ENDURE IN THIN AIR

Master Thesis
in Advanced
Product Design

by Patrick Krassnitzer

UMEÅ INSTITUTE OF DESIGN
UMEÅ UNIVERSITY

supported by

eurac research

THE NORTH FACE

Introduction
Scope 6
Cooperations 8

Research
Field studies 12
Background 18
Statistics and existing solutions 20
Conclusions 22
Goals and wishes 23

Creative Process
Creative workshop 26
Individual ideation 28
Concept directions 30
Evaluation workshop 32
Basic idea 34
Use case 36
Exploration 38
Testing and validation 40
Visual expression 42

Result
Function 48
Vital observation 54
Foldability and stowability 56

Appendix
Timeplan 60
References 62

INTRODUCTION

THE SCOPE
OF THIS PROJECT

Ascending to high altitudes can cause severe threats for the human body. Hypoxia, the lack of oxygen due to a low atmospheric pressure and decreased temperature are the main dangers at great heights.

Millions of people live or travel in elevated areas, means that mountain sickness due to hypoxia is a public health problem. The worst forms of mountain illness, known as high-altitude pulmonary edema and high-altitude cerebral edema, are potentially fatal. (1)
Due to a lack infrastructure and especially bad accessibility it is very challenging to support people with first aid or transport.

Acclimatization is needed to adapt the human body to the environmental conditions that exist in high altitudes. However, especially for unexperienced persons a too fast ascent most likely end with headache, lack of sleep and difficulties to eat.

The aim of this master thesis in Advanced Product Design was to explore the field of hypoxia in extreme altitudes in order to create a product solution that can contribute to overcome this threat and protect people from it.

My focus was on developing a solution even for extreme situations that protects the user in general or helps to treat when she or he is affected.

I started this project with a general approach to mountain safety with the goal to identify diverse opportunities within this field. Therefore, different medical topics appear in the research chapter of this report.

COLLABORATIONS
WHO WAS INVOLVED?

The North Face
Is a North American outdoor company founded 1966 in San Francisco. The company supported me with research opportunities and athlete interviews.

Eurac Research
I held a validation workshop at the Institute of Mountain Emergency Medicine at Eurac Research Institute with Hannes Gatterer, the Head of Research.
The aim of the workshop was to validate the concepts, find and define use cases and get scientific background and support for my ideas.

Mountain Rescue Mellau, Austria
With 25-30 members the Mountain Rescue Mellau is one of many local rescue organizations in Austria. I was able to see their operations center and equipment storage with the rescue car. During two field studies I followed them where they judged the avalanche situation in the ski resort.

Air Ambulance Christopherus 8, Austria
The air ambulance in the state of Vorarlberg is a sub-organization of the Mountain Rescue Vorarlberg. They have two emergency rescue helicopters on two different base stations. I got the chance to visit the Christopherus 8 station in Nenzing.
The air ambulance has very different tasks. They fly missions from mountain rescue to car accidents.
During my talk to Artur Köb, a rescuer and the head of the Christopherus 8 station and one of their pilots, I got very diverse insights into their job and equipment.

Department of Nursing - Umeå University
My contact person at Umeå University was Jonas Aléx. He did his dissertation about: Cold exposure and thermal comfort among patients in prehospital emergency care. I gained a basic understanding of hypothermia and was able to identify opportunities within the field of heat loss of the human body.

Austrian Organization for Alpine and High Altitude-Medicine
The „Österreichische Gesellschaft für Alpin- und Höhenmedizin“ is an Austrian organization which offers a platform for information around alpine and high altitude medicine. I got access to their research archive as well as input to medical questions related to high altitudes and hypoxia

RESEARCH

MOUNTAIN RESCUE
& AIR AMBULANCE

To get input from rescuers point of view I visited the mountain rescue and air ambulance in Vorarlberg Austria. Together those two organizations oversee all accidents that happen in the region of Vorarlberg.

„The most important thing is to bring the doctor to the accident as fast as possible - that is our main mission“ Artur - flight rescuer

The team in an air ambulance helicopter consists of a pilot, a rescuer and a doctor. Priority one of their mission is to bring the doctor as fast as possible to the accident for optimal first aid of the patient.

„The helicopter is a flying hospital - we have all we need“ Artur - flight rescuer

The helicopter is the first choice for serious accidents. It is the fastest way to rescue a patient.

„I am never 100% sure how to treat hypothermia“ Thomas - rescuer

Thomas explained that the treatment of hypothermia patients is a tricky situation due to the different stages of hypothermia. It is hard to identify the stage of coldness the patient might be in. Also, the first aid is very different according to the degree of coldness. A mild hypoxia can be treated with insulation while severe hypoxia is life-threatening and requires correct positioning and rewarming actions.

“Education is the best protection“ Hans - mountain rescuer

Means that education and preparation in advance is a good protection against alpine risks. And many accidents happen because of a lack of experience,

Andreas Rüf - mountain rescuer

Hans Schwarzmann - mountain rescuer

Artur Köb - flight rescuer

Air Ambulance Christopherus 8 station, Nenzing Austria

Jim Morrison and Hilaree Nelson, Athletes, The Nort Face

HILAREE NELSON & JIM MORRISON
PROFESSIONAL MOUNTAINEERS

During my interview with Hilaree and Jim I had the opportunity to gain insights about the hostile situation in extreme altitudes. They also explained their methods on how to manage the lack of oxygen, the cold and the risks. Altogether this helped me to imagine the situation in high altitudes.
The following represents a few of many quotes and insights I gathered during the talk:

„The brain is not firing any more - it is also a mental issue“ Hilaree

They pointed out that the mental capacity decreases due to the high altitude. Which makes it hard to avoid failures and to take clear decisions. Every mental and physical effort takes a lot of energy. This needs to be considered in the product design. The solution must be intuitive and failsafe.

„I found out that I am good at high altitudes and that is basically genetics. Small things count - I sleep better than others and I can eat at high altitudes - so I have more energy “ Hilaree

Acclimatization has a lot to do with genetics. Some people adapt better to heights then others. People with poor adaption don´t sleep good, freeze more and have problems to eat. Improving things like those could help to preserve energy which in turn helps to avoid mountain sickness and other risks.

„Hypothermia and Hypoxia relate to each other - when you take the oxygen you can feel that your arms get warm“ Jim

Hypothermia and Hypoxia affect each other. People who freeze need more oxygen and in other words, a higher oxygen intake can help to avoid cold.

„It is cold... sooo cold. On Everest we had -50C. You freeze but at the same time you feel claustrophobic - you have 10 layers of clothing, googles, helmet, oxygen...“ Hilaree

A lot of gear is needed to manage the extrem situation in high altitudes. Unifying and simplifying would help to interact with the equipment. A better temperature adaption of the insulation could also help.

„The cold is everywhere - If you take your goggles off, your eyes freeze and you are blind - if you take your gloves off, you get frostbites and you can not control your oxygen any more“ Hilaree

They pointed out that small failures can lead to great risks. Another big cause of errors, next to the mental capacity is the cold.

DR. HEIDI KAUFMANN & JONAS ALEX Ph.D.
MEDICAL EXPERTS

After the interviews with the rescuers and athletes I had the chance to get input from medical experts. Heidi Kaufmann is a mecidal doctor in Mellau, a village with a lot of winter sport tourism. Jonas Alex works at the Department of Nursing at Umeå University and is an expert on Hypothermia.

„Hypothermia - There are pads but they get so warm that people immediately start to sweat - there should be something to regulate the temperature“ Heidi

In consideration that there are different levels of hypothermia and that every person reacts different, the temperature for hypothermia rewarming should be adjustable. Furthermore, insulation also lacks adaption to environmental temperature. Active heat sources could be considered in this case.

„Hypothermia is a underrated medical topic“ Jonas

Jonas pointed out that a better heat care of patients especially in pre-hospital care could be sustainable in many cases. For example, patients who freeze need more oxygen and medication to rewarm. Also, the healing process of people with fractures takes longer when they shiver during transport.
In other words, freezing means using a lot body energy to rewarm.

„Hypoxia - take a look at acclimatization - how to simplify that“ Heidi

One good input from Heidi was to tackle the problem of hypoxia earlier in the preparation phase. This could avoid mountain illness already in advance and reduce risks on the mountain.

Dr. Heidi Kaufman, medical doctor, Mellau Austria

Jonas Alex Ph.D., expert on hypothermia, Department of Nursing at Umeå University

(A)

HYPOXIA IN HIGH ALTITUDE
BACKGROUND

Hypoxia
The total atmospheric pressure decreases nearly exponential as one ascends from sea level. This decrease of atmospheric pressure causes a lower partial pressure of the blood oxygen which is defined as hypobaric hypoxia. (2)

Sea Level	Air Pressure
0 m	100 %
65 m - Umeå	99,2 %
2106m - Kebnekaise	80,2 %
4810 m - Mont Blanc	53,9 %
8848 m - Mount Everest	32,1 % (3)

Environmental conditions become increasingly hostile for the human body with progressive ascent. This requires greater degrees of behavioral and physiologic adaptation to preserve function and long-term survival. (2)

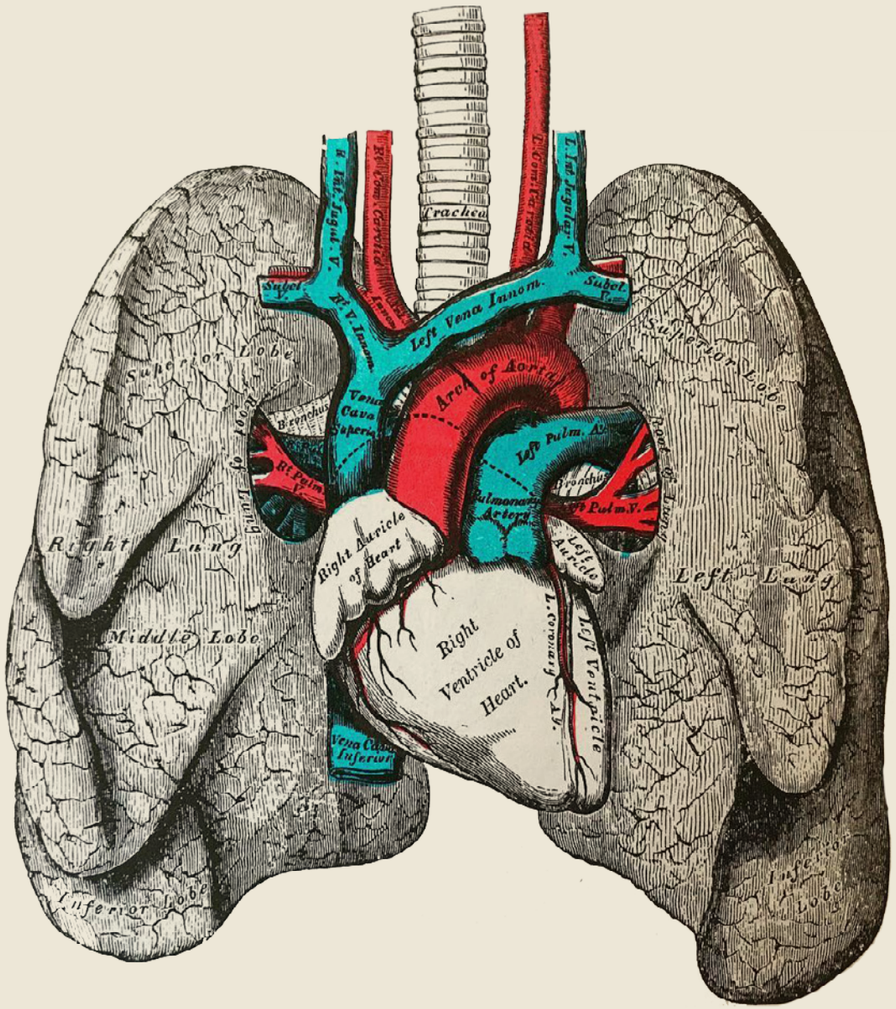
Acclimatization
Acclimatization is the process by which people adjust to altitude hypoxia. The body makes a series of adjustments, which increase the delivery of the available oxygen to cells and increase the efficiency by which that oxygen is used. The most important component of acclimatization is an increased rate and depth of breathing and this occurs relatively rapidly. (4)

High-altitude illness
The term high-altitude illness is reserved for three unique cerebral and pulmonary maladies that develop over hours to days at high altitude as a result of acute exposure to hypobaric hypoxia: acute mountain sickness (AMS), high-altitude cerebral edema (HACE), and high-altitude pulmonary edema (HAPE). (2)

Acute Mountain Sickness (AMS)
AMS is defined by the presence of a headache and at least one of the following symptoms after a recent increase in altitude: loss of appetite, nausea, vomiting, fatigue, weakness, dizziness, light-headedness or sleep disturbance. Rapid ascent to altitudes above 2500m will frequently cause AMS. Symptoms appear 6 - 12 hours after ascent, and usually resolve within three days if further ascent does not occur.
The major concern in identifying AMS is that it might progress to life threatening HACE or HAPE. (5)

High-Altitude Cerebral Edema
HACE can cause death because of brain herniation. (1)

High Altitude Pulmonary Oedema
HAPE accounts for most deaths from high-altitude illness and is caused by fluid retention in the lung. (6)



140 mio. people live **above 2500m** and **25 mio.** live **above 3500m** sea level. (7)

Handbuch der Trekking und Höhenmedizin

HYPOXIA IN HIGH ALTITUDE
STATISTICS AND EXISTING SOLUTIONS

Millions of people live or travel in elevated areas, meaning that mountain sickness due to hypoxia is a public health problem. 200.000 trekking and climbing tourists visit Nepal each year.(7)

Especially in extreme altitudes the accessibility is a problem. Evacuation of people affected to mountain sickness is almost impossible.

"There is not much to do about it - you need to get down as fast as possible" Hilaree and Jim, Atlethes, The North Face

There are existing product solutions which contribute to overcome mountain sickness but due to their bulkiness or bad usability, they are difficult to apply in situations up on the mountain.

Respiration treatment
Respiration support with medical oxygen can help to overcome mountain sickness and allow the patient to descent or enables transport. However supportive oxygen is often not available since it is mainly used as hypoxia protection in heights at 7000m and higher.


(A)

Pressure treatment
Pressure treatment can simulate a descent to lower elevation and can therefore temporary cure mountain sickness. The problem is that those pressure chambers are heavy and bulky and cannot be brought up to the mountain where they are most needed.
Furthermore, Pressure treatment is quite complicated and needs education.


(B)

RESEARCH
CONCLUSIONS

Existing solutions/Tools
Nowadays, treatment of hypoxia takes place mainly by medication which can help to a certain point. Hypobaric chambers are heavy and not designed for transport. They are not very common due to accessibility and this solution cannot be brought up to extreme altitudes.
A portable or wearable hypobaric solution could help to protect the user from low air pressure situations. A solution to temporarily overcome hypoxia and support people to descent to lower levels in emergency situation could have a great impact and save lifes.

In terms of hypothermia, active heat sources could be considered more often to accumulate heat. A better temperature regulation could also contribute to contain the body energy.

High performance and reliability
Due to the decreased mental capacity in high altitudes and outer conditions the product solution must be intuitive and failure proof. Errors can have fatal consequences. Less touchpoints and reduced interaction can help to avoid errors.

Integrated product solution
During interviews it turned out that an overload of equipment makes it complicated to interact with the gear. An integrated solution could help in this case.
Anyway, the high amount of gear must be considered in the concept and prototyping phase to make the product not interfere with other equipment.

Preparation is key
In fact that the human body can adapt to high altitudes, an assisting product solution in the acclimatization phase could have a big impact.
A product could support, inform and sensitize people before the ascent and thereby avoid dangerous situations.

Accessibility
Since transport is always an issue in mountain areas the solution must be lightweight and stowable.

GOALS
& WISHES

What?
A solution that helps people to deal with high altitude dangers known as hypoxia or hypothermia.

Why?
The interviews stated out that there is a need of supportive solution for high altitude protection and medicine.

Who?
Preferable for mountaineers but could also be for trekkers, rescuers and sherpas.

Where?
In classic outdoor environment but also in tough weather situations.

Goals
Create a protective atmosphere for people exposed to altitude dangers.
Ease the transport and preparation of the equipment.

Create a design which can fulfill the high demands caused by extreme weather conditions.

Wishes
Sensitize and help people to prepare better for high altitudes.

Include users and experts in the process as much as possible to achieve a feasable solution.

Express the brand values and strategy of the collaboration company in the product design.

CREATIVE PROCESS

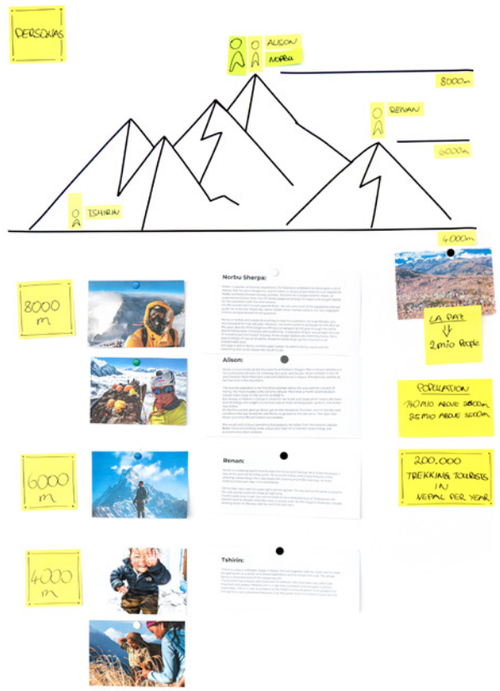
CREATIVE WORKSHOP
HOW MIGHT WE...?

A one-hour brainstorming session with my creative classmates led to 91 ideas regarding to the following topics:

How might we **protect people from low oxygen** situations?

How might we **enhance rescue/first aid in high altitude** areas?

How might we **improve the body awareness** of mountaineers?

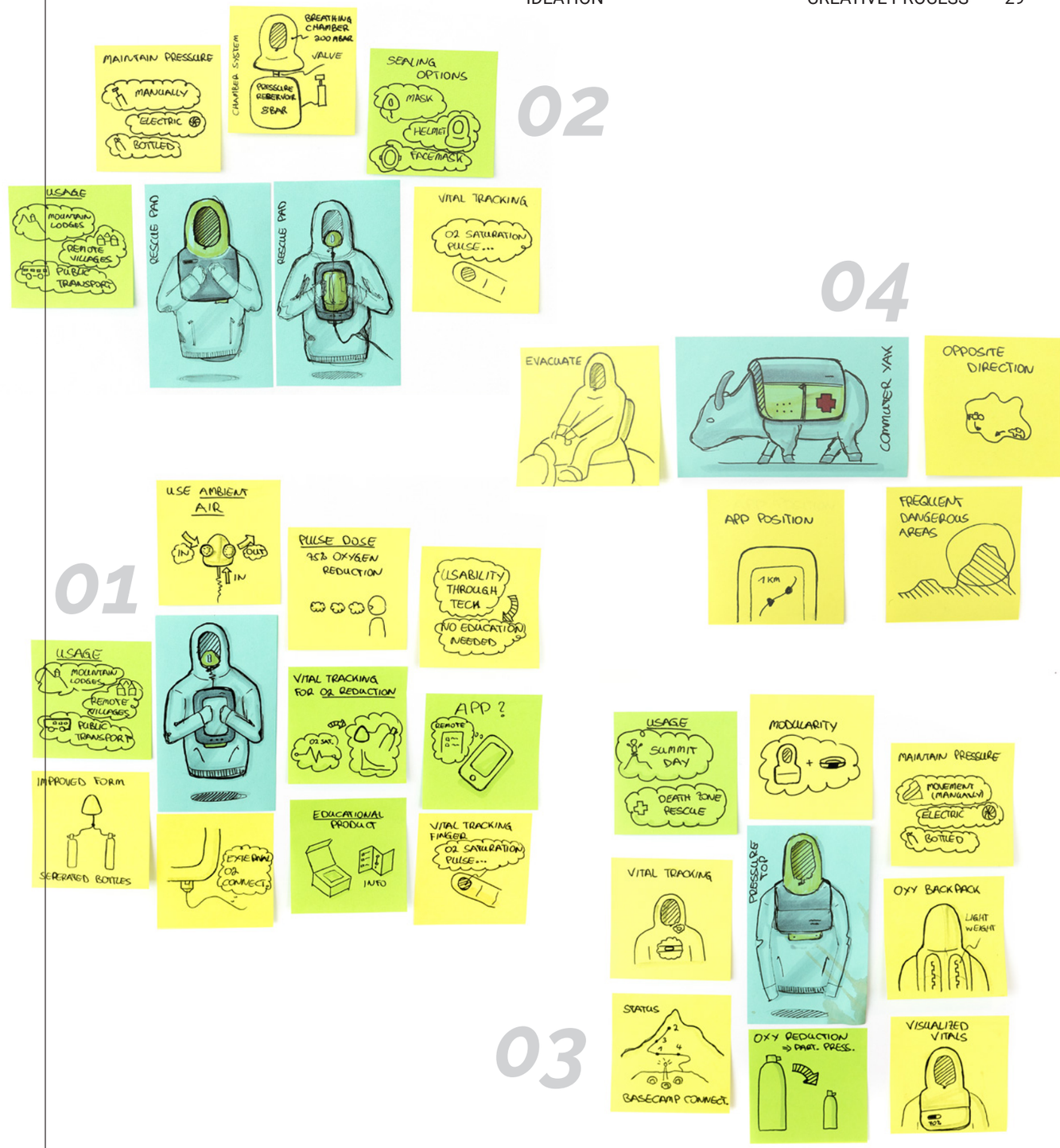


INDIVIDUAL BRAINSTORMING
USER JOURNEYS AND EARLY SKETCHES

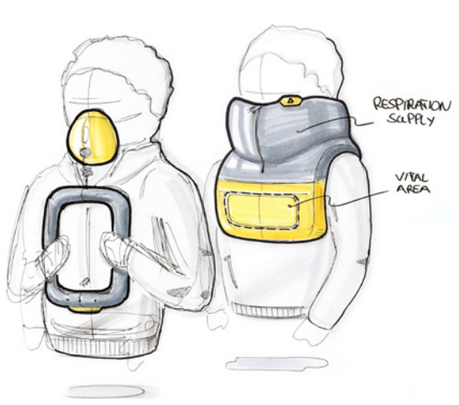
Based on input from the „How might we“ workshop and individual brainstorming, I started to cluster ideas, form early concepts and define the ingredients for possible product solutions.
Storyboards were created to visualize use cases and understand the context which the product would be used in.

The topics of the brainstorming were:

- **Respiration support**
- **Hypoxia treatment**
- **Accessibility in remote areas**
- **Hypoxia awareness**



CONCEPT
DIRECTIONS



01

A portable and intelligent respiration support unit for an intuitive hypoxia treatment, protection and vital observation.

Optimized O2 bottle sizes for hypoxia treatment can help to make the device portable. Smart oxygen regulation linked to vital data could make the product small, intuitive and could replace the need of education.

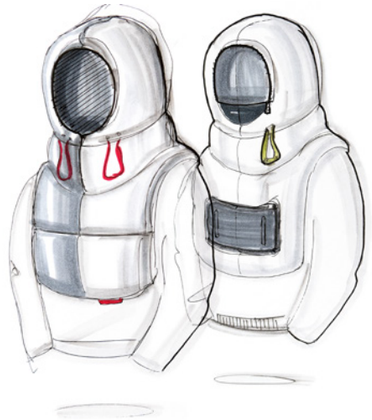
Use case: High altitude villages, mountain lodges, high altitude airports, busses, hotels and maybe also as support for trekking tourists.

02

A portable pressure unit for hypoxia treatment and vital observation in extreme altitudes.

Pressure treatment simulates a descent to lower elevation and can therefore temporary cure mountain sickness and pulmonary edemas. Instead of the existing closed chambers all around the body, a small pressure atmosphere around the mouth and nose would allow a way more convenient treatment and would make the device portable and allow transport of the patient.

Use case: On hikes or climbs in heights of 5000m and higher.



03

A portable and self-adjusting pressure unit to create a protective atmosphere against hypobaric hypoxia in altitudes 7000m+.

A pressure atmosphere can simulate lower elevations and therefore protect from hypoxia in extreme altitudes. This solution could replace oxygen support climbers to reach the summit and solve the logistic challenges caused by oxygen bottles.

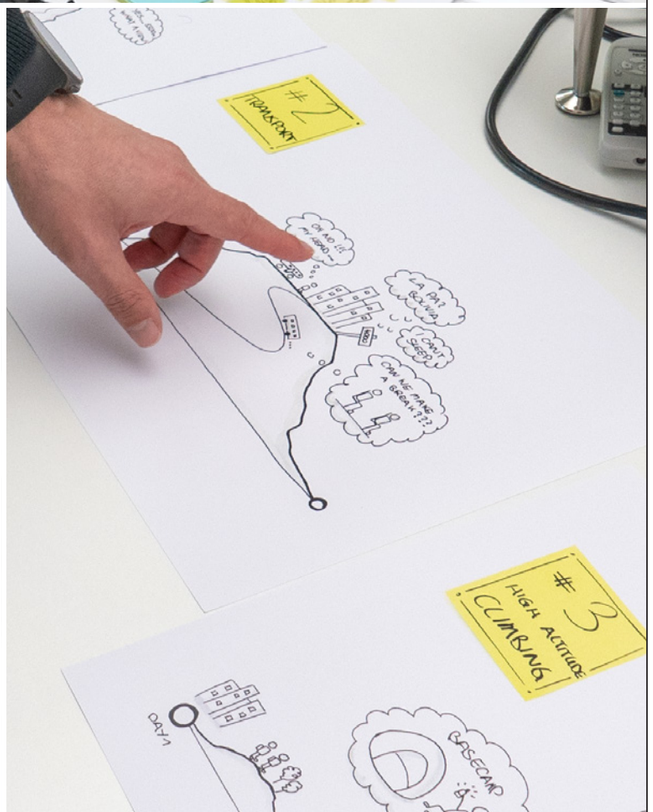
Use case: For climbs and rescue situations in altitude 7000m+.

04

A paramedic saddle for animals in the Himalaya area to make medical care accessible to tourists and inhabitants.

Accessibility is in general a problem in high altitude areas due to a lack of streets and infrastructure.
Creating a paramedic saddle for animals to transport and supply with medical care could help to realize a system which could be affordable and supplementary to helicopters.

Use case: High altitude regions in Himalaya or Andes



EVALUATION WORKSHOP
HANNES GATTERER PH.D.

After the ideation phase I went to Bolzano, Italy for an evaluation workshop. I met Hannes Gatterer, the lead researcher at the Institute of Mountain Emergency Medicine at the Eurac Research Institute.

The aim of the workshop was to validate the concepts, find and define use cases and get scientific background and support for my ideas.

01 ***„Oxygen support has proven its reliability - It is used for prevention and treatment and relatively easy to use. I could imagine that a smart respiration device like this would be recommended by physicians as hypoxia treatment or prevention tool of choice“***

02 ***„I would recommend the portable pressure unit to use in altitudes of 5000m and higher. The scientific background is not as strong as for oxygen support. This solution would cause more discussion but it is an interesting direction“***

A main benefit of pressure treatment is that it can contribute to overcome Pulmonary Edemas.

04 ***„As a concept the commuter yak could have big impact. The medical system in high altitude areas is not advanced and this could show a way in the right direction“***

Hannes mentioned that horses and yaks are used to transport tourists up to passes and basecamps in the Himalayan region for an unreasonable amount of money. But there is no system yet to use those animals for medical support and paramedic transport.

Continous positive airway pressure helmet which is used in hospitals.

BASIC IDEA
SCIENTIFIC BACKGROUND

My basic idea was to create a sealed pressure chamber around the mouth and nose. This would allow the patient to breathe pressurized air which in fact simulate a descent to a lower elevation and increases the oxygen saturation in the blood.

The pressure would be created manually with an air pump. A second air chamber would be used as a pressure reservoir and a valve in between the two chambers would maintain a constant pressure on the patient's lung. Instead of a closed chamber all around the body, this small and portable pressure atmosphere allows a way more convenient treatment and ensures the portability of the device.

The papers to the right support this basic idea and show that the oxygen saturation can be increased significant by breathing pressurized air. Studies also show that continous positive airway pressure has positive effects on Pulmonary Edemas.

Clin J Sport Med • Volume 19, Number 1, January 2009

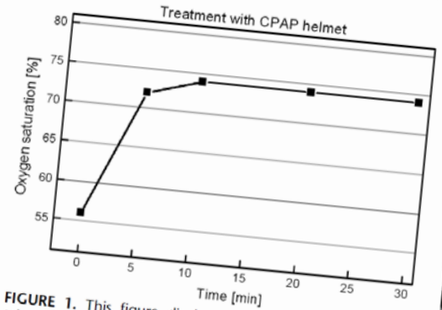


FIGURE 1. This figure displays the course of the oxygen saturation before and during 30 minutes of treatment with continuous positive airway pressure (CPAP) helmet.

results, it is tempting to speculate that the use of a CPAP helmet might be useful in the treatment of HAPE.

FIGURE 2. This photo shows a 52-year-old mountaineer suffering from high-altitude pulmonary edema (HAPE) who is treated with a continuous positive airway pressure (CPAP) helmet on Lenin Peak at 5300 m. Oxygen saturation was initially 56%, and the Lake Louise Score was 13 of 15 points.

(8)

High Altitude Pulmonary Edema and Exercise at 4,400 Meters on Mount McKinley*

Effect of Expiratory Positive Airway Pressure

Robert B. Schoene, M.D.; Robert C. Roach, M.S.; Peter H. Hackett, M.D.; Ginette Harrison, M.B., Ch.B.; and W. J. Mills, Jr., M.D.

Breathing against positive expiratory pressure has been used to improve gas exchange in many forms of pulmonary edema, and forced expiration against resistance during exercise has been advocated for climbing at high altitude as a method to optimize performance. To evaluate the effect of expiratory positive airway pressure (EPAP) on climbers with healthy subjects. The HAPE subjects demonstrated an increased SaO_2 percent, no change in HR or $\dot{V}_I$, and a decrease in RR on EPAP as compared to control. In normal subjects, SaO_2 percent, $\dot{V}_I$, and heart rate were significantly higher on EPAP 10 cm H_2O than 0 cm H_2O control ($p<0.01$, 0.01, and 0.05, respectively). The RR and $PaCO_2$ were not

(9)

CPAP-Anwendung verbessert die Oxygenierung in normobarer und hypobarer Hypoxie

Robert Koch[1], Evelyn Punter[2], Hannes Gatterer[2], Markus Flatz[2], Martin Faulhaber[3] und Martin Burtscher[2]

[1]Klinische Abteilung für Gastroenterologie und Hepatologie, Universitätsklinik für Innere Medizin, Medizinische Universität Innsbruck, Innsbruck, Österreich
[2]Institut für Sportwissenschaft, Universität Innsbruck, Innsbruck, Österreich

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Application of CPAP improves oxygenation during normobaric and hypobaric hypoxia

Summary. This pilot project was performed to investigate the possible application of a portable CPAP helmet (continuous positive airway pressure) to treat high altitude diseases. Arterial oxygen saturation increased from 80.6 ± 3.4 % to 90.6 ± 3.8 % ($p < 0.01$, $n = 14$) when using the CPAP helmet (PEEP (positive endexpiratory pressure): 10–15 cm H_2O) in normobaric hypoxia (F_IO_2 12.9 ± 0.4 %, corresponding to about 4300 m). Furthermore arterial oxy-

von 80,6 ± 3,4 % auf 90,6 ± 3,8 % erhöht werden ($p < 0,01$, $n = 14$). Auch in natürlicher Höhe (3150 m) wurde nach 20-minütiger Anwendung ein Sättigungsanstieg von 88,1 ± 1,9 % auf 93,5 ± 3,0 % ($p < 0,01$, $n = 11$) beobachtet. Es bestand ein Zusammenhang in den $PaCO_2$- und Sättigungsveränderungen unter CPAP ($R = -0,97$, $p < 0,01$, $n = 6$). Weitere Studien in diesem Bereich müssen die Wirksamkeit und deren Mechanismen bei Höhenerkrankungen sowie die praktische Anwendbarkeit unter extremen Bedingungen klären.

(10)

USE CASE
CONTEXT

The product is dedicated for use on expeditions, climbing and trekking in altitudes higher then 4500m. The Product can be brought all the way up to camps or even to the summit and can support patients with medical treatment in severe situations.

Additionally, the device could be placed in spots with high risk of hypoxia like high altitudes accommodations, basecamps or cable car stations.
The picture to the right shows a person with a severe stage of mountain sickness. The device could be operated by his climbing partner and directly help to overcome this life-threatening situation.

(A)

(B)

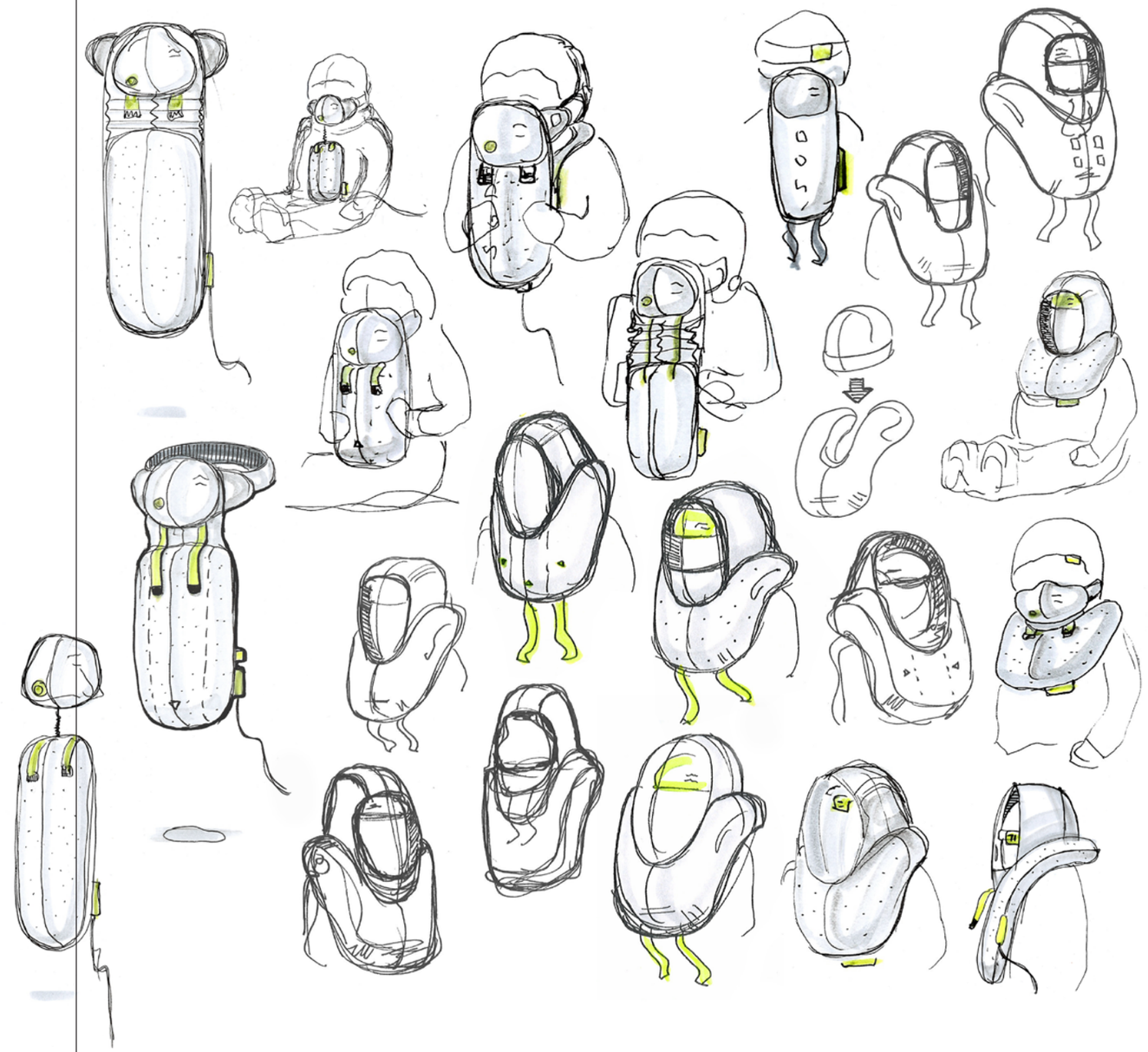
EXPLORATION
SKETCHES AND PROTOTYPES

How might a portable air pressure treatment device for extreme altitudes look like?

The exploration phase was characterized by a mix of investigative sketches and prototyping with soft foam. This allowed me to try out ideas early in the process an get an understanding of feasibility, proportions and the position of split and welding lines.

The prototypes also allowed me to test in real time and get valuable feedback in discussions with classmates, tutors and experts.

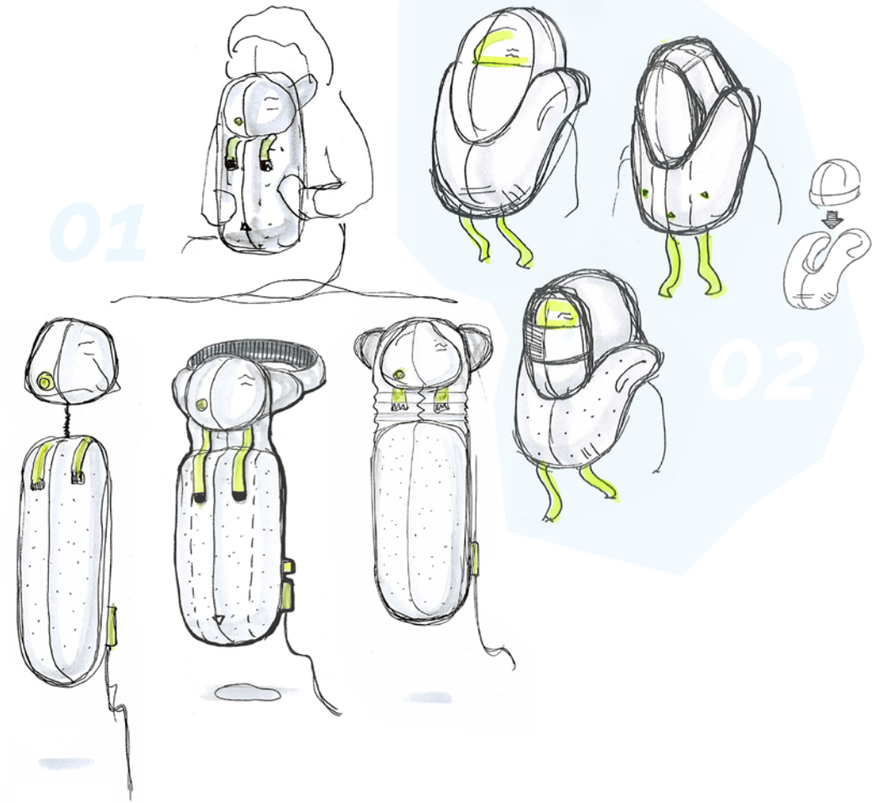
1:1 scale prototypes



TESTING
AND VALIDATION

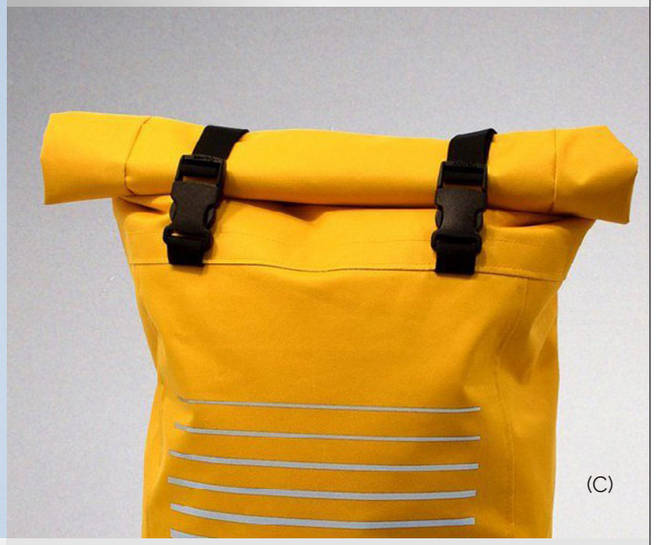
After the ideation phase I was at a „cross road“ and had to decide if I would continue with a mask or a helmet based archetype.
Tests on mannequins and people showed that the mask is easier to attach and interferes less with existing mountaineering gear.
Interviews with my classmates stated out that most people experience the mask as more convenient in an emergency situation.

Personally, I was more convinced with the helmet solution but since the arguments were stronger for the mask archetype I went on with that solution.




ACTIVE
(A)

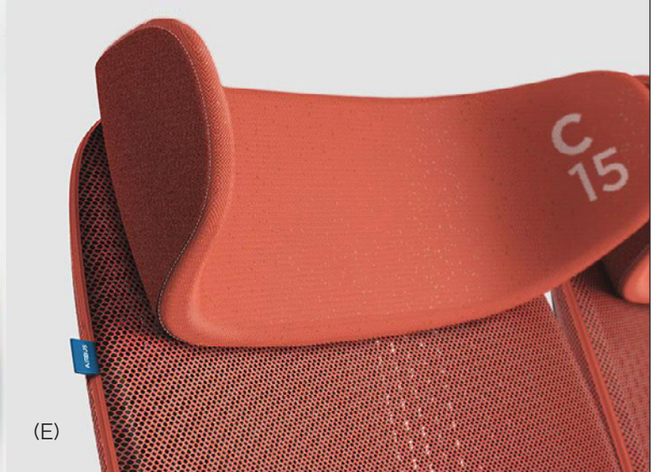

INVITING
(B)


(C)

INSTRUCTIVE

(D)

PROTECTIVE



(E)

VISUAL
EXPRESSION

The visual aim for the product was a simplistic, inviting, gender and age neutral primary shape. Instructive graphics should guide the user and assist the usability. Functional details create the outdoor look and feel. Colorwise the product should express the emergency situation it is used in. A high visibility will support the usability in those severe situations.
Contrast colors mark the interaction points. A simple dot display shows the current oxygen saturation of the patient.

The product appearance should meet in between of a medical emergency device but also of an outdoor product.

RESULT

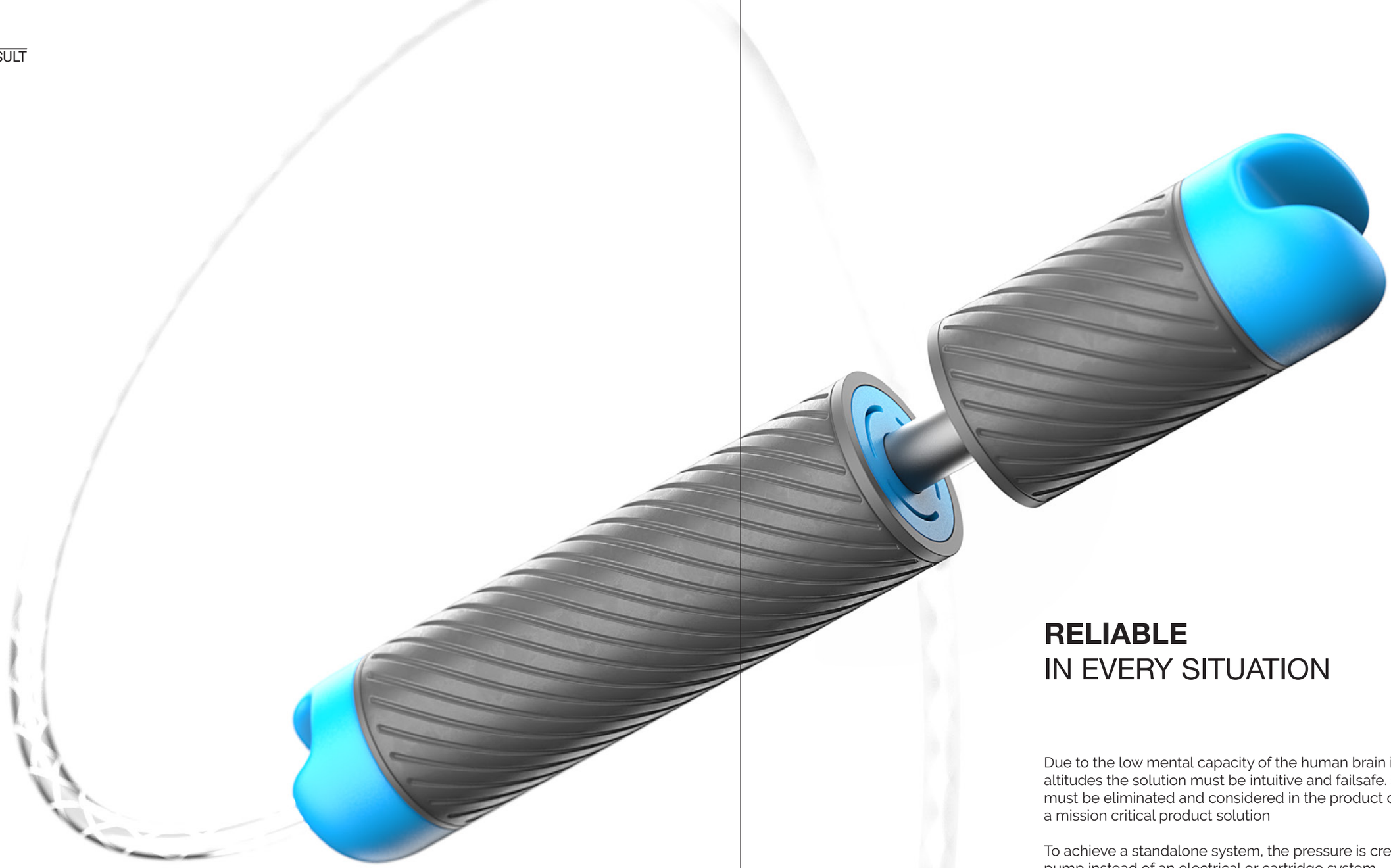
VNT

Vento is a continuous positive airway pressure mask designed for emergency hypoxia treatment in extreme altitude conditions.

The product enables an intuitive and standalone hypoxia treatment and vital observation even in rough environmental situations. Pressure treatment increases the oxygen saturation, simulates a descent to lower elevation and can therefore temporary cure mountain sickness and pulmonary edemas.

FUNCTIONAL
PRINCIPLE

The air pressure is maintained by a mechanical pump which is connected to an inflatable pressure reservoir. A pressure valve between the reservoir and the mask regulates the pressure on a constant level. Sensors track the blood oxygen saturation and the heart rate of the patient. The display in the front showes the important data about the patients health progress.



RELIABLE
IN EVERY SITUATION

Due to the low mental capacity of the human brain in extreme altitudes the solution must be intuitive and failsafe. Sources for errors must be eliminated and considered in the product design to achieve a mission critical product solution

To achieve a standalone system, the pressure is created by a manual pump instead of an electrical or cartridge system.

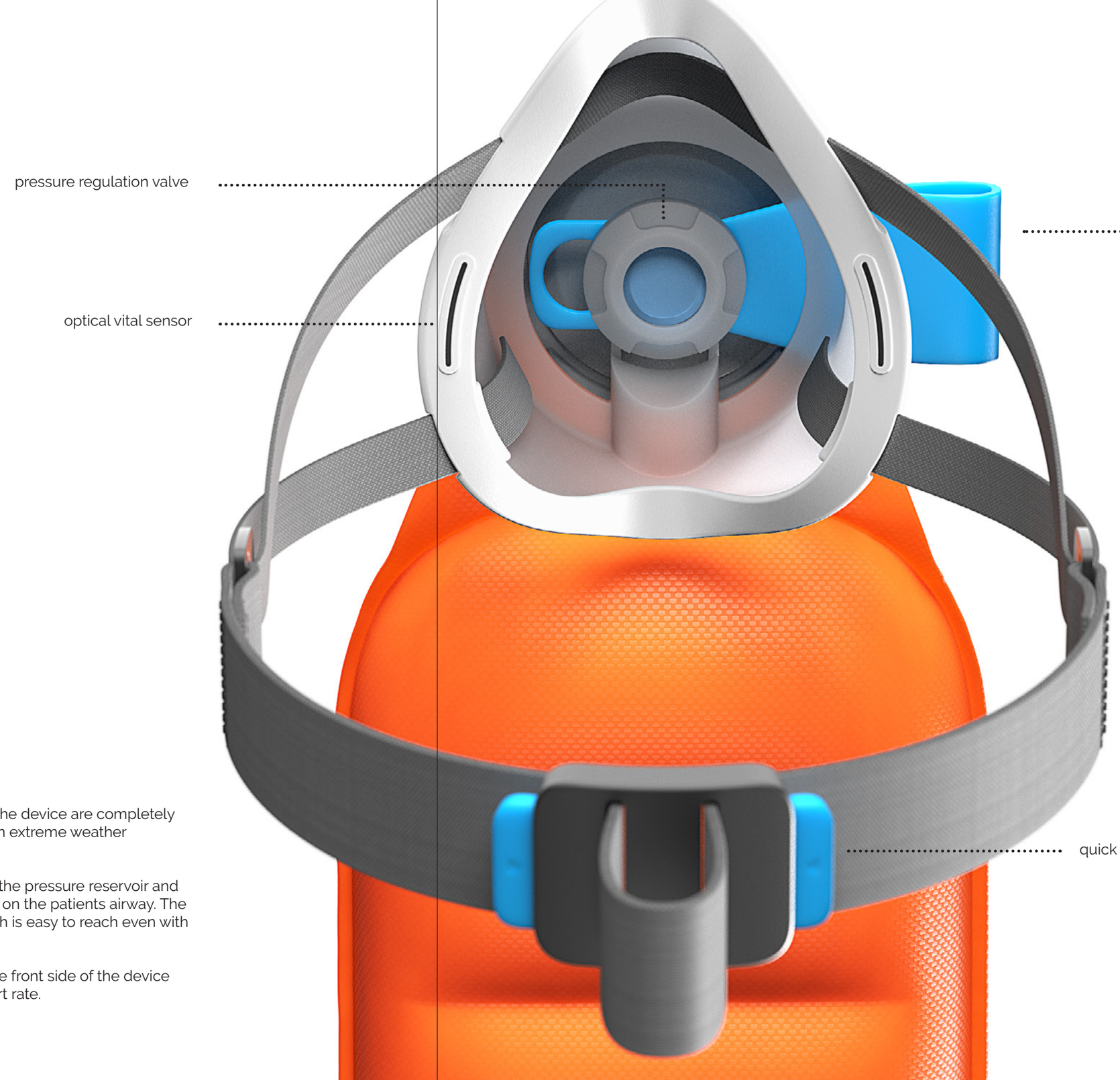
An ergonomic size and grip areas ensure a pleasant usability for the operating person.

RELIABLE
IN EVERY SITUATION

Apart from the vital observation, the functions of the device are completely mechanical to assure the highest reliability even in extreme weather conditions.

A mechanical pressure regulation valve between the pressure reservoir and the mask ensures constant 200 mbar air pressure on the patients airway. The valve can be activated by an activation strap which is easy to reach even with gloves.

Two optical vital sensors provide the screen on the front side of the device with data about blood oxygen saturation and heart rate.



VITAL
OBSERVATION

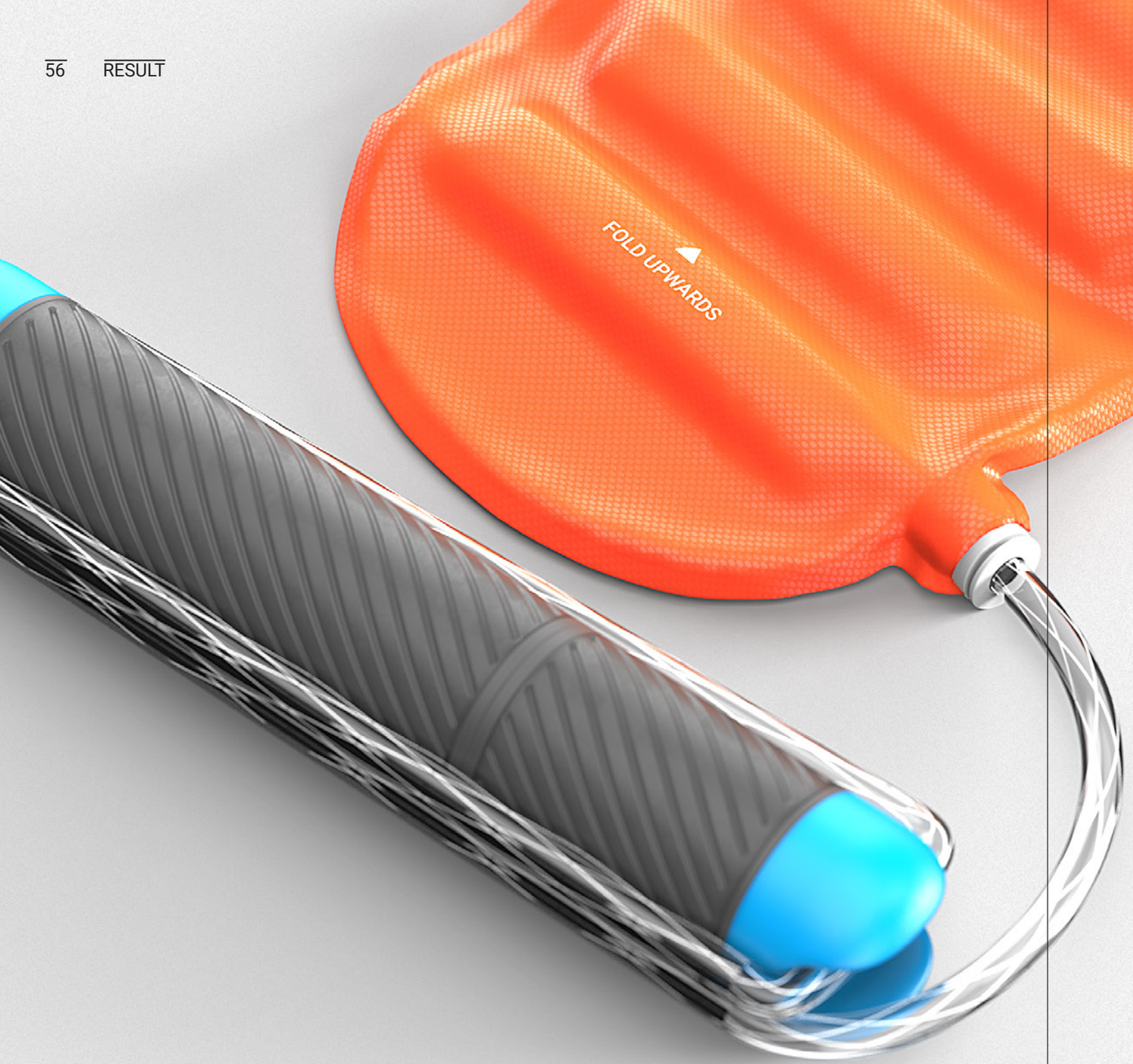
The research stated out that a vital observation is important for a successful hypoxia treatment.
The interface is realized with an energy saving dot matrix display on the front of the device and two optical vital sensors on the inside of the mask. The sensors gather information about the blood oxygen saturation and the heart rate of the patient, which is alternately displayed on the screen. Moreover, the progress in oxygen saturation since the beginning of the treatment is shown on the intuitive interface.

The low energy display is powered by a watch battery to keep the device lightweight.

MODULAR
FRONTPART

As an alternative version the device can be purchased without interface. In that case the product is a completely mechanical solution. The blood oxygen saturation and the heart rate can alternatively be measured and displayed by an oximeter if the customer prefers. Also, more and more smart watches and apps for high altitude activities incubate those functions.

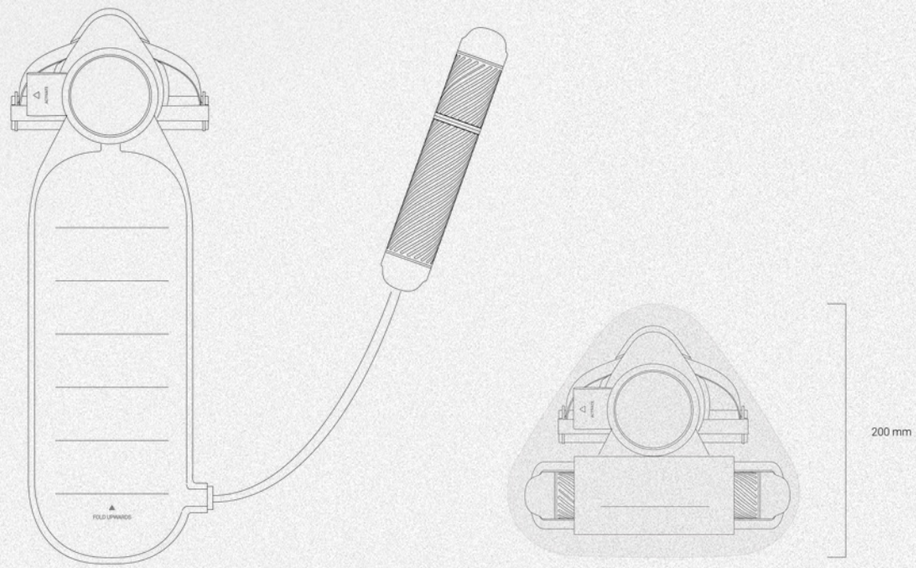
For best usability and visibility in emergency situations the product version with interface provides a tailormade and more intuitive interaction.



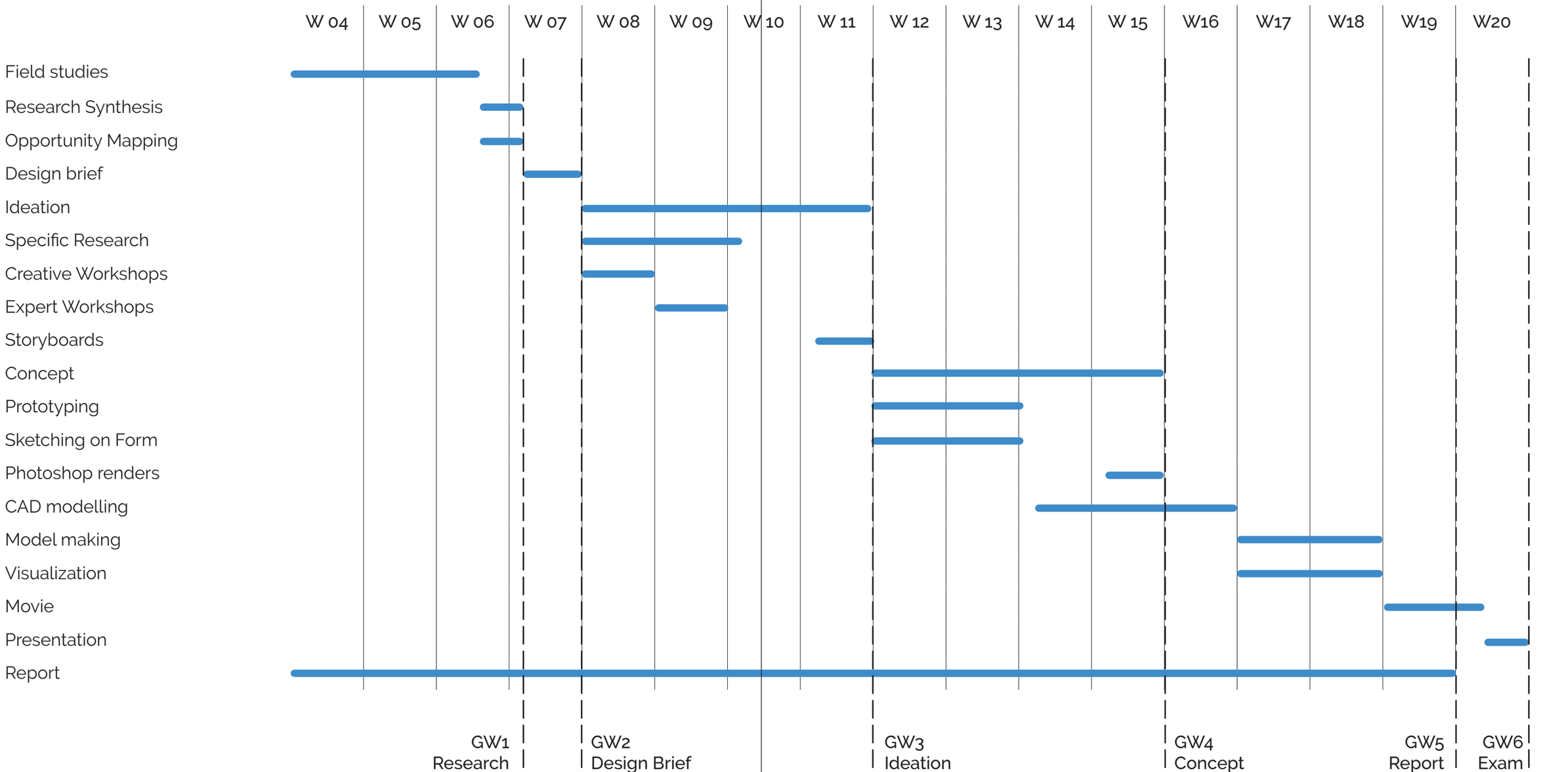
FOLDABLE
AND STOWABLE

As an outdoor device, Vento is light and space saving. Due to the inflatable pressure reservoir and the flexible air tube the product can be folded to very a small size. This ensures that the device can be brought even up to the highest peaks on earth.

Packed in a soft shell packaging the product will only have a size of about 200mm x 200 mm and can easily be stowed in any backpack.



APPENDIX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Field studies
Research Synthesis
Opportunity Mapping
Design brief
Ideation
Specific Research
Creative Workshops
Expert Workshops
Storyboards
Concept
Prototyping
Sketching on Form
Photoshop renders
CAD modelling
Model making
Visualization
Movie
Presentation
Report
GW1
Research
GW2
Design Brief
GW3
Ideation
GW4
Concept
GW5
Report
GW6
Exam

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Interviews

Artur Köb, Arno Scheiber (Air Ambulance, Nenzing, Austria), Hans Schwarzmann, Andreas Rüf, Thomas Natter, Guntram Felder (Mountain Rescue, Mellau, Austria), Hilaree Nelson, Jim Morrison (Athletes, The North Face), Dr. Heidi Kaufmann, Jonas Alex Ph.D. (Medical Expert Hypothermia, Umeå University), Ralph Zündel (Trekker), Hannes Gatterer Ph.D. (Medical Expert Hypoxia, Eurac Research, Bolzano, Italy)

Visuals

Cover	Christopher Burns [image] Available at: https://unsplash.com/photos/NBr-AjfKVD4 [Accessed 19. Feb. 2019]
page 7	https://trvl.com/nepal/alone-in-the-himalayas-of-nepal [Accessed 19. Feb. 2019]
page 17	image by Pontus Edman [22. Feb. 2019]
page 19	https://www.jestpic.com/medicalillustrations [Accessed 19. Feb. 2019]
page 20	https://boomerang-reisen.de/lateinamerika/bolivien/urlaub [Accessed 02.Aug. 2019]
page 21	(A) http://mitchj.info/suggest/altitude-illness-prevention-amp-treatment-mountaineers.html [Accessed 02.Aug. 2019] (B) https://thermarestblog.com/2019-summer-dream-team [Accessed 02.Aug. 2019]
page 36	(A)https://www.outdoorfederation.com/amazing-outdoor-survival-stories-in-history [Accessed 02.Aug. 2019] (original) (B) https://www.instagram.com/p/BuESSZVhZOg [Accessed 02.Aug. 2019]
page 42	(A) https://www.behance.net/gallery/75163589/Libratone-TOO [Accessed 02.Aug. 2019] (B) https://www.behance.net/gallery/64224783/Yolk-in-the-cloud [Accessed 02.Aug. 2019] (C) http://wheretoget.it/look/5819391 [Accessed 02.Aug. 2019] (D) http://oukas.info/?u=China+Lifejacket+manufacturer+The+Inflating+Boat+Tent [Accessed 02.Aug. 2019] (E) https://travel.nine.com.au/recommended/revolutionary-travel-seat-economy/00b75531-c7bb-466e-b9fa-bc32aebd2f72 [Accessed 02.Aug. 2019]
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