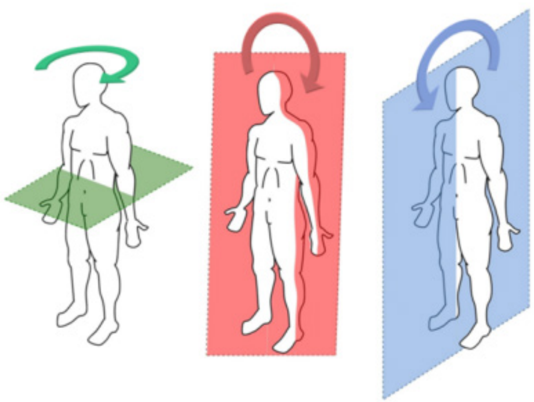
Locatelli, P (n.d)

During a fall, the human body's gravity, acceleration, displacement, and posture will change significantly and this dynamic range of motion produced from a sudden fall generates a large acceleration and angular velocity. Typically, a fall heading is in one angle which can affect the accuracy of outputs, which can be corrected with the Kalman Filter. Change in acceleration intensity (SMV), is compared against the body's angles during general behavioural Activities of Daily Living such as walking and standing and is calculated using the following equation:

$$SMV = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

However, pre-impact calculations, whereby lead time is the interval between fall detection time and collision time must be calculated with the following:

Lead time = Collision time – Fall detection time



Yaw Roll Pitch

Locatelli, P (n.d)

Naturally, falling will increase the tilt angle of the human torso, affecting Pitch and Yaw. To calculate threshold change of Pitch, measurements are made one second before and after the fall event and are subtracted from the calculated pitch angle of the fall itself.

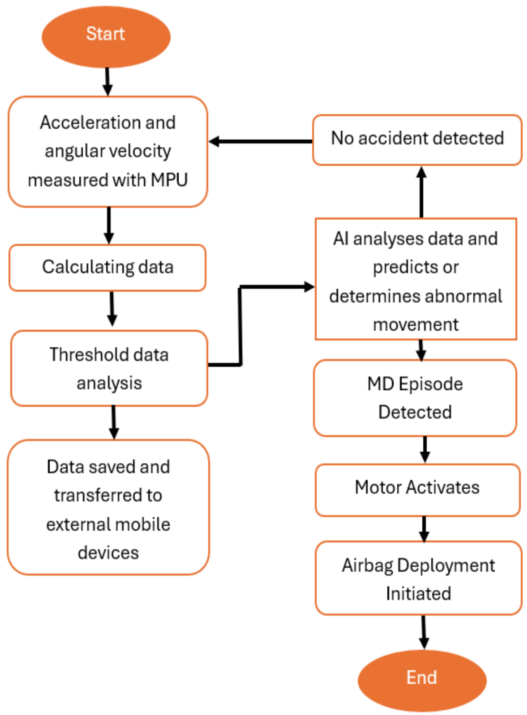
CALCULATING FALL ALGORITHMS

The availability of miniaturized, low-cost Micro-ElectroMechanical System (MEM) sensors has driven the development of inertial tracking systems.

As fall direction cannot be predicted in advance, the use of tri-axial accelerometers and gyroscopes help measure the current state of the user and the multiple scenarios and directions in which a fall event could occur, so a microcontroller can build a 3D understanding of human motion.

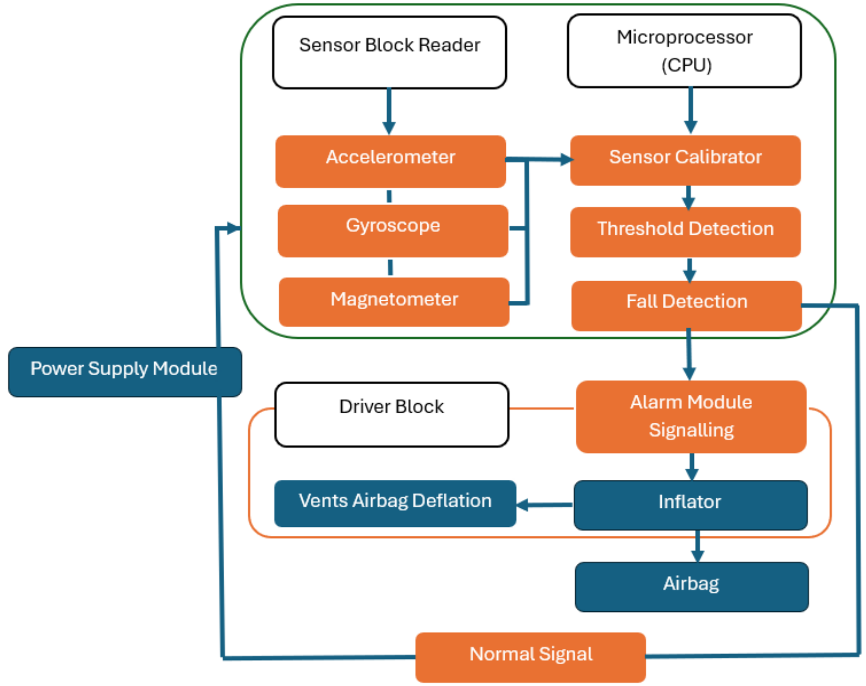
The microcontroller converts sensor values on acceleration, magnitude, angular change and velocity into a format it understands to feed to the algorithm, comparing the inputs against a threshold value.

AIRBAG ALGORITHM



Cocoon's Algorithm Circuit (Powell, 2024)

WEARABLE AIRBAG SYSTEM



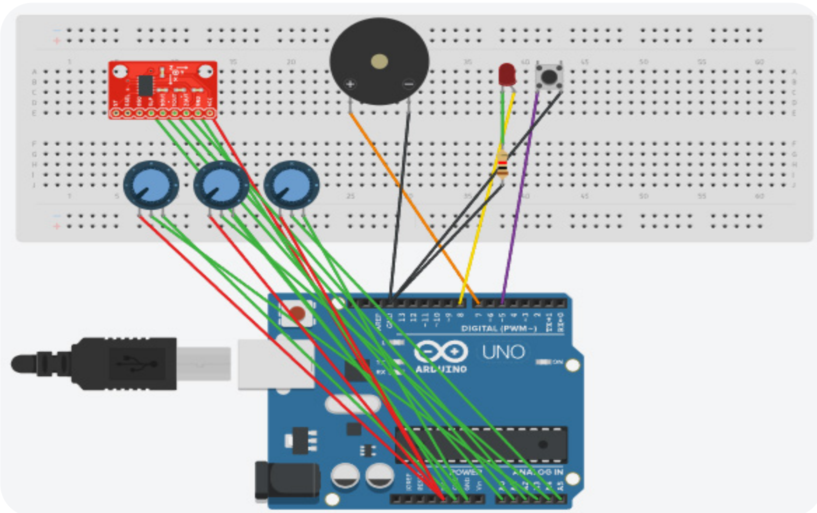
Cocoon's Airbag Inflation Circuit (Powell, 2024)

Sensor values can be combined to form a quaternion to make threshold calculations easier. The Kalman Filter merges quaternion data for the algorithm's judgement to determine a true fall event from false.

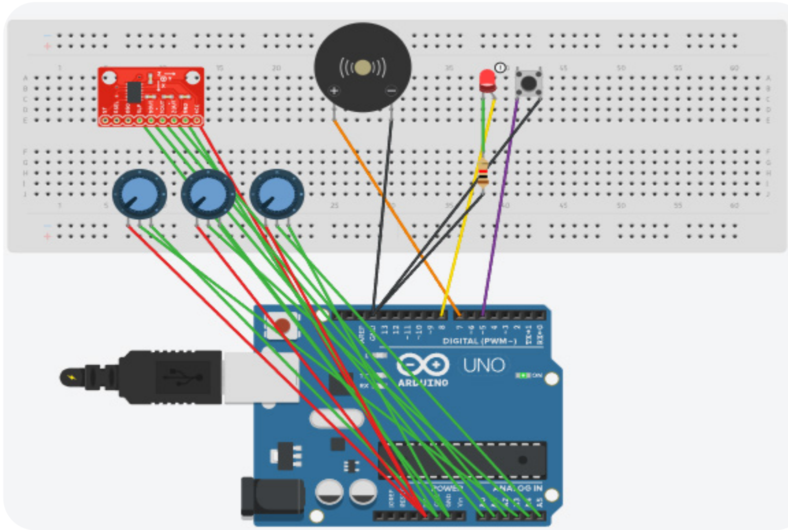
If a threshold is met or exceeded, e.g. Dangerous level of tilt is detected. The Microprocessor signals to the Driver Block to initiate inflation and wirelessly communicates event data to linked devices in live time. After airbag deployment, vents begin deflation but if abnormal movement remains undetected, the system continuously loops back to the sensor block, measuring user state until such time as that changes.

FEASIBILITY TESTING WITH ARDUINO

To demonstrate the working principle of Cocoon's proposed functionality, Arduino Create was used to build the system.



Inactive Connected Arduino Circuit of Airbag System (Powell, 2024)



Active Connected Arduino Circuit of Airbag System (Powell, 2024)

As a system, it is relatively low cost, has a rapid response time, consumes little power and has an accuracy rate of 90%.

Embedded C is a programming language commonly used in the development of specialised embedded systems for specific functions or tasks. It is used to programme the microcontroller as it uses less resources to execute commands compared to higher coded languages. Cocoon's system code can be viewed in Appendix IIII.

MARKET FORECAST FOR WEARABLE AIRBAGS

It is predicted that the worldwide Wearable Airbag market size is anticipated to be worth $1527.6 Million by 2032 with growth being observed in various industries like, motorsports, equestrian, athletics, and now healthcare.

This increase is due to outdoor recreational and high risks activities, popular within the tourism industry, requiring more substantial wearable safety as accident rates increase.

Vest airbags hold a major share, roughly 61.3%, of the wearable airbag market as of 2023 and head airbags in particular are estimated to show the highest CAGR increase in Europe, as of 2021, as bike racing and cycling tournaments have increased in popularity. However, the highest CAGR growth is anticipated in the Asia-Pacific due to the growing number of road accidents in population dense countries like China and India (Market StatsVille).

***CAGR = Compound Annual Growth Rate**

Major players in the global airbag scene, as represented in the chart to the right, are finding ways in which to strengthen their market position and maximise their share through acquisitions, mergers and contracts.

As a fledging business and concept, Cocoon would benefit from collaboration with these key players who have the experience, means and opportunity to adapt this next level of wearable airbag technology further.

MAJOR PLAYERS

EMERGING PLAYERS

Market forecast of competitors developing wearable airbags (Powell, 2024)

COMPETITOR RESEARCH

There are a vast number of airbag related technologies on the market that protect against falls, accidents and disasters. Five key technologies have been selected as the gold standard of wearable airbag technology. Analysis of these applications will shape the design and functionality of Cocoon.

1. MOCYCLE JEANS

Mocycle jeans are entirely unique in the current market. Retailing at €799 and designed as normal jeans, they seamlessly combine safety with fashion, considering the user and their lifestyle. Utilising Helite technology, its system airbags deploy the moment a user becomes separated from their motorbike. Tested in high-speed crash scenarios of 80km/h, all lower parts of the body such as the thighs, tailbone and the femoral artery are protected.

Inflation of Mocycle Jeans (Mocycle, n.d)

2. HÖVDING

Hövding is an urban airbag for cyclists, worn as a collar but inflates as a helmet. Deploying in 0.1 seconds, Hövding's algorithm continuously calculates and analyses a cyclist's body movements 200 times a second, via a black box, only triggering inflation if abnormal behaviour is detected. A dial allows the user to adjust the collar for comfort and its interface offers smartphone connectivity, automatically notifying contacts of an accident via Bluetooth. However, once deployed, it cannot be reused and has to be sent for recycling.

"Our airbag has three times better shock absorbance than other helmets. 8 times better protection, including reducing the risk of concussion, has been proven by Stanford University."

Hövding collar (Hövding, n.d)

3. GS EQUESTRIAN & COUNTRY

The GS Freejump Airvest is the first of its kind to be approved for horseback riding since 2019.

This airvest aligns with the NF S72-800-2022 standard of providing riders with increased protection. Retailing for £499.00, the vest can inflate in as little as 98ms, providing the optimal pressure to protect the upper spine, neck, hips, chest, back waist and vital organs.

GS Vest side and front on views (GS, n.d)

4. SKYVEST

SKYVEST is a category 2 PPE certified tear resistant reusable vest, designed to protect and reduce injuries in the event of falls from low heights. Retailing at €1,178.10, it's mostly for construction workers and mechanical engineers who may be required to be on a raised platform or ladder in their line of work as reflected in its Hi-Vis design.

It inflates within 200ms, protecting the chest, back, coccyx and back of the head. However, it uses a pyrotechnic inflator which has its risks.

SKYVEST surrounding view of airbag deployment (SKYVEST, 2024)

5. HELITE AIRVEST

Helite's vests are appropriate for motorcyclists, equestrian riders and cyclists. They are so highly regarded, that their technology is worn by our UK forces and used by other companies, such as Mocycle. Deploying within 80-100ms, it provides protection for the neck, spine, chest, pelvis, coccyx, head, collarbone and internal organs.

Retailing between £385-£445, it has exceptionally high abrasion resistance due to its internal cowhide and foam layer, allowing it to withstand forces of 30kg upwards. However, their design is mechanically triggered which is more appropriate for users who engage in high-risk activities.

Recently, they have launched a rucksack which can be mechanically or electronically activated with additional storage for recreational use.

Helite Equestrian vest front view and canister location (Helite, n.d)

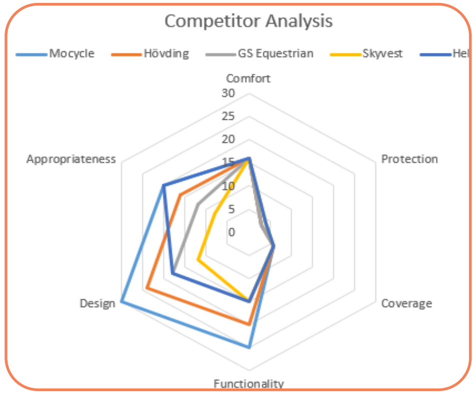
COMPETITOR ANALYSIS

Competitor products were then ranked out of 5 against a weighting from 1-5, where 1 is least and 5 is most on importance, on the following criteria:

Comfort - How comfortable it is for the user to wear?
Protection - How well does it protect the user?
Coverage - How much of the user's body does it cover?
Functionality - What else can it offer the user besides protection?
Design - How is the design visually appealing to the user?
Appropriateness - Is the design realistic in how it can be worn and protect the user?

Attribute	Mocycle	Hövding	GS Equestrian	Skyvest	Helite
Comfort (4)	4	4	4	4	4
Protection (1)	3	3	3	4	4
Coverage (2)	3	3	3	3	3
Functionality (5)	5	4	3	3	3
Design (6)	5	4	3	2	3
Appropriateness (4)	5	4	3	2	5
Total	100	85	70	61	79
Ranking	1	2	4	5	3

Chart 1: Heuristic evaluation of market competitors (Powell, 2024)



Radar graph of Chart 1's results (Powell, 2024)

THOUGHTS

The above products were designed for user's who engage in high-risk activities which do not represent a realistic picture of the day-to-day activities of someone with a movement disorder. As such, their programmable algorithms have inappropriate activation triggers and deployment round the body is only focused on specific regions, such as the chest or lower body, which doesn't provide enough support for Cocoon's intended application.

Mocycle ranked highest because of its; performance, easy maintenance and versatility for everyday use. Helite's approach of branching into rucksack applications is interesting as they offer better capacity, functionality and comfort compared to a vest.

COMPETITOR ANALYSIS S-AIRBAG VEST

The purchase of a S-AIRBAG Vest was kindly subsidised by the Sanjay Mortimer Foundation, keen investors in Cocoon's journey, for further primary research to be conducted in order to understand the circuitry, placement and quantity of airbags in a well-established and thoroughly tested competitor product. Retailing for roughly £1,000, subject to fluctuating market offers, canisters are sold separately.

It is relatively lightweight when internal airbags are removed, fig 1 and 2, is easy to wipe down and water resistant. Airbags are secured inside the vest with buttons and zips, fig 8, making it easy to detach so new gas canisters can be fitted and the vest washed or replaced.

When the airbag structure is fully unfolded, fig 13, the full footprint of protection for the head, neck, chest, back and hips of the user is shown. Ergonomic features like adjustable toggles allow the user to tighten and loosen the jacket comfortably, fig 5.

When zipped and clipped on, its circuit becomes activated, playing a musical tune to indicate the algorithm is on and measuring user movement from this point onwards.

Airbag inflation is triggered when the clasp completing the user circuit, fig 10, is disconnected, fig 4, from a sudden change in inertia, physically snapping the halves apart. An alarm sequence, fig 6, is initiated, signalling to registered carers with the user's location via an app.

S-AIRBAG Vest Analysis (Powell, 2024)

Once contact with the ground has been made and fall sequence finished, the airbags begin deflation and require canister replacement. Canisters are located on the hips and the sides of the user and are contained inside a zipped pouch, fig 11, so they aren't damaged.

As a product, it is effective at mitigating fall injury however, body coverage is somewhat limited as joints like elbows and knees are exposed to potential fractures. The vest itself is very unappealing and could be improved so as not to look like a medical aid.

PROPOSAL SUMMARY

In summary, although wearable airbags have been successfully calculated for free fall scenarios, the challenge of uncontrollable movement post deployment remains.

Moving forwards, a more sophisticated algorithm is required, coverage must be from the head to the knees and airbag deflation delayed so the user remains cushioned for longer to prevent muscle traumas and fractural damage. Something which current competitors do not offer.

S-AIRBAG Vest Analysis (Powell, 2024)

LEGAL CONSIDERATIONS

The legal implications of wearable airbags are multifaceted, considering; product liability, regulatory compliance, GDPR, intellectual property, consumer protection and insurance.

Historical events have highlighted the consequences of not following legal procedures correctly.

In 2008, the “largest and most complex safety recall in U.S history” of Takata airbags happened after they explosively deployed without warning and sent shrapnel into drivers. This improper inflation was due to an ammonium-nitrate based propellant being used without a chemical drying agent making the airbag highly susceptible to environmental moisture, high temperatures and age.

After 27 deaths, 400 injuries and failing to resolve their criminal conduct, Takata declared bankruptcy after being charged $1 billion in penalties.

On reflection, an airbag’s design should not compromise on quality or consumer safety just to undercut the market. Complete transparency and correct protocols must be met at all times to avoid costly legal battles.

Cocoon is only offered as a medical intervention to prevent hospitalisation from severe secondary injury. However, as a manufacturer there is a duty of care to ensure Cocoon appropriately deploys to protect a user from a fall at height and aggressive movement. Failure to deliver on this could result in legal costs over negligence and misinformation.

AIRBAG INJURY

Severe airbag burn (IStock, n.d)

Airbag chest wound (Fletcher L, 2020)

Honda airbag burn (Reddit, 2024)

Critical airbag facial injury (Fletcher L, 2020)

A table of mandatory legal considerations have been summarised that Cocoon must adhere to, to ensure the product is safe and compliant to safeguard the company reputation and built loyalty and trust with its consumers:

Consideration	Risk of Claim
1.1 Defects	Design and manufacturing defects or failure to inform users about potential product risks can result in a liability claim. Thorough testing must be conducted in order to resolve potential product deficiencies.
1.2 Warranty	Warranties are an assurance that the condition of the service is as advertised. False advertising results in fines, lawsuits and damage to company reputation.
2.1 Safety Standards	Product must comply with the standards set by the Consumer Product Safety Commission, CE marking and ISO for personal protective equipment
2.2 Medical Device Classification	As a medical device, it must adhere to the stringent regulations set by the FDA and the EMA. Approvals must be made before marketing the product
2.3 Environmental Regulations	Environmental regulations concerning the types of materials used, waste management and recycling of components such as the CO2 gas cylinders
3.1 User Data	The collection of user data for Cocoon's fall algorithm. E.g. Movement patterns of patient's episodes must adhere to GDPR
3.2 Consent	Informed consent of the user must be given and the purpose in which data is used to be transparent
3.3 Data Security	Strict security measures required to protect against hacking, ensuring sensitive client data is stored securely
4.1 Patents	Patents are to protect the airbag's technology and prevent competitors from copying the design. Filing patents for unique designs, materials and deployment mechanisms
4.2 Trademarks	Trademark is required for product name, logo and other branding involved
4.3 Copyrights	For software and documentation associated with Cocoon to prevent unauthorised use and distribution
5.1 Labelling and Instructions	Clear and comprehensive labelling, user manuals and instructions to ensure correct usage and maintenance of Cocoon
5.2 Marketing Claims	All marketing literature to be truthful and substantiated to not mislead consumers
6.1 Product Liability Insurance	To cover potential claims arising from defects or injuries caused by wearing Cocoon
6.2 Professional Indemnity Insurance	Is essential for developers and manufacturers to protect against claims of negligence or inadequate product performance
7.1 Monitoring	Ensuring there is a system for post-market surveillance to monitor Cocoon's performance and safety once it has been launched to market. This is in order to identify any unforeseen issues and addressing them accordingly
7.2 Recalls	Establish a clear procedure in case a defect or safety issue is discovered after product distribution
8.1 Dispute Resolution	Extended customer service: Provide clear information for consumers to resolve disputes or file complaints regarding Cocoon

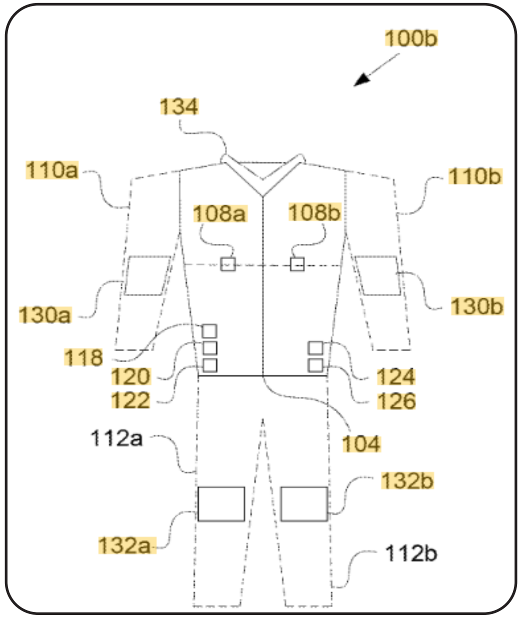
Chart 2: Legal considerations for Cocoon (Powell, 2024)

PATENTS

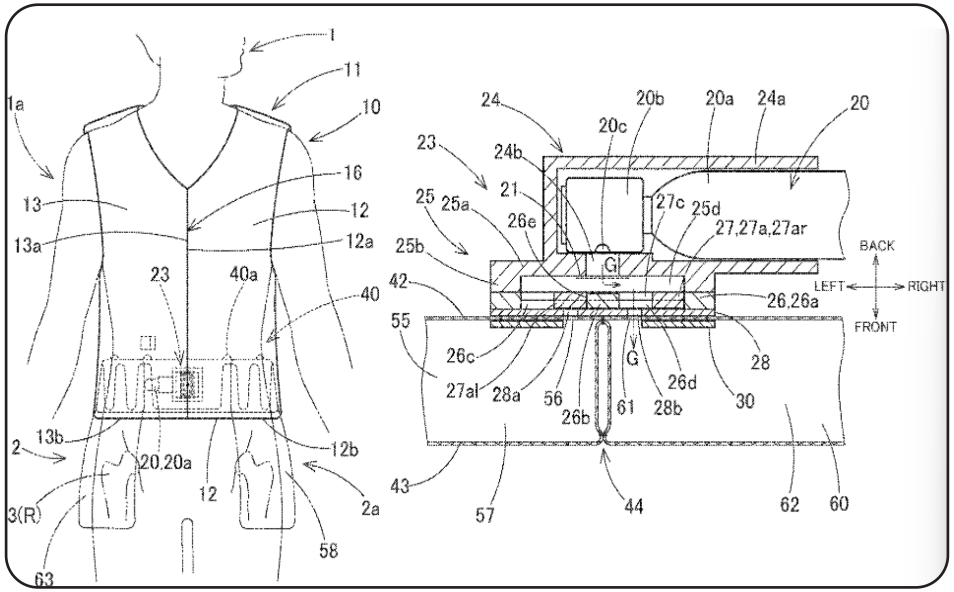
There are already a vast number of wearable airbag patents registered globally by indiviudals and large scale competitiors like Toyota.

Some are as detailed as an entire inflatable suit and others are patented on their inflator technology.

As a fledgling business and concept, it would be impossible to purchase the rights to these already well established patents. Instead, Cocoon would aim to seek collaboration with these big name companies whilst also agreeing a financial sum.



US20170325521A1 Filed by Toyota (Toyota, 2016)



US11910850B2 Toyoda Gosei (Toyoda, 2016)

DESIGN CONSIDERATIONS

AIRBAG SAFETY

Although lifesaving, sudden frontal impact from airbags has caused fracturing, abrasions, lacerations, whiplash, torn ligaments, burns and other traumas. Force exerted during release is so strong that some could be left will life-long injury such as brain damage or

AIRBAG INFLATION

A serious design consideration is the rate of airbag deflation. As airbags immediately begin to deflate after impact, the user won't stay protected for long once they have reached the ground.

The solution is to delay deflation rate however, sustained inflation is a safety risk when considering airbag injuries. Zhengzhou University found that not all the gas in a cylinder needs to be released, just 80% of the airbag volume needs to be filled to guarantee safety. Potentially, airbags could be sectioned based on their placement round the body and have scheduled deflation timers manually operating an 80% fill rate until an ambulance arrives.

AIRBAG DURABILITY

Choosing the right material to contain the airbag system is crucial, so that the integrity of airbags, gas cannisters and electronics are protected during a fall and aggressive movement.pressure as verified through impact tests (Massaro et al).

Airbag thickness can be correlated to airbag performance with thicker airbags being able to withstand a greater rate of inflation pressure as verified through impact tests (Massaro et al).

WEARABILITY OF THE PRODUCT

Airbags, cannisters and circuitry have a combined weight of roughly 2kg, this isn't especially heavy but a key consideration is how much additional weight is added when housing the airbags into a wearable application and how comfortable will it be for a user to wear for an extended period. To improve usability, using sensors that are small, lightweight and with combined functionality is more appropriate.

This product is for frequent use and so should complement the wearer's lifestyle needs and personal style. Exploring ways in which this product can be styled to conceal its true functionality whilst optimising functionality will be considered.

PRODUCT DESIGN SPECIFICATION

Chart 3: PDS (Powell, 2024)

1.	**Performance**
1.1	The airbag should be lightweight, flexible and not restrict the wearer too much
1.2	The airbag must be able to withstand impact after a fall from height and aggressive movement
1.3	The airbag system needs a reliable and rapid deployment mechanism to ensure inflation before user hits the ground
1.4	After impact, airbag deflation should be controlled and delayed keeping the user cushioned for longer in hazardous environments
1.5	The airbag's algorithm must detect a fall with at least 95% accuracy
1.6	Airbag coverage must protect the head, neck, torso, hips, and major joints
1.7	Airbag release should be within 100m/s and reduce impact force by at least 60%
1.8	Deployment should be made obvious through the use of light, audio and colour
1.9	The airbag's interface must communicate to emergency service, carer, medics, family and provide medical reports with listed consent to the hospital
2.	**Environment (Operational and Ecological)**
2.1	Should be operational in temperatures ranging from -10°C to 40°C.
2.2	Cocoon should be able to function optimally in up to 90% humidity
2.3	Cocoon must be durable, offering resistance to wear, tear, water and UV exposure.
2.4	Ensure materials used are free from unstable chemical and toxins
3.	**Service Life**
3.1	Airbags and canisters must be easy to change out for maintenance checks and reassembly
3.2	Cocoon should have a minimum lifespan of 5 years with regular use
3.3	Cocoon should be easy to clean to ensure its hygienic after contact with dirty outdoor surfaces
3.4	Collection service for end-of-life disposal should there be product faults
4.	**Maintenance**
4.1	Maintenance checks to be performed every 5 years to ensure system accuracy
5.	**Location of Use**
5.1	Suitable for indoor and outdoor use during activities of daily living
5.2	Unsuitable for any aggressive or high-risk activity
5.3	Shouldn't be worn when engaging in water related activity or near a naked flame
6.	**User**
6.1	It must support those with progressive neurodegenerative conditions that experience instability and episodes of abnormal movement
6.2	Must provide support to users who live alone
6.3	Must inform secondary users that are responsible for the care and well-being of the primary user such as carers, medics and next of kin
6.4	Should benefit the elderly, construction workers, athletes, thrill seekers and individuals in rehabilitation
6.5	Licensed and promoted to charities, patient advocacy groups, public and private healthcare providers and research institutions

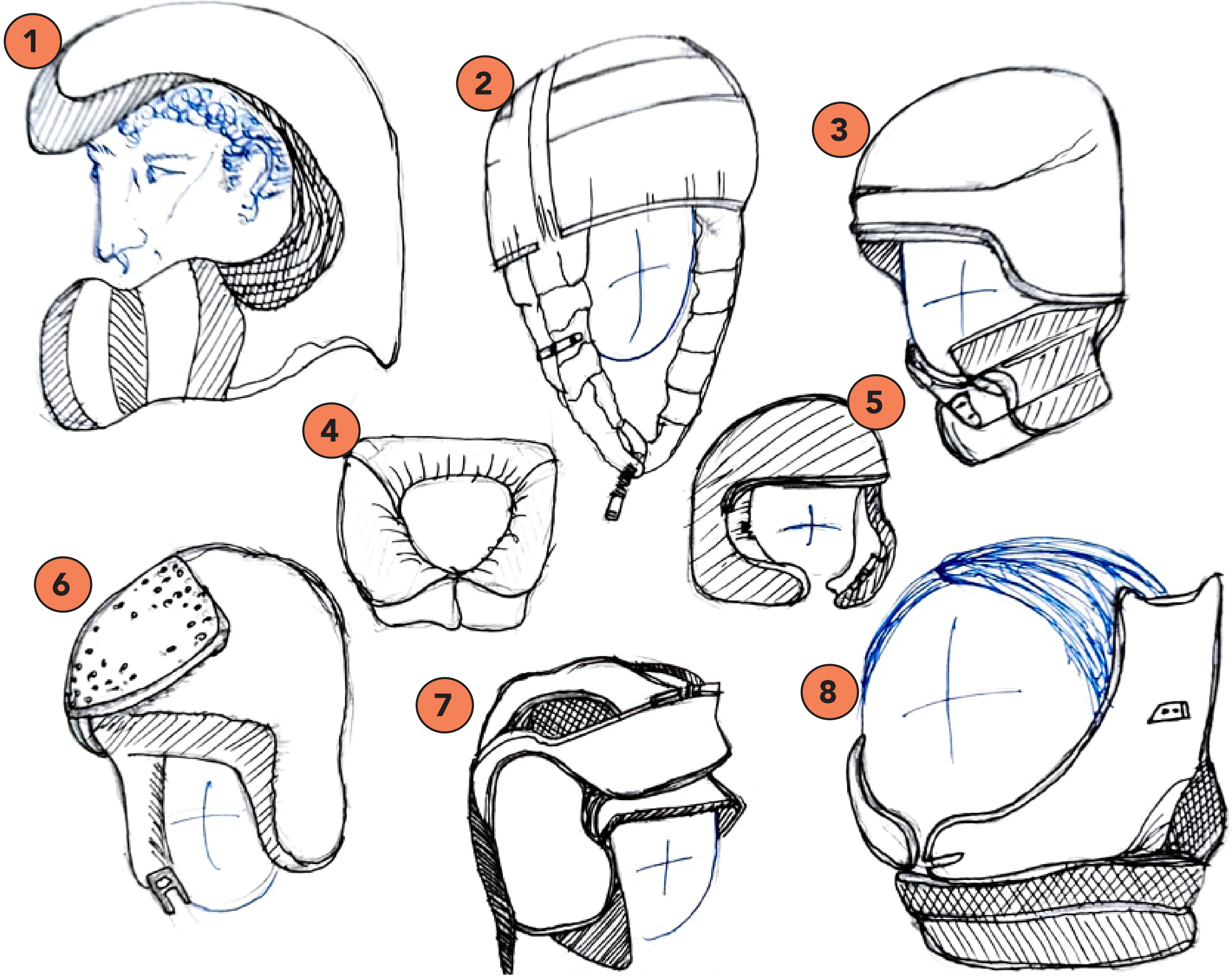
7.	**Safety + Compliance**
7.1	Must meet relevant safety standards for Personal Protective Equipment, such as CE and ISO standards
7.2	System programming must have a 'redundancy' to ensure deployment in case of single-point failures
7.3	Extensive testing must be undertaken under various conditions to ensure reliability and effectiveness
7.4	Must ensure that the rate and volume of airbag inflation does not cause critical harm to wearer
8.	**Ergonomics + Design**
8.1	It should be lightweight, not weighing more than 20% of a user's body weight, to ensure comfort and safety
8.2	It should not give the impression of being a medical aid, design must be customisable to encourage use
8.3	Sensor and hardware placement should be unintrusive so as not to cause discomfort.
8.4	Soft and breathable padding across shoulders, back and waist to enhance comfort during long term daily use.
8.5	Even weight distribution of the airbag system across the body to minimise strain
8.6	Must be easy to put on and take off and when not inflated and allow for freedom of movement
8.7	There should be fastenings to allow the airbag to be adjusted to fit different body sizes
8.8	Cocoon's design should be versatile allowing it to be worn with any item
8.9	Simple fasteners for users who struggle with fine motor skills.
9.	**Materials**
9.1	Airbag layer to be made from a durable coated material like TPU for airbag chamber flexibility and airtightness
9.2	The airbag should be made from a reinforced nylon for durability and puncture resistance.
9.3	Integration of flexible components to reduce restriction of movement
10.	**Technology**
10.1	Must utilise high-precision accelerometers and gyroscopes sensors
10.2	Inflation mechanism must produce enough CO_2 and not be pyrotechnic
10.3	Must use a rechargeable battery with a minimum operational time of 8 hours
10.4	Range of USB ports or wireless charging capability
10.5	Centralized microcontroller to airbag trigger inflation
10.6	Simple on/off switch
10.7	CO_2 canisters should be small for user comfort
11.	**User Interface + Feedback**
11.1	Comprehensive user manual and customer support with clear instructions for use, maintenance, and troubleshooting
11.2	System for collecting user feedback to inform future improvements.
11.3	Clear LED and audio indicators for power and system status.
11.4	Clear and simple connectivity to various mobile devices
11.5	Accessible algorithm data to be structured into comprehensive reports to aid product development
11.6	Connectivity to smart devices using Bluetooth and SMS.
12.	**Cost + Manufacture**
12.1	Target manufacturing cost per unit should be within a specified budget to ensure affordability.
12.2	Target retail price to be somewhat competitive within the market segment
12.3	Should allow for scalable manufacturing processes against a product range
12.4	Energy-efficient manufacturing processes to be adopted to reduce production carbon footprint.
12.5	Waste reduction strategies to be implemented such as optimising material usage both new and recycled.

INITIAL IDEATION

Airbag elements have been individually designed based on the area of the body they will protect post deployment. Vulnerable areas such as the neck and head are considered in more detail so as to appropriately protect the user before all elements are merged into a full body design.

The neck is particularly vulnerable and requires extra cushioning as the spine connects to the brain stem, which if damaged, can cause paralysis or brain damage. A neck brace design that expands into a hood has been explored.

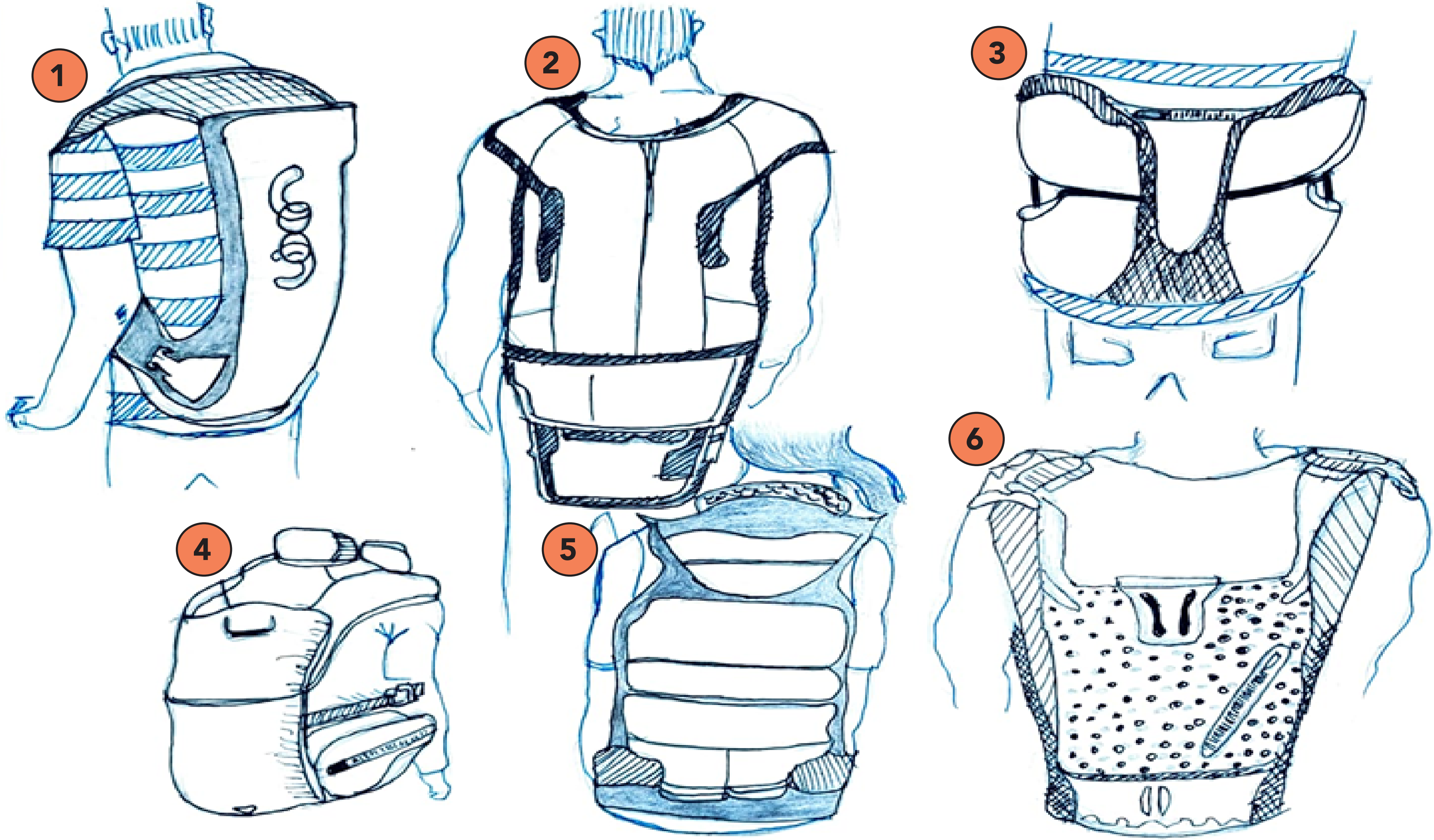
HEAD PROTECTION



INITIAL IDEATION

A rucksack is a viable solution for containing a large-scale airbag system close to the body in a discreet and unrestrictive way whilst maximising on functionality.

RUCKSACKS

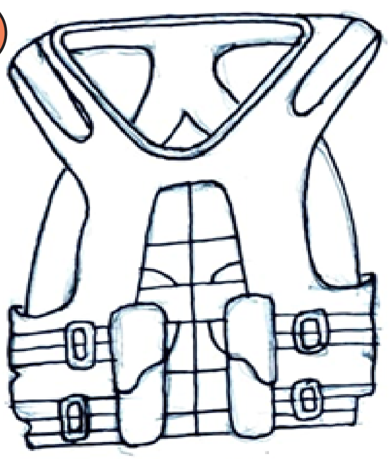


INITIAL IDEATION

Clothing airbags were also considered, as they can ensure an even distribution of protection however, it can limit the user's personal style and in varying climates, this may be inappropriate on a hot day.

JACKETS AND VESTS

1



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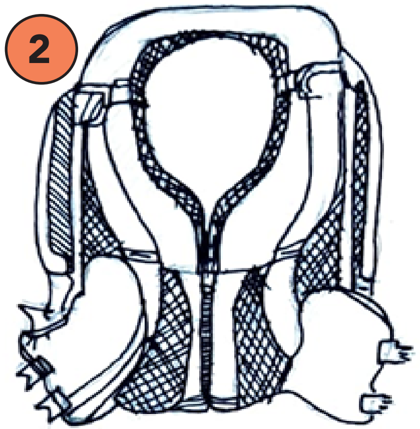

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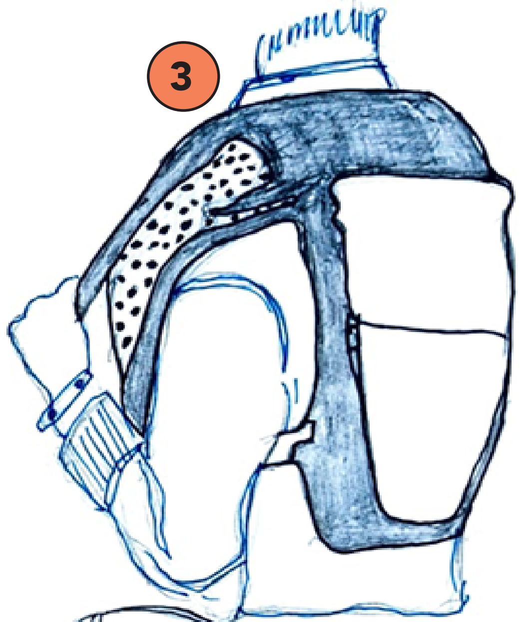

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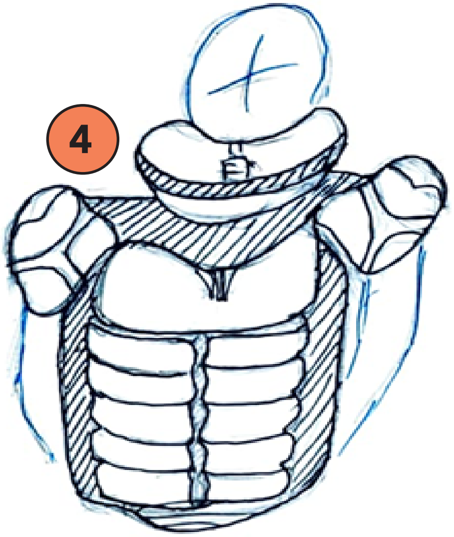

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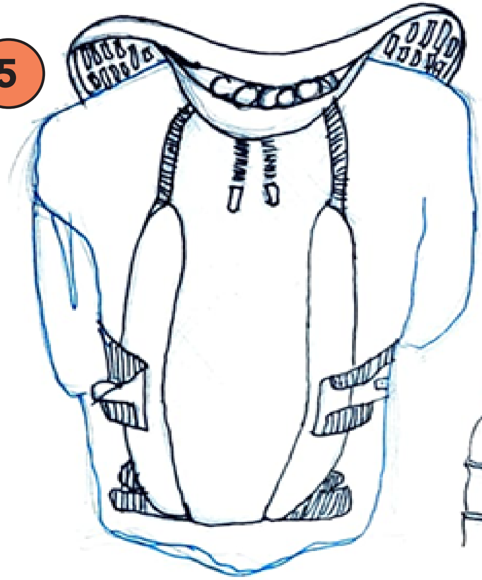

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NORMATIVE EVALUATION

Initial designs were ranked within each category, using the same evaluation criteria on competitor products. The highest ranked designs with the best individual attributes will be merged and developed further.

HEAD PROTECTION

Attribute	Concept							
	1	2	3	4	5	6	7	8
Comfort (4)	3	2	3	3	4	2	3	2
Protection (1)	5	3	4	3	4	3	3	2
Coverage (2)	4	3	4	3	4	2	3	2
Functionality (5)	3	4	3	3	3	2	3	3
Design (6)	3	2	4	3	3	2	3	2
Appropriateness (4)	3	3	3	4	3	3	4	2
Total	70	61	75	70	73	49	70	49
Ranking	3	6	1	4	2	7	5	8

Chart 4: Heuristic evaluation of head protection (Powell, 2024)

Concept 3 ranked overall best as it has the most comprehensive coverage for the head and stabilises the user's neck. The helmet could curve more round the head like Concept 5, for a more ergonomic fit and the neck should allow more freedom of movement. Concept 1 demonstrates this however, it doesn't support the sides of the head enough and the neck was too bulky that this may be uncomfortable to the user.

RUCKSACKS

Attribute	Concept					
	1	2	3	4	5	6
Comfort (4)	5	3	2	4	4	4
Protection (1)	4	3	2	4	4	4
Coverage (2)	4	4	1	5	4	3
Functionality (5)	3	3	1	5	4	5
Design (6)	4	3	2	3	3	4
Appropriateness (4)	5	2	2	4	4	4
Total	91	64	37	89	82	91
Ranking	1	5	6	3	4	2

Chart 5: Heuristic evaluation of rucksacks (Powell, 2024)

Concept 1 ranked the best as rucksacks are more efficient at carrying and distributing weight across the body compared to a vest which are fashionably limited to a user. It has a pleasing, streamlined fit with extra wide straps for stability and comfort. Shoulders are padded to reduce back pain. However, there isn't much additional functionality like concept 4 which has multiple compartments for storage.

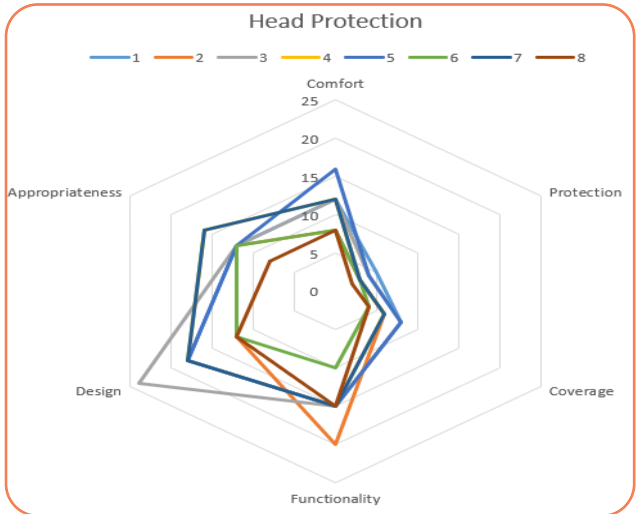
JACKETS AND VESTS

Attribute	Concept					
	1	2	3	4	5	6
Comfort (4)	2	2	3	3	4	4
Protection (1)	3	2	3	3	4	4
Coverage (2)	3	3	4	4	4	4
Functionality (5)	3	2	3	2	4	3
Design (6)	2	2	3	2	5	4
Appropriateness (4)	1	1	3	2	3	1
Total	48	42	68	53	90	71
Ranking	5	6	3	4	1	2

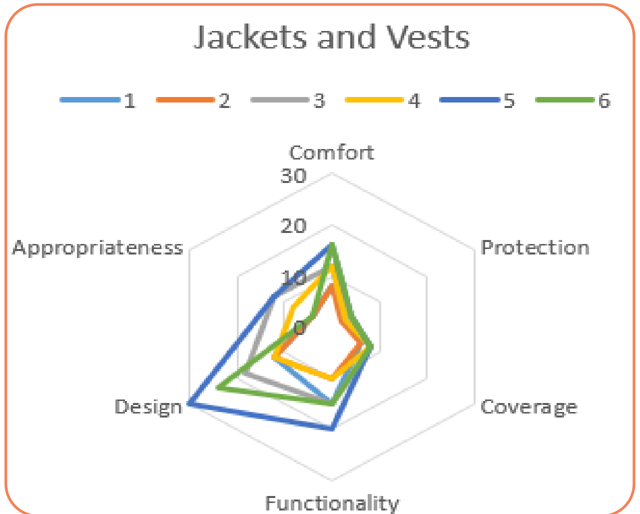
Chart 6: Heuristic evaluation of jackets and vests (Powell, 2024)

Concept 5 was the strong design, integrating an airbag collar, for neck and head coverage, with a rucksack, that facilitates full body coverage. However, having something clipped tightly round the neck could potentially be harmful or uncomfortable.

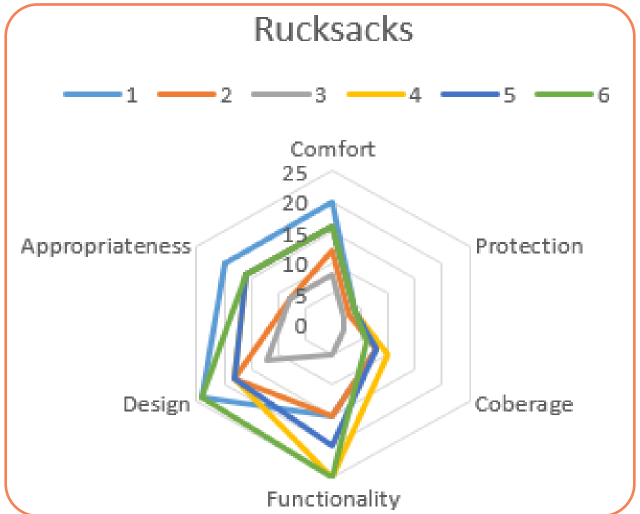
Concept 3 combined a vest and a rucksack together but a lot of bulk on the front of the user could restrict freedom of movement and unevenly distribute weight, destabilising the wearer.



Radar graph of Chart 4's results (Powell, 2024)



Radar graph of Chart 5's results (Powell, 2024)



Radar graph of Chart 6's results (Powell, 2024)

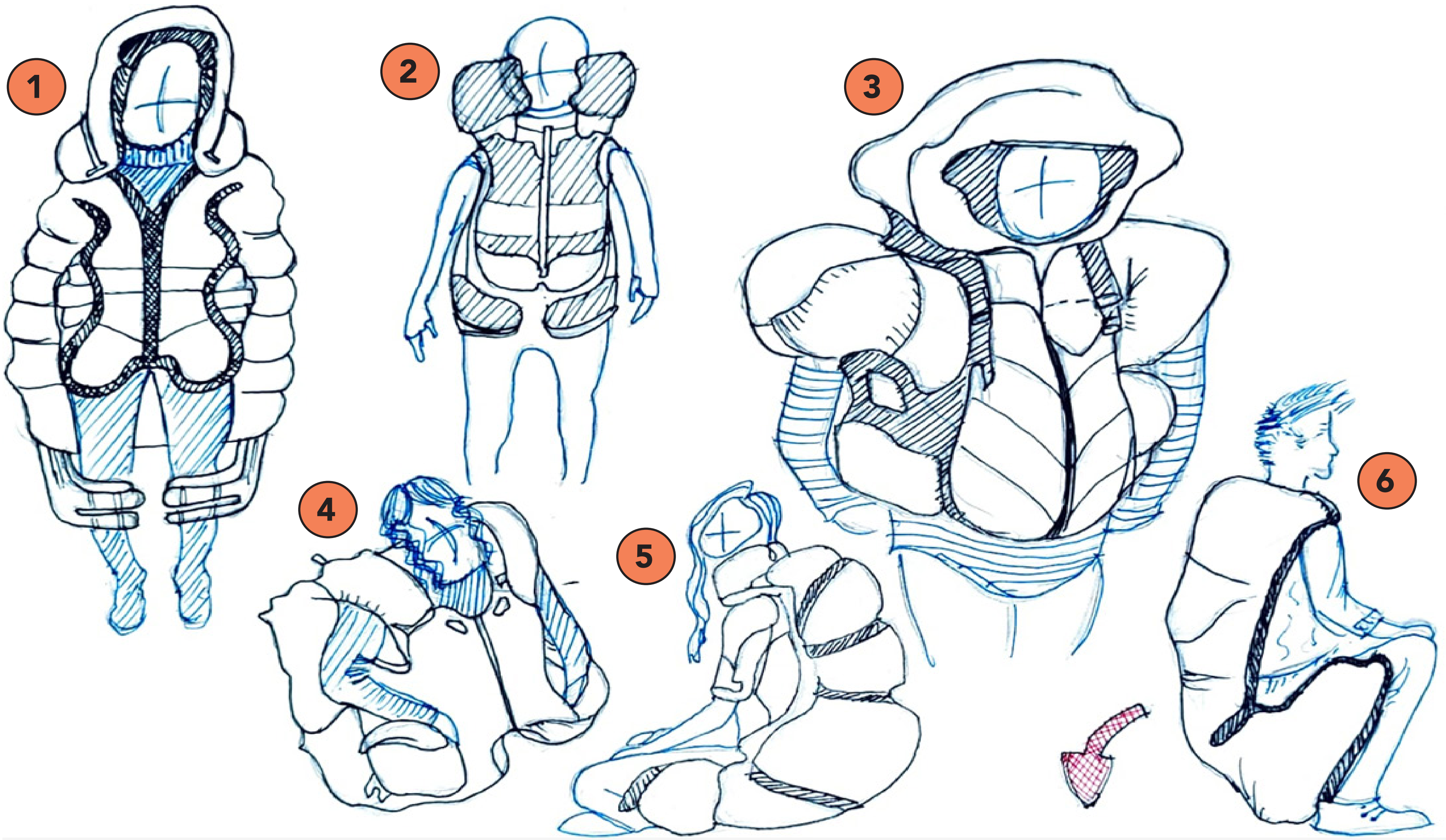
CONCLUSION

Cocoon will consider and implement where possible, these positive features, highlighted from this normative analysis into the final design.

DEVELOPMENT

These initial concepts explored the human form in; a relaxed stance, concepts 1 to 4, during a fall sequence, concept 6, and when the user has reached the ground post episode, concept 5. Concept 5 and 6 best illustrate how the rucksack will deploy the airbag, further ideation and ethnographic analysis is required to understand how to expanding on this concept potential further with the

FULL BODY COVERAGE



PRIMARY RESEARCH ETHNOGRAPHIC ANALYSIS

Dystonic attack (Powell, 2024)

Descriptions of a movement disorder do help support the reader's understanding however, they are still insufficient for a general layman who is unfamiliar with such conditions to understand or be prepared for what happens when an episode occurs.

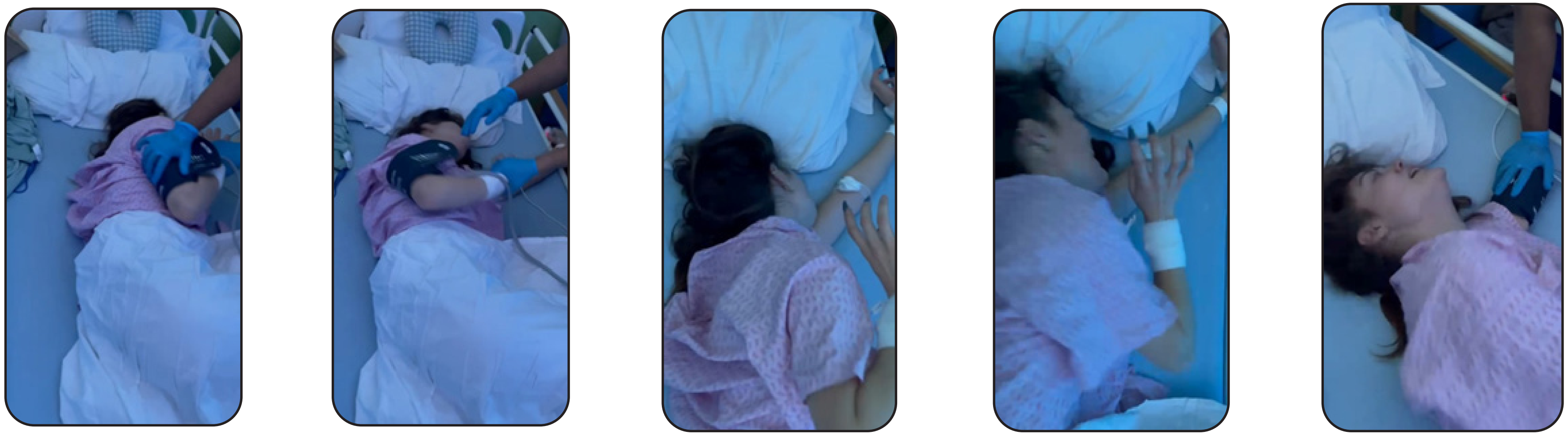
In October of 2023, I was hospitalised for a week with consecutive Dystonic episodes, frequently requiring strong benzodiazepines, oxygen and multiple diagnostic tests to be administered. Captures were taken of my Dystonic fit for the benefit of demonstrating the abnormality of my movement to not only my specialists but now the current reader.

Range of abnormal movement varies not only from each episode but also between individuals. In this specific example, aggressive movements tend to populate the left side of the body with the neck, head, arms and legs swinging to the left.

Unusually, there is a mix between Active movements, such as violent spasming and Passive movements, such as freezing of gait or limb rigidity which are more closely associated traits of Parkinson's.

Hands and ankles lock into place preventing the ability to stand, walk or use any fine motor skills. Without assistance, even the simplest task is not without difficulty or risk to myself. Violent movement such as neck swing can be so violent that oxygen flow becomes cut off and symptoms of nausea and light-headedness persist.

OBSERVING DYSTONIC MOVEMENT PATTERNS



Dystonic attack (Powell, 2024)

After these episodes, there is long-lasting chronic pain and fatigue. I am stiff and unsteady on my feet and remain very vulnerable to reoccurring episodes almost immediately. I'm reliant on the care of others to support my recovery for however long that may be which is socially limiting. This isn't a well understood or curable condition so finding ways to improve quality of life with it is essential.

In any case, a movement disorder should be allowed to happen and not restricted in any way. Any force applied to a patient to restrict their movement causes it to become more severe. Instead, cushioning is recommended around the user's limbs until the episode passes or medication is administered.

As the full body is affected Cocoon's design should reflect that, providing coverage and protection for the skull, vital organs and joints. Inflation should begin the moment instability and the start of an episode is detected and should deflate at a slower rate to keep the user cushioned from their surroundings until professional help can arrive.

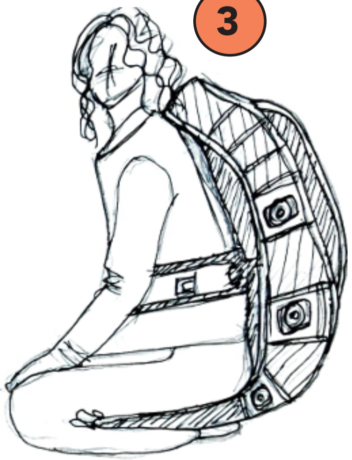
DEVELOPMENT FULL BODY COVERAGE CONTINUED

Of the designs below, only concept 6 considers a frontal fall. This must be readdressed for the final design as a fall triggered by a movement disorder could happen in any direction and won’t protect the wearer from continued spasming on the floor. Further to this, head protection is yet to be integrated.

1

6

3



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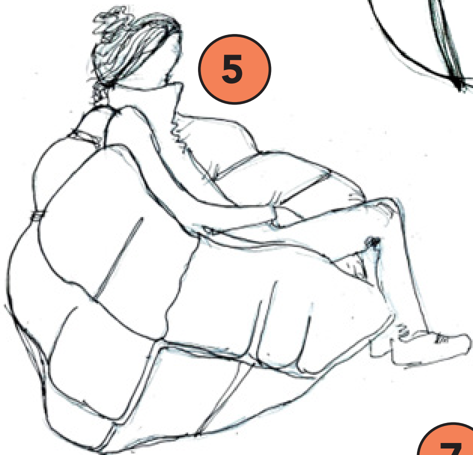

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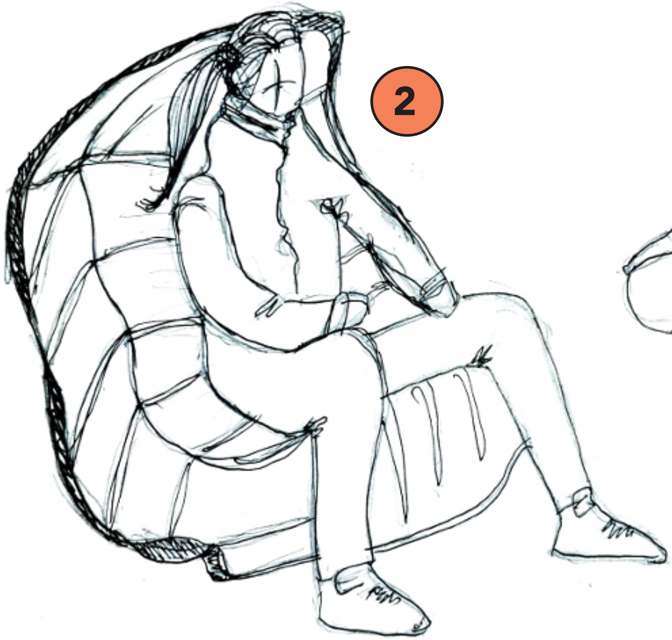

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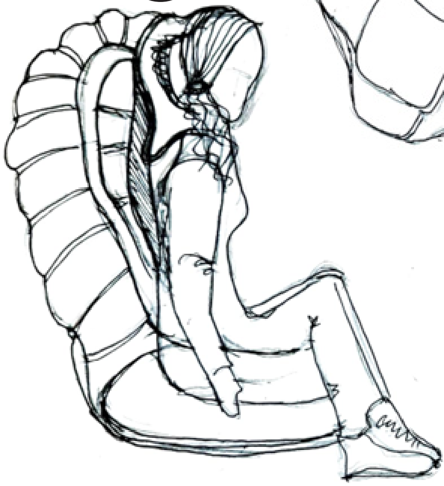


7

PROTOTYPING COCOON

Newspaper was utilised to mock up form fitting prototypes on a fairly true to size glass skull and dressmaker's mannequin to ascertain where coverage needed to sit on the body and how well this was achieved.

THE HEAD AIRBAG

It was really important that the neck was supported, given that it is such a vulnerable area, so a collar was made ensuring coverage of the lower jaw area. The collar also helped provide a framework for the upper airbags to attach to so that the flow of airbag material could continue to surrounded the entire head for absolute protection.

Fig 1: Right side of collar (Powell, 2024)

Fig 2: Left side of collar (Powell, 2024)

Fig 3: Front view of collar (Powell, 2024)

Fig 4: Collar (Powell, 2024)

Fig 5: Right side of helmet (Powell, 2024)

Fig 6: Left side of helmet (Powell, 2024)

Fig 7: Back of helmet (Powell, 2024)

FULL BODY INFLATION PROTOTYPING

Fig 8: Full body right view (Powell, 2024)

Fig 9: Full body left view (Powell, 2024)

Fig 10: Full Body front view (Powell, 2024)

Fig 11: Full Body back view (Powell, 2024)

Fig 12: extra support right view (Powell, 2024)

Fig 13: extra support right view (Powell, 2024)

I then redirected my focus to the rest of the body, modelling the 'airbags' into faux panels, fig 9, so that inflation would be more consistent and cushioning across the zones of priority on the body such as the head through to the knees.

The idea is, the airbags will release from behind and encapsule the wearer in a 'hug' like a Cocoon, keeping limbs close, but not restricted, to the body before impact is made with the ground.

Fig 14: neck reinforcement (Powell, 2024)

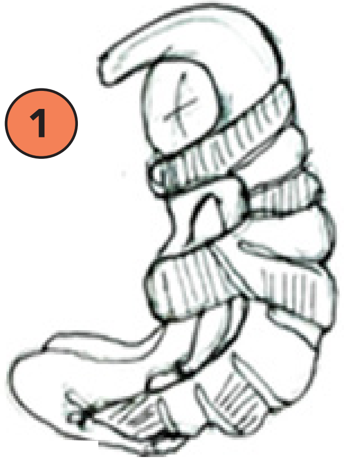
The front is panelled whilst the back is one piece, fig 11, and the helmet model added to complete the full airbag visual in order to determine if support was lacking anywhere.

It was decided that more support was required round the neck, as shown in Fig 14, to bridge the gap between the base of the collar and the start of the core airbags.

A mock rucksack, fig 12, was also constructed to demonstrate the intended principle of Cocoon with airbags flowing out from the sides, fig 13, where deployment would occur.

DEVELOPMENT

1



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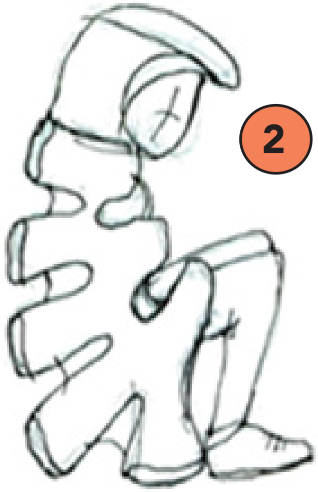
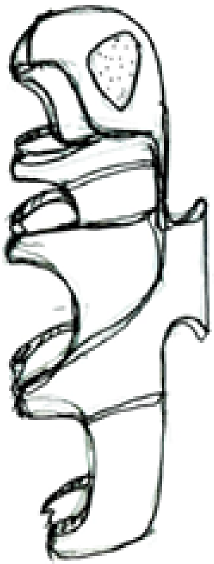


Developed from the previous concept ideations, these new designs have considered complete coverage from the head to the knees, featuring an integrated airbag helmet, neck brace, back brace and wraps round the front of the body so that no matter the direction of the fall, the user remains protected.

3



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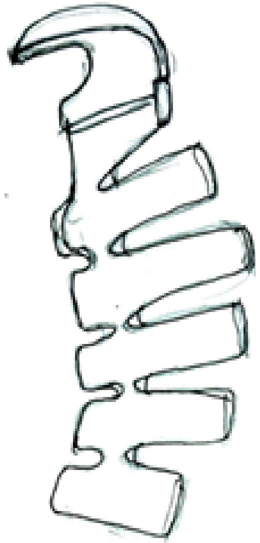


5

6

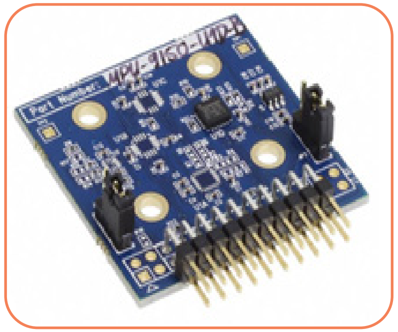
TECHNICAL BREAKDOWN MATERIALS AND MANUFACTURE

KEY TECHNICAL COMPONENTS

1. MPU9150 MEM Sensor

Is an integrated 9-axis motion tracking device that combines the functionality of a 3-axis accelerometer, gyroscope, magnetometer and motion processor. They are space saving, cheap, consume little power, resist shock and can provide an accurate analysis of body motor functionalities making them an attractive option for fall detection. They commonly feature in game controllers that require sophisticated calibration.

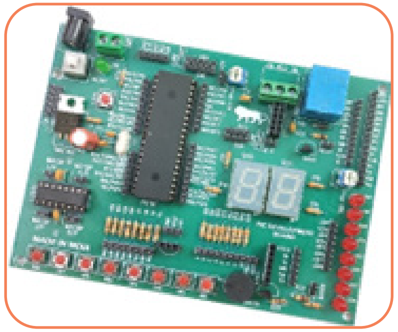
In particular, this wireless motion tracking technology could greatly benefit the rehabilitation field, allowing patients to manage their health remotely with their healthcare providers and share their performance feedback.



MPU9150 MEM Sensor (Digikey, n.d

2. ADUC7026 Analog Microcontroller

Is a 'special purpose computer', continuously processing in-real-time sensor data, to rapidly decide on airbag deployment. Microcontrollers are cost effective, intuitive, energy efficient and compatible with multiple interfaces like IoT. Error prevention is assured, they can only execute specifically programmed tasks which cannot be reprogrammed.

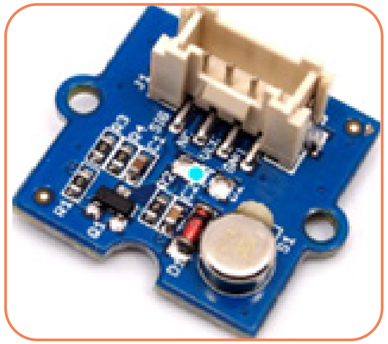


ADUC7026 Analog Microcontroller (HTS Editor, n.d)

3. Collision Sensor

Measure sudden changes in motion or force, using accelerometer data, to rapidly calculate impact so airbag deployment is activated. It absorbs shock, is cost-effective and easily integrated into a system.

However, detection is limited as it only accounts for impact not proximity to objects allowing for false positives from misinterpreted, non-hazardous, sudden movements to occur.



Collision Sensor (Seed wiki, n.d)

4. GPS Module

Provides precise real-time location data to facilitate faster patient response times by emergency medical services. User movement can be tracked and virtual boundaries set to detect if a wearer enters or leaves a designated area, benefitting carers to vulnerable people.

GPS Module (TOP, n.d)

5. SIM900 SMS Module + ESP32 Bluetooth Module

Can send automated text alerts with the user's location and status to predefined emergency contacts or services in the event of a fall or fit and allows for remote monitoring to ensure wearer wellbeing.

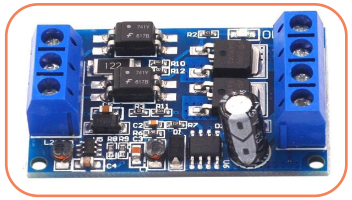
Additional Bluetooth integration allows for wireless communication to smart devices, logging fall data, system updates and device usage.

SIM900 SMS Module (Kunkune, n.d)

ESP32 Bluetooth Module (Waveshare, n.d)

6. MOSFET Switch

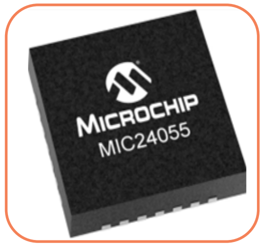
Is a smart switch pre-programmed and controlled by the microcontroller and ensures the airbag system only deploys in the correct conditions.



MOSFET (Banggood, 2024)

8. Voltage Regulator (Microchip MIC24055)

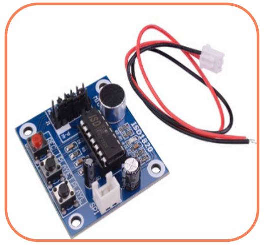
Wearable airbags are safety critical, it is vital to ensure all electronic components receive a consistent and appropriate voltage supply to avoid burn out or system failure. A switching regulator like MIC24055 can efficiently handle varying input voltages from all the components in the system, improving overall efficiency.



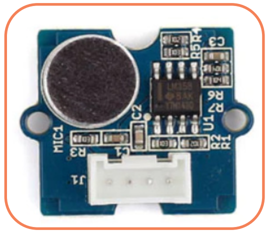
MIC24055 VR Microchip (Digikey, n.d)

9. Speaker Module

Communicates audio data to inform a user of systems changes, failures or airbag deployment. Additionally, integrating an ISD1820 Module allows for audio recordings and playback, to help medical professionals understand what was occurring at the time of the event that could have precipitated an episode.



Speaker Module (Ebay, 2024)



ISD1820 Speaker Module (Switch Electronics, n.d)

10. Airbags

Are typically made from woven nylon for its tensile strength and coated with polyurethane to enhance durability, wear, temperature and chemical resistance but can age easily and is costly.

Airbag bladders (SAIRBAG, 2024)

11. CO2 Canisters + ACH 27 Hybrid Inflator

CO2 canisters are compact, readily available, cost effective and can contain a large volume of gas in a small canister, either 16g or 20g, due to high pressure. When combined with an inflator, performance is enhanced as the CO2 ignites faster and sustains inflation for longer which is an important consideration of Cocoon's design.

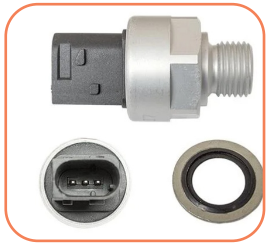
Compressed inflators cannot generate the quantity of gas required to fill an airbag and high-temperature flames produced by a pyrotechnic inflator make it too dangerous to be close to a human body but Hybrid inflators are harmless.

CO2 Canisters (Amazon, n.d)

ACH 27 Hybrid Inflator (XLMoto, n.d)

12. Pressure Sensor

Ensures the airbag inflates to and maintains correct pressure so the user stays protected for the full episode duration. Under or over inflation can compromise the airbag's efficacy and cause harm to the user. It can detect air leaks or punctures for quick corrective action and self-adjusts if pressure changes unexpectedly.



Pressure Sensor (VP, n.d)

13. Lithium Ion Battery

Li-ion batteries are relatively low weight and can store a large amount of energy in a compact size. Their long-life cycle allows for many recharges before efficacy begins to deplete and their low discharge rate means they can hold charge for longer even when not in use. The housing of Li-Ion batteries is extremely important as improper management can cause them to become damaged, short circuit or combust.

Lithium Ion Battery (Amazon, n.d)

14. Victron VE Battery Management System

A Battery Management System (BMS) continuously monitors the state of the battery, protecting it from operating outside of its safe limits like overcharging and overheating and ensures charging is equal among all modules in the circuit.

Victron VE BMS (Victron Energy, n.d))

MATERIALS

1.1. Cordura

Is a highly durable, water and abrasion resistant fabric commonly used for practical applications like military rucksacks and luggage. Even under extreme weather conditions, its polyurethane coating does not crumble, crack or peel and in the case falls, aggressive spasms and high-pressured airbags adding resistance, Cordura could appropriately withstand that.

Cordura Material (HLC, 2024)

1.2. Monolite Ripstop Nylon Mesh 35 g/m²

Is made from monofilament thread for its air permeability and strength. It is DWR treated to make it waterproof and commonly features in rucksacks as a lightweight, breathable lining material, perfect for reducing mildew build up.

Monolite Nylon (MYOG, 2024)

MANUFACTURING PROCESSES

1. Welding

Laser welding and friction inertial welding is commonly used to join sub-assemblies of the inflator together to ensure its assembly will be stronger and more durable. For airbags, Radio Frequency Welding creates airtight seals on thermoplastic polyurethane bladders or as an alternative, heat sealing can help bond plastic materials.
For synthetic fabrics, ultrasonic welding bonds fabrics instead of having to stitch, improving manufacturing consistency.

2. Coating

Protective coatings of silicone or polyurethane to fabric exteriors of the airbags in order to improve their durability and resistance.

3. Die Cutting

To reach economies of scale with high-volume production, die cutting is a viable way of cutting multiple layers of fabric simultaneously.

4. Industrial Sewing

TESTING PROCESSES

1. Pressure

Pressure tests on the airbags to ensure they can withstand full inflation without leaking.

2. Functional

Standardised testing of the airbag system to ensure sesnors are accurately detecting falls as they should and airbag inflation is happening within the set time frame.

3. Durability

Performing wear and tear assessments under various conditions like extreme tempertures and moisture exposure.

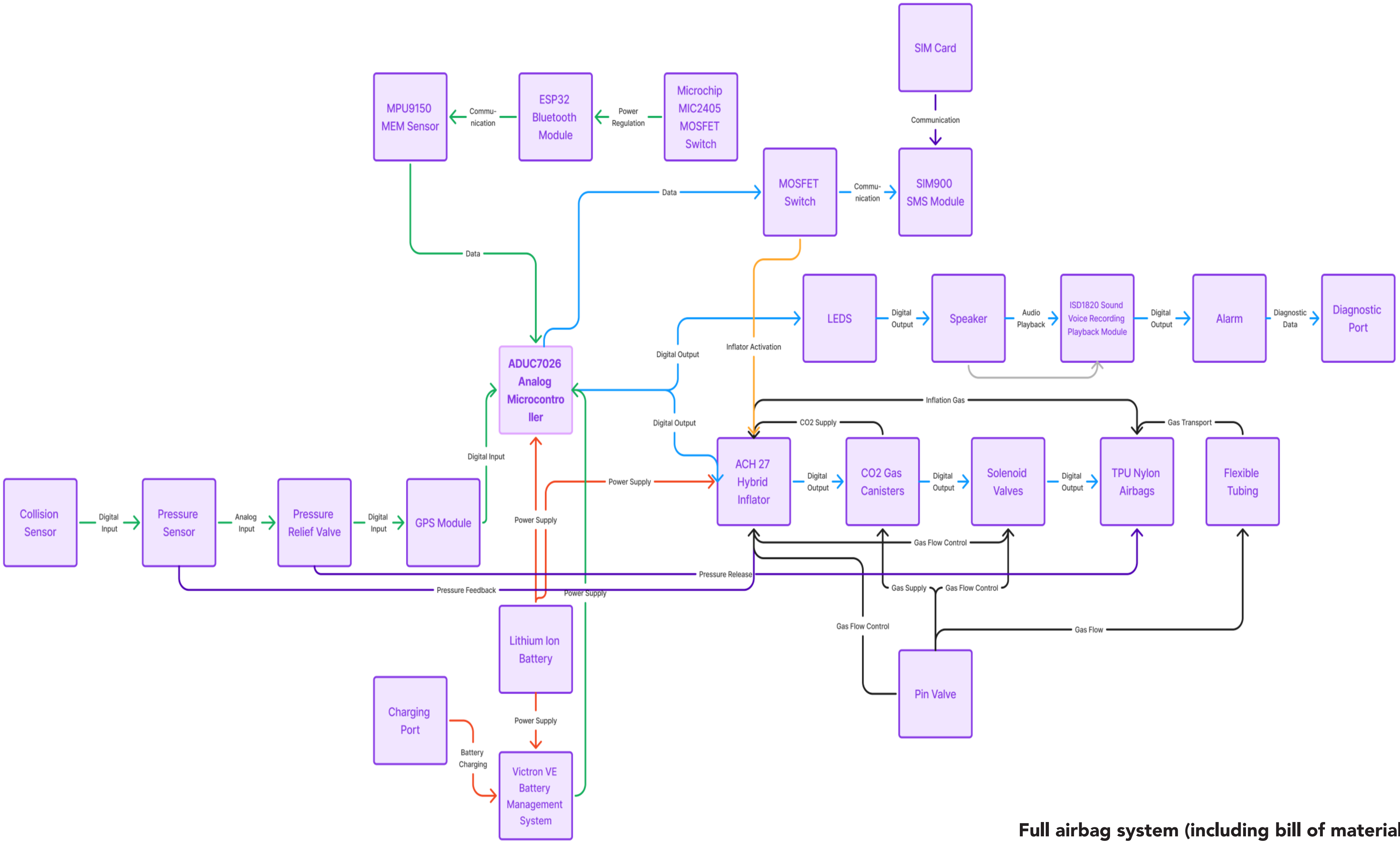
PRODUCTION FULL BILL OF MATERIALS

The estimated cost of each Cocoon is roughly £776.22 (assuming highest material price) however, this is likely to reduce as components can be purchased in bulk, improving economies of scale.

COMPONENT	PURPOSE	QUANTITY	COST
ADUC7026 Analog Microcontroller	Decides with the data it's given whether to deploy the airbag or not	1	£19.75
ESP32 Bluetooth Module	Wireless connection to smart devices for data transferral and messaging	1	£19.79
MPU9150 MEM Sensor	Tracks the body's motion in order to collect data so genuine fall scenarios can be detected	1	£25.30
ACH 27 Hybrid Inflator	For rapid airbag inflation	1	£90
Pin Valve	Punctures the gas canister to release CO2.	6-7	£11.56
GPS Module	To locate the wearer rapidly in real-time	1	£4.95
Collision Sensor	Detects sudden change in motion	1	£7.62
TPU Nylon Airbags	To protect a user by cushioning them from impact from potential hazards	6-7	£2.40 pm
CO2 Gas Canisters	For airbag inflation	6-7	£14.49 for 10
Flexible Tubing	To connect the CO2 cannisters to the airbag	1	£22.64
Solenoid Valves	Controls the inflation and deflation of the airbag	1	£30.72
Pressure Sensor	Regulates the pressure of the CO2 to ensure it is released at a safe and controlled rate	1	£84.55
Pressure Relief Valve	Prevents overpressure	1	£37.96
Lithium Ion Battery	To power Cocoon's circuitry	1	£5
Victron VE Battery Management System	To protect the battery from damage and regulate even distribution of charge to all components	1	£135
Microchip MIC2405	Regulates the voltage	1	£2.29
MOSFET Switch	Programmable system override on the activation or deactivation of the airbag system to ensure it is operating safely	1	£1.86
SIM900 SMS Module	Sends automated alerts to predefined contacts over a network	1	£13.20
SIM Card	Data plan to send texts	1	£6-25 tbc
LEDS	For status indication	2	£1.82
Speaker	To make the user aware of Cocoon's system status and activation	1	£5
ISD1820 Sound Voice Recording Playback Module	To playback recorded audio data of surroundings	1	£3.83
Alarm	To alert bystanders	1	£4.07
Diagnostic Port	For troubleshooting	1	£9.53
Charging Port	For charging	1	£3.76
On-Off Rocker Switch	To turn Cocoon on or off	1	£1.63
Cordura Fabric	To manufacture rucksack	2	£9.99
TOTAL		**47 Units**	**£776.22**

PROPOSED SYSTEM BLOCK

The below block diagram sets out the full functionality of the Cocoon airbag system using all the components listed in the bill of materials. For a system explanation, please refer to Appendix V.



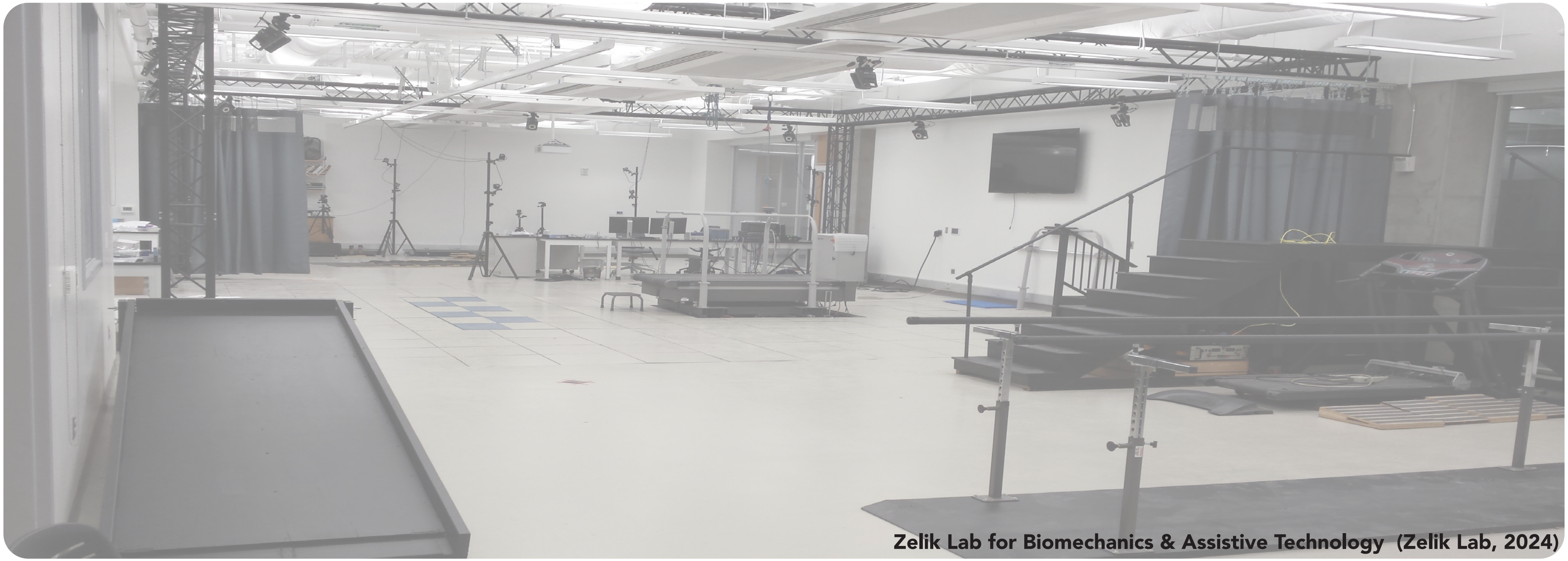
Full airbag system (including bill of materials) functionality visualised (Powell, 2024)

PRELIMINARY BIOMETRICS DATA COLLECTION

Users are invited into a clinical setting for metric tests to be performed like 6MWL and Get Up and Down, for data gathering. They will undergo height, weight and relevant strength tests and a discussion had on their medical history.

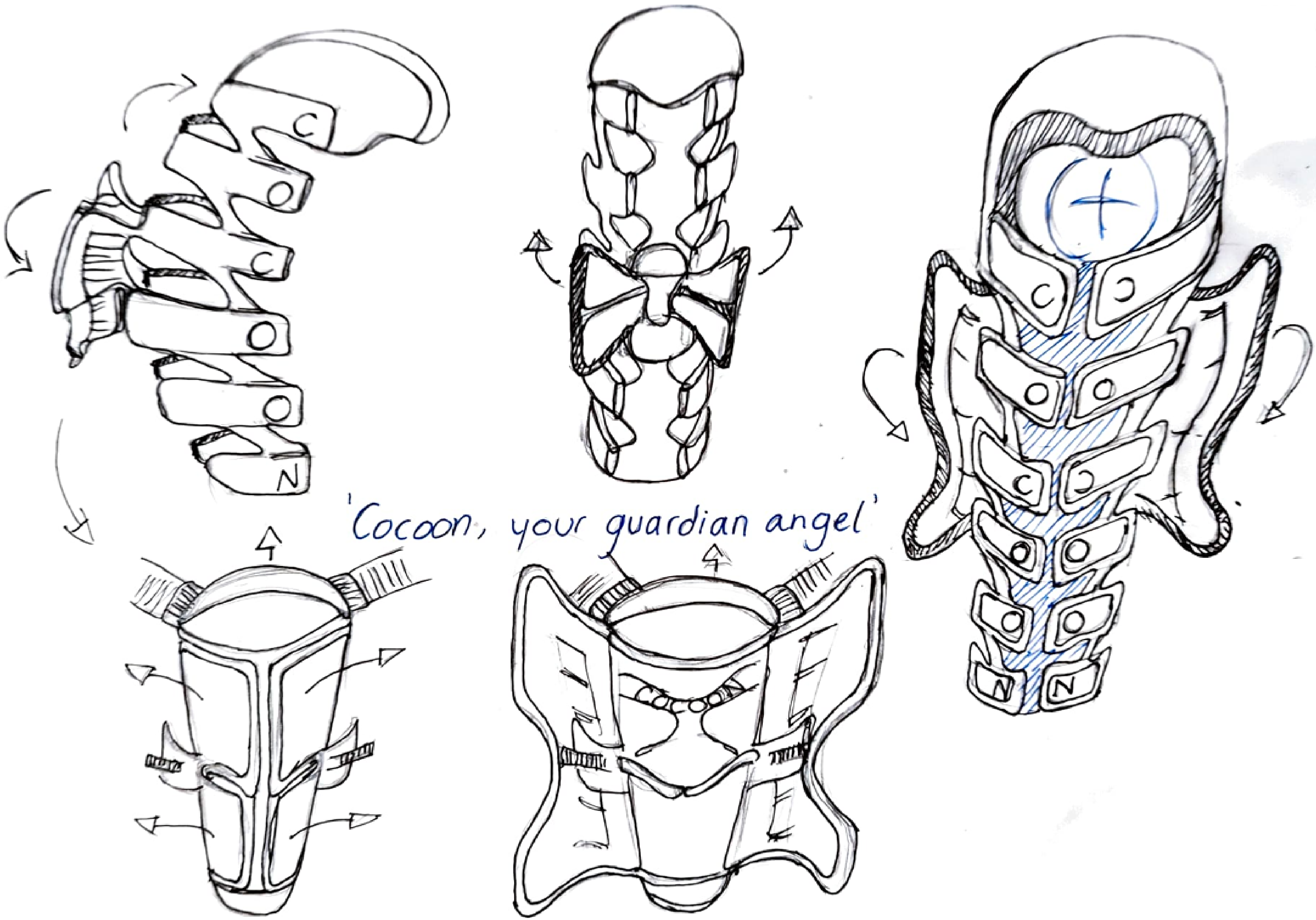
Often patients can be wrongly diagnosed when in these settings as examiners are unable to detect subtle changes in gait, especially if the patient is not experiencing any clear symptoms at that time. Therefore, to improve data accuracy patients will be sent home with a sensor network which they are expected to wear daily for a month as they go about their Activities of Daily Living and submit a patient diary so their routines are understood. Gait data is collected remotely by Cocoon professionals who modify the airbag algorithm according to the specific needs of the user who may exhibit drastically different abnormal movement.

A generalised algorithm is also created, forming the basis of ongoing data collection to benefit future clients and help medical professionals further medical understanding of complex diseases.



Zelik Lab for Biomechanics & Assistive Technology (Zelik Lab, 2024)

COCOON FINAL DESIGN



DESIGN DETAILS KEY FEATURES

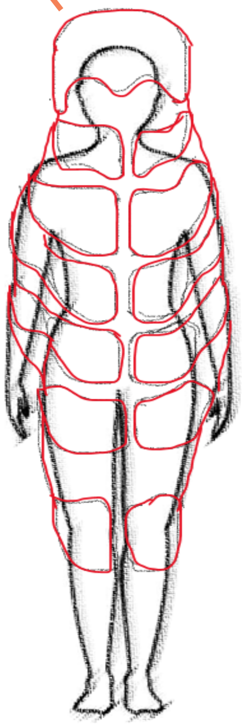
Cocoon's wearable airbag provides rapid and reliable full coverage protection using advanced sensor technology. It prioritises user comfort, ease of use and safety, adhering to stringent performance and environmental standards.

HEAD PROTECTION

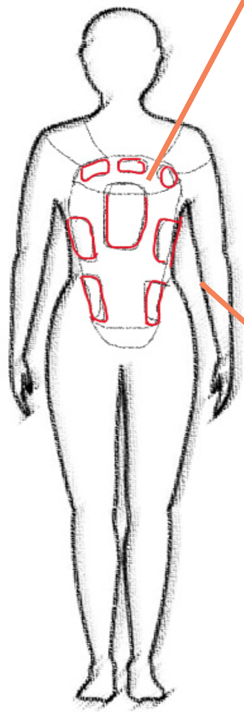
Airbags expand into a collared hood encapsulating the entire head and neck to prevent brain and spinal damage.

LIMB PROTECTION

Maintained inflation, providing cushioning even after initial impact.



Frontal airbags visual (Powell, 2024)



Cocoon on user visual (Powell, 2024)

DEPLOYMENT SYSTEM

The airbag central control unit is located against the lower torso to accurately measure the user's range of body motion.

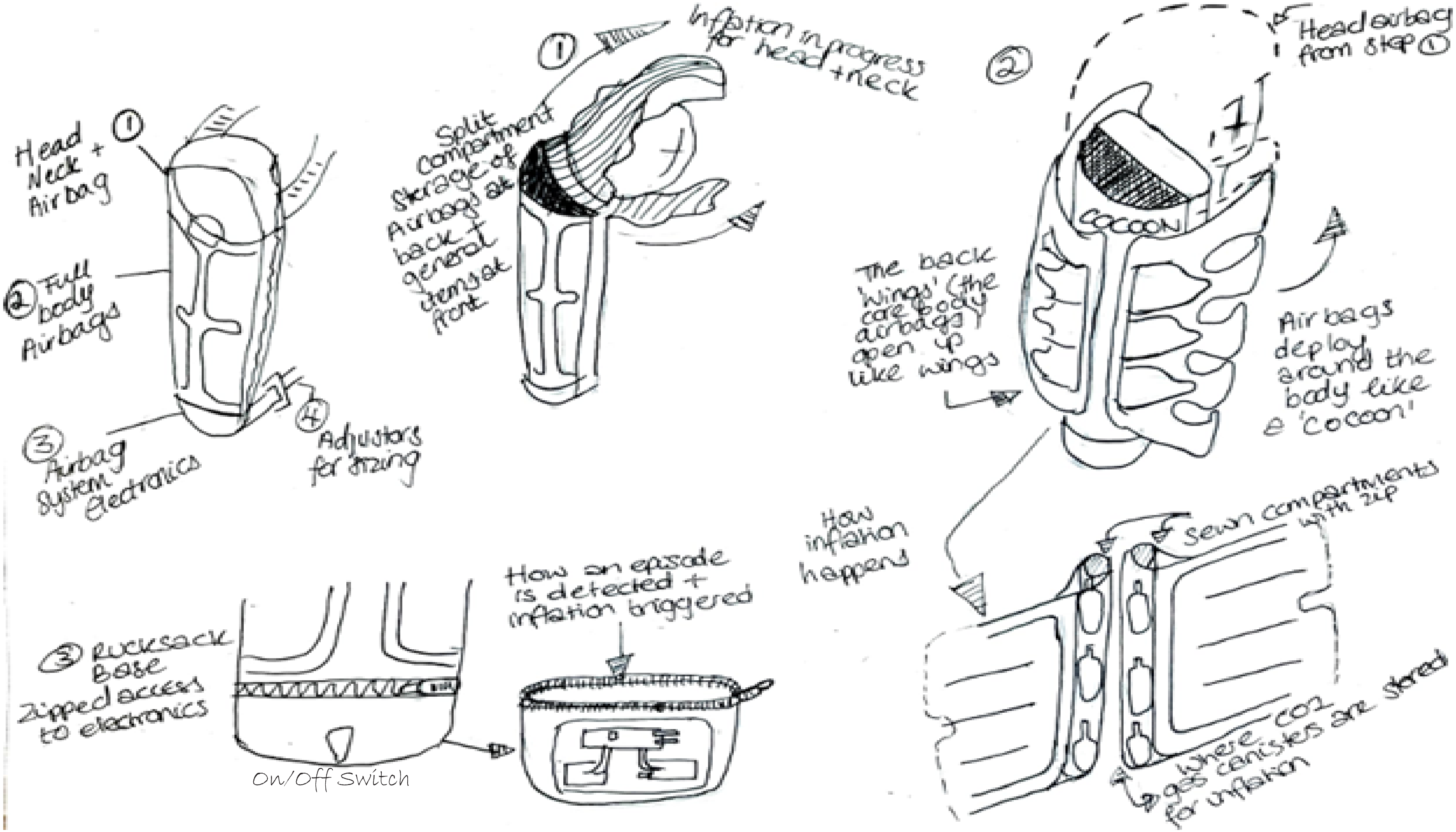
Gas canisters are distributed to minimise bulk and ensure there is rapid inflation.

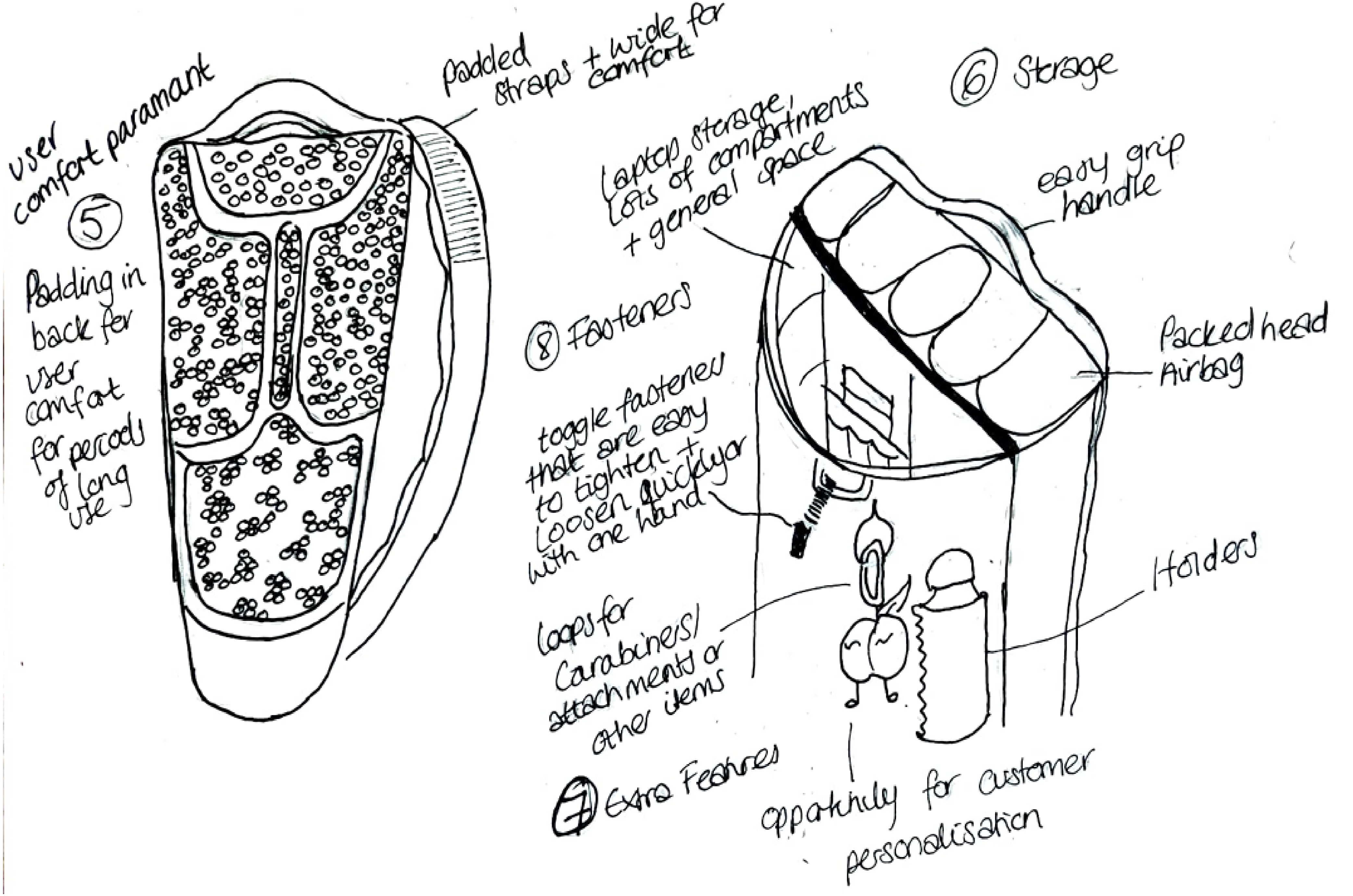
TORSO PROTECTION

Rucksack has multiple airbag chambers to ensure even inflation and coverage across the chest, back, sides, limbs, head and knees.

TECHNICAL VIEWS OF RUCKSACK

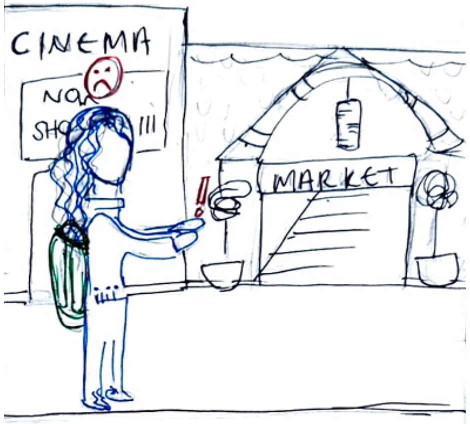
The below diagrams show the full sequence of airbag deployment from the rucksack and how its airbags expand round the user. Delicate components like circuitry and inflators are securely housed in the thick, shock absorbing base of the rucksack and gas canisters are integrated into the padded body of the rucksack of which are accessed with zips.



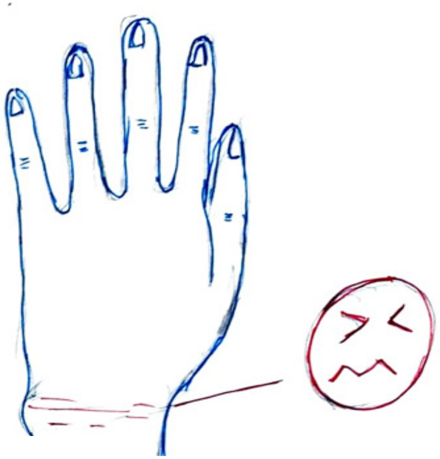

padded straps + wide for comfort
user comfort paramant
5
Padding in back for user comfort for periods of long use
6 Storage
Laptop storage, Lots of compartments + general space
easy grip handle
8 Fasteners
Packed head Airbag
toggle fasteners that are easy to tighten + loosen quickly or with one hand
Holders
Loops for Carabiners/ attachments or other items
7 Extra Features
opportunity for customer personalisation

STORYBOARD

1. Sophia has errands to run so she prepares to leave the house and puts her Cocoon on



2. She becomes stressed and unhappy as she starts to feel discomfort, knowing she is far from home

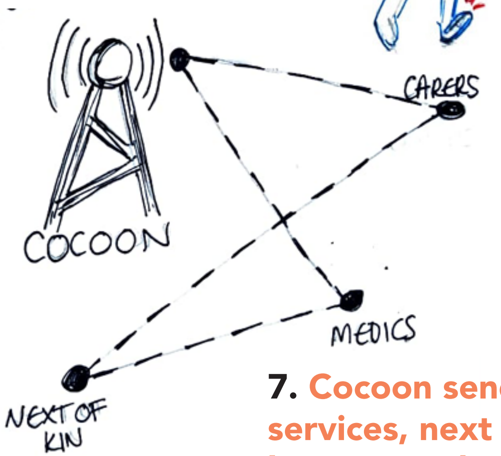


3. Her wrists begin to contort and lock into place

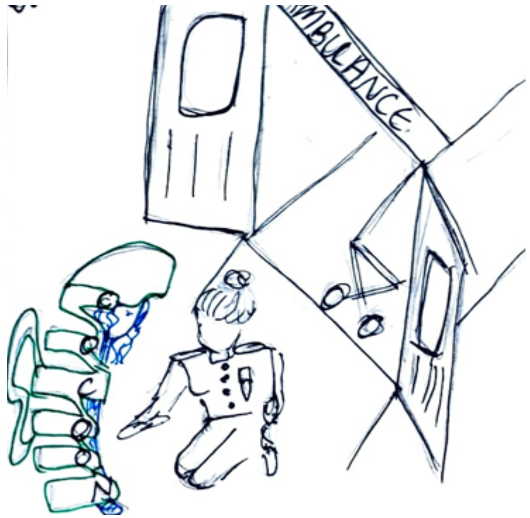
4. As her wrists lock, so do her feet making walking hard.

6. Cocoon rapidly inflates to protect Sophia

5. She is unstable and begins to fall and abnormal movement rapid worsens

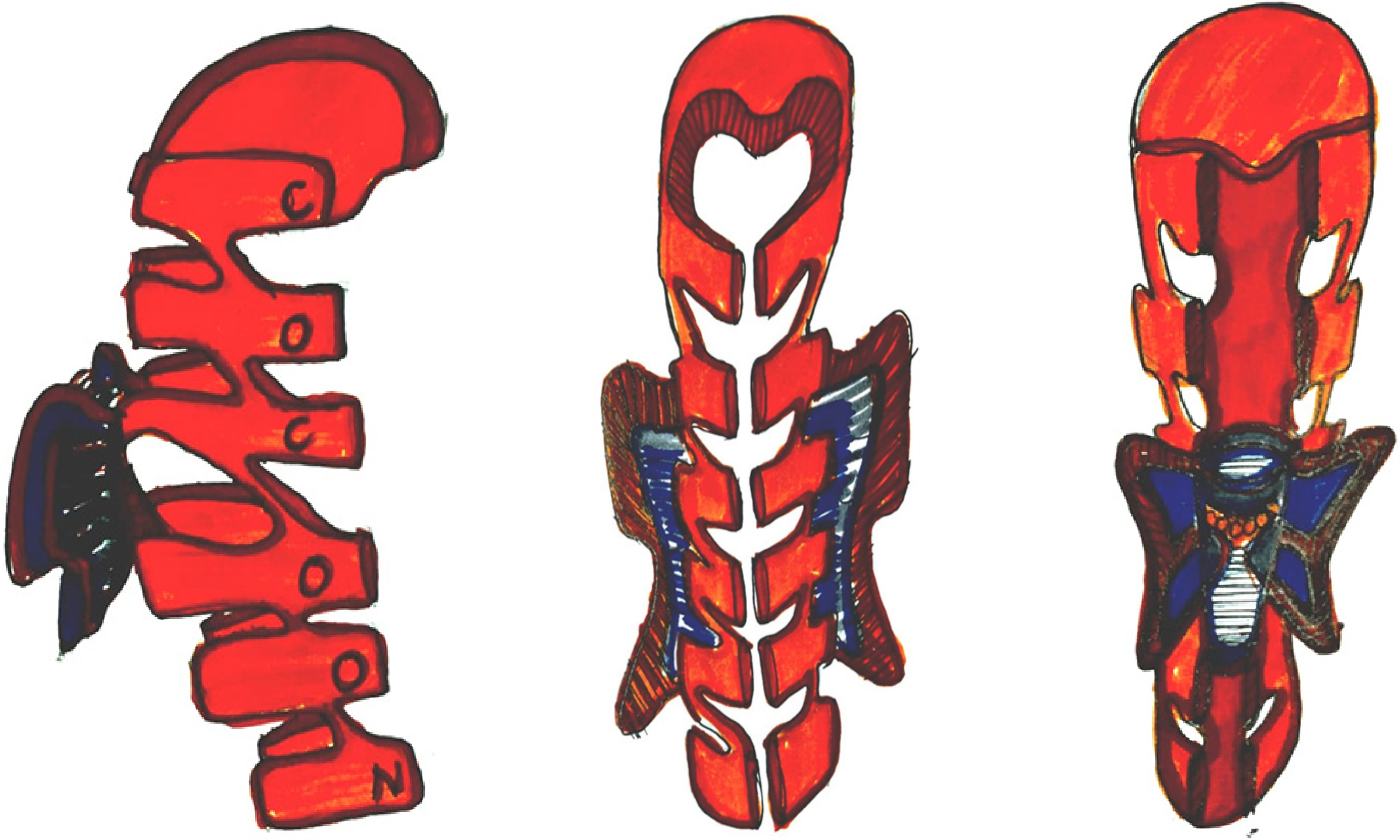


7. Cocoon sends out an alert to emergency services, next of kin and carers providing a location and Sophia's personal medical report



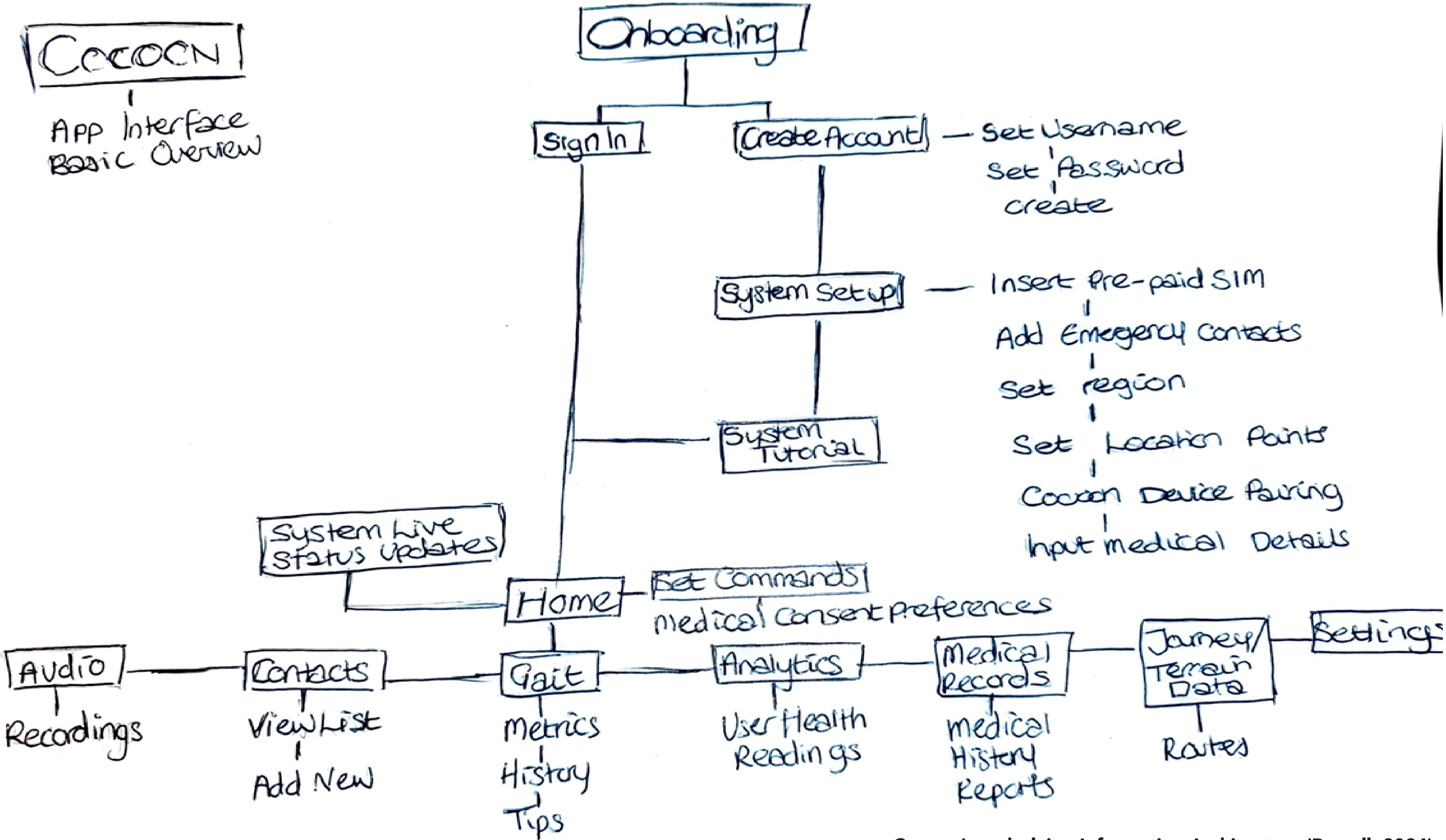
8. Cocoon stays inflated until paramedics arrive to take Sophia to hospital. Severe injury has been avoided

COCOON HERO IMAGE: “A NEW IDEA, USING PROVEN TECHNOLOGY”



COCOON'S INTERFACE MID-FIDELITY WIREFRAMING

INFORMATION ARCHITECTURE



Cocoon's underlying Information Architecture (Powell, 2024)

ONBOARDING

Fig 1: Cocoon loading screen (Powell, 2024)

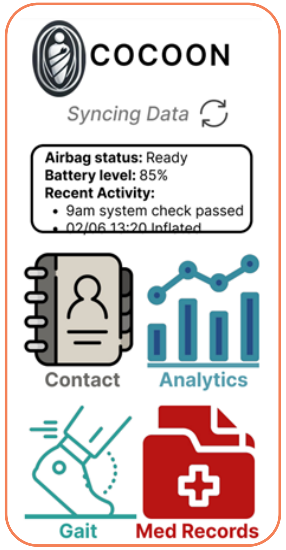


Fig 2: Home screen (Powell, 2024)

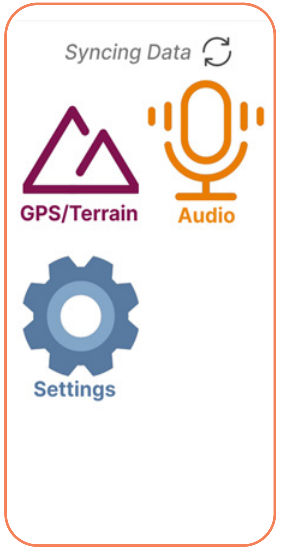


Fig 3: Rest of home screen (Powell, 2024)

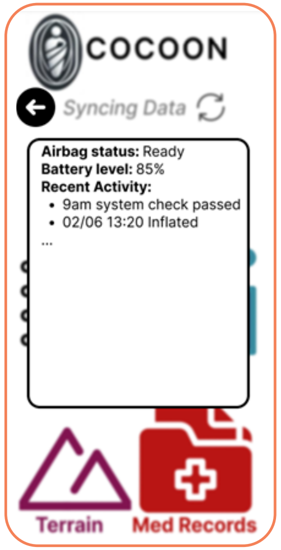


Fig 4: Cocoon system status report (Powell, 2024)

The Cocoon app syncs with its user's airbag device, sharing real-time data, health records, motion analytics, location and audio recordings to a predetermined set of emergency contacts.

The airbag's system status is displayed, indicating any required maintenance. For keen adventurers, the GPS and terrain analysis feature helps plan safe routes by assessing surface types and elevation changes, minimizing the risk of instability in hazardous regions. In case of an emergency, the app includes quick access to emergency contacts, enabling immediate calls for assistance.

Additionally, COCOON tracks health insights like heart to be shared with healthcare providers. With playback of incident recordings and journey logs, the app ensures users have all the necessary tools to maintain safety and health autonomy.

APP FUNCTIONALITY

Fig 5: Emergency contacts (Powell, 2024)

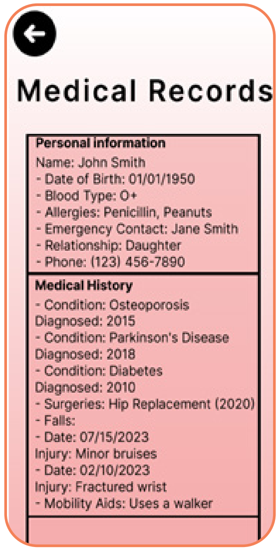


Fig 6: User medical records (Powell, 2024)

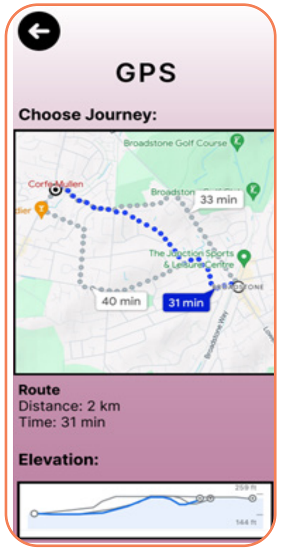


Fig 7: GPS tracker (Powell, 2024)

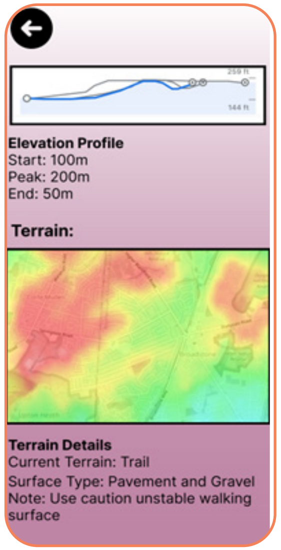


Fig 8: GPS terrain details (Powell, 2024)

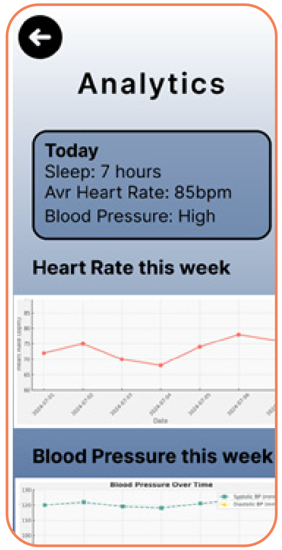


Fig 9: User health analytics (Powell, 2024)

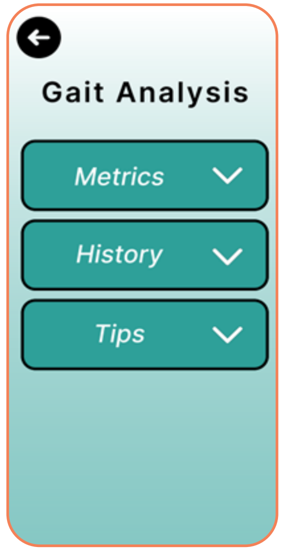
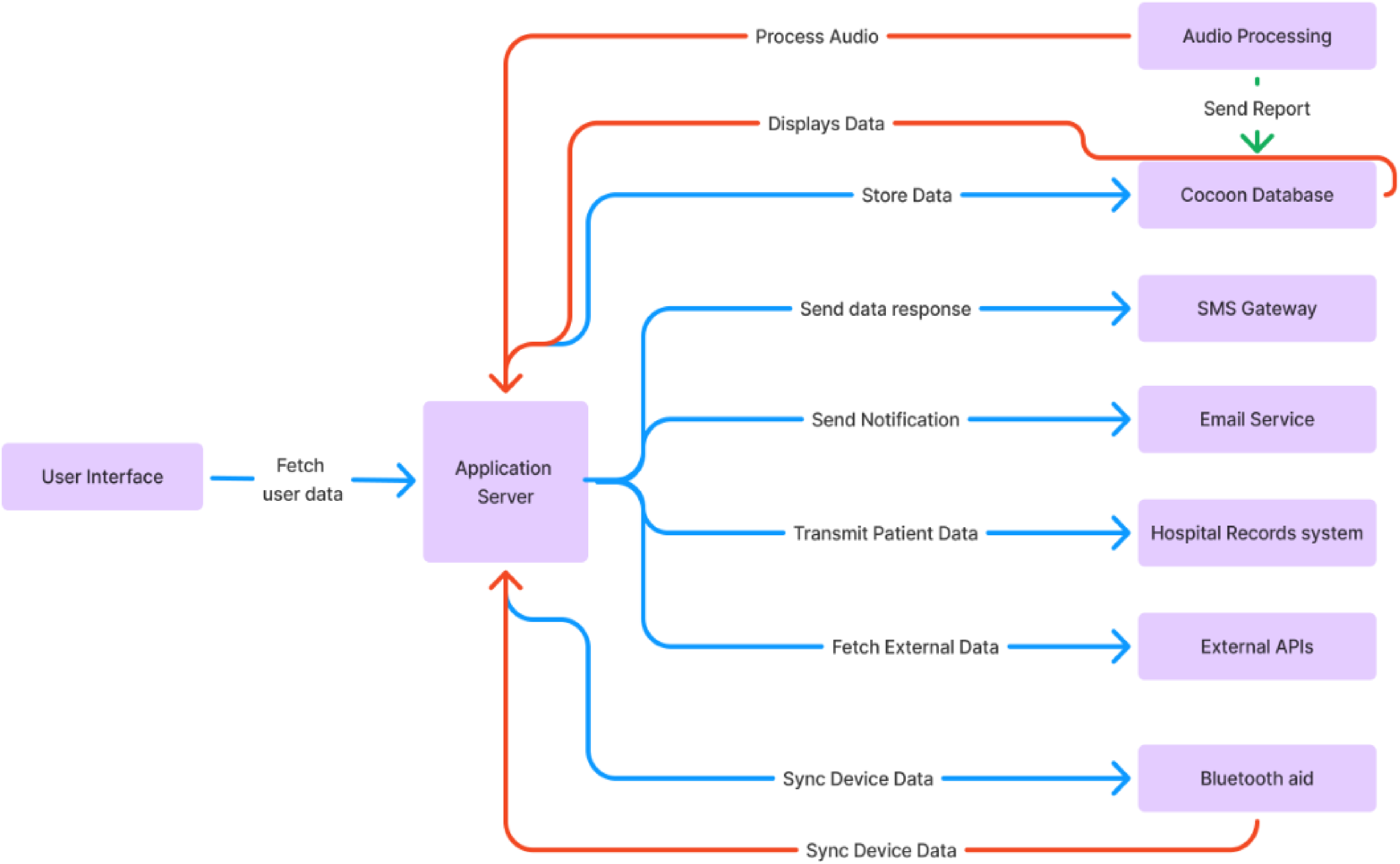


Fig 10: Gait analysis reports (Powell, 2024)

Fig 11: Audio recordings (Powell, 2024)

APP FUNCTIONALITY BLOCK DIAGRAM

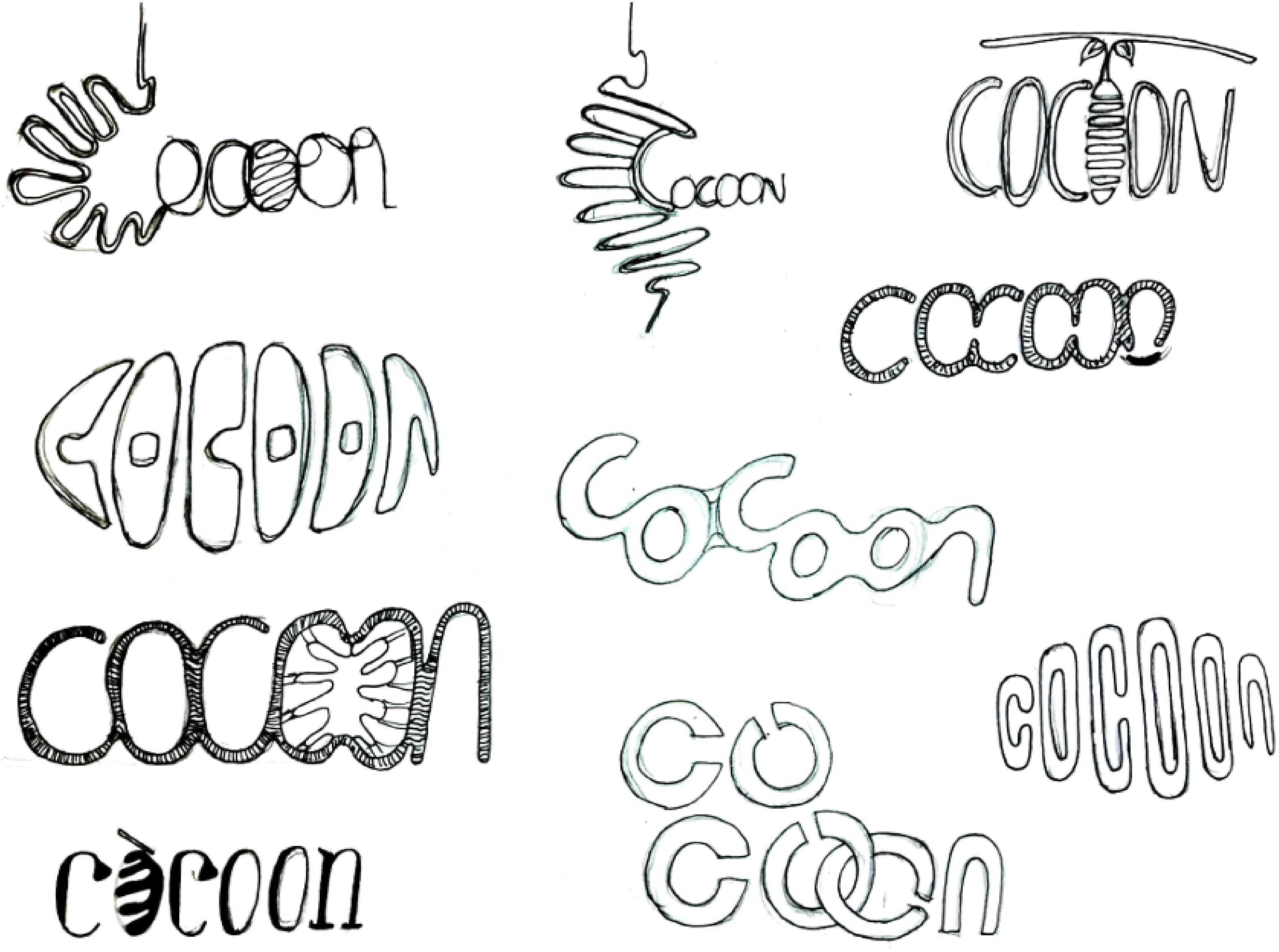
The block diagram below visualises the transfer of app data across Cocoon's interface and external smart devices.

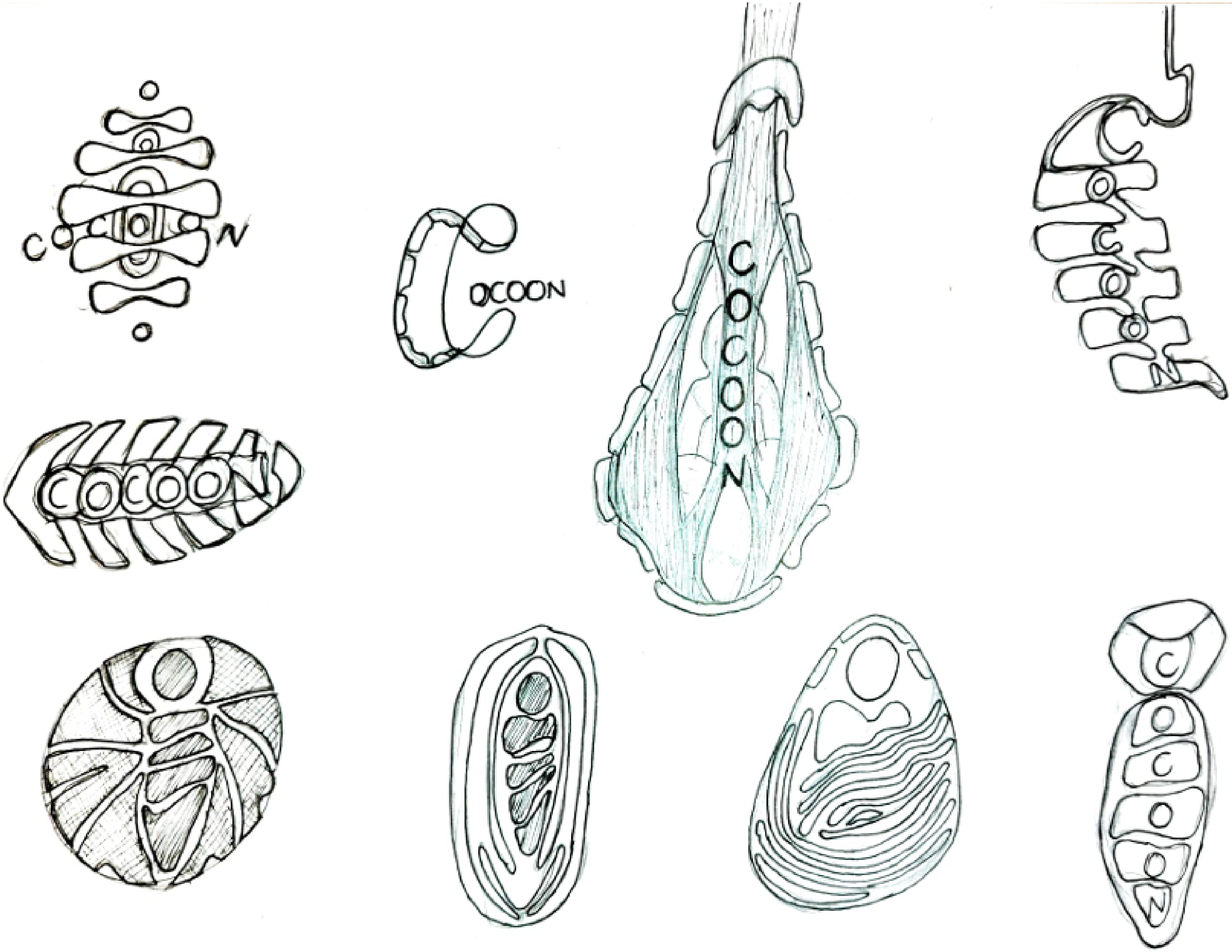


The transfer of data across Cocoon's Interface (Powell, 2024)

COCOON BRANDING

Proposed ideations for Cocoon's logo both written and iconographised




COCOON
COCOON
COCOON
COCOON
COCOON
COCOON

BRANDING BOARDS

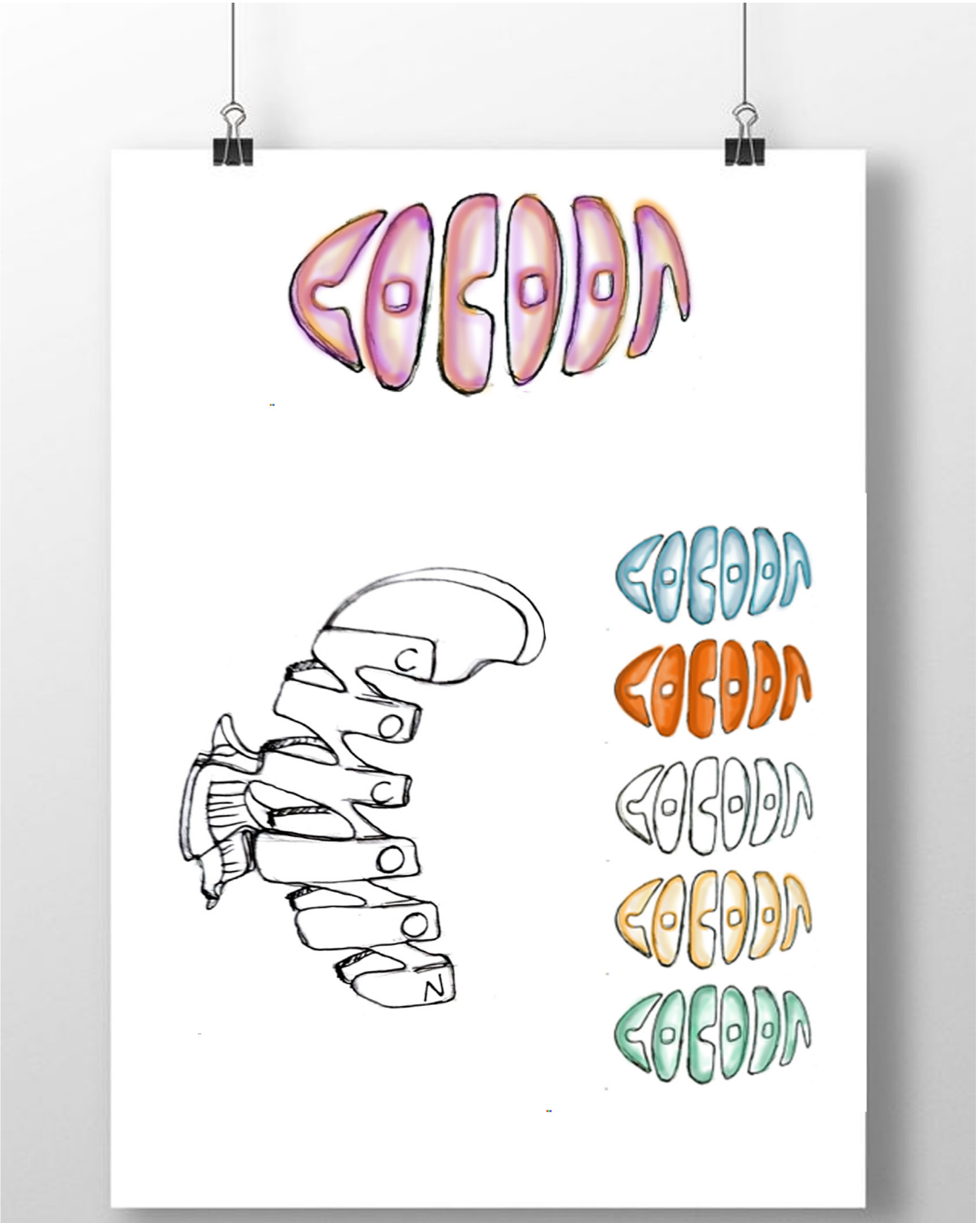
Loosely inspired by aerial yoga hammocks, Cocoon has been branded with tranquillity and reassurance in mind to symbolise the peace of mind Cocoon customers will have when leaving the house.

Light, soft pastilles and stronger more vibrant shades make up Cocoon's colour palette.

Softer colours are used in branding and promotion of Cocoon to give the consumer a sense of associated calm, whilst stronger tones are used in the airbag manufacture, to draw attention during inflation so help can be alerted and in the exterior rucksack design so that there is a customisable element to encourage consumer purchase.

Brand board 1 (Powell, 2024)

Brand board 2 (Powell, 2024)



Brand board 3 (Powell, 2024)

COCOON'S COLOUR PALLETE

STRAPLINES

Invisible Safety, Visible Confidence

Your Invisible Shield in Every Fall

Protecting You, Every Step of the Way

The Safety You Wear, The Protection You Trust

Safety Worn, Confidence Born

Predicting your unpredictable

THE FUTURE OF COCOON

MARKET TRENDS AND COMPETITORS

The Global Wearable Airbag Market will be worth $1,167.5 million by 2033, with a CAGR increase of 21.3% (Market Stats Ville, 2024) demonstrating the growing strength and direction airbag technology is taking in the near future.

Recent competitors, Stan, are leaving their development stage and are entering the market with their new wearable airbag rucksack designed to protect biker's head, neck, chest and back within 0.1 seconds. This is very in line with what Cocoon hopes to achieve but on a far larger scale across the body.

Furthermore, in the emerging market of smart airbags, the integration of smart sensors and AI, are anticipated to accelerate market growth on a global level.

The STAN backpack by In&Motion

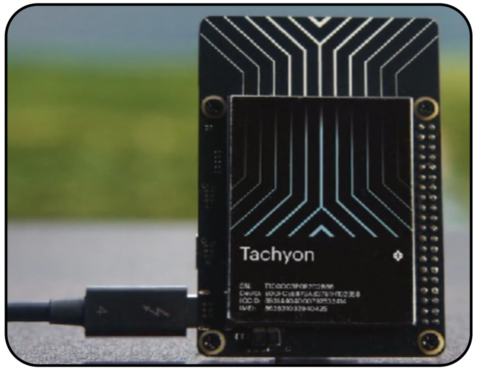
Stan backpack front view (Nepori, 2022)

Stan backpack side view (Burgos, 2022)

TECHNOLOGICAL ADVANCEMENTS

The Tachyon is a credit card sized, powerful, integrated microprocessor much like a modern smartphone with USB-C ports to connect with a range of personal devices like cameras, displays and sensors.

It is capable of networking configuration with built in 5G and WiFi 6E connectivity with firewall and bandwidth controls to prevent the overuse of data. It also harnesses the power of Artificial Intelligence to process sensor data into robust graphics and audio classification. Although still in its development, it has far exceeded its crowdfunding goal.



Tachyon (Kickstarter, 2024)

Moving forward in the development of Cocoon, once this microprocessor has made it to market, it will be utilised to positively improve Cocoon's design by reducing the number of individual components, such as the WiFi Modules, to make circuitry more compact and cost effective. Also, the inclusion of a powerful AI processing system will enhance data collection, algorithm performance and audio playback thus improving Cocoon's ability to protect its wearers.

FUTURE BUSINESS MODEL

Icon 15

Cocoon is invested in every user's wellbeing with a core product package offering:

- A personalised algorithm based on the customer's medical background, triggers, movement sequences and patterns of behaviour.
- Emergency contact database of trustees and personal medical advisors.
- Updates hospitals pre-admission, by sharing all recorded user data and their location to fast-track care.

However, more premium models can provide:

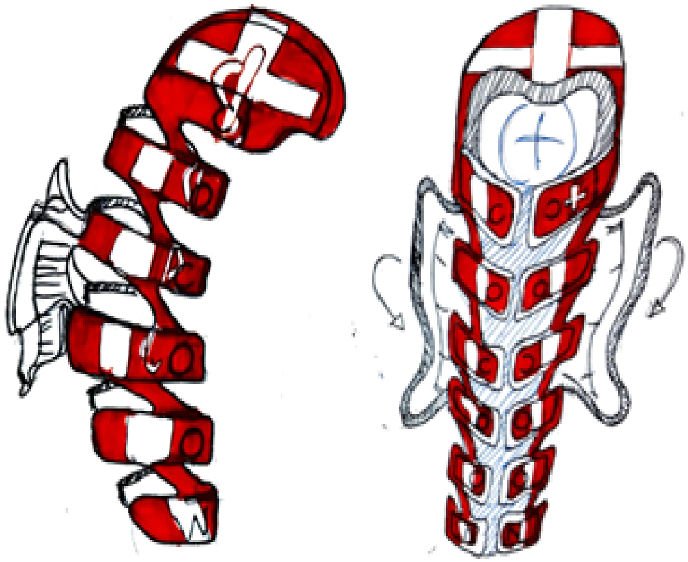
- Individual aftercare service, following up with patients as they convalesce after treatment, offering therapy or daily check ins if the individual lives alone.
- Influence over the design of their Cocoon
- Additional features like heated elements for winter use.

A future consideration is the management and outsourcing of staff to support a large pool of customers with complex needs. This may incur high costs to the business and legislation around GDPR and safeguarding could pose an issue.

FUTURE DESIGN CHANGES

In the future, deployed airbags are to be designed with the medical ID symbol on them in bright colours for clear identification so first responders can understand they are approaching a user with medical needs.

Medical ID Symbol (, 2024)



Cocoon future design change (Powell, 2024)

FINAL EVALUATION AGAINST THE PDS

Category	Specification	Status	Result
Performance	**1.6**		Cocoon provides coverage from the head to the knees
	1.3		Cocoon uses an ACH 27 Hybrid inflator to rapidly inflate the airbags within 100m/s and maintain inflation until help arrives
	1.4		
	1.9		Cocoon has an IoT Bluetooth and SMS interface to send calls and texts to a predefined list of contacts
Environment	**2.1**		Cocoon uses components that have good temperature stability like the MPU9150 MEM Sensor
	2.3		Externally and internally Cocoon utilises TPU as it's durable and easy to clean
	2.2		
Service Life	**3.1**		
	3.3		
Maintenance	**4.1**		There is no physical model for Cocoon so in theory this would be adhered to but in practice cannot at this time
Location of Use	**5.1**		Suitable for daily use but a rucksack indoors may be cumbersome if it has to be worn frequently
User	**6.1**		Appropriate for those with Parkinsons, Epilepsy, Dystonia and other overlapped disorders where instability occurs and control over the body is lost
	6.5		Client focus on the NHS institutions for product trialling with rehabilitation patients and advance medical understanding
	6.3		Users informed by SMS, Bluetooth and the Cocoon App
Safety and Compliance	**7.3**		Safety testing is not viable at this time until a working prototype is made
	7.4		The microcontroller, algorithm and inflator have set thresholds in which to activate inflation and how long to sustain it for to reduce error and danger
	7.2		
Ergonomics and Design	**8.3**		The rucksack is compartmentalised whereby airbags are in the back, circuitry in the base and general storage is utilised at the front chamber
	8.4		Rucksack back is quilted in a breathable fabric for comfort and moisture wicking
	8.5		The rucksack evenly distribute weight across the user's body
	8.7		The straps have fasteners and toggles to help tighten and loosen easily to accommodate different users of varying size and motor skill. Design is subtle.
	8.6		
	8.8		
Materials	**9.2**		The airbags and rucksack have been manufactured out of TPU and coated nylon
	9.1		

Technology	10.1		The triaxial sensor has combined functionality, signalling to the microcontroller to decide if the hybrid inflator begins inflation.
	10.5		
	10.2		
User Interface + Feedback	11.1		Extended customer care package provided with premium models. User manual not available at this time.
	11.2		SMS and Bluetooth connectivity for data sharing and management, all viewable via the Cocoon App
	11.3		Audio playback of recordings to explain to medical responders. LEDs show circuit is on.
Cost and Manufacture	12.1		Over time Cocoon will be scaled to be more affordable but as of now it will cost thousands to develop and produce due to the bespoke nature of the design and the high tooling, material and testing cost involved.
	12.3		
	12.4		

CONCLUSION

To conclude, Cocoon is an effective, premium product offering next level innovative support to an underrepresented and largely misunderstood market sector.

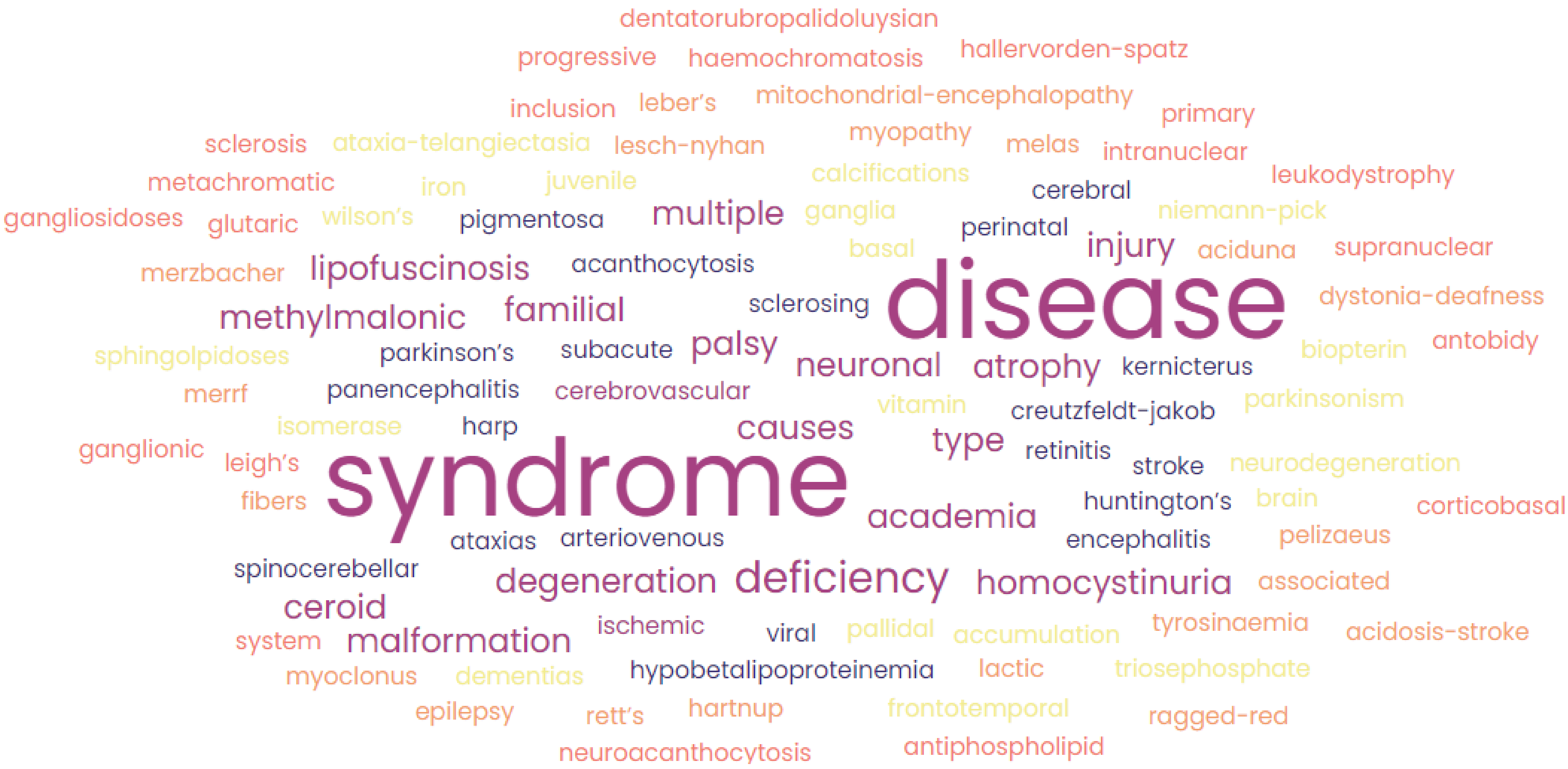
As the wearable airbag market is starting to gain foothold, Cocoon can capitalise on this, promoting its USPs.

Although, in-depth analysis of existing technologies have confirmed the efficacy of Cocoon, I haven't been able to manufacture a prototype of Cocoon or rigorously test it. In time I hope to achieve this and improve the affordability of the product.

In terms of completing this report, a Project Planner was made to give a rough outline of the progress that should be achieved each week. For the most part this was followed but took far longer than expected due to the complexity of this project. This can be viewed in Appendix VII.

APPENDIX I NEUROLOGICAL AND METABOLIC DISORDERS

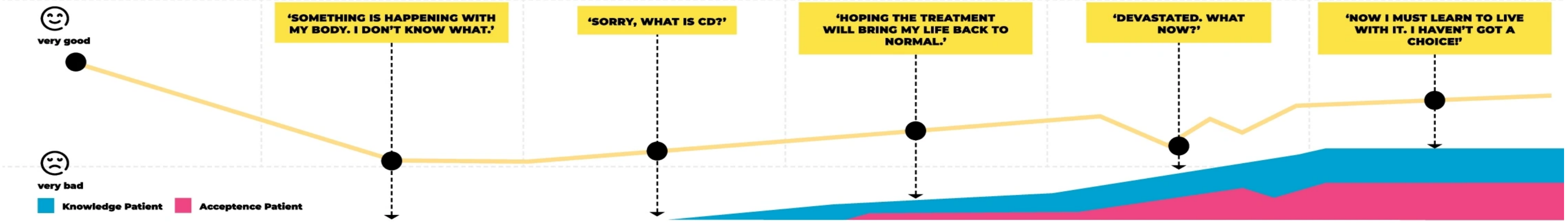
Dystonia can occur as part of many disorders and conditions. Research is ongoing and this list should not be considered comprehensive (Dystonia Ireland)



*This word cloud was generated using Free Word Cloud Generator

APPENDIX II CERVICAL DYSTONIA PATIENT MAPPING EXAMPLE

PHASE MAPPING	#0 PERSONA	#1 FIRST SYMPTOMS APPEAR AND THE MEDICAL JOURNEY BEGINS	#2 HOW DIAGNOSIS CD (CD) COMES ABOUT AND RELATIONSHIP WITH PHYSICIAN	#3 INITIATION OF CD CARE	#4 START OF TREATMENT AND IMPACT OF FOLLOWING INJECTIONS	#5 LIVING WITH CD AND THE TREATMENT(S)
PATIENT'S AGE		39-42	42	42	42 -44	> 44
EMOTIONS		**'SOMETHING IS HAPPENING WITH MY BODY. I DON'T KNOW WHAT.'**	**'SORRY, WHAT IS CD?'**	**'HOPING THE TREATMENT WILL BRING MY LIFE BACK TO NORMAL.'**	**'DEVASTATED. WHAT NOW?'**	**'NOW I MUST LEARN TO LIVE WITH IT. I HAVEN'T GOT A CHOICE!'**



	#0	#1	#2	#3	#4	#5
MOMENTS OF MEANING (QUOTES FROM THE PATIENT SURVEY)		**'I don't know what is happening with my body, and my husband and I are both anxious. I feel as if I am losing my identity and my spontaneity, and I'm afraid that my husband will stop loving me.'**	**'I did not feel understood, I felt it was all too fast, I did not feel supported by my neurologist and I did not feel reassured. I needed more time, more words to encourage me. The neurologist talked to me about the BoNT treatment but didn't mention anything about other complementary treatments.'**	**'Before starting the treatment, it would have helped me just to be told the truth by my neurologist, that the BoNT may help a lot, a little or not at all. And what further treatment might help.'**	**'When the following BoNT injections [after the 1st injection] did not work well, I lost all hope because I was told it was the only treatment option.'** **'My neurologist may not be my BoNT injector and not know me as well as my neurologist. There is a lack of communication on how I am feeling and if my treatment is working effectively.'**	**'It's a daily journey, a daily fight, Dystonia is a part of me, but I'm not only a patient living with CD and I've learned to look at myself and the world around me differently.'**
MEDICAL EXPERIENCE	**Meet Lilly**: 38 years old, before the onset of the disease **Demographic data:** 38 years old, teacher, middle income. Married to Ben, 45, employed electrician. 2 children, 5 and 7 years old. They live in a detached house in the suburbs of a larger European city. **Psychography:** financially responsible as she earns more than her husband. Lilly is always there for everyone. Her mother is still alive, her father recently died of cancer. She feels responsible for both her mother, who is living alone, and her mother-in-law, who suffers from the onset of dementia. **Hobbies:** jogging, reading, travelling, spending time with the family. **Habits:** busy social and working life, sleeps too little, eats mostly healthy food. **Personal goals:** time for family and travel, get out in nature more often, go horse riding. **Social environment:** good relationship with work colleagues and neighbours; she is liked by all. **Wishes & needs:** to live a self-determined life with her family for as long as possible. **Digital habits:** she chats with friends on WhatsApp, mostly sends photos of family and herself. She uses the internet mainly for her work as a teacher, to read the news and for online shopping.	**FIRST SYMPTOMS** She often uses her hand to keep her head still. When her stress level calms down a bit, the symptoms unfortunately do not disappear but intensify so that she can no longer go jogging and riding and is on sick leave for a few weeks. Multiple visits to her GP who prescribes strong pain killers and muscle relaxants, and refers her to different specialists. Most frequently suspected diagnoses: stress, psychological causes, herniated disc, tendonitis.	**DIAGNOSIS OF CD** Lilly's symptoms have worsened and she cannot keep her head still and straight. Her sleep quality is very poor, she is depressed and suffers from fatigue. Her GP finally refers her to a neurologist specialised in dystonia who diagnoses her with "CD". She does not receive clear information about the disease or support from the diagnosing neurologist. In an online article, she learns more about the disease and its treatment.	**DISCUSSED TREATMENT OPTIONS WITH PHYSICIAN** Lilly's neurologist refers her to a movement disorder clinic where it is recommended she get BoNT injections. The neurologist also suggests physiotherapy in addition to the injections but doesn't direct her to a physiotherapist who is knowledgeable about dystonia. He advises her to search for a physiotherapist in her area, one that ideally specialises in CD. She often struggles with fatigue which is caused both by the painkillers and by poor sleep quality. She hopes that the pain will get better with time.	**START OF TREATMENT: BoNT injections** In the beginning, the BoNT treatment provides Lilly with relief, but she experiences ups and downs. Lilly receives her BoNT injections every 3 months, but finds its particularly difficult in the days and weeks before her next scheduled injection. Nevertheless, the BoNT is the treatment with the greatest impact on her symptoms. On the advice of her physiotherapist, she applies to her health insurance company for an armchair with headrest to put her head on, and she gets this approved. After spending a considerable amount of time and effort on the paperwork, she finally gets disabled worker status. In phases when the BoNT is working well, she decides to try yoga and relaxation.	**TREATMENT STRATEGY** Lilly has often taken sick leave during bad phases. Lilly's treatment strategy is multidisciplinary: BoNT injected by an experienced neurologist, physiotherapy, acupuncture, painkiller gel application on the pain zones, sport (swimming, walking, cycling), healthy diet, benzodiazepines if needed and however, there is no central care coodinator and Lily is often left to find allied healthcare professionals (e.g. physiotherapist) on her own.
EMOTIONAL EXPERIENCE		**PATIENT** Exhaustion, anxiety and uncertainty are combined over time with great frustration with her doctors and therapists who cannot find a cause for her symptoms. **FAMILY/ENVIRONMENT** Her partner is very supportive and understanding and takes over all the roles she feels she can't do. Her friends and colleagues cannot understand what she is suffering from and wonder if Lilly has Parkinson's disease. She feels as if nobody is able to help her.	**PATIENT** She is very relieved to finally have a diagnosis. At last, she knows that she is not crazy. At the same time, shortly after the diagnosis and the conversation with her neurologist, she can't really grasp what CD means for her life, because she doesn't know anything about it. Lilly is disappointed and sad that there is 'no real cure' and that the available options are drugs and neurotoxin, which only serve to treat the symptoms. **FAMILY/ENVIRONMENT** Lilly's family and friends are also relieved that the cause of her symptoms has been identified. They feel that Lilly doesn't like to speak about it and accept her as she is. When her colleagues learn that she suffers from CD, they empathise. But they don't really understand.	**PATIENT** Lilly hopes that the treatment will help her to return to a normal life. She is suffering from a high level of psychological stress and severe limitations in everyday life. She avoids socialising because she can't stand the glances of others. Sometimes she cries, feels angry, and has mood fluctuations, asking herself 'why me?' **FAMILY/ENVIRONMENT** Lilly is surrounded by her family, her friends, and her colleagues who show a lot of support and understanding. A good friend encourages her to contact a dystonia self-help group where she learns about the importance of psychotherapeutic support and receives the contact details of psychotherapists.	**PATIENT** After being frustrated at first, Lilly has learned to cope with the varying success of the treatment. If the BoNT injections do not work well, she rests more and avoids going to work and socialising. When the BoNT injections work well, she can return to an almost normal life. She has good phases and bad phases with anxiety and depression. **FAMILY/ENVIRONMENT** Her family, especially her children, give her support and strength not to lose her courage to face life. Her husband helps her a lot with the preparation of her application to get disabled worker status.	**PATIENT** Today, Lilly does not have the same job because she had to give up her position as head teacher. She has learned to live with her illness and has begun to accept it. Step by step, she is rebuilding her life again and realises that she can still socialise, do her hobbies and help other people. **FAMILY/ENVIRONMENT** All in all, her family and friends have found a good way to deal with the disease. Sometimes they have conflicts because Lilly's husband forgets she is tired and everyday activities take her longer. Sometimes he forgets that she is not the same person as before.

APPENDIX III DYSTONIC PATIENT WELLBEING SURVEY

<table>
<tr><td>1st day</td><td>date:</td><td>Mon</td><td>Tue</td><td>Wed</td><td>Thu</td><td>Fri</td><td>Sat</td><td>Sun</td></tr>
<tr><td colspan="9">1. How do you assess your mood today?</td></tr>
<tr><td colspan="2">very good</td><td colspan="5"></td><td colspan="2">very bad</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">2. How strong has your mood been affected by your illness today?</td></tr>
<tr><td colspan="2">not at all</td><td colspan="5"></td><td colspan="2">very much</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">3. How severe was your experienced disease severity today?</td></tr>
<tr><td colspan="2">lowest</td><td colspan="5"></td><td colspan="2">highest</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">4. How satisfied have you been with the effect of BoNT therapy today?</td></tr>
<tr><td colspan="2">extremely satisfied</td><td colspan="5"></td><td colspan="2">extremely dissatisfied</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">5. How severe did you experienced involuntary movements and head deviation today?</td></tr>
<tr><td colspan="2">not at all</td><td colspan="5"></td><td colspan="2">very much</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">6. How severe did you perceived pain today?</td></tr>
<tr><td colspan="2">lowest</td><td colspan="5"></td><td colspan="2">highest</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">7. Did you use another method to reduce your symptoms today?</td></tr>
<tr><td>yes</td><td>no</td><td colspan="7">If yes, which method?</td></tr>
<tr><td colspan="9">8. To what extent have you been physically active today?</td></tr>
<tr><td colspan="2">lowest</td><td colspan="5"></td><td colspan="2">highest</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">9. How strong did you feel affected by your illness during these activities today?</td></tr>
<tr><td colspan="2"></td><td>lowest</td><td colspan="4"></td><td>highest</td><td>not executed</td></tr>
<tr><td colspan="2">everyday life at home</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>0</td></tr>
<tr><td colspan="2">work / education</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>0</td></tr>
<tr><td colspan="2">leisure time activities (hobbies, sports, vacation)</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>0</td></tr>
<tr><td colspan="2">social contacts (family, friends, colleagues)</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>0</td></tr>
<tr><td colspan="9">10. Did you abstain from activities due to your disorder today?</td></tr>
<tr><td>yes</td><td>no</td><td colspan="7">If yes, what?</td></tr>
<tr><td colspan="9">11. To what extent do you find yourself in today’s social situations (meeting / talking to other people) refraining from actions due to your illness?</td></tr>
<tr><td colspan="2">lowest</td><td colspan="5"></td><td colspan="2">highest</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
<tr><td colspan="9">12. To what extent did the symptoms worsened in social situations?</td></tr>
<tr><td colspan="2">lowest</td><td colspan="5"></td><td colspan="2">highest</td></tr>
<tr><td colspan="2">1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="3">6</td></tr>
</table>

APPENDIX IIII ARDUINO FEASIBILITY TESTING CODE

```
const int xPin = A0; // X-axis from accelerometer
const int yPin = A1; // Y-axis from accelerometer
const int zPin = A2; // Z-axis from accelerometer
const int gyroPin = A3; // Simulated gyroscope
const int magXPin = A4; // Simulated magnetometer
X-axis
const int magYPin = A5; // Simulated magnetometer
Y-axis
const int alertPin = 7; // Buzzer
const int airbagPin = 8; // LED for airbag inflation
const int ventsPin = 9; // Pushbutton switch for vents
const float fall Threshold = 2.5; // Adjust based on
sensitivity needed

void setup() {
 Serial.begin(9600);
 pinMode(alertPin, OUTPUT);
 pinMode(airbagPin, OUTPUT);
 pinMode(ventsPin, INPUT_PULLUP); // Using internal
pull-up resistor
}

void loop() {
 // Read sensor values

 int xReading = analogRead(xPin);
 int yReading = analogRead(yPin);
 int zReading = analogRead(zPin);
 int gyroReading = analogRead(gyroPin);
 int magXReading = analogRead(magXPin);
 int magYReading = analogRead(magYPin);

 // Convert analog readings to voltage (assuming 5V
power supply)
 float xVoltage = xReading * (5.0 / 1023.0);
 float yVoltage = yReading * (5.0 / 1023.0);
 float zVoltage = zReading * (5.0 / 1023.0);

 // Sensor calibration (example: subtracting an
offset)
 float xCalibrated = xVoltage - 2.5; // Assuming 2.5V
as a baseline offset
 float yCalibrated = yVoltage - 2.5;
 float zCalibrated = zVoltage - 2.5;

 // Calculate magnitude of acceleration
 float magnitude = sqrt(xCalibrated * xCalibrated +
yCalibrated * yCalibrated + zCalibrated * zCalibrated);


 // Print values (for debugging)
 Serial.print("X: ");
 Serial.print(xCalibrated);
 Serial.print(" Y: ");
 Serial.print(yCalibrated);
 Serial.print(" Z: ");
 Serial.print(zCalibrated);
 Serial.print(" Magnitude: ");
 Serial.println(magnitude);

 // Check if the magnitude exceeds the fall threshold
 if (magnitude > fallThreshold) {
  triggerAlert();
 }

 // Check if the pushbutton is pressed to simulate airbag
deflation
 if (digitalRead(ventsPin) == LOW) { // Pushbutton pressed
  deflateAirbag();
 }

 delay(100); // Adjust delay as necessary
}

void triggerAlert() {
 Serial.println("Fall detected! Triggering alert...");
 digitalWrite(alertPin, HIGH);
 digitalWrite(airbagPin, HIGH); // Indicate airbag inflation
 delay(1000); // Buzzer on for 1 second
 digitalWrite(alertPin, LOW);
}

void deflateAirbag() {
 Serial.println("Deflating airbag...");
 digitalWrite(airbagPin, LOW); // Turn off airbag indicator
}
```

APPENDIX V AIRBAG FULL CIRCUIT EXPLANATION

Gas Flow and Control System:

- Pin Valve to ACH 27 Hybrid Inflator "Gas Flow Control" - Controls the release of gas from the CO2 canisters to the airbags.
- CO2 Gas Canisters to Pin Valve "Gas Supply" - Provides the gas needed for airbag inflation.
- Flexible Tubing to TPU Nylon Airbags "Gas Transport" - Directs gas from the inflator to the airbags.
- TPU Nylon Airbags to Pressure Relief Valve "Pressure Release" - Releases excess pressure from the airbags to prevent over-inflation.
- Solenoid Valve to Pin Valve "Gas Control" - The solenoid valve controls the opening of the pin valve, regulating the flow of gas to the hybrid inflator.
- Solenoid Valve to Hybrid Inflator "Gas Flow Control" - The solenoid valve manages the gas flow to the hybrid inflator, ensuring proper inflation timing.
- CO2 Canisters to Hybrid Inflator "CO2 Supply" - The CO2 canisters provide the gas needed for airbag inflation. The solenoid valve controls the release of this gas to the hybrid inflator.
- Power Management and Control System:
- Victron VE Battery Management System to Lithium Ion Battery "Power Supply" - Manages charging and discharging of the Lithium Ion Battery.
- Charging Port to Victron VE Battery Management System "Battery Charging" - Connects to the charging port for recharging the Lithium Ion Battery.
- The MOSFET Switch to Hybrid Inflator "Inflator Activation" - The MOSFET switch controls the power to the hybrid inflator, allowing the microcontroller to activate the inflator when necessary.
- Sensor and Feedback System:
- Pressure Sensor to Hybrid Inflator "Pressure Feedback" - Provides feedback to the hybrid inflator to adjust the inflation process based on real-time pressure readings.
- Microcontroller (ADUC7026) to Collision Sensor "Digital Input" - The collision sensor sends an impact detection signal to the microcontroller.
- Microcontroller (ADUC7026) to Pressure Sensor "Analog Input" - The pressure sensor sends analog data to the microcontroller for monitoring and control of airbag inflation.

Communication:

- SIM Card to SIM900 SMS Module "Communication" - Provides the necessary connectivity for sending SMS.
- ISD1820 Sound Voice Recording Playback Module to Speaker and ADUC7026 "Audio Playback" - Plays recorded messages through the speaker, controlled by the ADUC7026.
- Microcontroller (ADUC7026) to MEM Sensor (MPU9150) "Data" - The microcontroller receives motion and orientation data from the MEM sensor.
- Microcontroller (ADUC7026) to ESP32 Bluetooth Module "Communication" - Enables wireless communication between the microcontroller and external devices via Bluetooth.
- Microcontroller (ADUC7026) to GPS Module "DIgital Input" - The microcontroller receives location data from the GPS module.
- Microcontroller (ADUC7026) to SIM900 SMS Module "Communication" - The microcontroller sends and receives text messages via the SIM900 module.
- Microcontroller (ADUC7026) to LEDs "Digital Output" - The microcontroller controls the LEDs for status indication.
- Microcontroller (ADUC7026) to Speaker "Digital Output" - The microcontroller sends signals to the speaker for audible alerts.
- Microcontroller (ADUC7026) to Alarm "Digital Output" - The microcontroller triggers the alarm in emergency situations.
- Microcontroller (ADUC7026) to ISD1820 Sound Module "Digital Output" - The microcontroller triggers the sound module to play pre-recorded messages.
- Microcontroller (ADUC7026) to Diagnostic Port "Diagnostic Data" - Allows external tools to connect to the microcontroller for diagnostics and troubleshooting.

APPENDIX VI PROJECT PLANNING OF COCOON

TERM 1

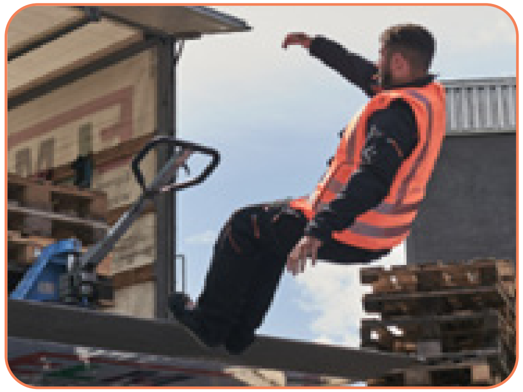
Task	Week Number												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Reading and understanding the major project brief	■												
Statement of intent		■											
Problem Exploration and opportunity identification		■	■										
Stakeholder identification			■	■									
Patient Mapping				■	■								
Literature Review					■	■	■	■	■				
Primary Research – Ethnographic Analysis							■						
Exploring existing solutions					■	■	■	■					
Market Research								■	■				
Patents Research									■				
Legal Considerations									■				
Analysis								■					
Initial concept ideation								■	■				
Concept development									■	■			
Draft Product Design Specification										■			
Initial Prototyping										■			
Interim Submission											■		
Viva Presentation													■

TERM 2

Task	Week Number																			
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Secondary research	■																			
Continued concept development		■	■																	
Technological breakdown			■	■	■															
Feasibility testing						■	■													
Development							■	■	■											
Usability modelling									■											
Refined Product Design Specification										■										
Final design											■									
Design detail												■	■	■						
Manufacture specification													■	■						
Evaluation																			■	
Report Compilation				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Final design package																	■	■	■	■

APPENDIX VII ADDITIONAL IMAGERY

Hövding crash scenario (Hövding, n.d)



SKYVEST fall scenario (SKYVEST, 2024)

Seizure Helmet (Guardian Helmets, n.d)

Epilepsy Helmet (Healthandcare, n.d)

Seizure cap (Ribcap, n.d)

Protective Helmet (RehabMart, n.d)

Epilepsy Helmet (Healthandcare, n.d)

Seizure cap (Ribcap, n.d)

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