

four degrees

by Oskar Daniel 2009

Master thesis form Lund University

Industrial design / LTH

Department of Design Sciences



LUND UNIVERSITY



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Supervisor: Guest lecturer Charlotte Sjödel
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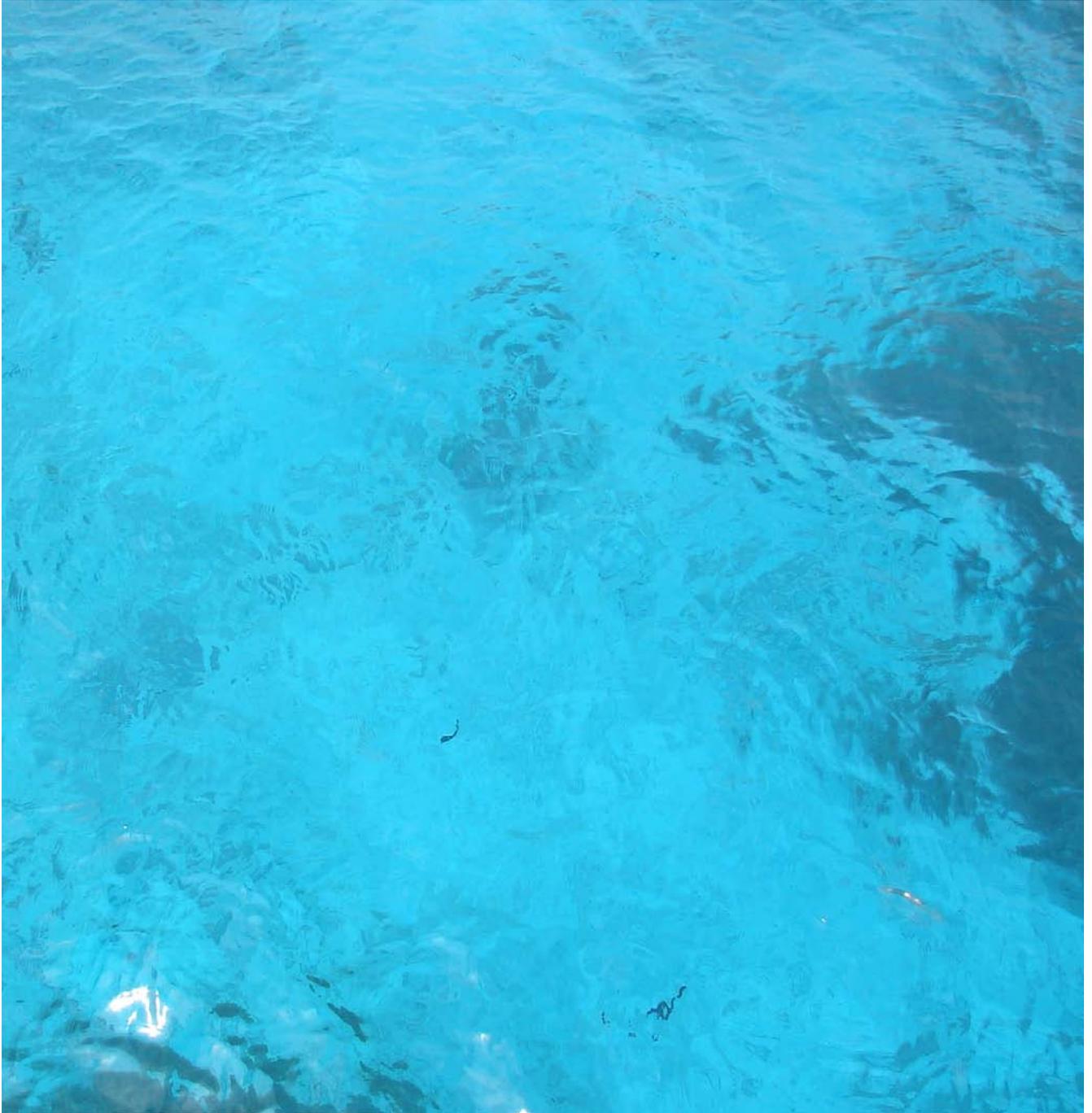
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Abstract

The aim of this project is to investigate whether scuba diving equipment can be made safer and more attractive for new divers. The thesis shows that most accidents occur because of poor equipment checks and misused equipment. This problem is the main concern of the thesis.

The resulting product, 4° (Four Degrees), is a buoyancy compensating vest with a focus on safer diving, non-complex appearance and easy use.

Summary

The aim of this project is to investigate whether scuba diving equipment can be made safer and more attractive for new divers.

The intention is to create a concept that is technologically plausible within the next few years, and within the scuba diving community's demands for lo-tech, reliable products.

By reading accident reports, studies concerning scuba diving accidents, books on safe diving and scuba diving manuals, it is proven that many incidents are caused by mistakes that easily could have been prevented. Through user observations common flaws in scuba gear are found, as well as common mistakes divers make when using the equipment.

The resulting product, 4° (Four Degrees), is a buoyancy compensating vest, that solves many of the problems that often lead to accidents, such as poor equipment check, unintentional weight dumping and poor awareness of remaining air. The vest is also aimed at a market gap between minimalistic equipment with an experienced target group and hi-tech equipment aimed at new divers. 4° is rather an attempt to attract new divers with its lo-tech looks, easy use and its safety features.

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Table of definitions

Bar

Unit of pressure. 1 bar = 1 atmosphere.

BC

Buoyancy compensator, compensates change in buoyancy under a dive. See *chapter 2.3*.

Buddy

Dive partner. Buddies should always stay within each others sight during the dive in order to help each other in case of emergencies.

Buddy breathing

Performed when a diver is out of air and needs to breathe from the buddy's *octopus*.

Buddy check

Safety check of equipment before a dive. Performed by the buddies on each others gear.

Cylinder/tank/bottle

Contains the air used during the dive. In this thesis only referring to cylinders filled with normal air to a pressure of between 200 and 300 bar.

Depth gauge

Measures the dive's current depth, often used in the form of a *dive watch* or *-computer*.

Dive charts

Lists the maximum time allowed for each depth, in order to prevent decompression sickness. A *dive watch* or *-computer* uses these charts to automatically calculate the remaining dive time.

Dive computer

Depth gauge, *dive chart* and sometimes *pressure gauge* combined to a computer. Worn on the wrist or mounted on a hose from the *first stage*.

DIR

Doing It Right. A set of guidelines on how to dive and what equipment to use, originally created for cave divers, but has recently spread fast in many dive communities. See *chapter 2.7*.

DCS/decompression sickness

Potentially lethal condition most commonly caused by rapid ascents during scuba diving. See *chapter 2.2*.

Inflator

Control of the *BC*. Either fills or empties the *BC's* air bladder. See *chapter 2.3*.

First stage

The first stage of the *regulator* decreases pressure from the *cylinder* to around 30 bar.

NAUI

National Association of Underwater Instructors.
Scuba diver training organization

Octopus

Backup *secondary stage*, used for *buddy breathing* in case a diver runs out of air.

PADI

Professional Association of Diving Instructors.
Diver training organization

Pony bottle

Miniature *air cylinder* used by some divers for emergency situations.

Pressure gauge/manometer

Monitors the pressure of the *air cylinder*. Is sometimes integrated into the *dive computer*.

Recreational diving

In this thesis scuba diving refers to recreational diving, using regular air to a depth of around 30-40 meters. Diving using other mixes of gas to greater depth is referred to as *tech diving*.

Regulator

Used to decrease the air pressure from the up to 300 bars of the *cylinder* to the ambient water pressure. The regulator consists of a *first stage* and one or two *second stages*.

Second stage/Demand valve/DV

The second stage of the *regulator* decreases the

air pressure of the *first stage* from around 30 bar to ambient pressure, and feeds the air to the diver. Confusingly enough commonly known as a *regulator*. Sometimes referred to as a demand valve, since it only releases air on inhalation.

Scuba

Self Contained Underwater Breathing Apparatus. The system needed to breathe under water. In this thesis, scuba will only refer to the “open circuit” type of scuba gear, consisting of an air cylinder and a regulator.

Snuba

A cross-over between scuba diving and snorkeling. In snuba, the air cylinder floats on the surface, feeding the diver with air through a long hose.

Tech diving

Tech diving usually refers to diving to depths that requires the diver to perform decompression stops and use gas mixes other than air to prevent *decompression sickness*.

Vest

A kind of BC. See chapter 2.3.

Wing

A kind of BC, most often used by more experienced divers. See chapter 2.3.

Whistle

Regular whistle, always attached to BC's to be used in surface emergencies.

Air cylinder

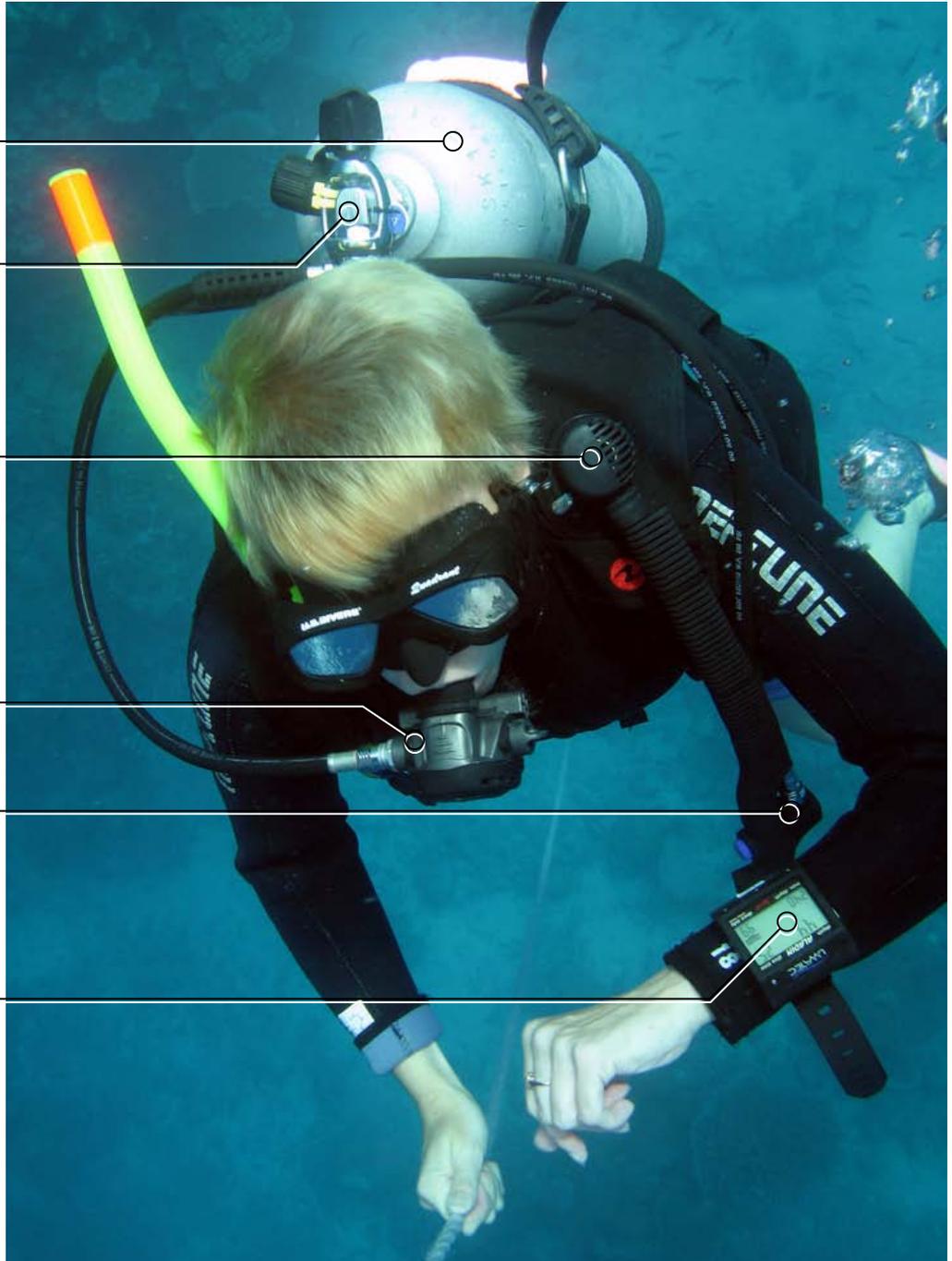
First stage

Air valve

*Primary
Second stage*

Inflator

Dive computer



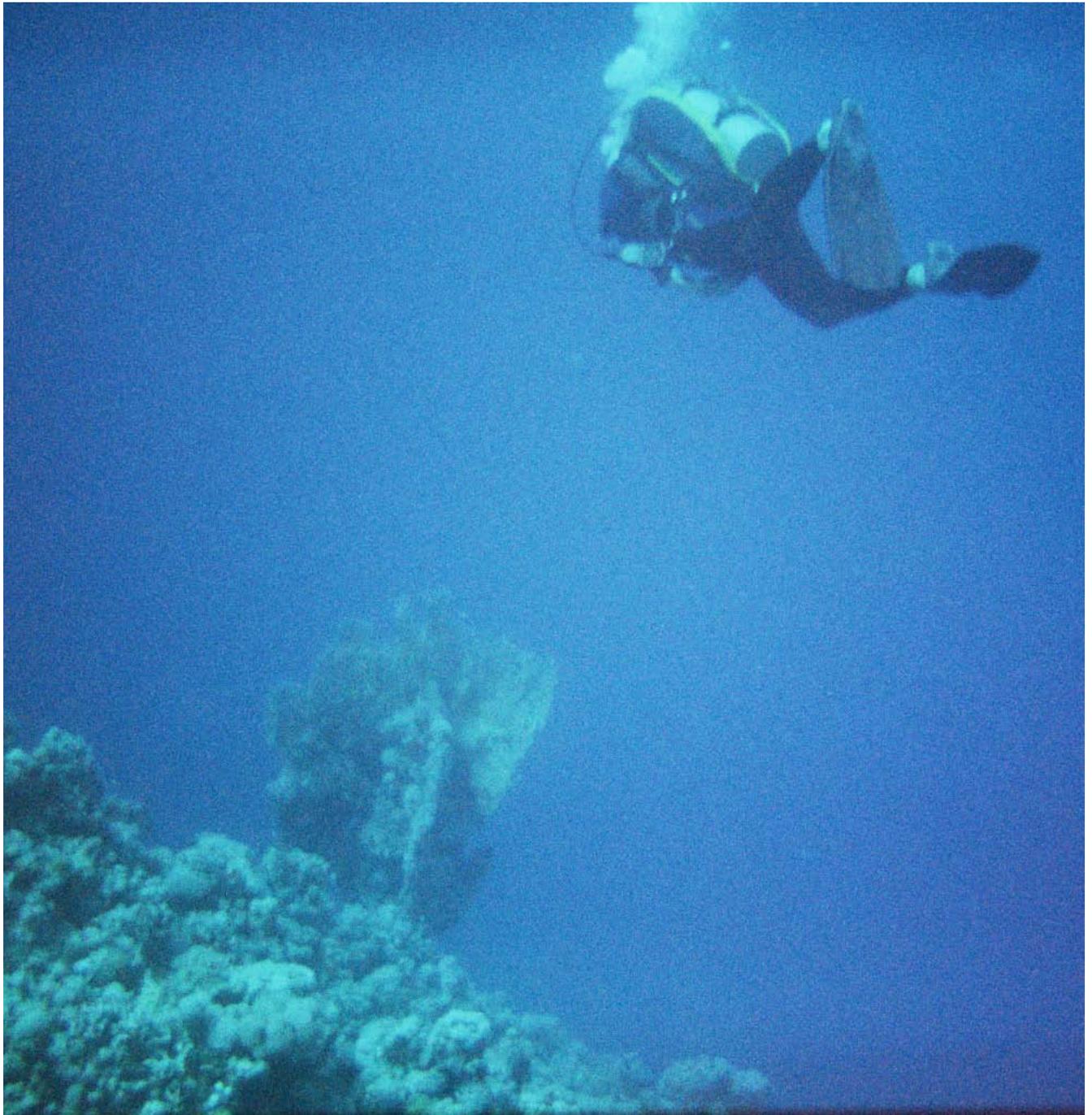


(Vest type)
Buoyancy Compensator

Secondary
Second stage
(octopus)

1. *Background*

- 1.1 Introduction
- 1.2 Initial brief
- 1.3 Initial research
- 1.4 Project ideas
- 1.5 Brief
- 1.6 Time plan



1.1 Introduction

Ever since my father taught me snorkeling when I was ten, different underwater sports has been some of my biggest passions. Because of this, I have always wanted to work with products for scuba diving or free diving, but never gotten around to actually do it. Until now.

Choosing between the different underwater sports, I found free diving (and related sports such as underwater rugby) very unknown sports, hard to relate to for people who are not involved. Because of this, I opted for scuba diving, the biggest of the underwater sports.

Scuba diving, i.e. diving with the aid of a Self Contained Underwater Breathing Apparatus, has grown rapidly the last years. Nobody knows the exact number of divers in Sweden, but an estimation says the number is over 250.000 certified divers,¹ and about 500.000 recreational dives are performed in Sweden every year.²

About four of these yearly Swedish dives go wrong enough for someone to die.³ In 2008, 6 divers in Sweden were killed, just between may and august.⁴ Scuba diving is actually considered one of the most dangerous sports to perform.⁵

Scuba diving is an extremely gear-focused sport,

where many companies focus on high-tech aesthetics and -functions. This is somewhat odd since many accidents occur because of this complex functionality.⁶ The marketing of these high-tech product could also be an important part of why scuba diving still has a reputation of being an overly complicated and expensive pass-time among many non-divers.⁷

Lastly, the title of the thesis, 4° or four degrees, derives from the fact that sea- and ocean water is never colder than 4° below the thermocline.⁸



1.2 Initial brief

At the start of my project I only knew that I wanted to work in the field of underwater sports. My brief was simply to create a product that improves the diving experience



www.sexygadgets.net, www.bob-diving.com, www.poseidon.se



1.3 Initial research

In order to find my area of interest, I started my thesis with a short survey among my friends and among the divers on the internet community www.dykarna.nu.

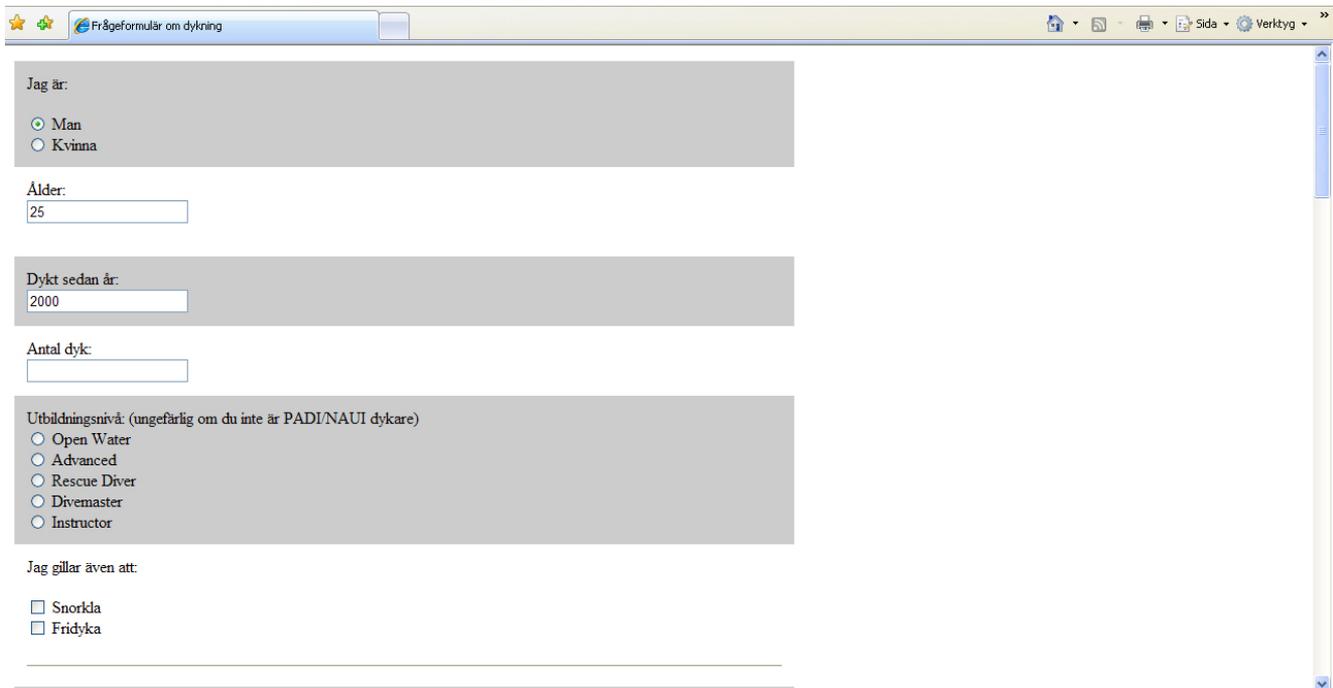
What I wanted to know was:

- What keeps people who are interested in scuba diving from taking their license?
- What are the most common problems among divers?

- Are there any ideas on improvements or products among the divers?
- What attracts people to scuba diving?

I also asked questions about the way people dive to see the duration and depth of an average dive.

See Appendix I for the full survey.



The screenshot shows a web browser window with the address bar containing 'Frågeformulär om dykning'. The page content is as follows:

Jag är:

- Man
- Kvinna

Alder:

Dykt sedan år:

Antal dyk:

Utbildningsnivå: (ungefärlig om du inte är PADI/NAUI dykare)

- Open Water
- Advanced
- Rescue Diver
- Divemaster
- Instructor

Jag gillar även att:

- Snorkla
- Fridyka

1.3.1 Conclusions

63 non-divers interested in diving answered the survey. One third of these stated that the perceived complexity of scuba diving is part in why they haven't started scuba diving yet.

16 of the respondents have tried scuba diving and two even started a scuba diving course. Of these 18 people nine claimed that price was a factor for not getting a license, while five were, even after trying it, among the people that thought it was too complex.

Quite a high number of respondents were also worried about the safety. 11 people gave danger as a reason for not diving.

Among the divers, it was clear that there is a big group of divers that has been active for a long time, but only does a few dives per year, or not even every year. This is also the group that reports the most problems during dives, while the more frequent divers are quite happy with the way they dive.

The most frequent problems concern buddy communication, field of vision, trouble with finding instruments and buoyancy control.

The survey made it very clear that new divers and infrequent divers would be more interested

in a new product than experienced divers that most often are very happy with their equipment. It also showed that there are a number of areas that needs attention and development.

1.4 Project ideas

I developed a number of ideas and areas to work with, some totally random and some based on the survey.

I. Communication during dives. Communication between dive buddies needs to be improved in some way. The area felt a bit too small for a master thesis, though.

Ib. Improve buddy diving. Work with a system that has the benefits of a buddy line connecting divers, without the down sides of tangling. Also a small area, with a big risk of being a boring hi-tech gadget.

II. Improved sense of freedom under water. The first idea that struck me was having the air tank floating on the surface. I immediately found that this already exists in the “Snuba” line of products.

IIb. Improved sense of freedom and mobility by mixing snorkeling and scuba. For example by carrying a small air tank on the front, so that the diver easily can swim on the surface before and after dives. This would, though certainly lead to safety issues, since it gives the impression that you are free to move up and down as you please, and might be tempted to do regular scuba dives without sufficient air.

III. Lightweight diving. Thinking that short and shallow dives are safer than long deep ones, maybe this could be developed with the added bonus of mobility from a lighter equipment. I realized that this idea wasn't all new, but also that these products were in quite low standing in the dive community, which affected me in my decision to drop the idea.

IV. Diving equipment focused on the needs of new divers. It was obvious in the survey that new divers are much more interested in new ideas, so why not make them the focus of the project?

1.4.1 *Idea development*

I realized that the market for dive products is very conservative, with its extreme demands for simple, working technology and high quality. New technology based products often fail miserably, and I wasn't really interested in doing another hi-tech product either.

I also felt like there was a risk of developing a "light" version of diving that would only work under supervision by instructors, and be forever despised by scuba divers.

This is why I chose to work with an existing product, not inventing a new one but developing a tried and working concept. Working with the unforgiving nature of the market instead of against it was simply an interesting challenge.

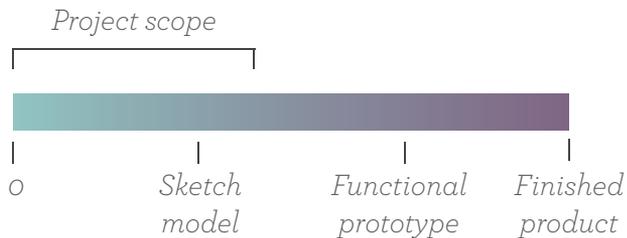
The survey showed clearly that the more experienced divers won't be that interested in a new product, which is why I chose new divers as my target group. Also, since the major issues for non-divers were safety and simplicity, I knew this would be my focus.

Creating an additional product to increase dive safety didn't make any sense, it would just increase the complexity. In order to increase safety and reduce complexity, I would have to rework a major part of the equipment.

1.5 Brief

Investigate whether a BC (Buoyancy Compensator, see *glossary*) can facilitate intuitive use and improve dive safety for the non-experienced diver. Through its simple use the BC should attract new divers, but it should also be their first choice as they grow more experienced.

In order to create a full concept, other pieces of equipment might also be added to the project.



1.5.1 Demarcations

This thesis will only discuss scuba diving done according to the boundaries set by the “advanced scuba diver” course held by both NAUI and PADI scuba diving organizations. This means diving to a maximum depth of 40 meters with standard air in the cylinder.⁹ I will in this thesis refer to diving within these boundaries as “recreational diving”, in contrast to “tech” diving or professional diving.

I wanted to do a project that was close to a commercially viable project. This is why I early on chose to work with a concept that was technologically plausible for today and not a futuristic one. Economically, though, I have allowed myself more freedom when it comes to theoretical development and production costs.

The time frame of the project will of course limit the final result. Thus, the intention of the project is limited to creating a conceptual model of a plausible product.

1.5.2 Purpose

Almost every scuba diving incident in Sweden could have been prevented by correct handling of the equipment. I consider the education of divers as the most important when it comes to decreasing the number of accidents, but also believe that improved equipment is a part of the solution.

The purpose of my master thesis will be to create products that promote correct use, and offer better safety and overall handling.

The equipment should have a focus towards dive schools and inexperienced divers, while professional divers are totally excluded. The equipment should look simplistic in order to attract the large number of people who perceive scuba diving as being too complex.

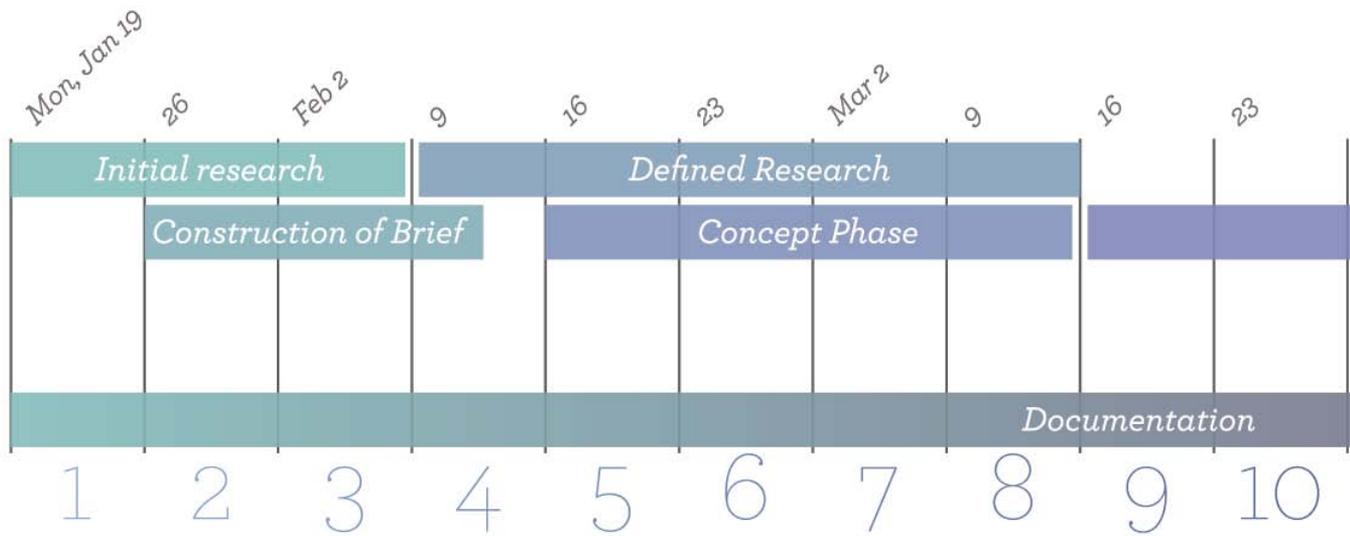
1.5.3 Goal

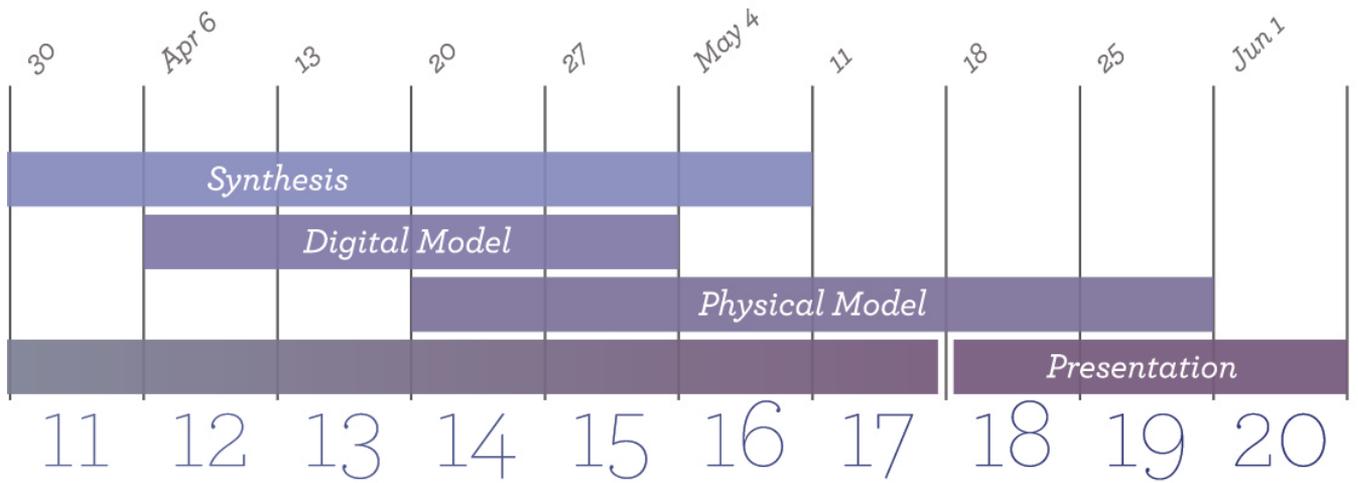
The goal of the thesis is to present one or several products aimed at scuba diving in the form of a written report, sketches and 3D renderings, as well as a full scale mock-up. The result should be based on problems and findings from research on scuba diving as it is performed today.

My personal goal is to improve my skills in in-depth research when it comes to on site studies, interviews and usage scenarios and to increase my knowledge of shaping complex products. I have never before worked with textile products, which will be an interesting challenge.

The diving equipment market is saturated and has since the 50's developed a reliable standard. Also, subgroups within the diving community have created manifests on how a safe diver should be equipped and how equipment should be constructed. Because of this, creating equipment that will have a chance of acceptance while still being innovative and unique will be a very challenging task!

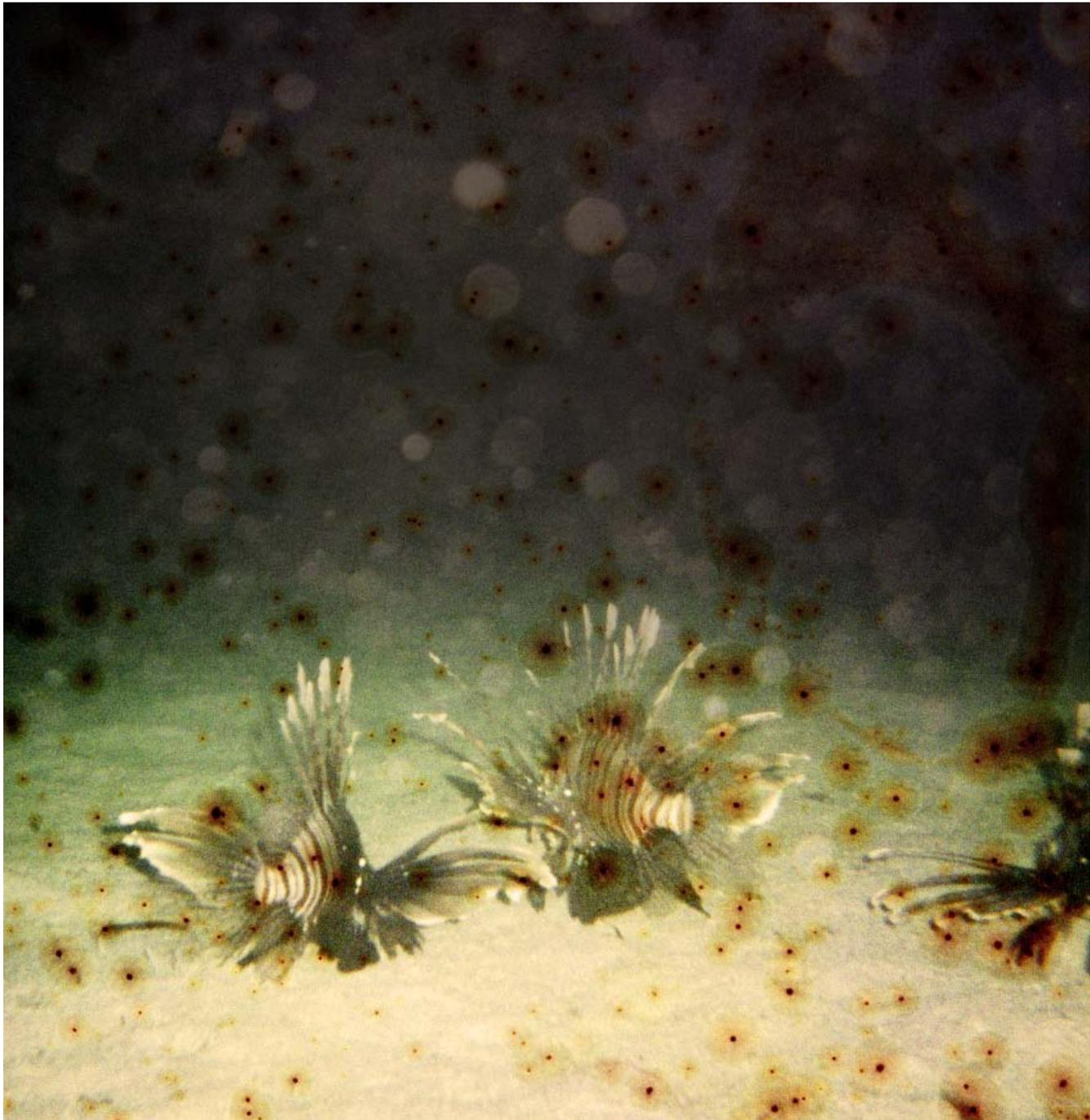
1.6 Time plan





2. *Research*

- 2.1 A history of diving
- 2.2 Dive theory
- 2.3 Diving equipment
- 2.4 Target group
- 2.5 A typical dive
- 2.6 Diver training
- 2.7 Dive praxis
- 2.8 Dive accidents
- 2.9 User observations
- 2.10 Market research
- 2.11 Technology



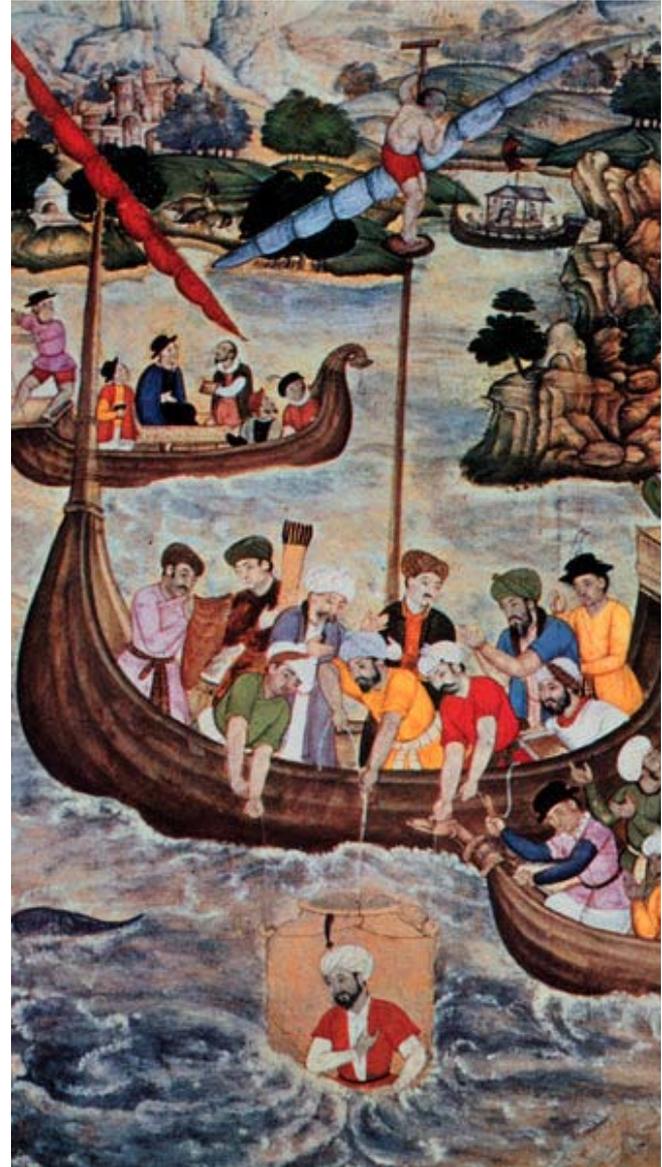
2.1 A history of diving

Humans have since thousands of years been free diving for food, pearls and sponges. The first functional aid to stay below the surface was the diving bell, first described by Aristotle in the 4th century BC: “...they enable the divers to respire equally well by letting down a cauldron, for this does not fill with water, but retains the air, for it is forced straight down into the water.” He also mentions Alexander the great using a diving bell made entirely out of glass in 332 BC.¹⁰

The diving bell didn't reappear until the 16th century, when the first use was confirmed.¹¹ Diving bells were soon used by harbours for salvage operations. For example, 50 cannons were salvaged from the warship *Vasa* at 32 meters depth directly after it sunk in 1628.¹² It wasn't until 1654 when an air pump was invented, that the diving bell could be used to any real depths.¹³

A more mobile set up was created by John Lethbridge in 1715 where the diver was lying in a wooden barrel with his arms sticking out. This could be used to depths of 20 meters for half an hour.¹⁴

For even more mobility, a working dive helmet was developed in 1828, open in the bottom so that the air that was pumped in from the surface could leak out. The downside was that if the



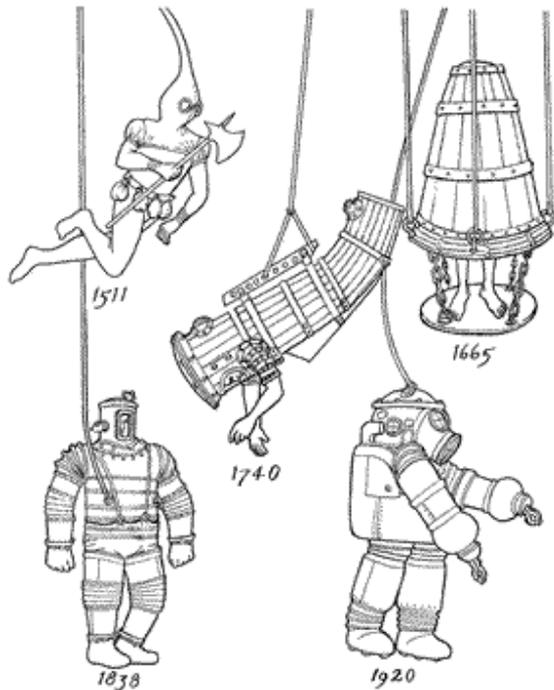
www.wikipedia.org

diver, who would walk on the ocean floor, would fall, the helmet would fill with water.¹⁵ The solution to this was the invention of the full suit that kept the air in. Air valves on the helmet allowed the diver to adjust the amount of air in the suit, but the diver still walked around on the ocean floor. This kind of diving gear made it possible to use, not only for salvaging ship wrecks, but also for underwater construction that became increasingly demanded during the 19th century. The same kind of suit is sometimes still used today by construction divers.¹⁶

The first real steps toward today's scuba diving equipment were taken in 1865 when the "Aero-

phore" was invented. The diver wore a compressed air tank on his back, and was fed air through a mouth piece only when inhaling. The tank was still fed by air pumps on the surface, but the diver could disconnect himself for a few minutes, thus making the Aerophore the first self contained underwater breathing apparatus ever.¹⁷

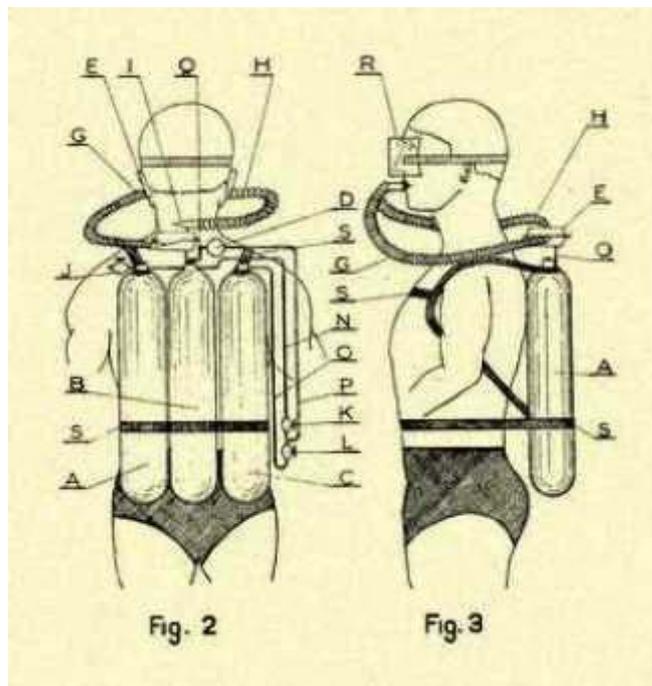
A second important step was the introduction of masks and fins during the 1930's. The fins were patented in 1933 as "swimming propellers".¹⁸ At the same time a French navy captain, Yves Le Prieur modified Aerophore by combining a valve with a high pressure air tank,



The "Aerophore" from 1865.

without any connection with the surface. For some reason, the apparatus didn't use a regulator like the Aerophore. Instead, the diver got fresh air by opening the valve while exhaled air escaped under the edge of the mask.¹⁹

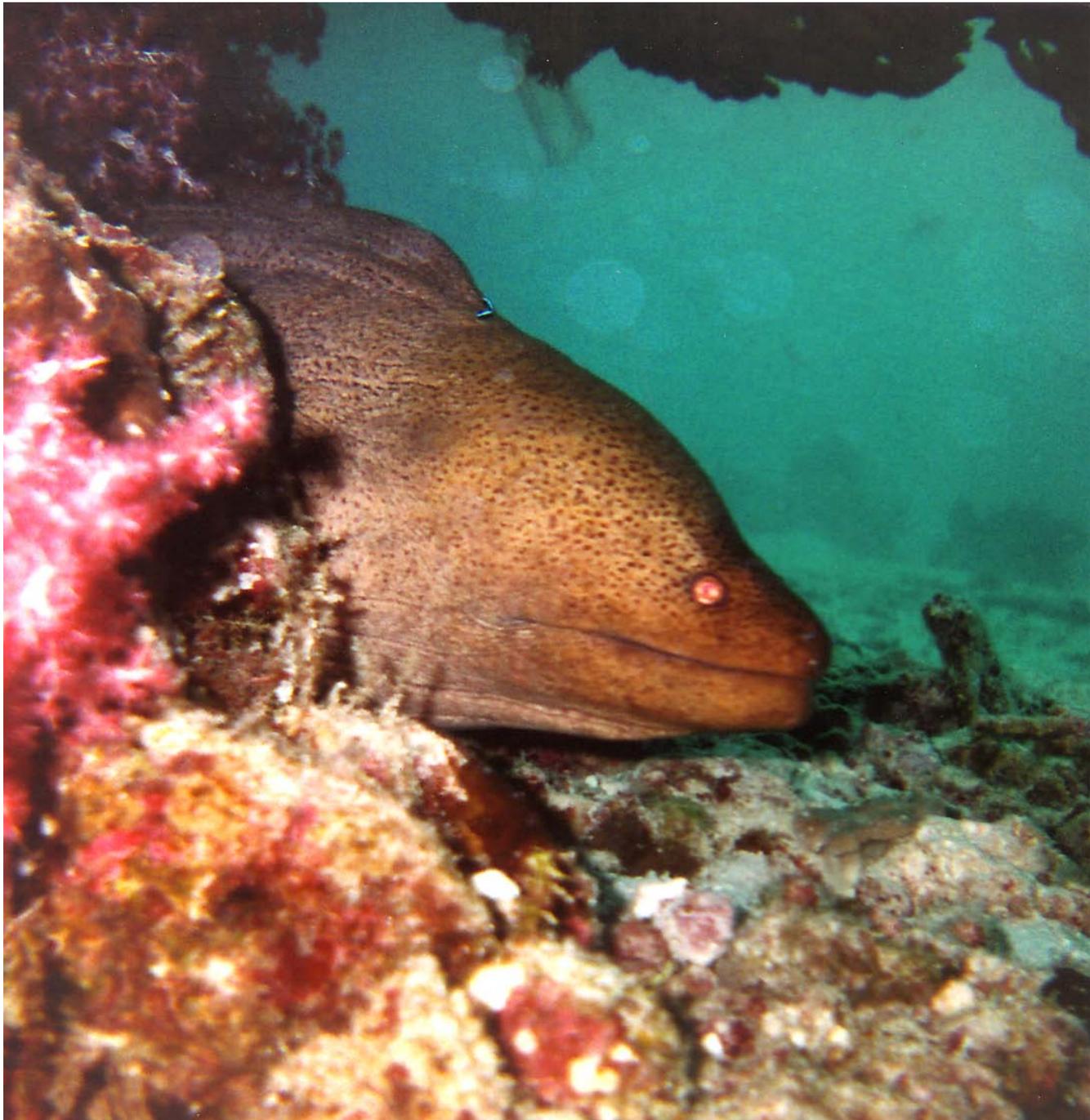
The last piece of the puzzle was Jacques Cousteau's modifications on the regulator, creating a new demand valve that only fed air when the diver inhaled. This equipment proved cheap and reliable and the "Aqualung" was launched in France 1946.²⁰



Costeau's patent for the Aqualung.



1950's diving suit.



2.2 Dive theory

To understand the basics of scuba diving it is essential to have a grasp on basic pressure physics and diving medicine. This is also the first thing becoming divers learn during their training.

Pressure

The atmospheric pressure on sea level is around one bar. For every ten meters depth of water,

the pressure will rise approximately one bar. This means that pressure is doubled when you move from the surface to ten meters depth. It also means that compared to a breath taken on the surface, the volume of air will be halved in a breath taken on ten meters depth, and a quarter on 30 meters depth. Because of this, air consumption while scuba diving gets bigger the deeper down the diver goes. Furthermore, if a full breath



Divers performing a safety stop at the end of a dive. Three minutes at five meters to minimize the risk of getting decompression sickness.

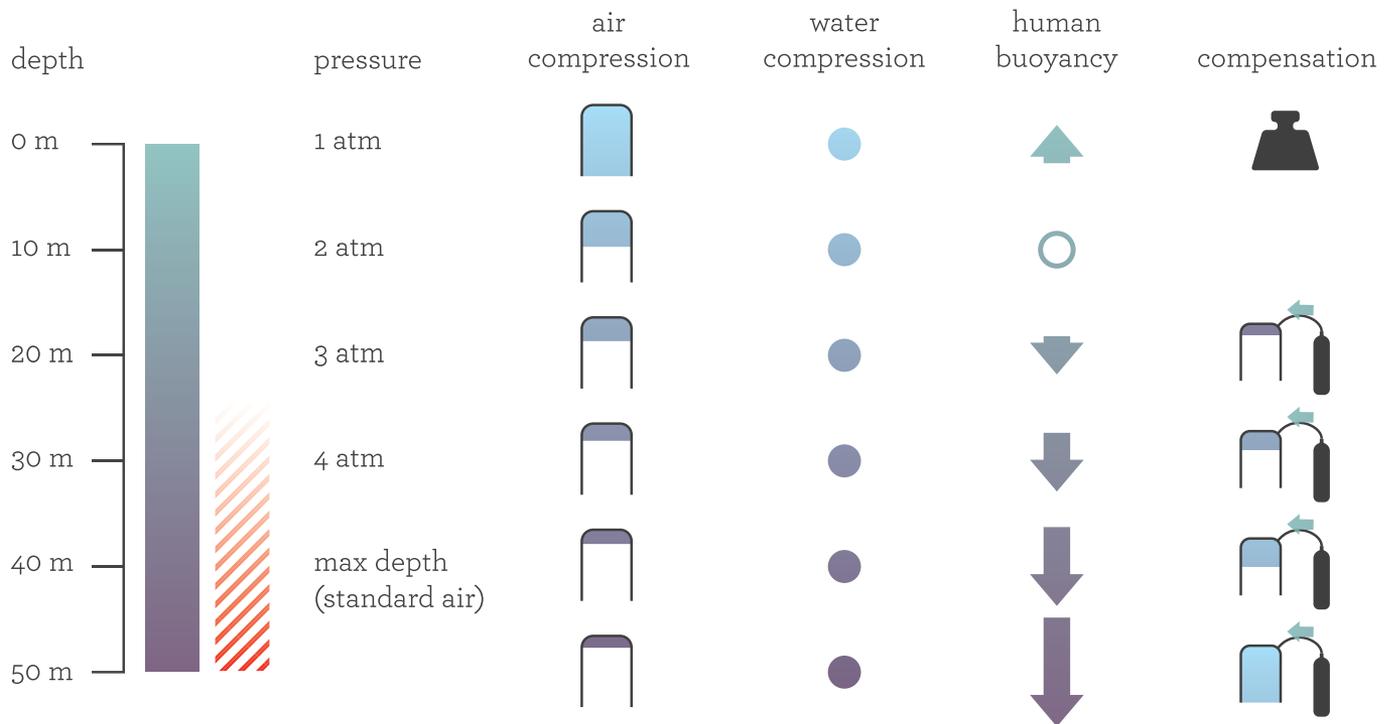
is taken from a scuba cylinder at 10 meters and the diver ascends to the surface without exhaling, the lungs will burst from the expanding air.²¹

The pressure of the lungs is equalized when breathing, but the air in the inner ear and the sinuses needs to be equalized by squeezing ones nose and forcing air up in the inner ear.

Ignoring equalization could lead to ear-drum rupture, which in turn leads to vertigo, total loss of orientation and balance due to the shock of cold water on the vestibular system.²²

DCS

Decompression sickness can occur when ambient pressure drops fast, for example if a diver



The density of the air increases dramatically under pressure, while the density of water remains roughly the same. Since the air in the suit and lungs of the diver becomes compressed, his/her buoyancy decreases.

Because of this, a diver needs to have weights to achieve negative buoyancy on the surface, and an extra air compartment to fill in order to achieve positive buoyancy during a dive.

ascends too quickly. Since larger quantities of gases can be dissolved in the tissues of the human body when under pressure, the level of gas saturation in the body is higher during a dive than on the surface.²³ When pressure drops, the gases (mostly nitrogen) are forced out into the blood. If this happens too fast, the nitrogen will form small bubbles that can clog up capillaries in the body.²⁴

The symptoms can range from harmless tingling skin to paralysis, brain hemorrhage and death. Because of this it is vital to use dive charts or dive computers to know how long time the diver can spend on a certain depth, and to keep the speed of ascent low.²⁵

Nitrogen narcosis

The body responds differently to gases depending on the partial pressure of each gas. That means that even if the percentage of nitrogen in the air is the same, the body will respond differently to it if under elevated pressure.

The reaction of nitrogen differs from person to person, but at 30 meters many start to feel some indication. The symptoms are very similar to being intoxicated with alcohol, but can easily be removed by ascending a few meters.²⁶

Oxygen toxicity

Oxygen gets toxic the same way nitrogen does when its partial pressure gets too high, but has greater effects on the human body. The symptoms includes tunnel vision, twitching and nau-

sea, and in later stages spasm and unconsciousness.²⁷ Pure oxygen gets toxic when the ambient pressure is 1.6 bar or more. In other words, pure oxygen should not be used for diving below six meters. When the oxygen level is around 21%, like it is in normal air the diver has to go below 60 meters to feel any symptoms.²⁸

Heat conduction

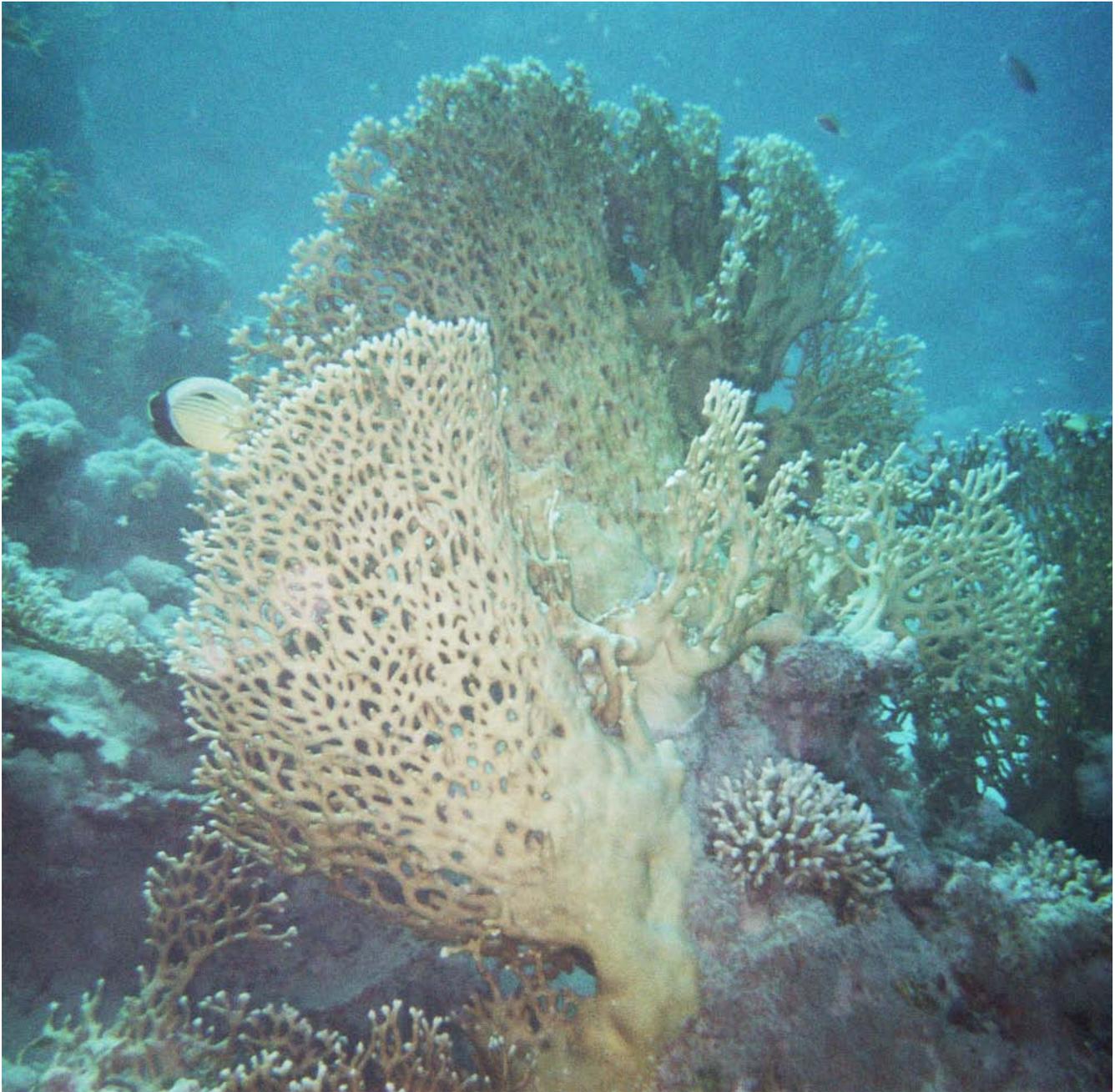
Water conducts heat around 20 times faster than air, which is why a wetsuit should be used even if the water is very warm.²⁹ Because of this, divers need to wear wetsuits even in very warm waters.

Transmission of sound

Sound transmits faster under water, making it impossible to hear the direction the sound came from.

Colour absorption

Colours are absorbed at different rates in water, which is why everything is blue under water. The first colour to be filtered out is red at five meters depth, then orange at ten meters, yellow at 15, green at 20 and at last blue at 25 meters.³⁰



At fifteen meters, artificial light has to be used to bring any colour to the surroundings.

2.3 Diving equipment

As stated in the brief, this thesis is aimed at recreational divers only, which is why I will limit my investigation to non-professional equipment.

Buoyancy Compensator

The deeper the diver goes, the more the density of the air in the suit and lungs increases. This means the diver at some point will be unable to compensate for the loss of buoyancy and will start to sink. Instead, the diver must increase the buoyancy by filling some kind of container with air from the tank.

For most divers this container, called a Buoyancy Compensator or BC, comes in the shape of a vest that can be filled with air via an inflator connected to the air cylinder. The vest can also be filled with air from the diver's or the buddy's lungs via a nozzle on the inflator, which is vital in case of an out-of-air situation.

The vest is the preferred choice of BC for a new diver, since it is easy to put on, and gives good balance as the diver is upright with the head above water, because of the inflatable bladder that reaches around to the front of the diver. This also means that when the diver is horizontal during a dive, the vest will give the diver poor balance due to the high center of gravity. It also means that the vest squeezes the body when it

inflates. Since the pockets are located on top of the inflatable bladder, they are also very hard to use when the vest is full of air.

BCs can also come in the shape of a “wing“ that has a bladder that only inflates on the back of the diver, around the tank. This improves balance in the water, but also means that it is harder to stand upright when on the surface. It is often easier to modify wings after your needs because of the harness used to attach it to the body. Pockets, straps, weights etc can be attached as the need grows.

For more information on BCs, see chapter 2.10.

Air cylinder

The air cylinder contains air, or other gas mixtures, usually under 200 or 300 bar pressure. The air is contained in one or two steel or aluminum cylinders. The benefit of aluminum is the corrosion resistance, which is why they are used in most warmer countries. The benefit of steel is the durability and the bigger weight, which means that less extra weights has to be used.



www.allproducts.com,



Air valve
Releases air if the inflator
hose is pulled

Hose from first stage
20-30 bar pressure

“Inflate” button

Mouthpiece
For emergency inflation

“Deflate” button
Releases air via mouthpiece

Integrated
weight system

The pressure of the air cylinder is lowered to about 20 bars in the “first stage” attached to the top of the cylinder.

Other gas mixtures than air is often used to do longer or deeper dives, referred to as “tech diving”. I will not deal with anything other than diving with air in this thesis.

Pressure gauge

The pressure gauge or manometer is used to measure the remaining pressure in the cylinder. It can be used as a single instrument, mounted on a console with a dive computer, or be built into the computer, making it “air integrated”.



Depth gauge and dive watch

The depth gauge is used to measure the current depth of the diver, while the watch is needed to keep track of the nitrogen saturation, in order to prevent decompression sickness. Most divers exchange both of these for a dive



www.poseidon.com, www.suunto.com

computer that keeps track of these calculations for you. Computers can also be air integrated, so that it replaces the pressure gauge, and also calculates how long the air will last on the current depth.

Second stage

The second stage/demand valve/reg brings the air pressure down to the ambient level, and is responsible for giving air only when the diver inhales. It is recommended to have a backup regulator, called an octopus, or even a separate source of air, such as a small extra air cylinder - a pony bottle.



Weights

To counter the buoyancy of the suit, the diver needs to have extra weights. For beginners, they are most often attached to a belt hung around the weights, but can also be integrated in the BC vest pockets. The weights are often used as an emergency ballast to be dropped if there is no other way to ascend.

www.mares.com

Fins

The fins are vital to be able to get around at all. Without them, the slightest current would take you away.

Mask

The mask makes it possible for you to see under water. It must be equalized when descending, by blowing air through the nose. If the glass isn't curved, the mask will make everything appear 30% bigger under water.

Suit

Even in warm waters, you will probably dive with a thin wetsuit. They come in long and short sleeve



Wetsuit



Drysuit

versions, with or without hood and from one to seven millimeters thick. The principle is that water is led into the suit, where it will be warmed and insulate the diver. For colder waters, a dry suit is often used. These do not let any water in, and you can have warm clothes underneath. Air is blown into the suit from the cylinder through a hose and the valve on the chest. The air is free to move around in the suit, making it a bit more demanding than a wet suit to dive in.

Snorkel

The snorkel is used if there will be any swimming on the surface before or after the dive, in order to save the air in the cylinder.

Buddy line (optional)

The buddy line is much debated among divers. It is a two meter line with loops in each end and with a float half way. The loops are worn on the buddies wrists, keeping them from separating. The Swedish scuba diving association thinks it is necessary equipment, while most divers never use them because of the distraction and risk of entanglement.

Classed as basic equipment by SSDF.

Knife (optional)

Used to cut the diver free when entangled in wires or nets.

Classed as basic equipment by SSDF.

Tablet

A simple plastic slate and a pencil for writing messages under water.

2.4 *Target group*

Since the diving community is very heterogeneous, there is really nothing to say about the preferences of the target group. Divers come in all shapes and sizes, all age groups and dive because of different reasons. Because of this, any real target group analysis was never made. Instead, I decided to use the information I found in my own survey as a basis for the needs of my target group.

Interestingly enough, while investigating the target group by looking through pictures on the internet, I had a very hard time to find a single picture where the subject had actually assembled his or her equipment correctly.



A Google image search provides countless photos on how NOT to assemble one's scuba gear.



2.5 *A typical dive*

Transport of the equipment to the dive site is usually done in plastic boxes or big trunks. The equipment is heavy, usually almost 30 kilos.

Surface organization

Any dive should always be done with a dive leader and with alternating dive pairs so that there are divers on surface in case of an emergency. The dive should be planned by someone

who knows the site, and a maximum depth and dive time should be set. The dive plan is communicated to the divers through a quick briefing before the dive. If the divers do not use dive computers during the dive, charts are used to set maximum dive time according to the pre-determined maximum depth that may not be exceeded.



Buddy check

The equipment is assembled, suits are donned, and the BC is put on, usually with help from the buddy.

Before every dive, the two dive partners check each other's equipment to insure that everything is in order. The things that are recommended to be checked are according to Håkan Jörgensen in his book *Säker dykning* (Safe Diving):

BC - Proper adjustment, functioning inflator, correct cylinder attachment, inflated BC and dry suit.

Weights - Easily dumped and attached properly.

Belts & buckles - Properly placed, functioning clasps, nothing caught in the straps.

Air - Correct pressure, functioning valves and regulator, correct placement and function of alternative air source.

Tools - Functioning light and computer and correctly placed knife.

The Dive

Diving is for obvious reasons always done with a partner. You should never be further than a few meters away, so that your buddy's back up air supply is within a short distance if you get any problems. Some organizations recommend you to always be connected to your buddy via a



buddy line. This is an issue that is frequently discussed in dive communities, since a buddy line could cause many accidents by tangling, or by involving both divers in an accident.

Communication with the dive partner is done with hand signals, a plastic tablet and pencil and/or flashlights. Getting your buddy's attention can be harder, since you cannot use your voice, snap your fingers or clap your hands. Some divers use a stone to knock on their tank, or use a "tank banger", see *chapter 2.10.2*.

The dive should be planned so that a diver never has less than 50 bars of air left when surfacing.

A safety stop is always made at five meters for three minutes to insure that as much nitrogen is ventilated from the blood as possible.

After the dive, a few hours of surface time is required to ventilate nitrogen. This time is set either by the dive computer or the dive charts used.

Cold/warm water

Diving can be very different depending on water and air temperature, current, wind, visibility etc. Colder water requires a dry suit that will hinder your movements considerably more than a wet suit. The use of a dry suit also means that the



diver will have to control the air in his suit in order to maintain neutral buoyancy and to stay warm. In most dry suits, the air is also free to move around, which might create a problem for inexperienced divers ending up with air in the legs of the suit, far from the exhaust valve on the upper arm.



2.6 Diver training

The two largest organizations when it comes to diver training is PADI and NAUI. Both are global networks found almost anywhere in the world, and offer almost identical education.

The first course, Open Water Scuba Diver, is built on a theoretical part and a practical part. Before the education starts, though, the students have to pass a simple medical examination.

The theoretical part is often completed in under a week and consists of reading a short manual containing basic dive physics and dive praxis as well as brief advice on how to choose, use and maintain the equipment. It ends with a multiple choice test which has to be passed in order to continue.

The practical part starts with pool dives where the divers accustom themselves with breathing



underwater and using the equipment. When the divers are able to breathe, swim and control their buoyancy, they start to train emergency situations like running out of air, losing the mask, retrieving a lost mouthpiece etc. The divers also practices ascending from five meters without air, and various life saving exercises.

Diver training is usually finalized with a few outdoor dives. These usually repeat the exercises performed in the pool, so that the divers are accustomed to colder water and poor visibility. The last dives are usually made so that the divers take turns to lead the dive, and the instructor is merely an observer. After a completed Open Water course the divers are certified to dive to a depth of 18 meters of open water, ie the diver must not go into caves, wrecks or other places where the route to the surface is blocked.

Later, additional courses like Advanced Scuba Diver, Rescue Diver, gives further knowledge in underwater search and rescue, dives to 40 meter depth, night dives etc.

Specialized courses like wreck diving and underwater photography can also be taken to increase the field of diving.

2.7 Dive praxis

There are of course, many different theories on how safe diving should be performed. Apart from the two largest diver training organizations, NAUI and PADI, who have a relatively relaxed view on how the equipment should be used, there are also other, more rigid views on how safe diving is performed.

Safety thinking is also different depending on location. Divers in Denmark are taught to dive with a buddy line which is in turn connected to a surface buoy, something that most other divers would find directly dangerous. Many divers also believe that people taught outside of the Nordic countries receive far less safety training when it comes to for example the buddy system and proper use of equipment.

SSDF

The Swedish scuba diving society is closely tied to CMAS, one of the bigger training organizations, and follows their standards of diving.³¹ SSDF has gotten quite a lot of criticism concerning their rigid views on the use of a buddy line. SSDF wants all divers to use one always, while many divers think it would be better to adapt to reality, where most divers find it obstructive and on some kinds of dives directly dangerous.

While the praxis does have an accessible section on minimum equipment, the rest of it mostly concerns with things like what angle the fins should have, and to what pressure the pressure gauge must have been tested. In short, it concerns mostly with small details regarding the equipment, but avoids the question of how to use it as a full system.

DIR

Doing It Right is a set of rules originally created by and for cave divers. The intention is to increase safety by streamlining the equipment, and having a fixed protocol for emergency situations. The idea is also that new divers should have the same equipment as experienced divers, so that you always know how your buddy is equipped, and you can grow accustomed to the positions of your tools.

The concept of redundancy is central in cave diving. It means that there must be at least one backup for every piece of vital equipment the diver has brought. This goes for second stages as well as air cylinders, knives and flashlights.

A DIR diver always uses a wing instead of a vest type BC, because of its simplicity and balance. The primary regulator is mounted on a two meter hose, worn around the torso, so that it can

be offered to the buddy instead of the backup. The benefit of this is that your own regulator is known to be working, while the secondary is filled with water, which might increase the panic of the out of air diver upon inhalation. The two meter hose means that two divers breathing from the same tank can easily swim behind each other in a narrow cave.

The secondary regulator is mounted below the chin so that it can easily be found. Weight belts or other dumpable weights are never worn, since they cannot be dumped in an overhead situation such as a cave anyway. Instead, extra weights are placed by the tank.

The problem with DIR is that it is aimed at experienced divers, and is a way of diving that should be learned from a DIR instructor. Many of the solutions they have to problems are totally rational to a skilled diver, but not to the average one. Furthermore, DIR divers are also a group with strict norms, sometimes even compared to a sect, and not diving with beginners is a part of DIR diving. This is not, of course, encouraging for new divers, nor is it good for the diving community in general, since a many beginners are fascinated by the rules of DIR, but are unable to follow them correctly, thus being an even less safe diver than if he or she wouldn't have tried DIR diving at all.

When it comes to the equipment, the idea of always using the same setup might be beneficial when doing more or less the same type of



A correct DIR setup. Notice the hose running around the torso, and the primary second stage under the chin.

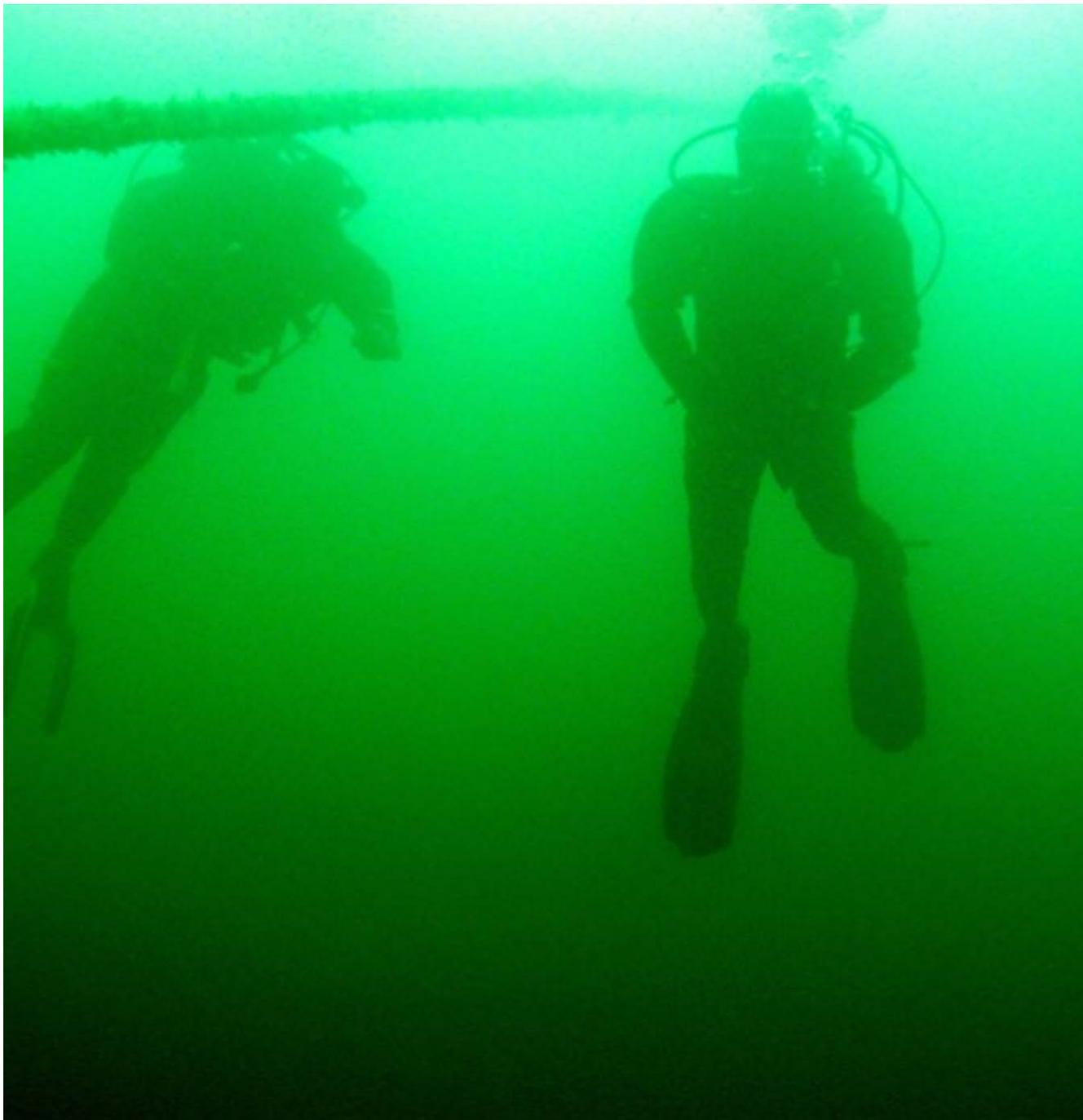
www.baue.org

dives. For the average diver who maybe dives in both Nordic and tropical waters it might not be a good idea to bring two flashlights to a reef dive in daylight.

The idea of a long hose wrapped around you for your primary second stage is also adapted for cave diving, but the rules are too rigid, making it a bad choice for a new diver. The idea of handing an out of air diver your own second stage, though, is something that should be learned to recreational divers already, since a panicked diver is known to often grab his or her buddy's second stage out of their mouth.³³ Also, a compromise between the two meter hose and a regular octopus hose could be a good idea to have more freedom to manoeuvre when in a buddy breathing situation.

The ban of dumpable weights is interesting, since the research shows that weight belts cause a large number of accidents (*see chapter 2.8*). But new divers should always dive with open water between themselves and the surface, so the last resort of the weight belt is still vital.

The most important thing to learn from DIR divers is that you are the one that decides whether to dive or not. If something doesn't feel right, or if you don't trust your buddy enough, don't do the dive.³²



2.8 Dive accidents

Accidents in scuba diving are quite frequent, even though good statistics is hard to find. The Swedish scuba diving society, SSDF, publish annual reports on scuba accidents, but divers choose themselves to report their accidents, making the statistics unreliable. What is known is that between 50 and 75 reports are made each year out of the 500 000 dives that are believed to be made in Sweden every year. 2-6 of these accidents are fatal.³⁴ As a reference for the

uncertainty of the statistics, Swedish hospitals reported during the last few years reported in average 34 treatments for decompression sickness in Swedish pressure chambers every year, while SSDF only had three reports of compression chamber treatments.³⁵ Apparently, the number of accidents is far greater than reported, and on top of this, Swedish divers are involved in countless accidents abroad.

Clipboard		Font		Alignment		Number		Styles		Cells		Editing	
AO21 Tappade viktbaljet vid uppgång i gummibåt, pga problem att öppna spännet.													
AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP			
952	Seac sub		Spänne, haveri	Normal			Luft	Tankspännet gick sönder när det skulle spänna fast flaskan i västen under enstjärnig kurs. Spännet var 1 år gammalt.		Spänne gick sönder vid fastsättning av flaskan på väst.			
953	Aqualung			Okontrollerad uppstigning			Luft	Inför kurs avslutningen köpte klubben in 10 nya viktbaljet från Seaprodivers modell pro. En elev tappade viktbaljet under första utedjekt på kusten. Djupet var 7 meter, säkerhetslinan tappades mellan instruktör och elev. Ytterligare en incident inträffade med		Elev tappade viktbalje vid kursdjt.			
954	Apex	ATX 200	2:a steg, inriklade	Normal		Egen	2004-03-31	Luft	Ytorganisation: Djkledare, men ingen iödningsdjkare/lysbjare. Säkerhetsutrustning: Ingen ombox pga att den chattrade djkbaljet ej dök upp och vi hyrde en taibåt. Döck 3x7 i dekolflaskor med 50 % syrgas. Parlina mellan två djkare + en		Frysningar av regulatorer för alla tre i djkparet.		
955	Hydro Tech		Lossnade	Normal		Egen		Luft	Skulle bli upplöckad av djkbaljet efter avstukat djk. Jag blev påbackad av baljet och trycktes bakåt av baljets badbrygga. Fropade till båtaren att stanna. När jag kliver upp på badbryggan lossar viktbaljet och går förlorat i vattnet. Upprepad djkning		Djkare påbackad av djkbaljet.		
956	Poseidon		Kran, stängd	Normal		Egen	2004-03-01	Luft	2004-05-20	Flaskan ej öppnad tillräckligt mycket.			

SSDF accident reports, available for download at www.ssdf.se

Accident statistics

The statistics presented here are mainly from a study of SSDF's annual reports between 1983 and 1989. The study is made by Owe Magnusson, a Swedish police officer, and is one of very few reports of this kind. The report is old, but it should be noted that the equipment as well as the way people dive is essentially the same today as during the 80's. I will also present statistics that I have compiled from SSDF's accident reports that can be downloaded from www.ssdf.se.

Magnusson finds that the two categories of divers that are most prominent in the accident statistics are divers that were recently licensed, and divers who dive without any dive leader on the surface.³⁶

His statistics also shows that the peak in accidents occur in spring and early summer, before the peak in the number of performed dives occurs. The reason for this is arguably that people are unfamiliar with their equipment, and to diving in general after the winter months.³⁷ This is further proved by the fact that divers with rented or borrowed equipment are in majority in the statistics.³⁸

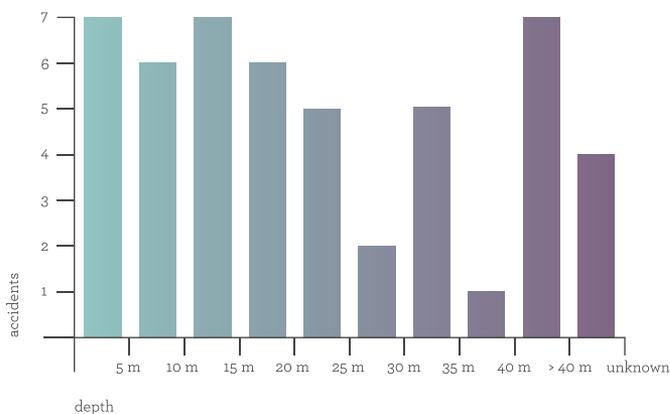
Contrary to what many think, depth is not as big a factor as one could imagine. In fact many fatalities occur in only a few meters of water. This shows that accidents happens even if you think you are only doing "safe" recreational dives.

Accidental weight belt dumping is by far the

most common triggering factor for accidents with 43 reported incidents between 1994 and 2007.³⁹ Despite this, only in 2 out of 48 accidents that were investigated in Magnusson's report did the diver dump the weight belt.⁴⁰

Other common accidents in SSDF's reports are air valves that were not opened enough, air cylinders that slid out of their straps, dump valve strings that got caught in open position, regulators freezing up, inflator buttons getting stuck and buddy lines tangling.⁴¹

Many accidents could easily have been avoided



with a thorough buddy check. Weight belts that are not properly attached, dump valves that are caught in the vest and air valves that has not been properly opened are frequent accidents that all should have been noticed during the check.⁴²

It is also apparent that most accidents happen because people react irrational, misuse their

Magnusson, Owe. Undersökning om dykolyckor i Sverige

equipment, or panic over smaller incidents. A common reaction during panic seems to be to spit out your second stage. The second stage will position itself behind the divers back because of the stiff hose, causing even worse panic when the diver can't find it. It is not uncommon to find drowned divers without the regulator in their mouth, and air still in the tank.⁴³

The conclusion of Owe Magnusson's report is a few recommendations on how to dive, mainly concerning attitudes: you should dive with an organization or at least with a dive leader on the surface. You should dive with a buddy line or at least have very close contact with your buddy. There should be a "low air" warning for the air cylinder. The BC should be equipped with a separate air bottle, so that even if you run out of air, you can still achieve positive buoyancy. This should be coupled with better education on when and how to dump your weights.

Magnusson's conclusion has a few good points, but fail to mention the lack of proper buddy checks. Neither does he mention the fact that weight belts seem to cause more accidents than they save divers. To me, the problem of accidental weight dumping seems just as big as the problem om not dumping at all.



Divers practising buddy breathing during certification.

2.9 User observations

In order to watch new divers in the water, I followed a group of Padi Open Water students both during their pool- and ocean dives.

My main interest was of course problems related to the equipment. I found many interesting things during these two days, the most relevant for my project being:

- Problems with assembling the equipment: remembering what hose goes where, how to fasten the octopus to the vest etc.
- Hard to get into the vest, the shoulder straps turn and tangles with hoses. Dump valve string often get caught, potentially leading to a lethal situation!
- Problems with remembering a full buddy check, with all the separate items that should be controlled.
- Buddy breathing via octopus is hard to perform.
- Hard to carry the heavy tanks from the car to the dive site.
- It is hard to practice retrieving a second stage lost from the mouth, since it moves to the back of the diver.



- Divers using vest style BCs often tuck in the instruments under the arm straps, regularly leading to dangling hoses and lost instruments.
- Its hard to maintain balance in water since the high center of gravity pulls the diver around.
- The vest style BC makes it hard to breathe when inflated, but is to loose when deflated.



- The BC and the suit makes it extremely hard to reach for ones feet, for example in order to put the fins on.
- It is very hard to attract your buddy's attention underwater, since it is hard to make any sounds.





2.10 *Market research*

The market for BCs is quite homogenous, and do not offer much innovation. To generalize, the market can be split into two major groups: hi-tech and lo-tech. Most experienced divers go for lo-tech equipment, where reliability and safety is key. The hi-tech look attracts mostly new divers, and this is also where most of the innovation happens. In my eyes, though, and many divers with me, this innovation is misdirected and over complicates the equipment instead of rethinking it. A perfect example of this is the Mares HUB to the far left in the chart on the next page, further analyzed on the next spread.

On the opposite side of the market chart is the lo-tech equipment which is mostly aimed at tech divers, using double tanks and has a specialised layout of their equipment. These BCs are expensive and highly modular which might not be the best choice for a beginner.



2.10.1 Buoyancy compensators

Seac Sub Airone is the perfect example for a basic vest style BC aimed at beginner divers. Since it is a vest style BC, the air bladder wraps around the stomach of the diver. This means that an inflated vest will inhibit the divers breathing, while a deflated one will become loose, making the cylinder move around a lot on the back of the diver. It will also give a high center of gravity during a dive, which means that the weight of the cylinder will try to force the diver around, facing the surface.

The benefit of the air bladder is that the diver easily can position herself upright in the surface, since the air on the front will stabilize her. This is the reason why practically all dive schools world wide use vest style BC's.

As the picture shows, the BC is covered with hanging straps and rings even though this is one of the more minimal vests on the market.

Its very uncommon for BC's to have standardised places to attach instruments and the octopus. Instead, the diver usually tucks the pressure gauge under the arm strap, and push the octopus hose in a loop into the large D-rings on the shoulders.

Vest style BC - summary

- + Good surface balance.
- + Easy use.
- Poor balance during dive.
- Squeezes when inflated, loose when deflated.
- Hard to open pockets when inflated.
- No specific tool attachments.



Mares HUB

This vest is probably the most complex BC on the market. The idea is that the diver should buy the whole package as one unit. It features a mechanical control handle instead of controls on the inflator, integrated weights in the sides, foldable carrying handle, integrated pressure gauge etc. The hoses are hidden inside the vest, and the octopus is stored in a pocket, as is the inflator hose for manual inflation of the vest. The octopus is even connected to the same hose as the other second stage. Unfortunately, this means that a leak from a hose can be extremely hard to notice, and can even render BOTH of the second stages useless.

All the mechanic parts are of course increasing the number of parts that can potentially fail during a dive. Further, the idea of storing the octopus and inflator in zippered pockets will probably lead to lethal situations if a panicked diver is looking for a source of air, or a way to inflate her vest.

Mares HUB summary

- + One single package
- + Integrated weights.
- Hidden potential failure points.
- Hidden octopus and inflator.
- Secondary and primary second stage shares hose (!)
- Extreme complexity
- +/- Control handle increases mechanical complexity but is preferred by some divers.



The Poseidon 54

This is a wing style BC, meaning that the whole air bladder is situated behind the diver, lifting the air cylinder. This has the benefit of improving the diver's balance during a dive. The down-part of this is that it requires some more practice to effortlessly stand upright in the surface.

It is clear that this type of BC is aimed at more experienced divers, both through the high price, larger air bladder for bigger depths and the fact that it is stripped from equipment such as pockets, weights and any mechanical luxuries. Instead, the user needs to buy any of these extras separately.

Instead of a full vest, the diver fastens the wing BC with a harness. This ensures a tight fit during the whole dive, but is a bit more complicated to use than a vest.

Wing style BC summary

- + Good balance during dives.
- + The air lifts the weight of the tank
- + Few loose straps.
- + Stripped and modular.
- Any extras are bought separately.
- Less stable on surface.
- Unconscious diver will float face down.
- +/- Harness instead of vest.



Other BC styles

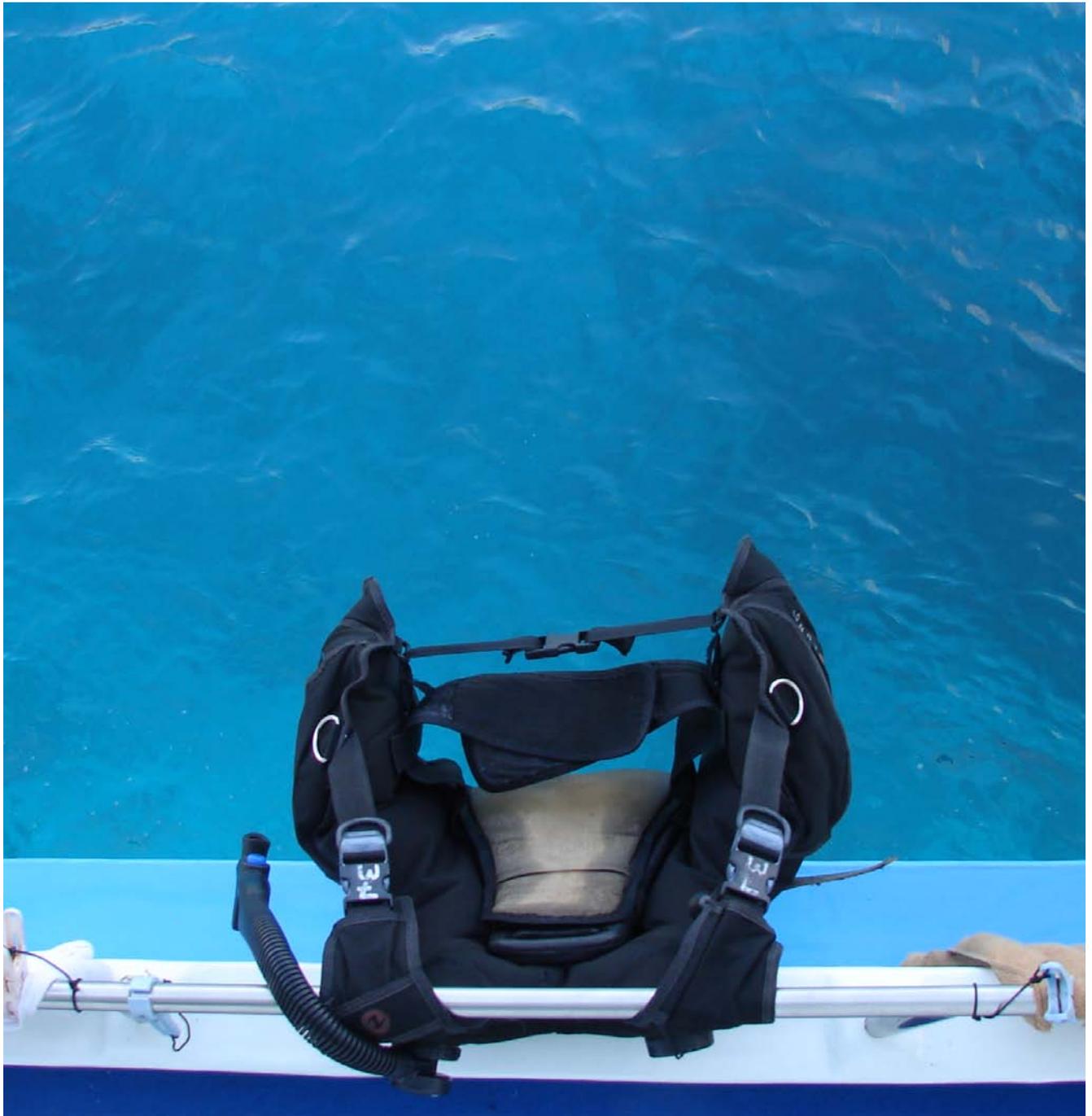
The Zeagle (top right) is developed for non-civilian use, where it is vital to have equipment that can be donned in a short time. The small cylinder is worn on the stomach which leads to a low center of gravity, but also means that it is hard to bend over forward. The small cylinder will lead to at least halved dive duration.

Life saver style vests (far right) with the air bladder on the chest of the diver, has almost completely disappeared from the market. They were common in the 60's because of the low production cost, but offer very poor balance in the water and also needs a separate harness to carry the cylinder.

The Mini breather (bottom right) is quite a new product for shallow and short dives in warm waters. It is simply a backpack with a small tank and all equipment packed into it. This does of course leads to numerous safety and usability problems.



www.diverightinscuba.com, www.minibreather.com



2.10.2 Additional equipment

I also looked at other parts of the equipment that could be interesting to include in the project, such as underwater communication, second stages and dive computers. These are some examples of interesting products on the market.



Classic pressure gauge, monitoring remaining air.



Wrist watch dive computer. In this case air integrated, so that it also monitors remaining air. The plug to the right is a pressure gauge and a wireless transmitter mounted on the first stage.



Console with dive computer and compass. The computer is air integrated via the hose running to the first stage.



Classic Mares second stage. Almost every second stage is built on the exact same technology and has the exact same layout.



Poseidon Triton second stage. Because of revolutionary technology it was once the smallest second stage on the market, but was withdrawn due to production costs.



Tank banger, a simple rubber band with a plastic ball to be mounted on the cylinder. Pull the ball and release to create a bang that attracts the buddy's attention.

Siren that can be mounted on a hose to be used in emergencies on the surface.



Pony bottle, a small bottle with a fixed second stage to be used in out of air situations. Not very common among recreational divers.

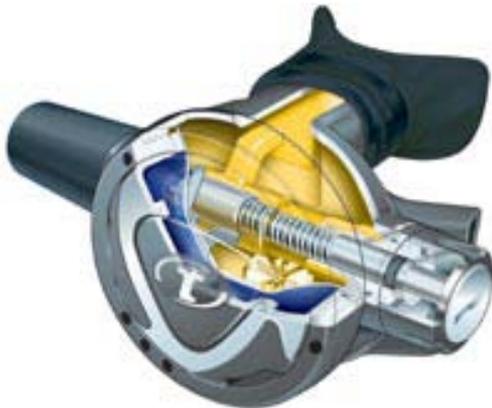
2.11 Technology

With the exception of digital dive computers, technology in scuba diving is mostly extremely simple mechanics. Everything must be fail safe and have very high durability.

The function of a second stage is fully mechanic. A membrane is pulled in when the diver breathes in, pushing down a lever that opens the air valve. When the diver exhales, the air is released through a one way valve. This solution is the same in all second stages on the market, although Poseidon revolutionized the system by creating a mechanism that is less than a quar-

ter of the size. Due to the tolerances required in production, the price became too high, and the product was eventually taken off the market.

The mechanics of the BC's valve is even simpler. Here, a plastic and rubber seal is pressed by a spring against a rubber gasket in the BC's air bladder. When the diver pulls the release string, it pulls the seal against the force of the spring, releasing the air.



Cross-section of a standard second stage.



An opened air valve on a vest style BC. The spring holds the valve shut, and is opened by pulling the string that runs down to the front of the vest.



The Poseidon Triton, once the smallest second stage on the market, due to its revolutionary mechanical solutions.

3. *Analysis*

3.1 Research conclusion

3.2 Function analysis

3.3 Values

3.4 Feedback



3.1 *Research conclusion*

During the research phase, a large number of problem areas and ideas were collected, some of which can be seen in the mind maps on the following pages. The main conclusions of the research were:

- Inadequate buddy checks and poorly constructed weight locks are the two most common causes for dive accidents. Many accidents would not be as severe if the diver frequently would have checked his remaining air.
- Out of air divers has a tendency to rip their buddy's primary mouthpiece out instead of going for their secondary. Panicked divers sometimes lose the mouthpiece, in which case it will be hard to retrieve from behind your back. Also, buddy breathing can be hard to perform due to the limited length of the octopus hose.
- New divers have a hard time to assemble the equipment properly. Straps get tangled, hoses mixed up and the lack of specific places to attach tools leads to loose, hanging equipment.
- The vest style BC is cumbersome and is too loose or too tight depending on if its inflated or deflated. It also offers poor balance under the surface.
- Communication under water is difficult, especially when it comes to getting the buddy's attention.

I tried to make a list to give the different issues priority. This list did however change throughout the process, depending on what compromises I was forced to make, and how some solutions affected each other. The issues chosen as main priority in the end are marked in red.

Main issues:

- *Dropped weights*
- *Hose management problems*
- *Inadequate buddy checks*
- *Losing reg from mouth*
- *Balance problems*
- *Problems with buddy breathing*
- *Complex appearance*
- *Infrequent air checks*
- *Poor streamlining*
- *Tangling straps*
- *Poor buddy communication*
- *Poor pocket usability*

3.2 Function analysis

Basic functions

Provide	Buoyancy control	MF
Allow	Carrying	RF
Be	Attached to body	RF
Provide	Emergency buoyancy	RF
Offer	Intuitive use	RF
Offer	Dry suit compatibility	RF
Provide	Storage space	RF
Be	Visible	RF
Allow	Tool fastening	RF
Express	Function	DF
Simplify	Assembly	DF
Simplify	Washing	DF
Offer	Diverse use	DF
Offer	Balance	DF
Simplify	Gear up	DF

Safety

Prevent	Tank slipping	RF
Prevent	Acc. weight dump	RF
Prevent	Loss of DV	RF
Simplify	Use of secondary DV	RF
Offer	Stream lined profile	RF
Offer	Surface safety	RF
Prevent	Tangling	RF
Allow	Quick release	RF
Assist	Buddy check	DF
Simplify	Buddy breathing	DF
Prevent	Out of air situation	DF
Simplify	Buddy diving	DF

Ergonomics

Offer	Ergonomic use	RF
Offer	Mobility	RF
Offer	Size adjustment	RF
Minimize	Breathing resistance	RF
Improve	Tool organization	DF
Offer	Tight fit	DF
Minimize	Discomfort	DF
Minimize	Back strain	DF
Minimize	Shoulder strain	DF

Construction/production

Simplify	Assembly	RF
Offer	Exchangeable parts	RF
Simplify	Mass production	RF
Maximize	Wear resistance	RF
Maximize	Eco friendliness	RF
Prevent	Ripping	RF
Offer	Simple production	DF
Simplify	Sowing	DF
Use	Local (Swe) materials	DF
Simplify	Disassembly	DF
Use	Standard components	DF
Simplify	Repairs	DF
Allow	Swedish production	DF

Transport

Be	Travel friendly	DF
Simplify	Transport to dive	DF
Simplify	Logistics	DF
Minimize	Weight	DF

Marketing

Express	Simplicity	RF
Express	Quality	RF
Be	Differentiated	RF
Attract	New divers	RF

MF - Main function

RF - Required function

DF - Desired function

3.3 Values

The emphasis of the project and expression of the final product should be:

1. Safety

The product should prevent the most common accidents, and should encourage correct use.

2. Market gap

The product should inspire non-divers with its simplistic appearance, and be set apart from today's equipment through both look and function.

3. Usability

The product should be easy to use, and solve the usability issues of today's equipment.



3.4 *Research feedback*

Interview with Patrik Jeppsson, H2O dive school

My interview with Patrik Jeppsson, instructor at H2O dive school in Lund, confirmed that new divers can be confused by the polarity of the dive community. DIR diving on one hand is a growing trend that many new divers have heard about, but they are a somewhat secluded group, often looking down on non-DIR divers. On the other hand there is the hi-tech diver, interested in complicated stuff and looking for new functionality.

Many dive schools have an attitude that is tech-oriented and masculine, probably scaring off potential customer. With this attitude, the reputation of diving being complex is reinforced.

The evolution of diving equipment is virtually non-existent. The products change colour and details, but the layout remains the same. It seems like none of the major companies are daring enough to question today's equipment. Many new divers do have problems with the equipment, but gradually learn to accept them. In short, there is place on the market for new kinds of equipment, but it seems like none of the major manufacturers are willing to take the risks of developing innovative products.



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4. *Ideation*

4.1 Brainstorm

4.2 First sketch phase

4.3 Feedback

4.4 Concept proposal

4.5 Moodboard

4.6 Second sketch phase

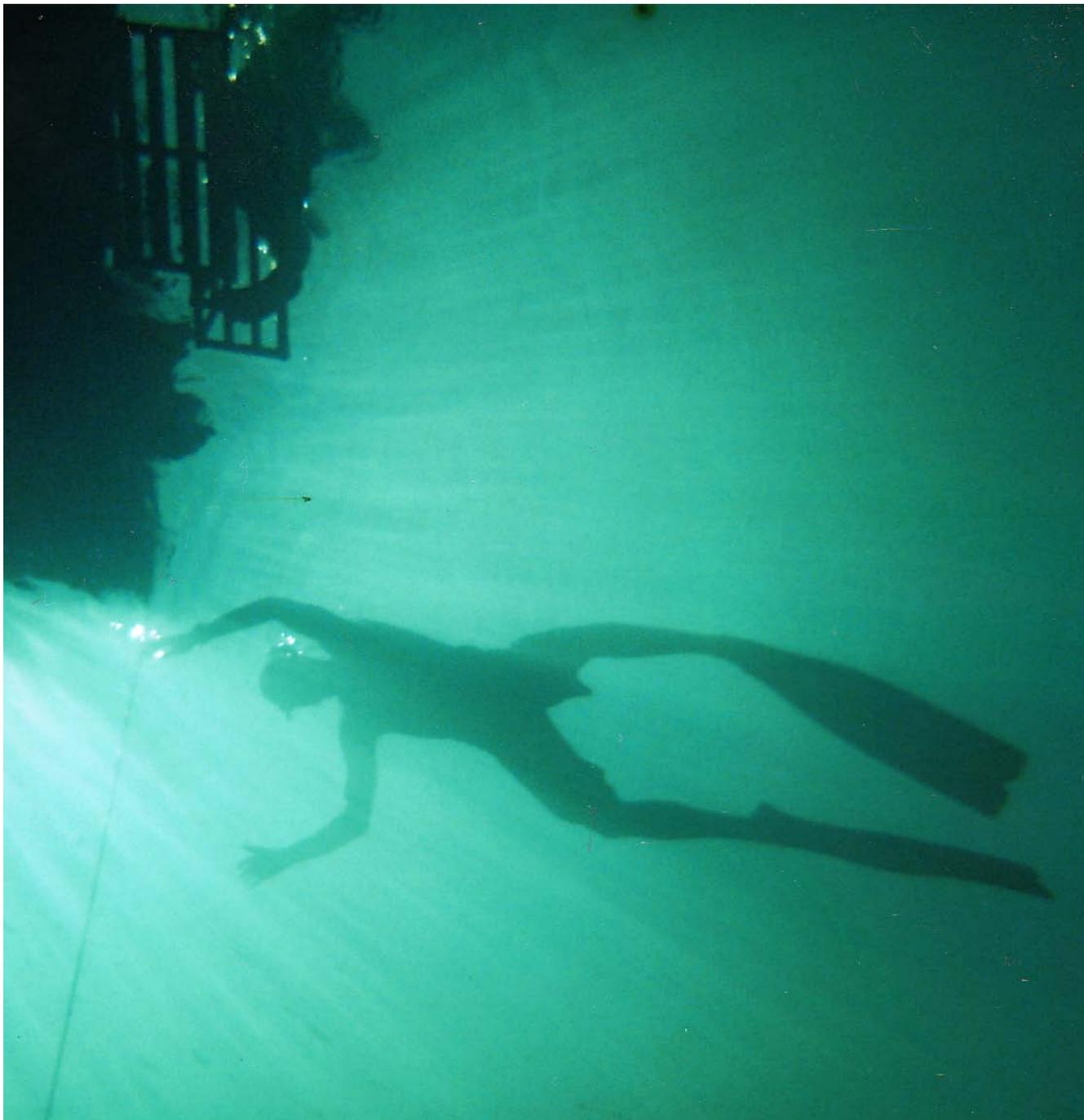
4.7 Second sketch model

4.8 Feedback

4.9 Third sketch phase

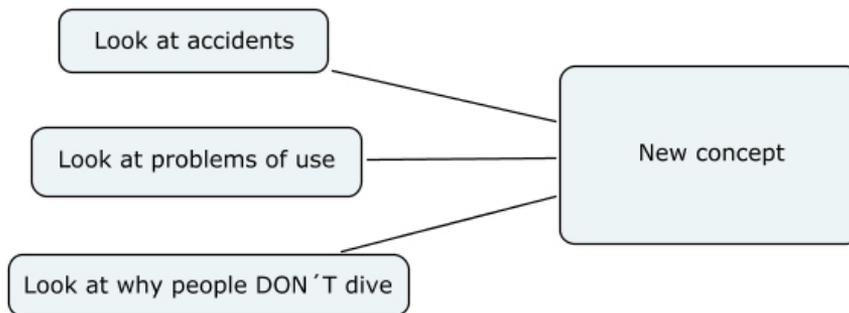
4.10 Fourth sketch phase

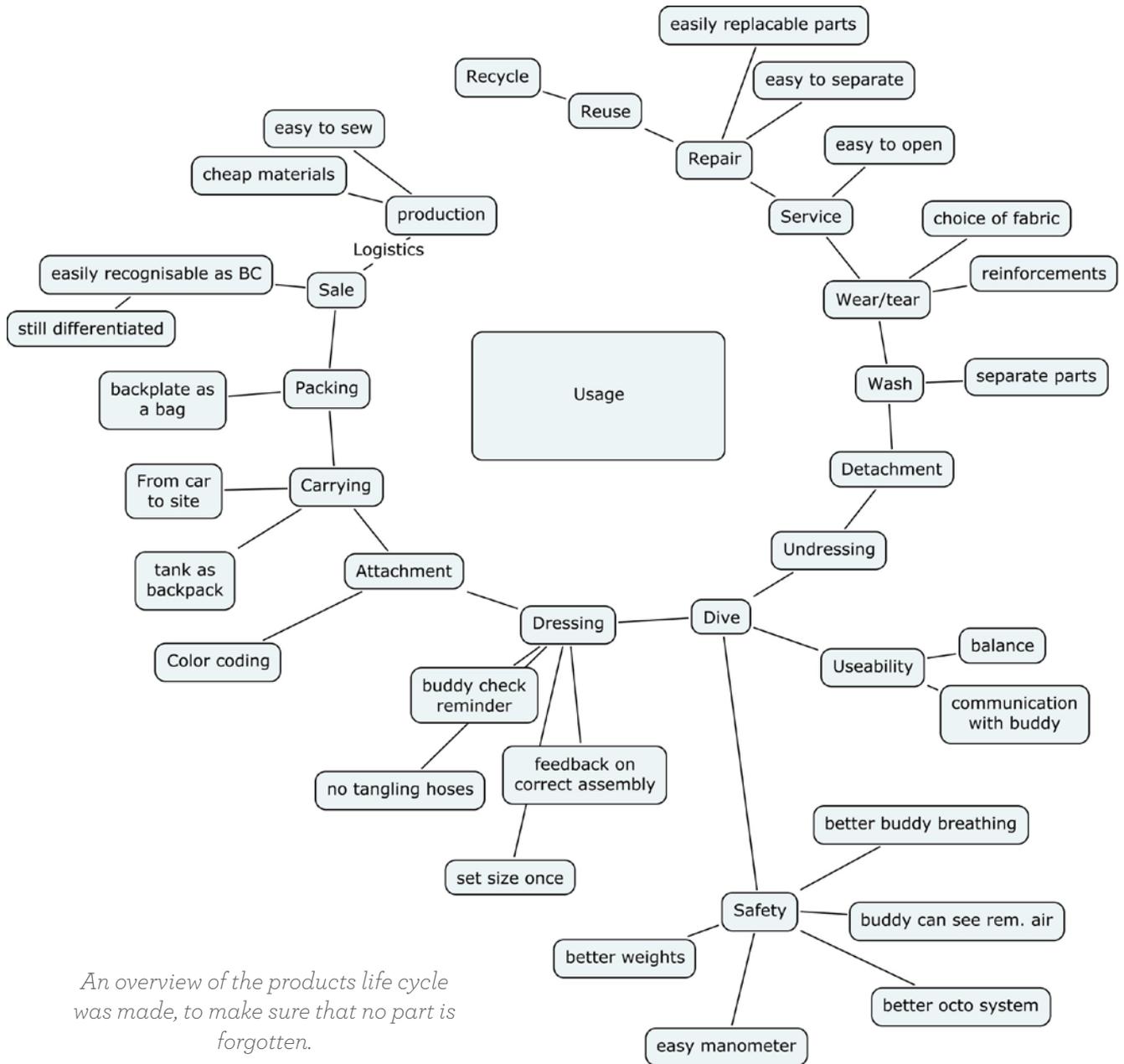
4.11 Demographics



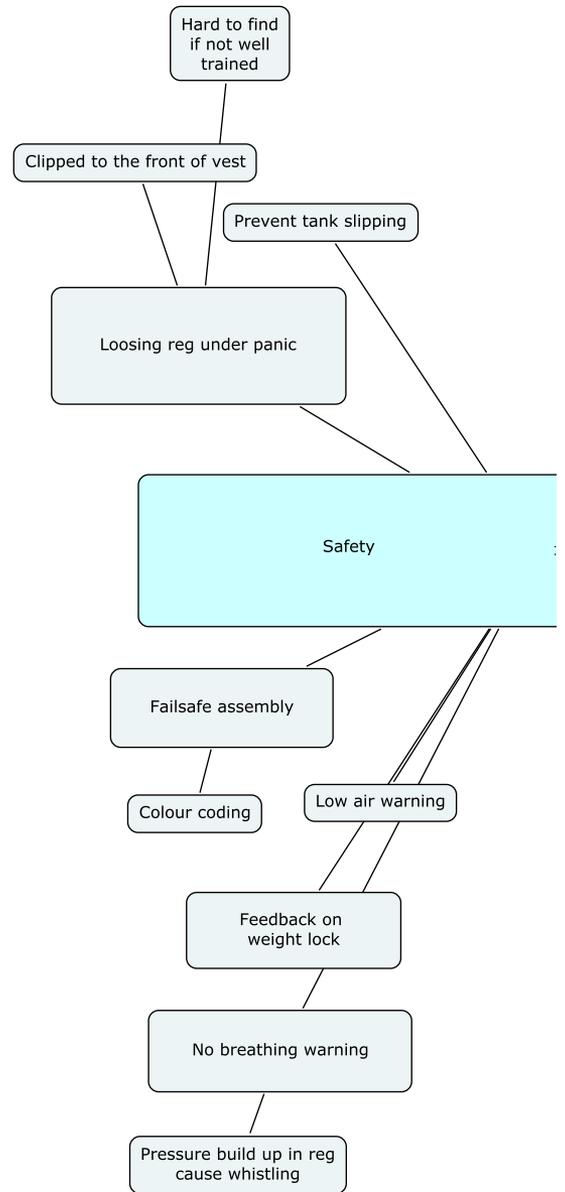
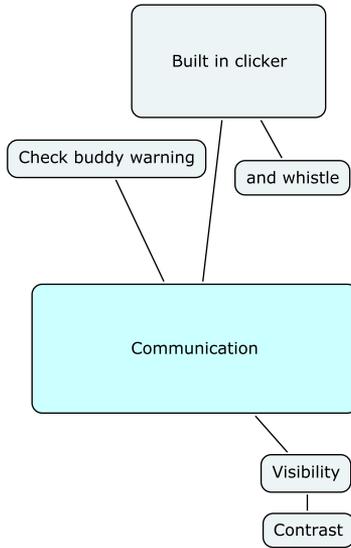
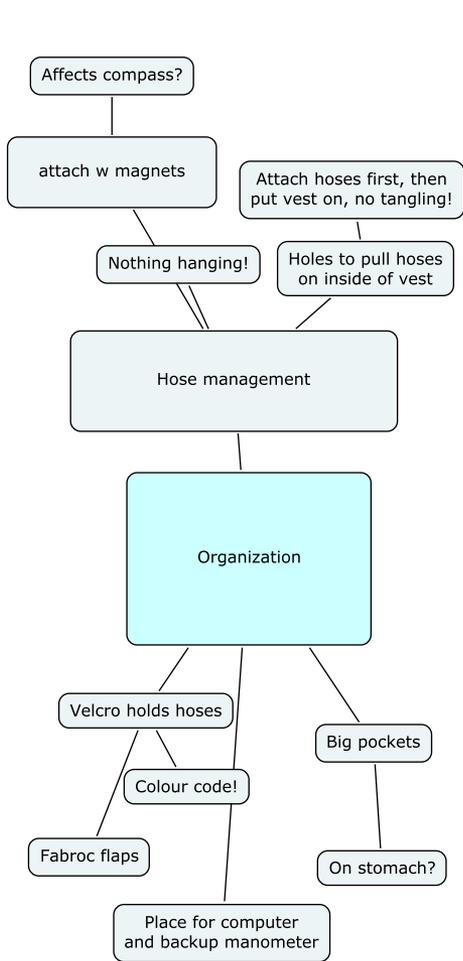
4.1 *Brainstorm*

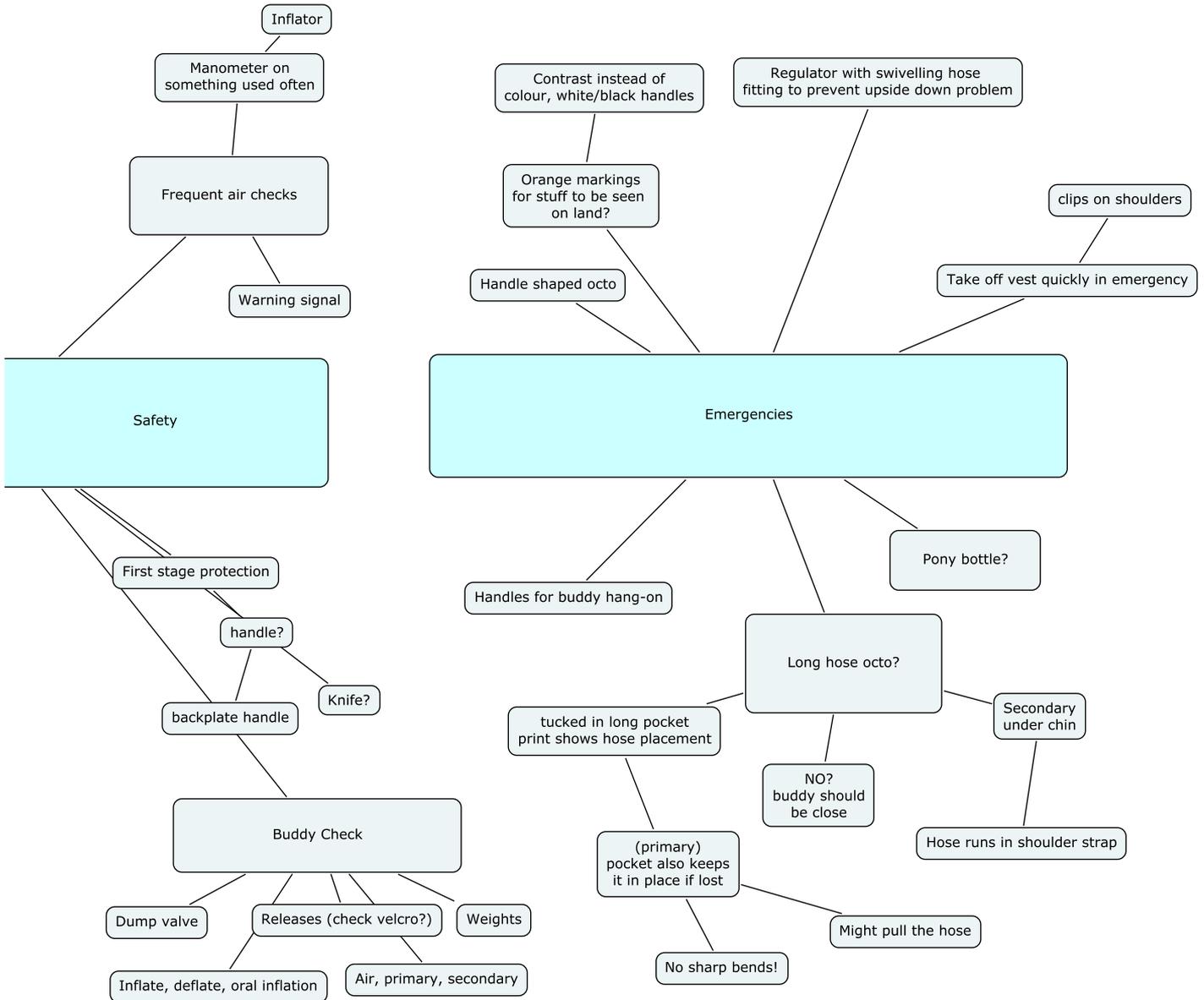
Ideas and problems were collected both during and after the research phase. Some are presented here, some in the mind maps on the following pages, some in sketches and others are not presented at all, since they were disregarded early on.

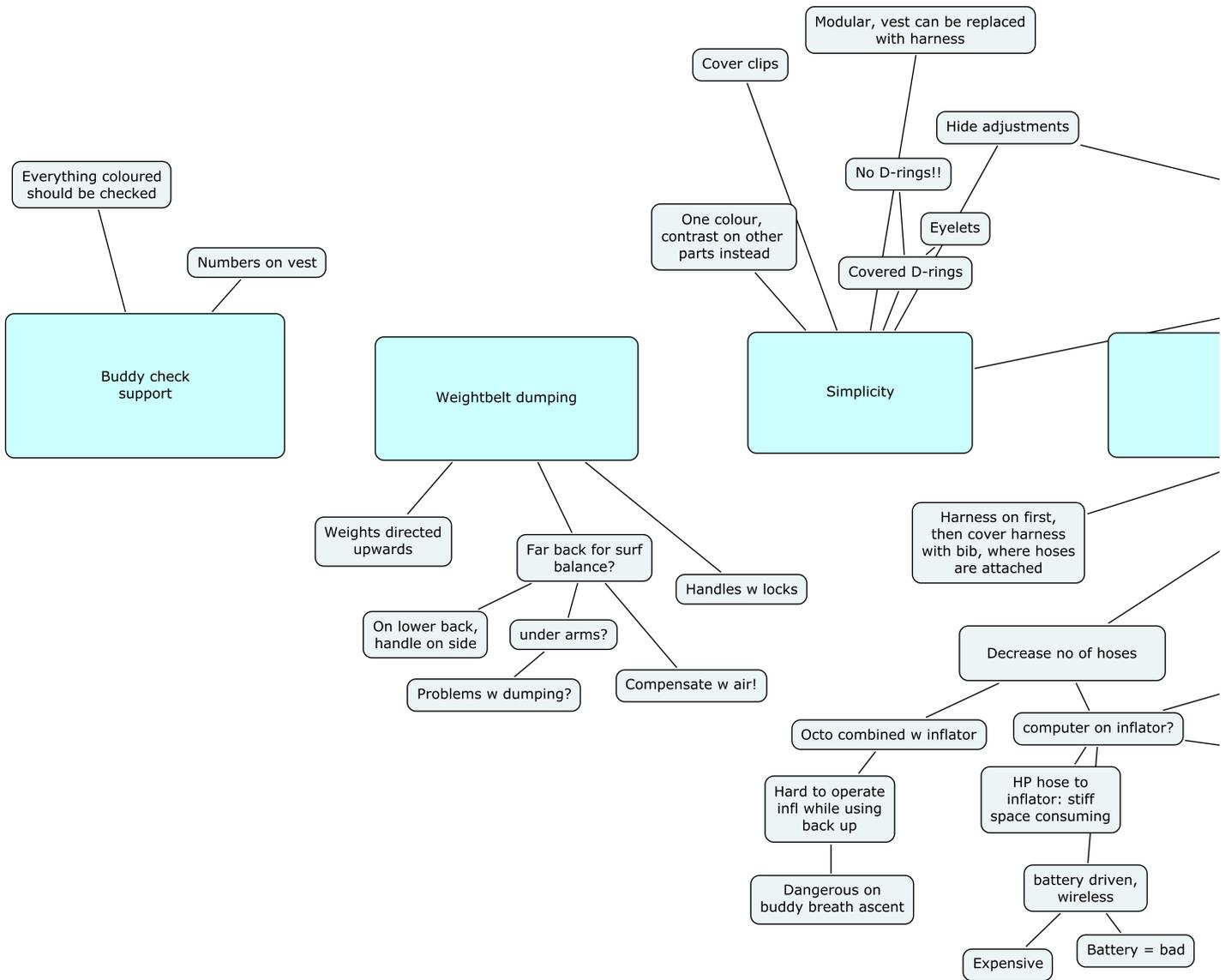


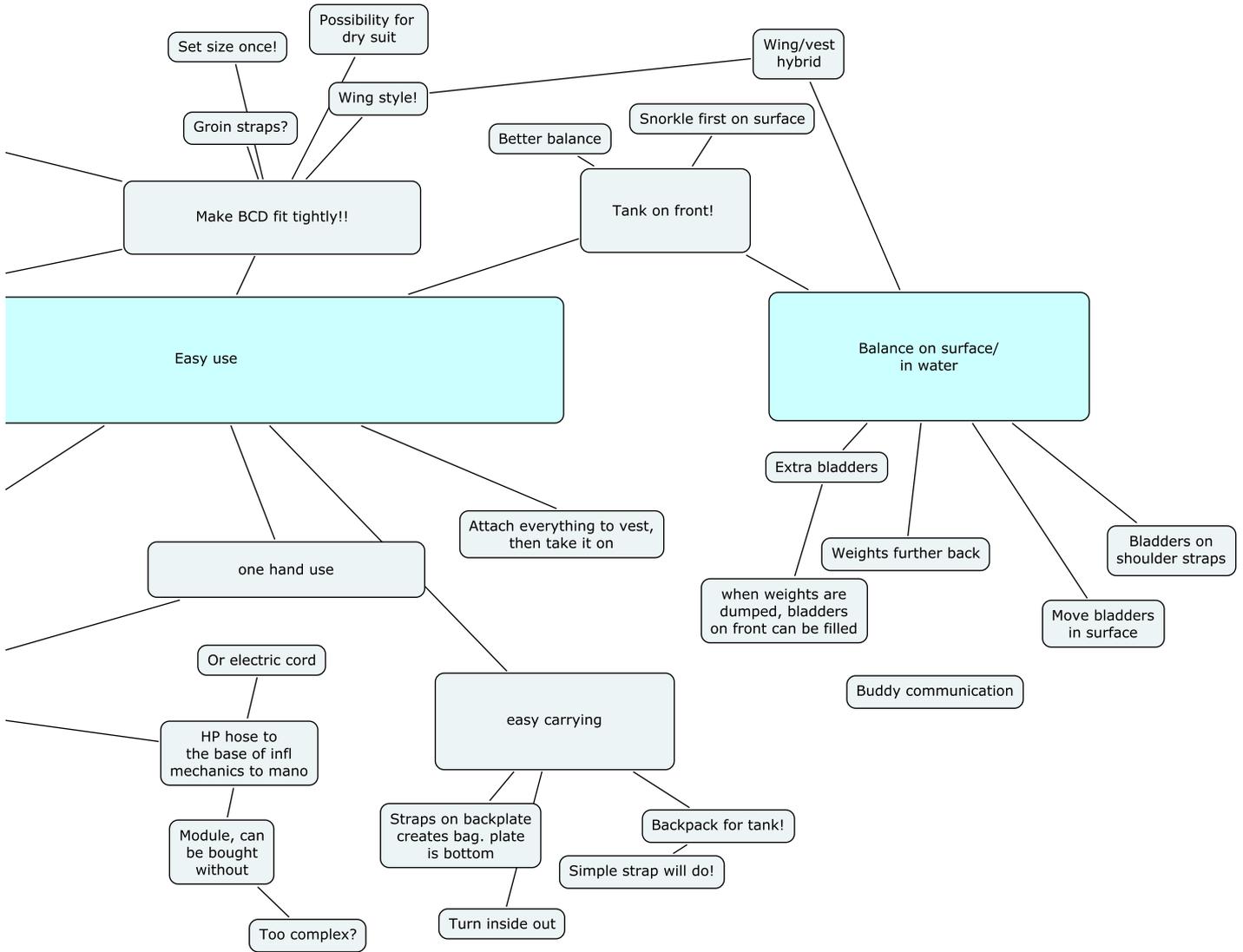


An overview of the products life cycle was made, to make sure that no part is forgotten.







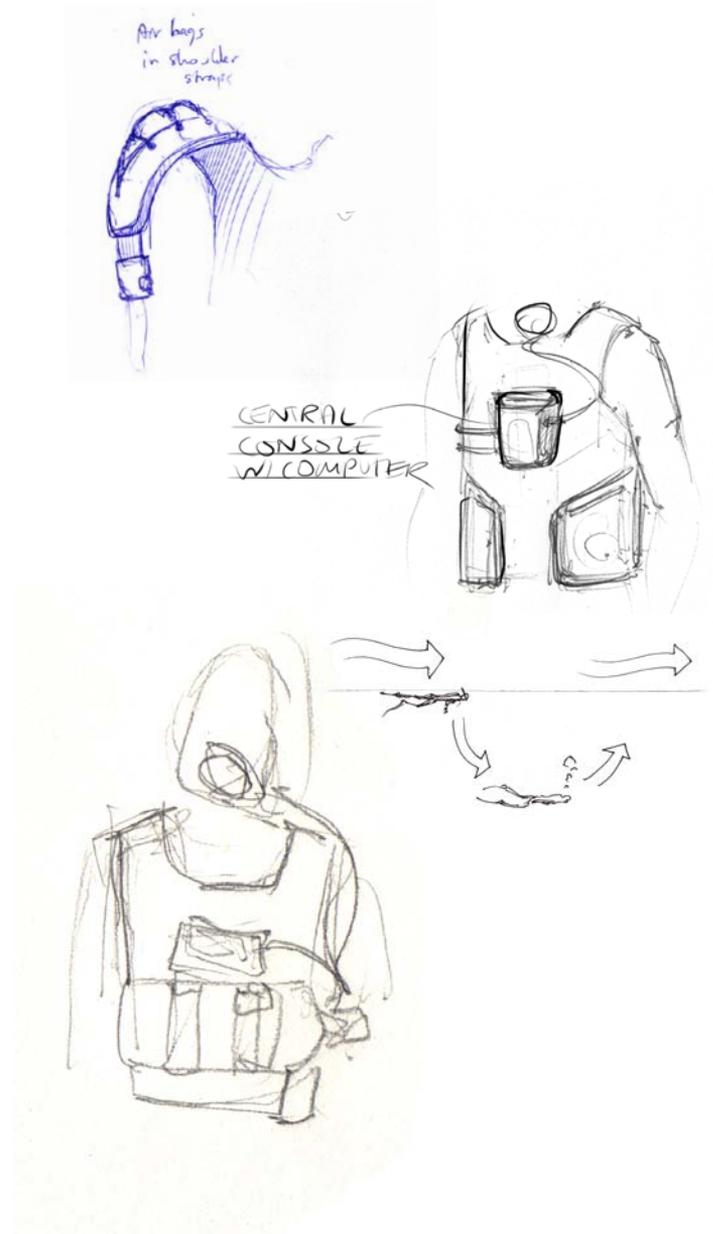


4.2 First sketch phase

The first ideas were, as often is the case, technology focused. Many were also radical changes to the layout of diving equipment, while others included warning systems of different sorts. I was interested in letting the user as well as other divers know when the air level was too low, if the diver hadn't checked his air level or his buddy frequently, or if the diver didn't breathe properly.

I was also working on different ways of reducing the number of hoses and instruments. For example by having some kind of control box on the chest, where the second stages were attached, and the pressure gauge was fixed. I was also still working on the early ideas of combining scuba diving and snorkeling, so that you could search for nice dive spots on the surface and then do a shorter dive.

Other ideas were focused on the issue of balance on- and under the surface. These included a number of ways to alter the point of gravity depending on the situation. This could for example be done by inflating the shoulder straps, flipping the inflated air bladder over from the back to around the neck, or by having air compartments on the front of the vest that is only inflated when the diver has dumped his weights. This would mean that the diver would float face up if he or she surfaced unconscious after an emergency.





When weights are dumped, a valve opens - allowing air to forward cushions



Wing is flipped to front of diver on surface



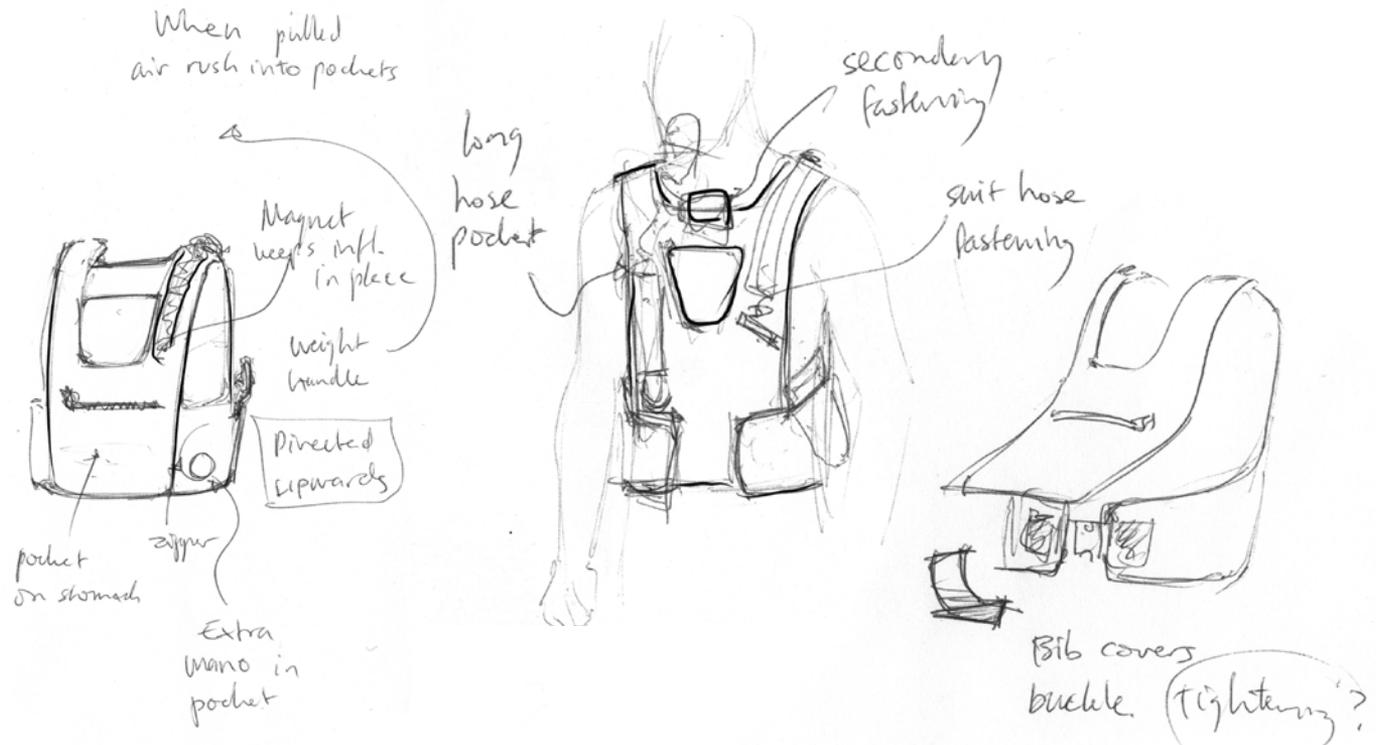
move weights further back!



Inflatable cushions on shoulder straps

Some of the ideas on how balance on the surface can be improved. Eventually, all ideas were deemed to complex, apart from the one addressing the problem in the simplest way: carefully placing the weights and the air bladder in such a way that the center of gravity easily can be changed by leaning backwards.

4.2.1 Lo-tech, lo-tech, lo-tech



I realized that almost all of these technology focused ideas were counterproductive, as they only increased the complexity of my product. Furthermore, an additional safety measure can often decrease overall safety, since you tend to rely too much on the system. A diver who is accustomed to a warning signal when his air is low will probably check the air level even less often, thus ending in an even more dangerous situation when the warning system fails.

Instead, I changed my focus to encouraging the diver to behave in a safe manner, and also trying to simplify the equipment in order to make

it easier to use. With this in mind, I was sketching on how to place air and weights, and how to achieve a less complex and more streamlined BC by hiding the straps and clips, and still be able to adjust the size. I also started to work on how hoses could be attached or hidden to create a logical layout.

Simplicity

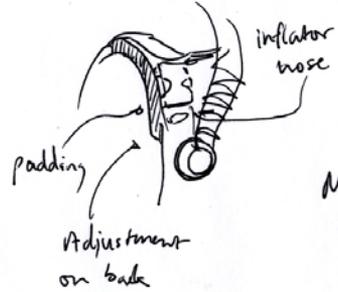
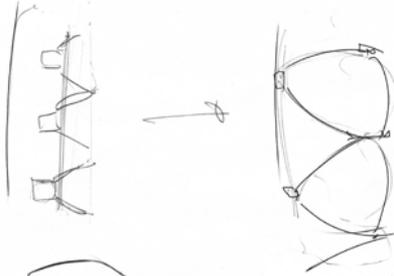
Cover strap

Replace straps → How to adjust?

Many sizes

Velcro

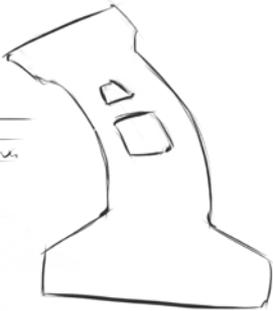
hooks & loops



Move clip forward?

Quick Release!

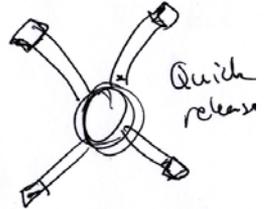
ATTACH HOLES FIRST FOR CASIEC DRESSING.



weights under (below) back-plate



HOLE FOR DRY SUIT CONNECTION



Quick release

WILL PULL NECK DOWN WEIGHT!



CLOSE TO ORDINARY CLOSING



Adjust once!

not every time you put on

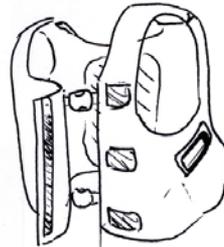


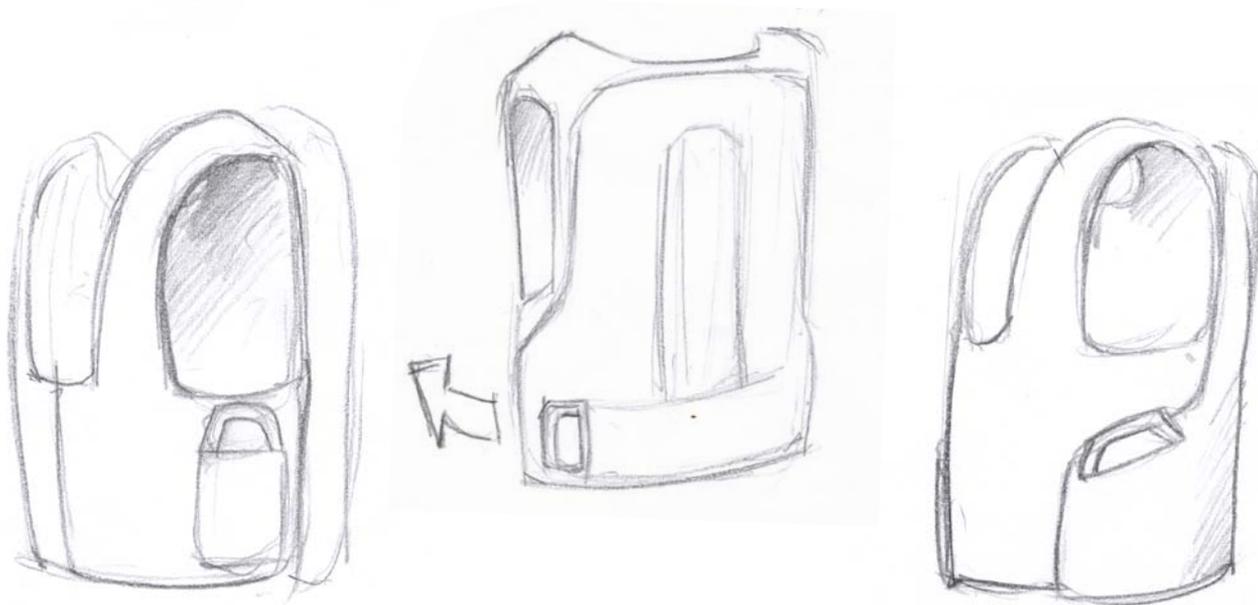
Move adj. back

Adjustments in back?

Behind back plate?

bag + pocket on stomach



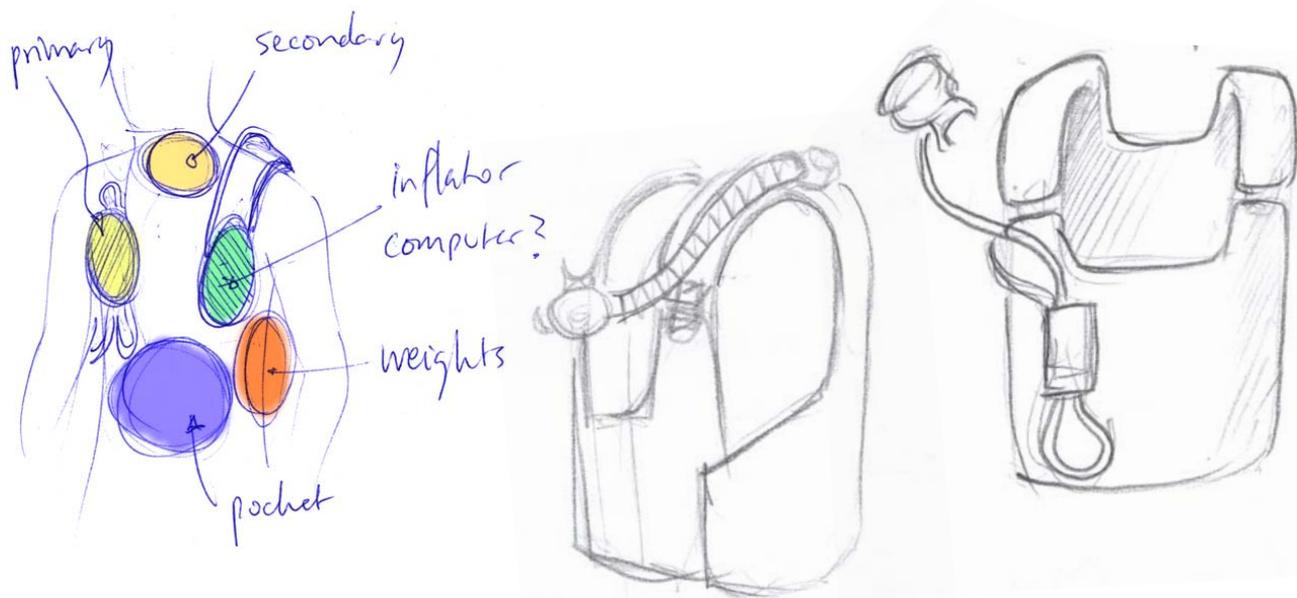


Ideas on weight placement and shape of the air bladder.

Gradually, the basic layout of the BC was formed. I realized that I wanted to create a hybrid between a vest and a wing style BC, taking the best of both worlds. The air bladder was to be positioned on the back of the diver to improve below surface balance, but also to lift the weight of the tank in order to decrease back pains. The air bladder was also to extend a bit forward to support the diver in an upright position if he or she leaned back. The weights were positioned far back, so that they are lifted by the air and also helps the diver to stand up in the surface. Still, they are below the air bladder so that balance under the surface is not ruined. The benefits of

the vest style layout is used to give a better fit, easier use, and to create space for pockets and fastening for tools.

In parallel, the organization of instruments and tools such as the inflator, pressure gauge and secondary stages were addressed. I tried to separate the different tools as much as possible, so that every item gets its specific place on the vest. To minimize the number of hoses I also experimented with combining the inflator and secondary second stage as well as the inflator and pressure gauge.



Thoughts on instrument management, combined inflator/second stage and fastening of the long hose.

From the rules of DIR diving, I lent the idea of a long hose to simplify buddy breathing. In the DIR philosophy, though, the two meter hose is worn under the right arm, across the chest, around the neck and to the mouth. I found that very complex, and decided to simplify it by storing the hose under a velcro flap, which has the added bonus of keeping a lost secondary stage on the front of the diver, making it so much easier to retrieve, thus eliminating another of the more common accident triggers.

Other things I knew would be in the product was some kind of color coding for the hoses, so that

the equipment always would be assembled correctly. I also wanted to assist the buddy check, possibly by numbering or marking every item that should be checked before the dive.

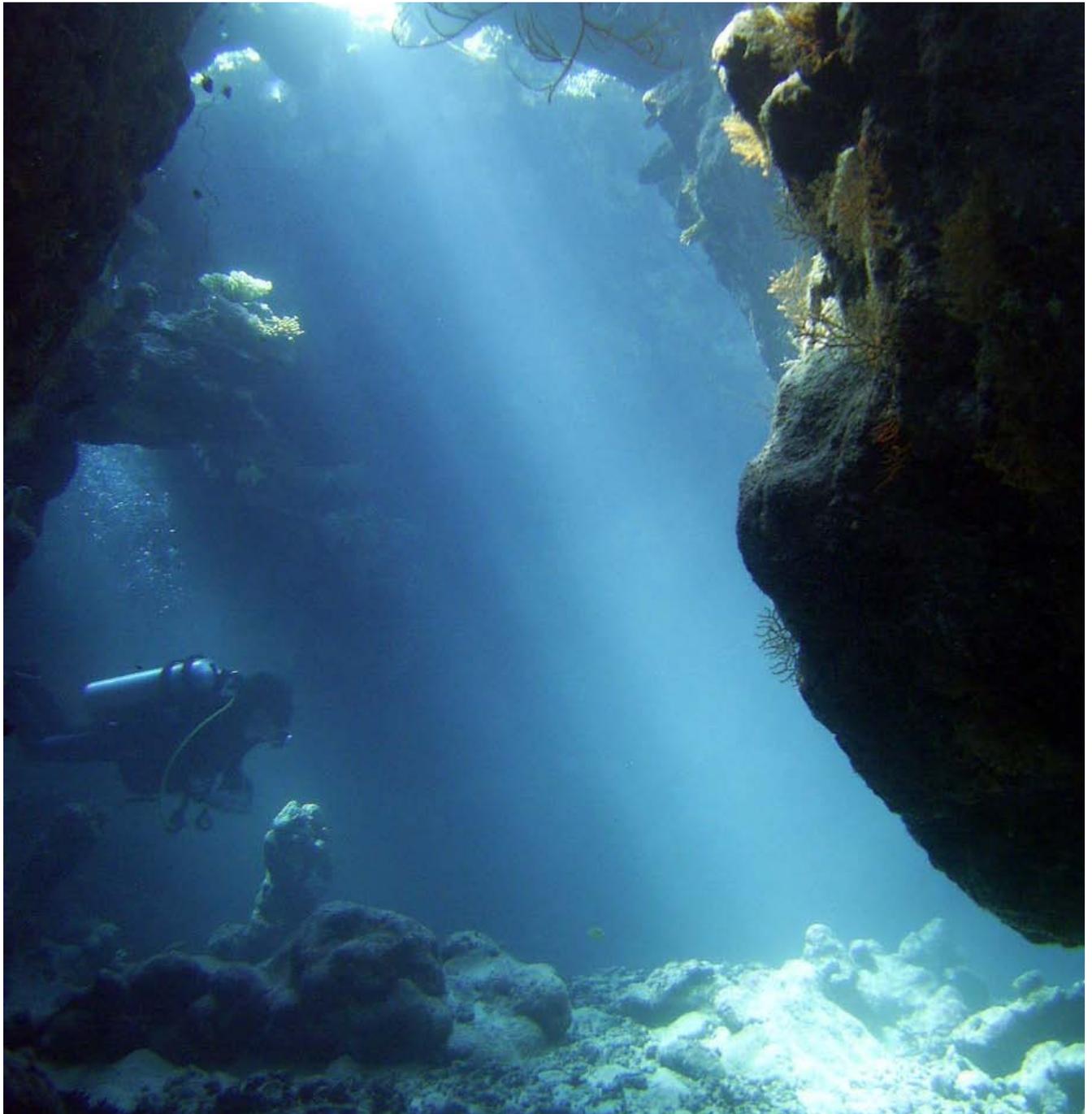
4.3 Feedback

Interview with Patrik Jeppsson

H2O dive school - feedback on sketches.

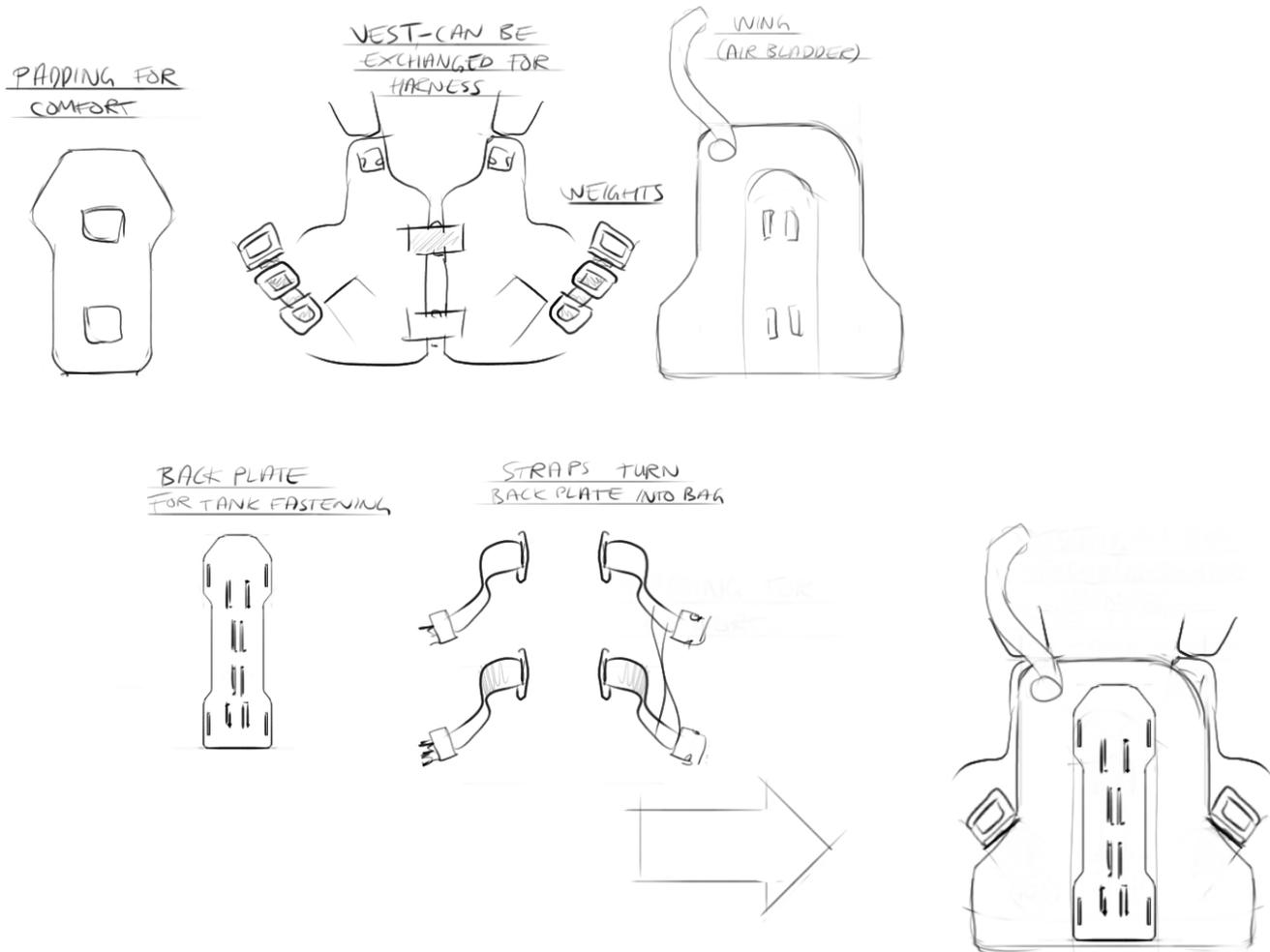
Wing BCs are becoming increasingly popular. Dive schools still use vests because of the easier use and better surface balance. But balance on surface with a wing type BC is only an experience issue, and it would be interesting to look into wing style BCs even for new divers. The ideas of altering balance on the surface seems to increase complexity too much though. The placement of the weights further back is quite enough!

The issues of buddy breathing are interesting. Giving the primary DV to a diver out of air is being discussed in many dive schools and might actually be taught in the future. Combined inflators and secondary stages has been tried and failed, because of the short inflator hose, and the obvious problems of operating the inflator when someone is breathing in it.



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4.4 Concept proposal



Since the equipment should be easy to wash and repair, I wanted it to be made from separate parts that can be separated and even replaced. If the user rather would change to a harness instead of a vest, they are easily exchanged.

The idea was tested with a very crude sketch model sewn out of old bed linen, which showed that the idea will probably need a lot of adjustments to become a rigid, tight fitting vest.



4.5 *Moodboard*

My intentions were to create a simple looking product with a low key colour scale so that any markings and colour coding shows clearly. Even if I wanted the product to stick out on the market by not having a tech look, is still wanted the robust reliable look that “engineered” mechanical products often have. I was also inspired by Arcteryx´ backpacks, that have all the necessary straps and adjustments, but still maintains a simple and smooth appearance.



FOOL PROOF



ROBUST

DETAILED INSIDE



EXHAUST



FAVORITE

SAFETY



INTAKE

CORDS ON INSIDE

ZIPPER REINFORCEMENT

SIMPLE COMPLEXITY



GREYSCALE

LIGHTNESS - FEELDOM

CONTRAST/VISIBILITY

PATTERNS

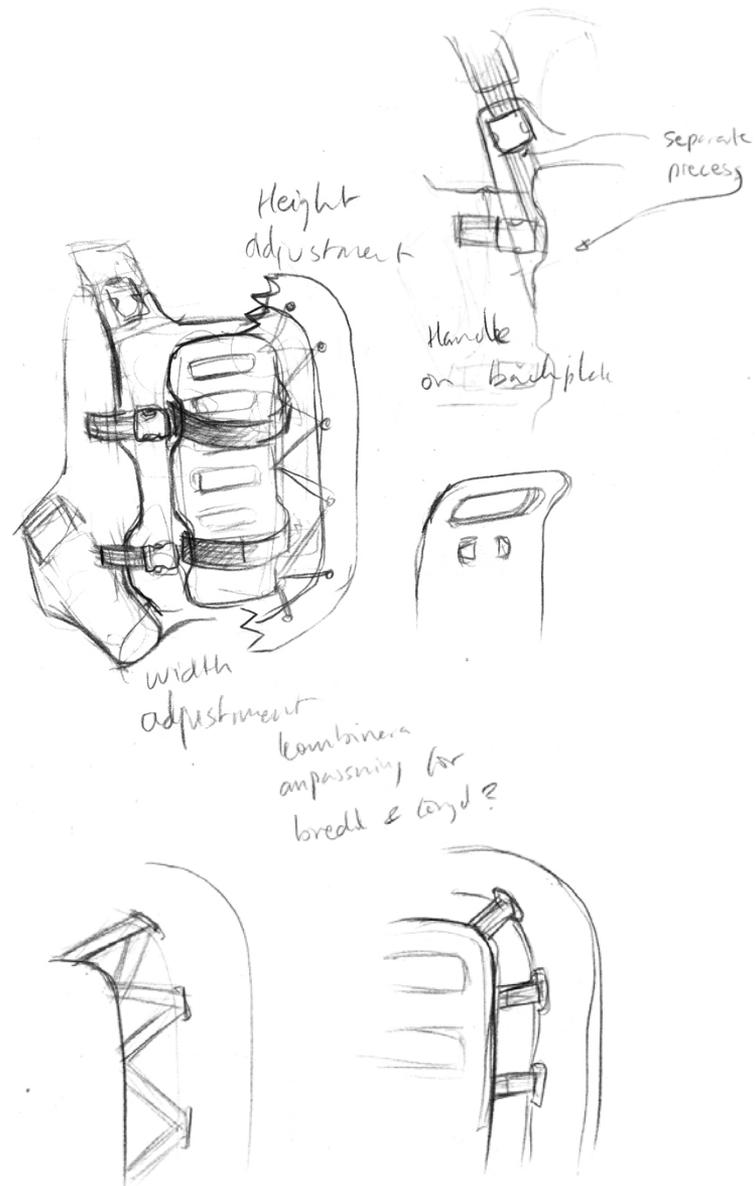


4.6 Second sketch phase

I felt that the main direction was working, and started to sketch more in detail on things like the look of the vest, width and height adjustment and placement of the weights.

The adjustments needed actually created the frames of how the vest would look. It was also a bit depressing to realize the amount of straps and plastic clips that would be needed in order to create the product. A totally clean, simple looking BC was simply impossible to create.

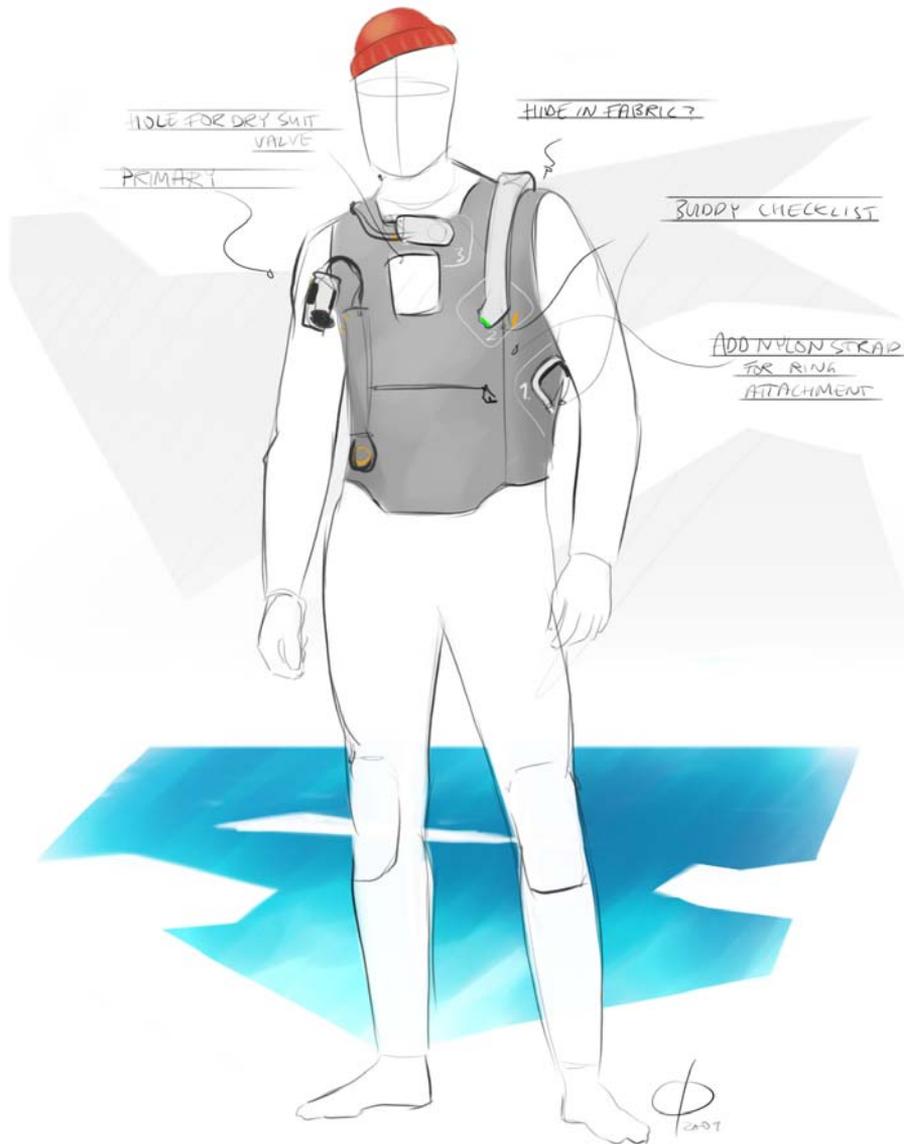
In order to get the proportions right, I sketched possible layouts directly on a mannequin. This was extremely helpful when it came to weight placement and hose management, and also meant the death of a number of promising ideas that simply wouldn't fit when the sketches were given correct proportions.



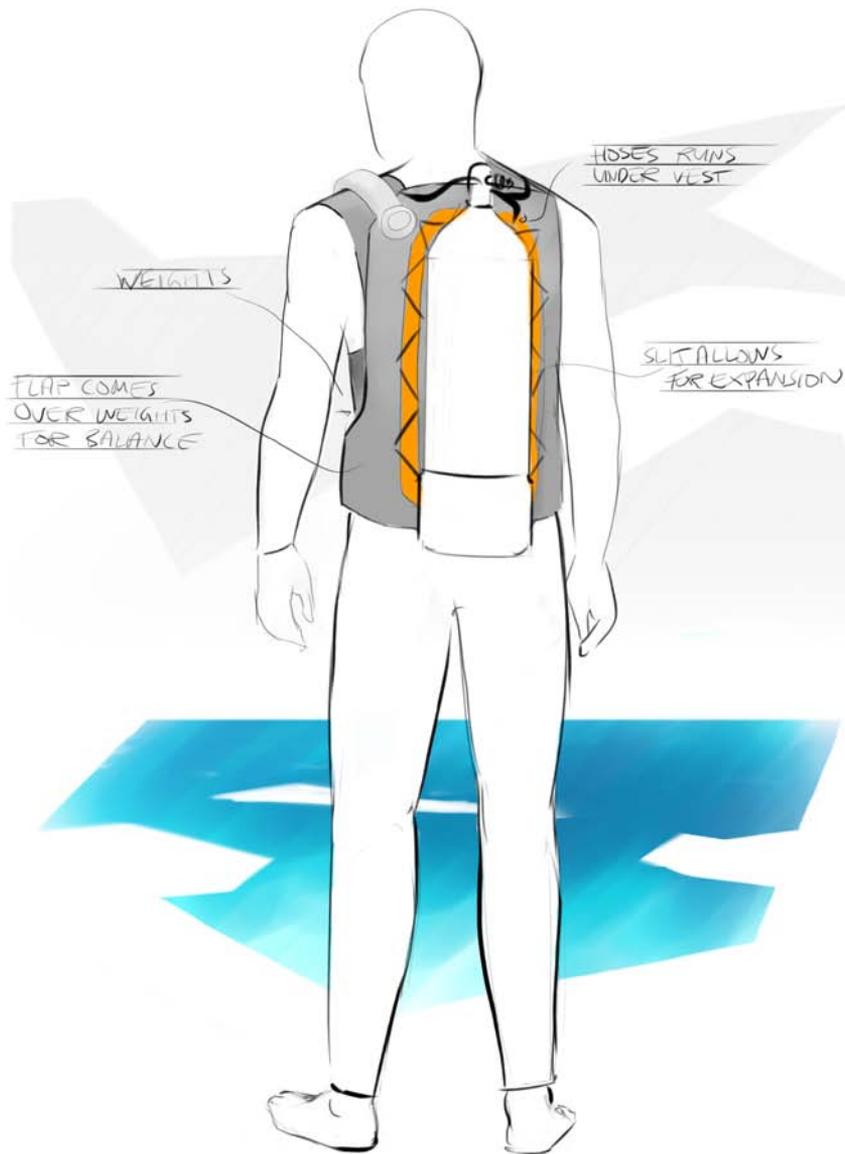
Sketches on how to accommodate the needed adjustments and the flexibility of the air bladder.



Early sketching was made directly on the mannekin.

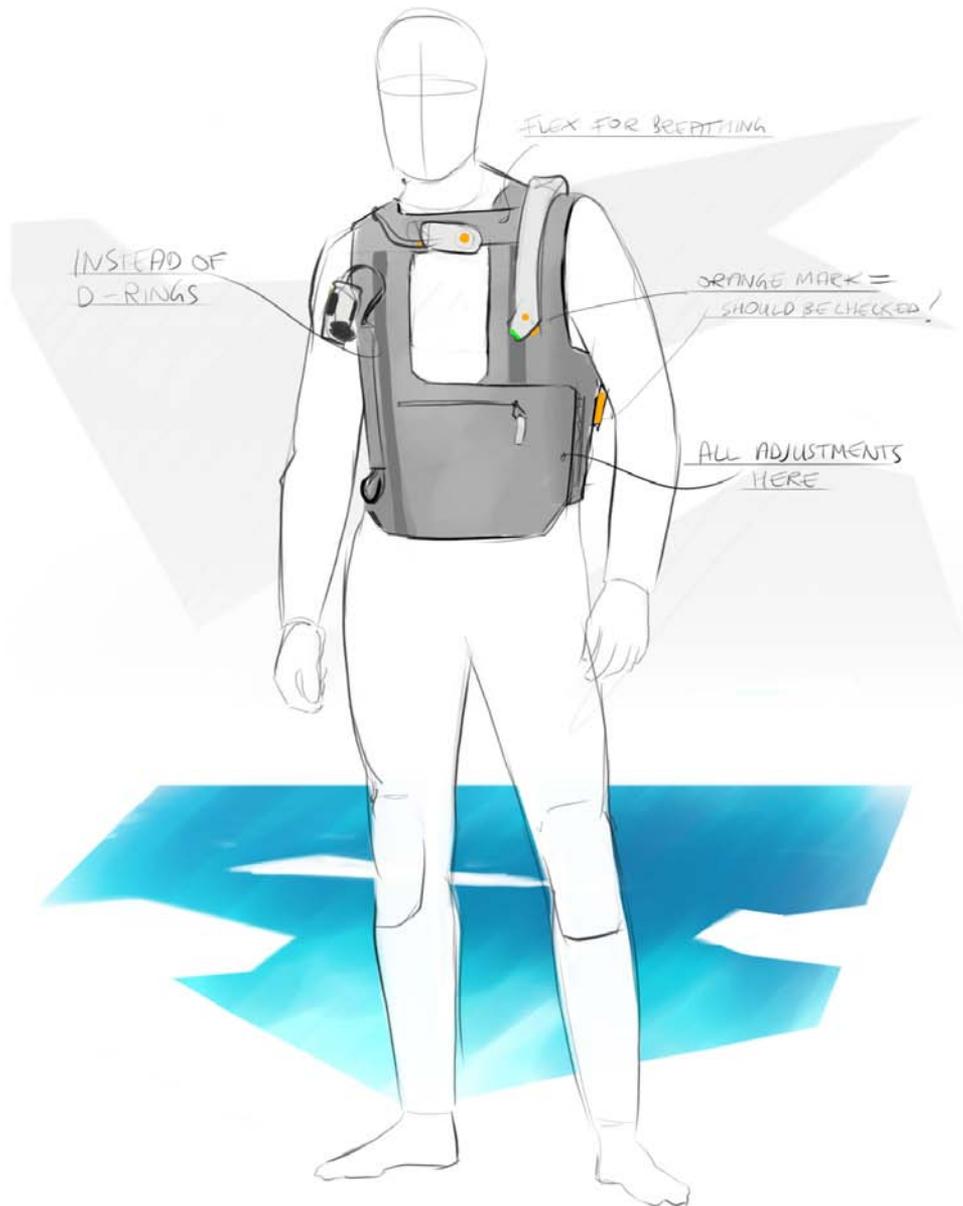


The first real sketch where most of the concept is gathered in one product. The hole on the chest is for the dry suit air valve. The idea was that strips of stretchy fabric on the sides and back of the vest would give way for the diver's breathing. The weight handle protrudes from behind underneath the arm



In order to create a streamlined profile the hoses can be drawn through a hole and under the air bladder so that they are held down, also, the air bladder is held together by rubber bands, and can expand through in the slit in the outer fabric when inflated.

The weights are pointed upwards to prevent them from falling out of the pockets if the lock should fail.



I realized that the idea of stretchy fabric would never work in combination with a heavy tank on the back. Instead, the chest area was opened up totally to allow proper breathing. The buddy check support was now reduced to giving every item that needs to be checked a bright orange colour.



To simplify the look, adjustments are hidden under the belly flap and instead of the standard, large D-rings to fasten tools there are sewn on straps that can be used for fastening. The weights are hung from the air bladder instead of the vest, so that the air will lift them from the back of the diver.

4.7 Second sketch model



The second sketch model was used to try out the shape of the vest, placing the different pockets and to create a pattern for the final model.



F.O.V. was kind enough to supply me with a large number of material samples as well as the fabrics i chose for the final product. The material is Cordura, a polyamid fabric that is very tough and often used for backpacks and, in thinner variants, for outdoor jackets and trousers.

4.8 Feedback

Interview with Anders Bergman

Owner, H2O dive school

The concept seems plausible, H2O has considered running Open Water courses using wing style BCs.

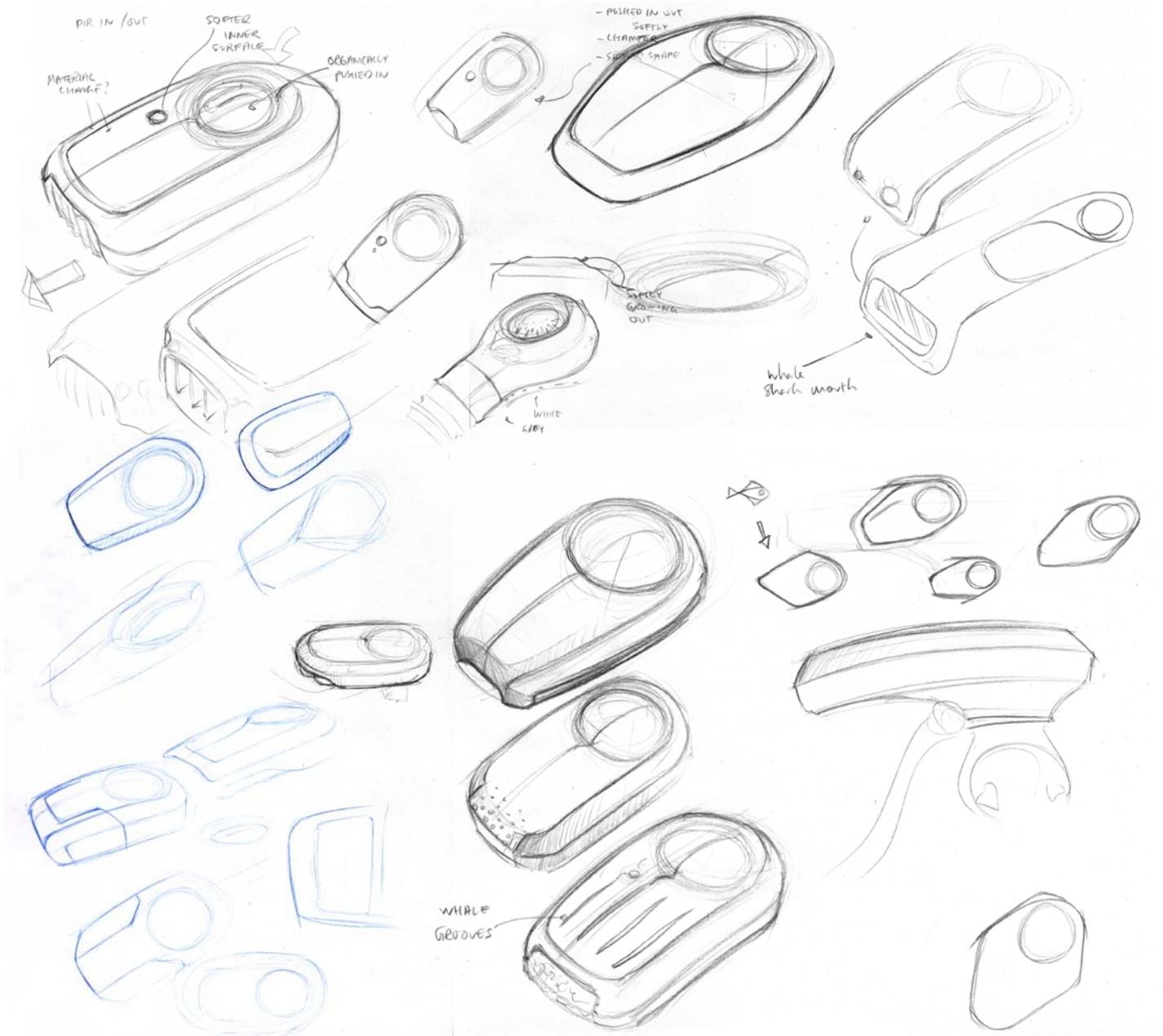
A two meter long hose is only necessary in cave and wreck diving, ocean long hose 1,5m is an option. When a long hose has been tried during courses, people were observed using the length of the hose to stay away from each other, which might pose a risk in an emergency. This might not be a problem in real situations though?

Wireless air-integrated computers coming fast, and the price is falling quickly. Suunto is removing most non-air integrated computers. Maybe that could be used for combining the inflator and pressure gauge? The vest should have small pockets with a zipper for extra weights.



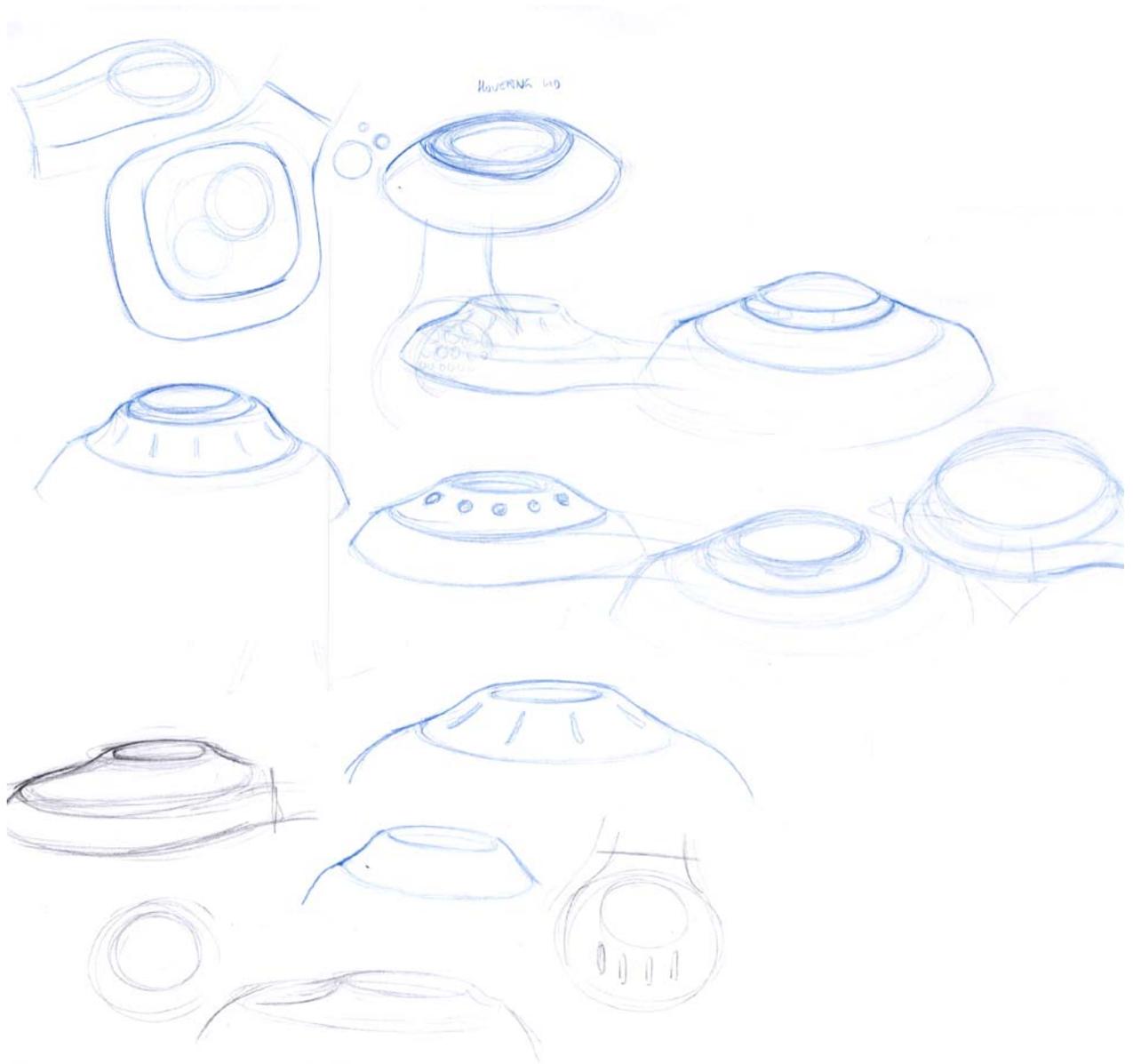
Blacktip reef shark, Koh Tao, Thailand

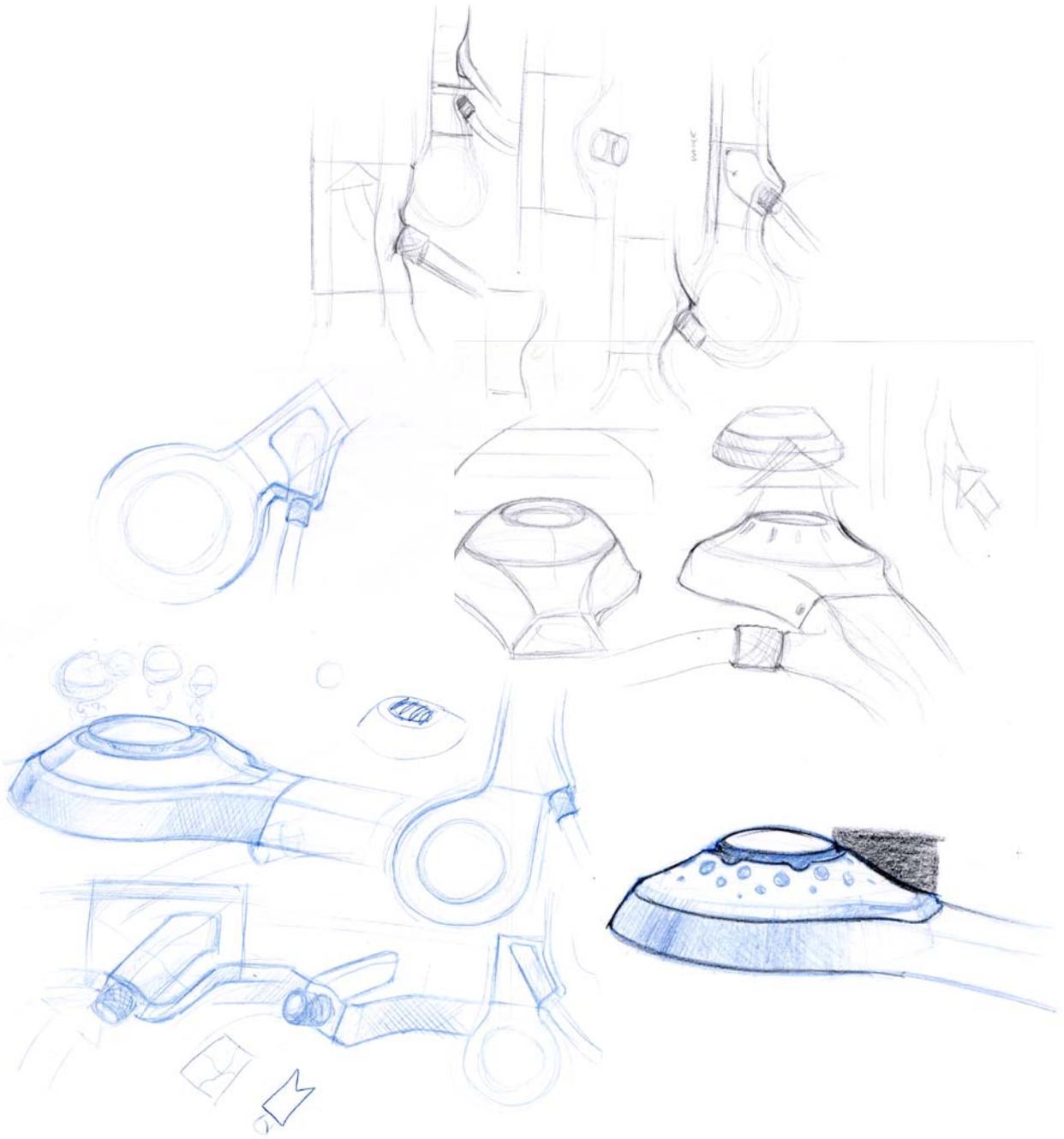
4.9 Third sketch phase

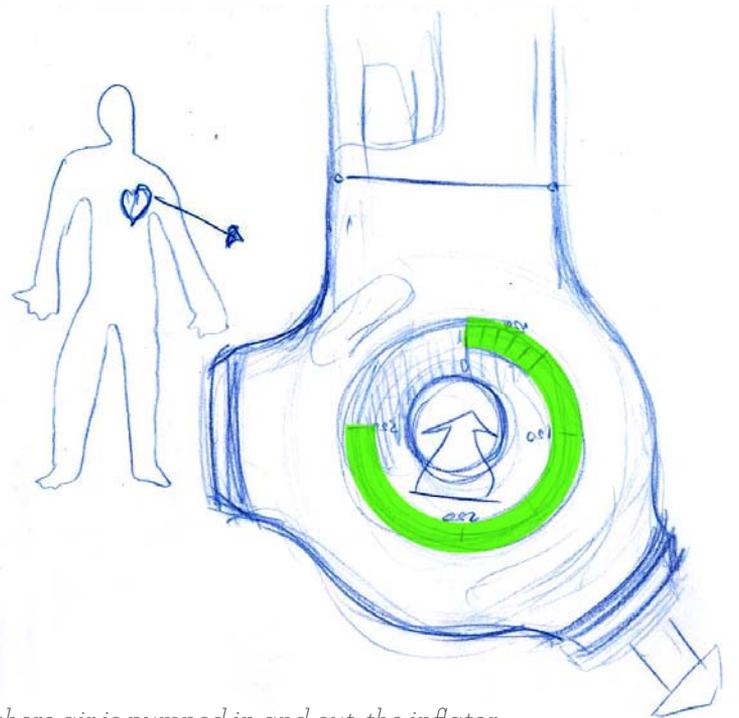
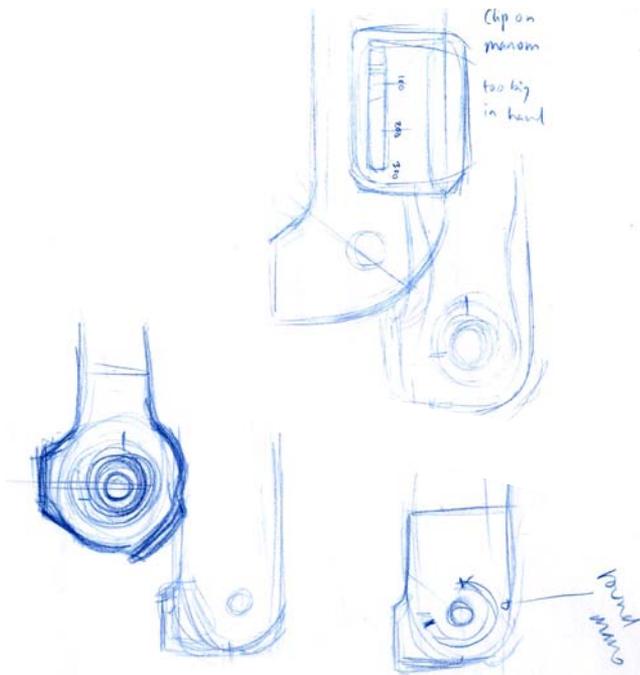
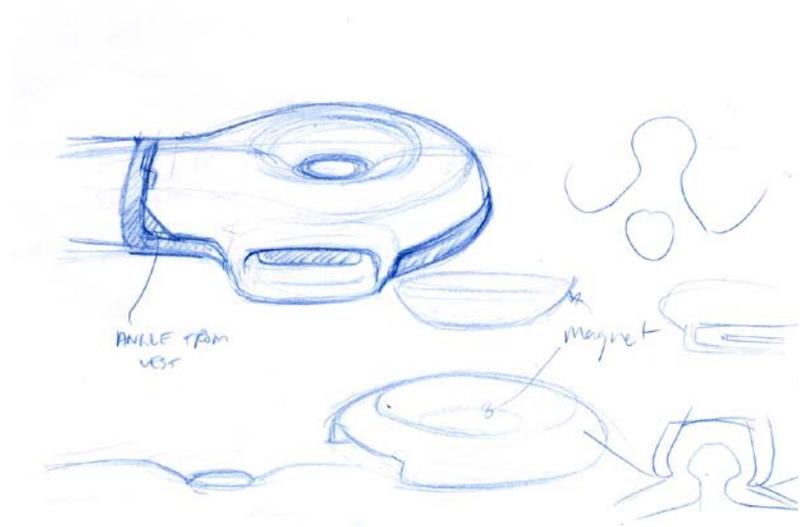




The idea emerged that the different items should convey the air movement inside the equipment. For example, an air vent should have a protruding surface, while inflate buttons should be set in concave surfaces.

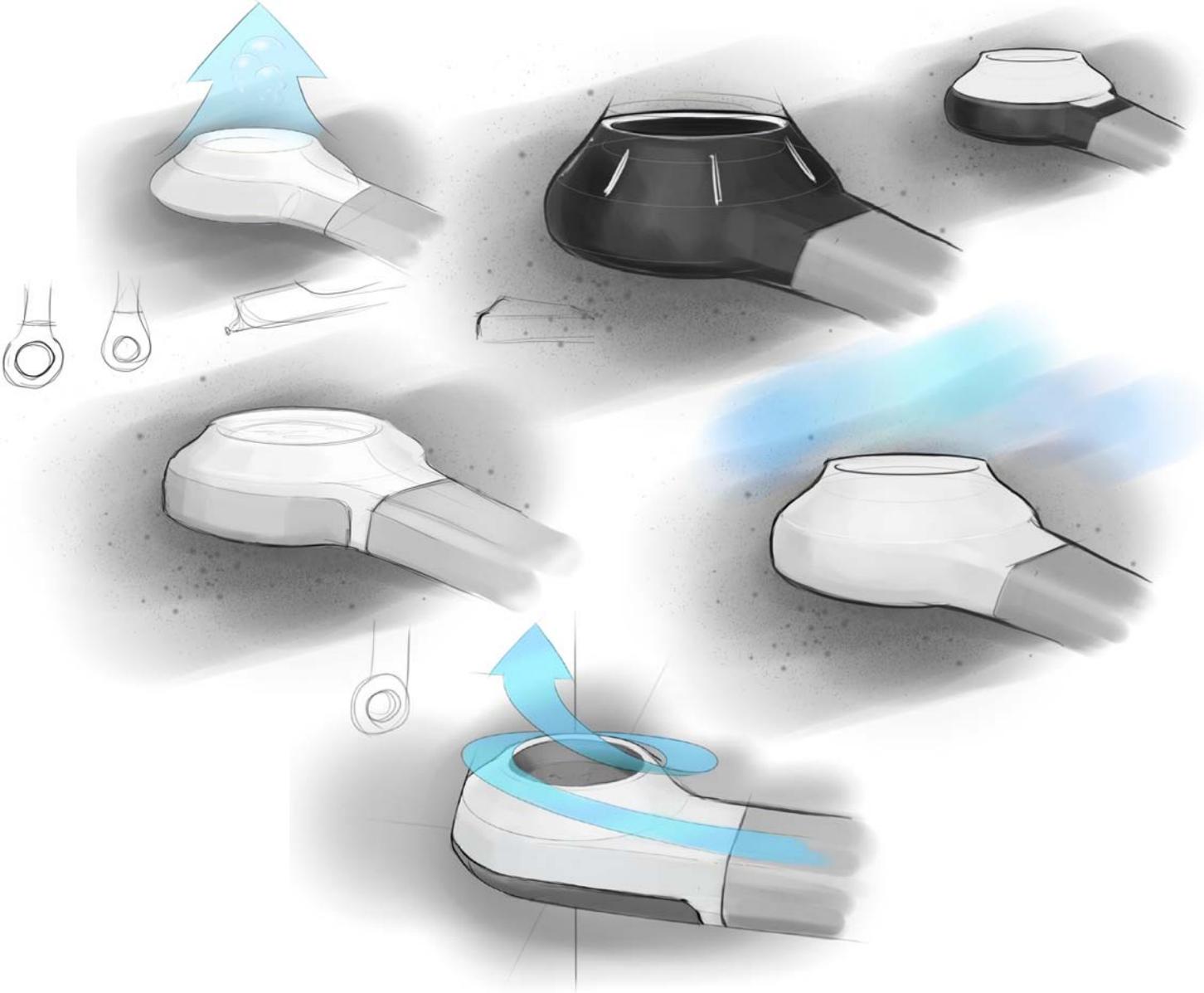


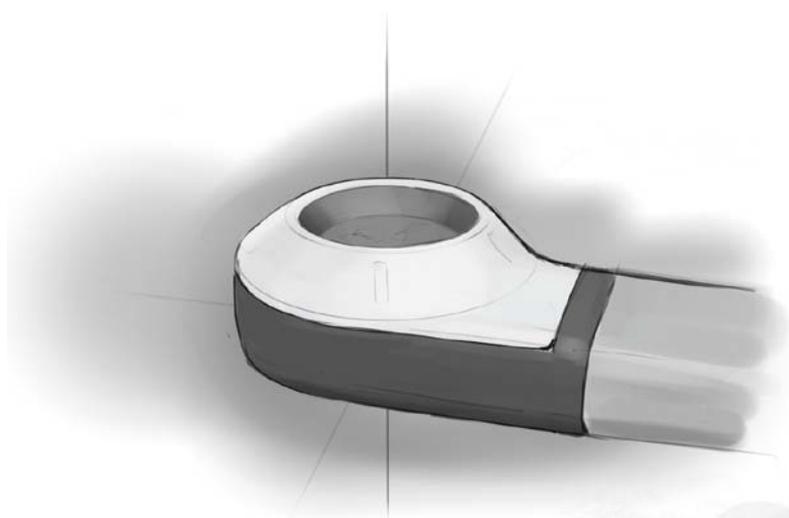


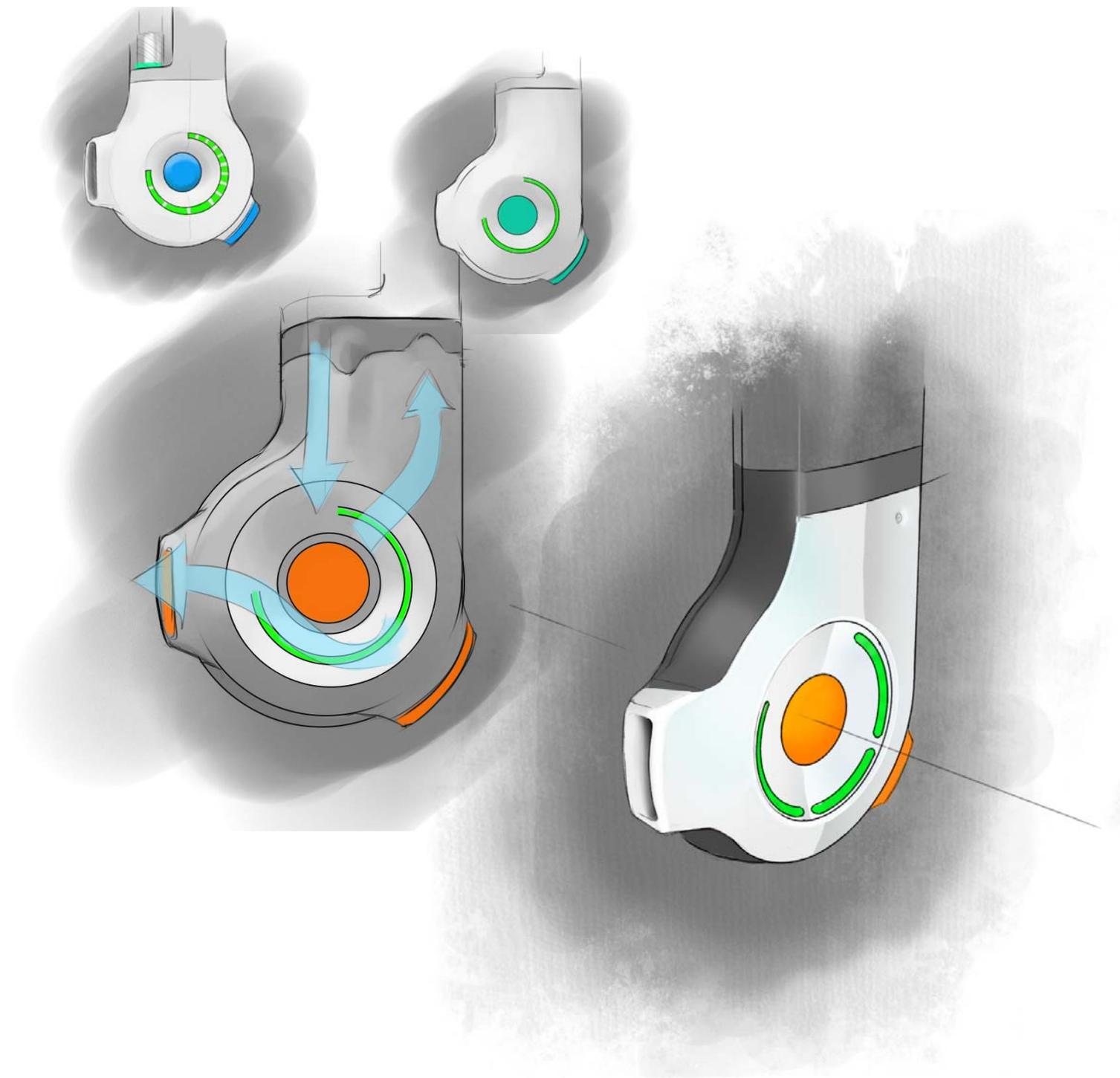


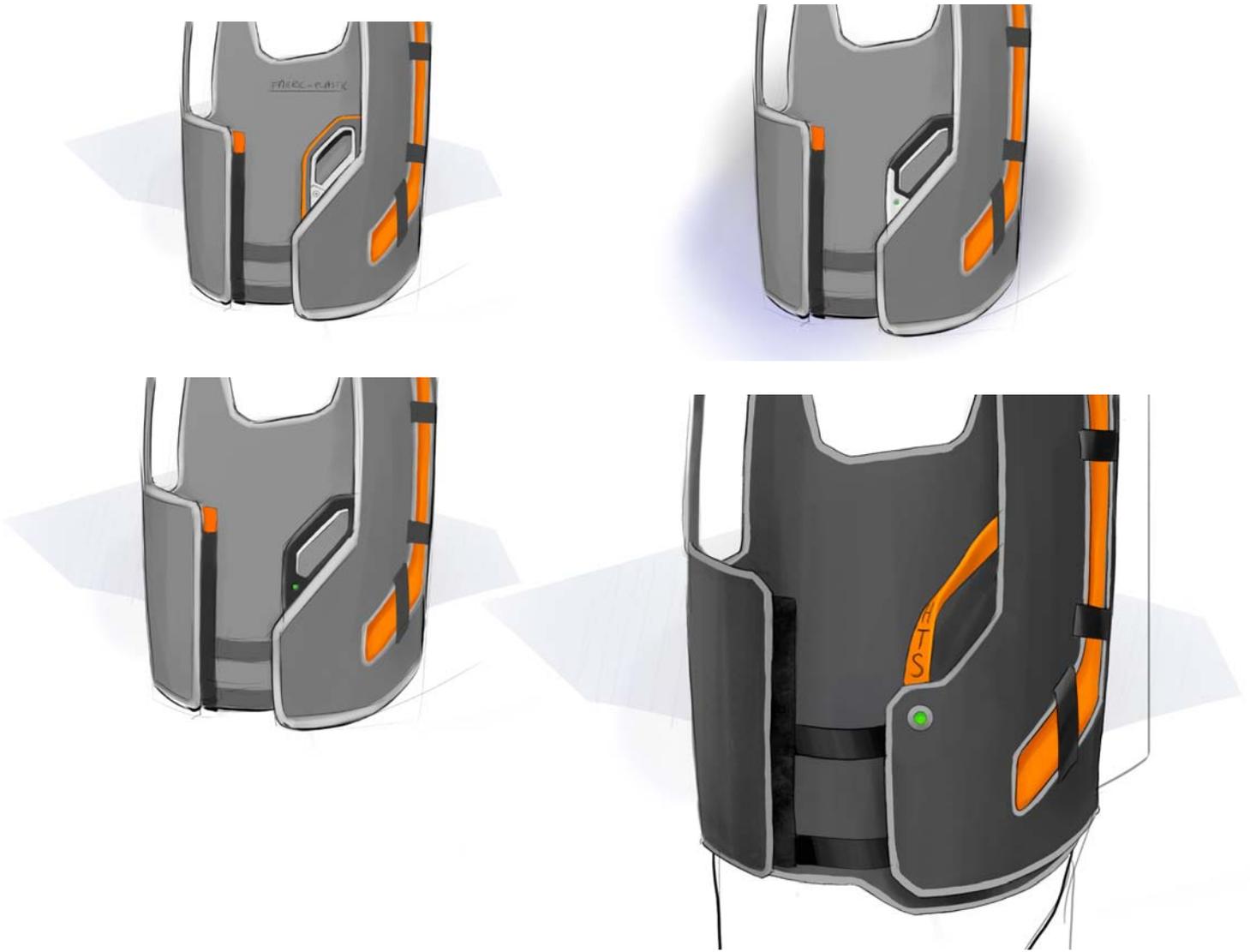
Being the heart of the equipment, where air is pumped in and out, the inflator developed into this shape. The wireless, LED pressure gauge wraps around the inflator button, making it clearly visible to other divers.

4.10 Fourth sketch phase









The weight handles were originally one of the parts where I initially laid focus, but eventually realized that the most versatile and easiest way to solve it was with a simple strap. At first, there was supposed to be a button on the outside that gave feedback if the weights were correctly locked in. This made the lock too complex, though, and the idea was scrapped.



These were the last sketches that were made before the work was started on the final model. I knew that there was still a long way to go designwise, but it felt like the decisions couldn't be made without seeing the product in real life.



4.11 Demographics

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1		5%	50%	95%											
2	Dutch adults 31-60 yrs														
3															
4	Women								Total	XS	S	M	L	XL	
5															
6	Stature	1559	1652	1745					Stature	1559-1626	1626-1693	1693-1761	1761-1828	1828-1895	
7	Upper body length	404	420	436					Upper body length	404-423	423-441	441-460	460-478	478-497	
8	Chest	818	1013	1208	z				Chest	818-897	897-975	975-1054	1054-1132	1132-1211	
9	Waist	650	863	1076					Waist	650-745	745-840	840-936	936-1031	1031-1126	
10	Hip	912	1066	1221					Hip	906-969	969-1032	1032-1095	1095-1158	1158-1221	
11															
12															
13	Men														
14															
15	Stature	1645	1770	1895											
16	Upper body length	436	467	497											
17	Chest	877	1044	1211											
18	Waist	772	949	1126											
19	Hip	906	1031	1156											
20															
21															
22	Total					span	span/3	span/4	span/5						
23															
24	Stature	1559	1711	1895	336		112	84		67,2					
25	Upper body length	404	443,5	497	93		31	23,25		18,6					
26	Chest	818	1028,5	1211	393		131	98,25		78,6					
27	Waist	650	906	1126	476		158,6	119		95,2					
28	Hip	906	1048,5	1221	315		105	78,75		63					
29															
30															

I knew that I would probably not be able to create a one-size-fits-all product, so I experimented with the how many different sizes that was needed to cover all of the measurements.

I decided to go for five sizes, XS to XL where each size had to span around 10 cm around the waist. I also realized that a dry suit would considerably change the waist and chest measurement compared to a wet suit, so a diver that uses both suits during the year would probably need a vest with a bit larger span anyway.

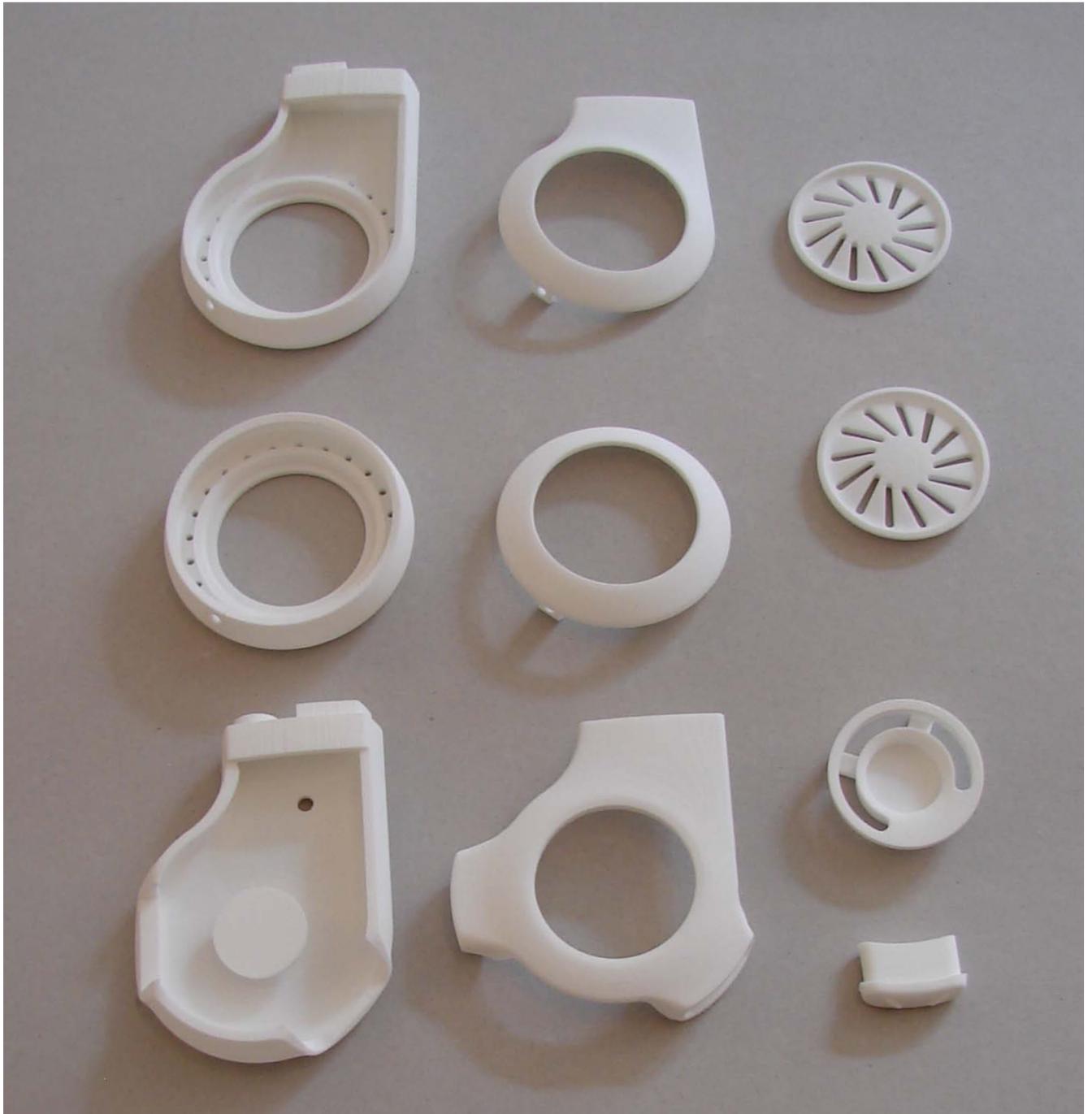
All measurements were taken from DINED, the anthropomorphic database created by Delft University.



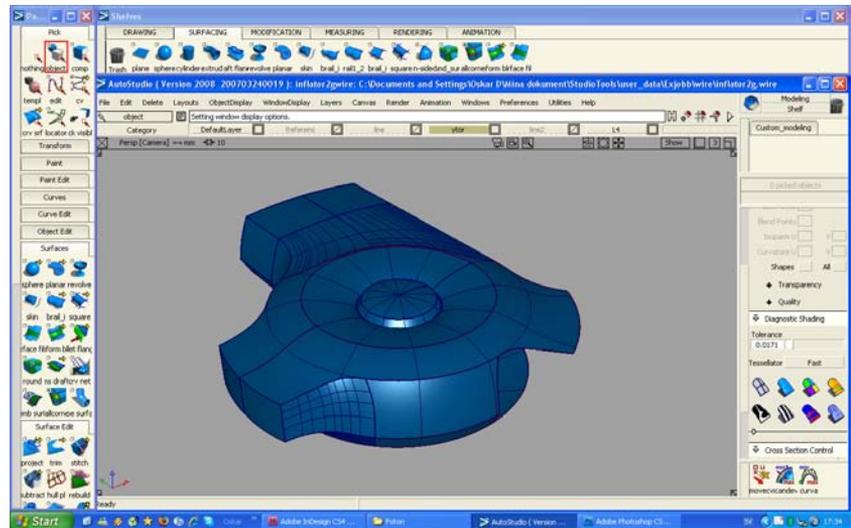
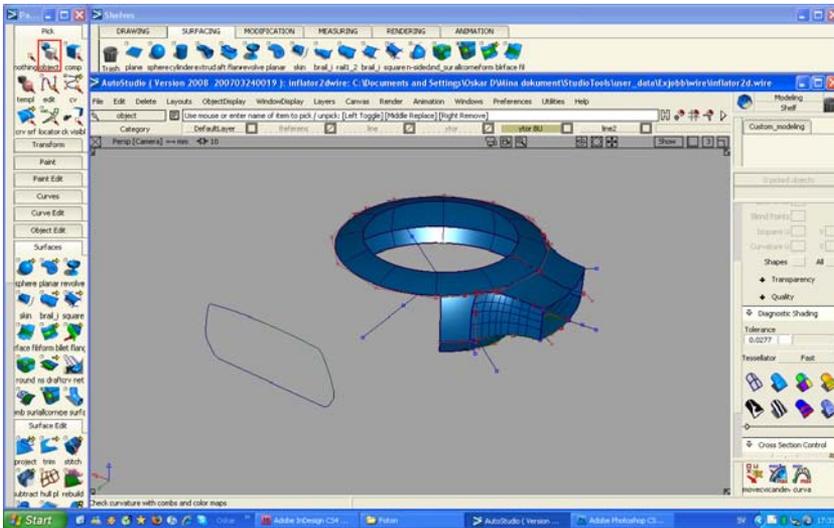
5. *Creation*

5.1 Digital model

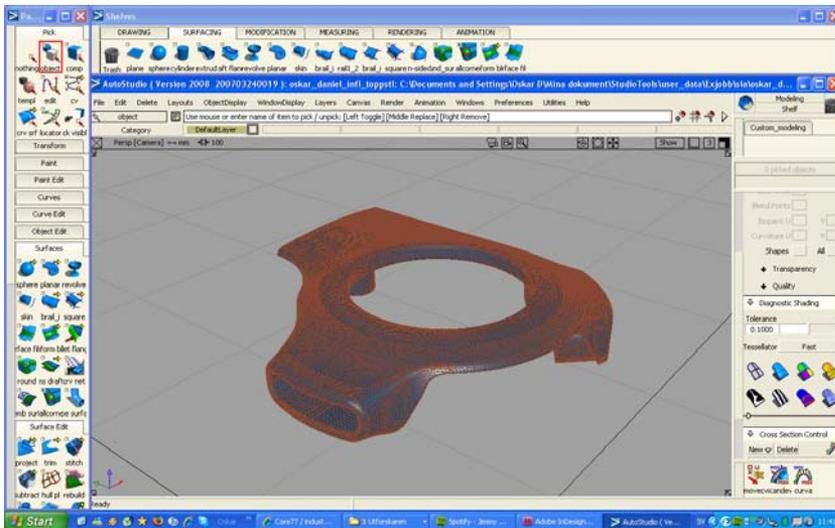
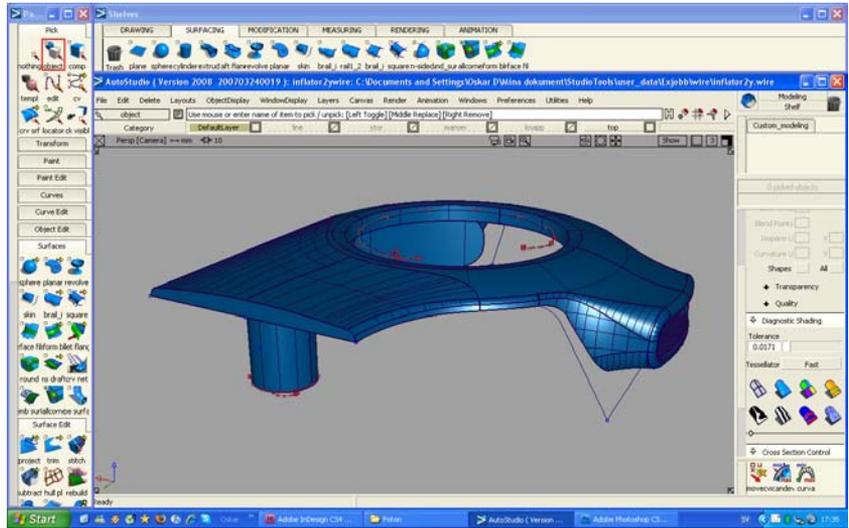
5.2 Physical model



5.1 Digital model



The digital models were built in Autodesk Alias Studio. Since it was very hard to visualize the shape in sketches, a lot of time was spent with experimenting with small changes in the organic top surfaces.



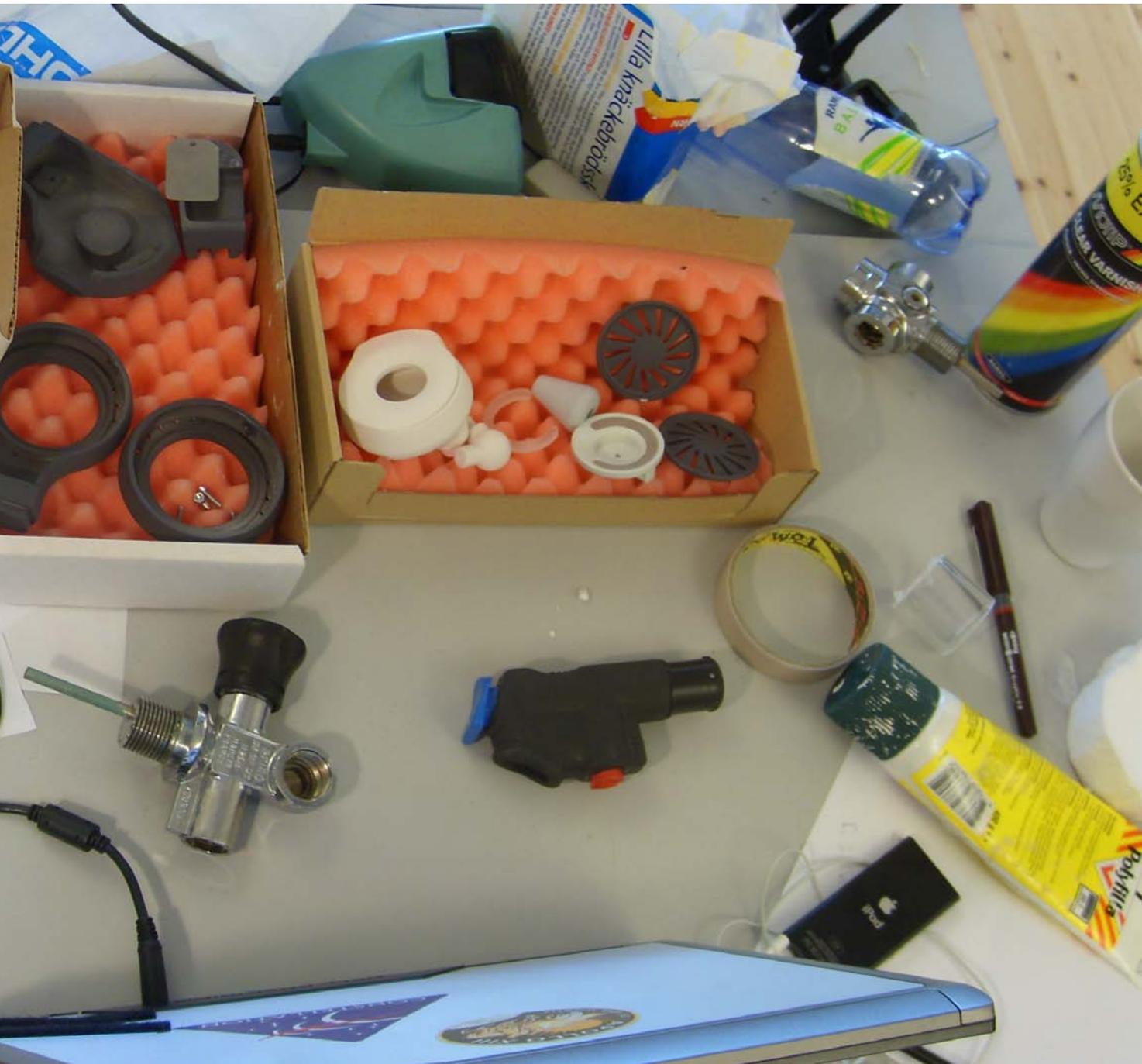
5.2 *Physical model*

The hard parts were laser sintered in polyamide by GTP in Ystad, while the inflator hose was produced by Skara Modell & Prototyp in a flexible material called Tango Grey.

I knew that I would never be able to sew the vest myself, but fortunately my dear mother, a skilled amateur seamstress, was willing to help me. During almost a month the vest was sewn and designed in parallel. Many issues were dealt with, and many ideas had to be scrapped, while new ones emerged.

One of the latest additions were a communication tool, a combined whistle and clicker.





6. *Final result*

6.1 4°

6.2 Use

6.3 Materials



6.1 4°







All the different parts of the equipment. It is only necessary to separate the parts are if you need to repair or replace a part or if you want to wash them



1. Back padding, covering the clips of the fastening straps.
2. Tank belt.
3. Fastening straps, holds the vest, air bladder and back plate together.
4. Back plate, holds and stabilizes the tank.
5. Clicker/whistle.
6. Air bladder.
7. Vest.
8. Pressure data transmitter.
9. Primary and secondary second stage.



1. Velcro flaps hold the hoses in place and close to the body. This makes the instruments easier to find, and reduces drag when swimming. The flaps are colour coded, so that if the diver is interested in using the recommended setup, it is obvious which hose goes where.

2. Clicker/whistle. The communication tool combines a clicker and a regular whistle for emergencies on the surface. The clicker is used to get the attention of other divers with its loud clicking sound.

3. The secondary second stage is worn close to the mouth and is used when the primary second stage is given to a buddy out of air. The “flush” button is marked in orange to remind the diver to check the second stage before a dive.

4. The inflator and pressure gauge are combined, so that regular air checks are encouraged, and other divers easily can see your remaining air. The air level is shown with illuminated LEDs. The inflate and deflate buttons are marked in orange, to remind the diver to check the inflator before a dive.

5. Primary second stage long hose. The hose is looped and stored under a velcro flap. This means that a lost second stage will stay in front of the diver instead of moving behind the divers back, making it easier to retrieve. In a buddy breathing situation, the hose can be ripped out from the flap, so that the full length is released and the buddy breathe can be performed safely.

6. Sewn on straps can be used to attach hooks that holds instruments such as back up pressure gauges, flashlights etc.

7. A large front pocket to store things like a writing tablet or other extras.





1. Wireless transmitter transmits data to the pressure gauge on the inflator.
2. Separate air bladder on the back ensures that weight of the tank is lifted from the diver to prevent back pains. It also improves the diver's balance in a horizontal position.
3. Weights are placed far back on the body to support the diver in an upright position, but is still placed under the air bladder so that the center of gravity is not too high when the diver is swimming in horizontal position. The weight pockets are directed upwards in the picture to prevent the weights from putting force on the lock. The lock is constructed so that it can only be opened by pulling the weight straps, marked in orange since the lock should be checked before the dive.
4. Extra pockets can be used to add more, non dumpable, weights.
5. Primary second stage mounted on its 1,5 meter long hose.

6.1.1 4° - summary

- Loose straps and rings have been removed to decrease complexity and reduce the risk of tangling.
- Orange markings reminds the diver of items that must be checked before the dive.
- Balance on- and under the surface has been addressed by the placement of weights and shape of the air bladder.
- Remaining air is clearly visible for other divers, and frequent air checks are encouraged by the placement of the pressure gauge on the inflator control.
- The weight locks assures that the weights cannot be dropped unless the diver pulls the weight straps.
- Air-sharing is made easier with a long hose for the primary mouth piece. This is shared in an emergency situation, while the secondary is easily found on the chest.
- The fastening of the primary second stage insures that a lost mouth piece stays within sight of the diver.
- Hose management is improved with colour coded hoses and velcro flaps to fasten hoses and improve streamlining, and simplify correct assembly.
- A “clicker” combined with a whistle provides a means of communication both under and on surface.



6.2 Use



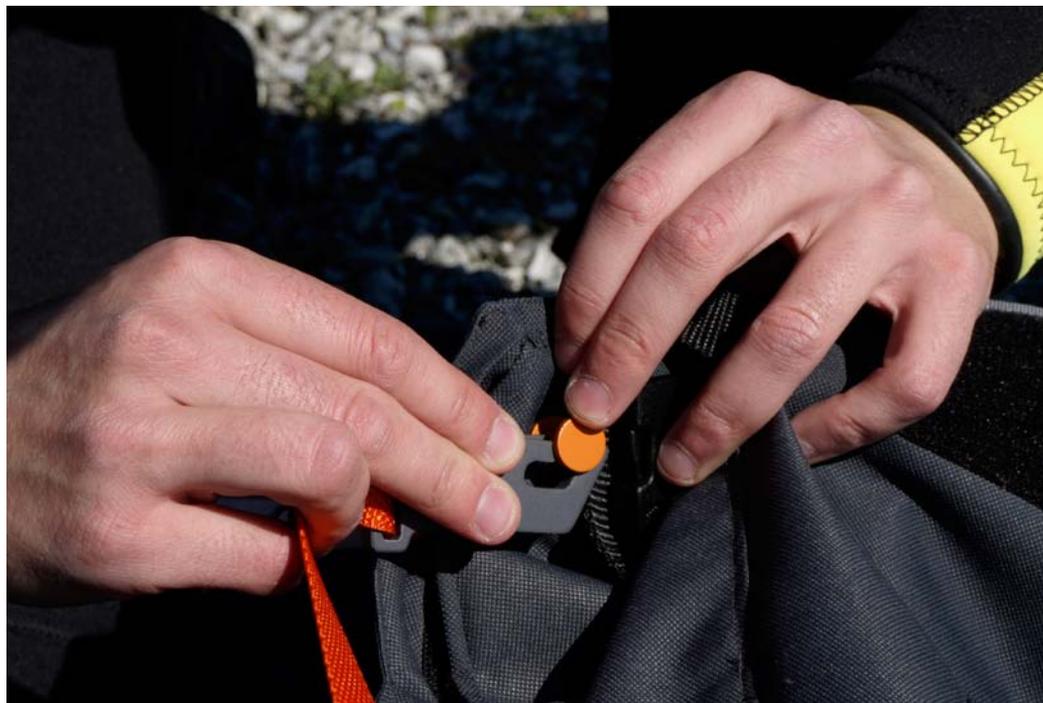
The hoses are screwed on to the first stage and fastened in their appropriate places, following the colour coding.





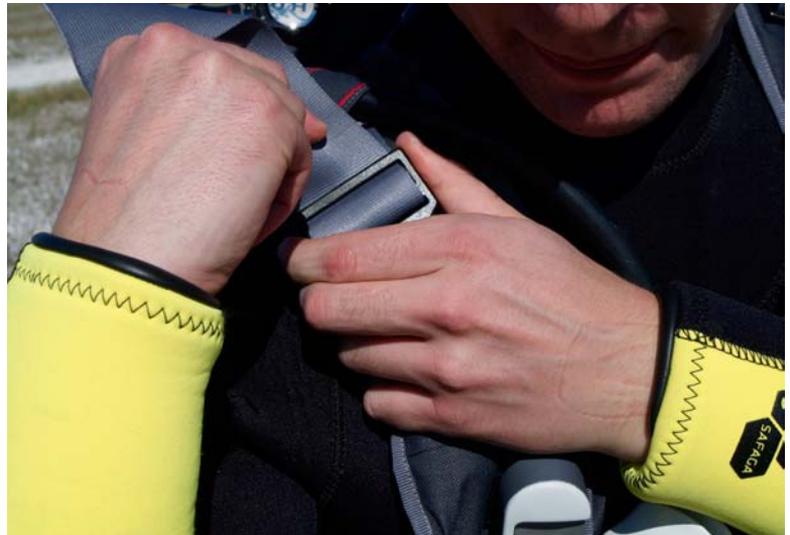
The weights are put into their pouches, which in turn are put in the weight pockets on air bladder.

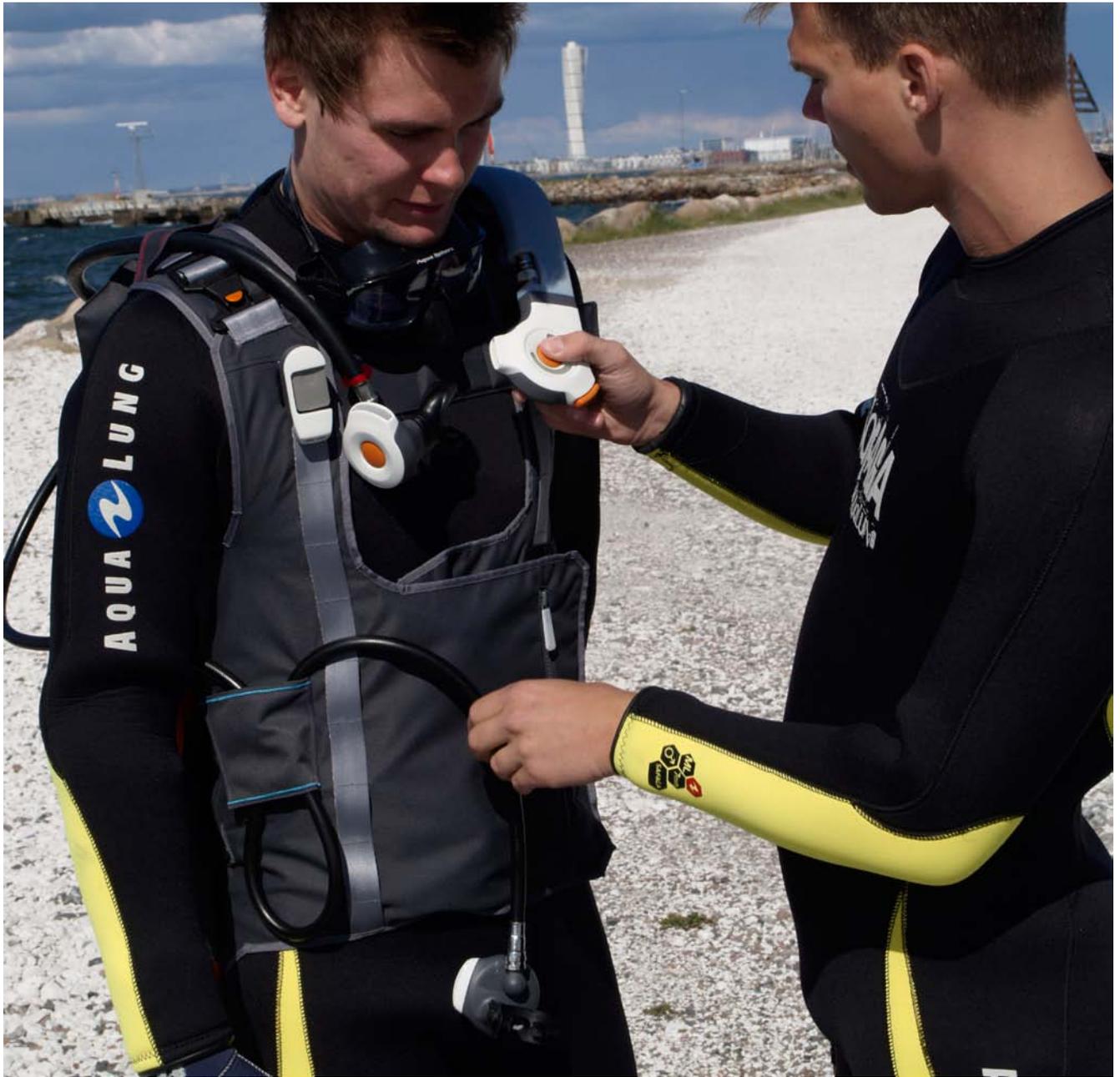
The locks are fastened to the pin on the air bladder. The weight locks are only opened when the straps are pulled.





The first time the vest is used, it has to be adjusted in size. It is set with the clips across the stomach and on the shoulders.





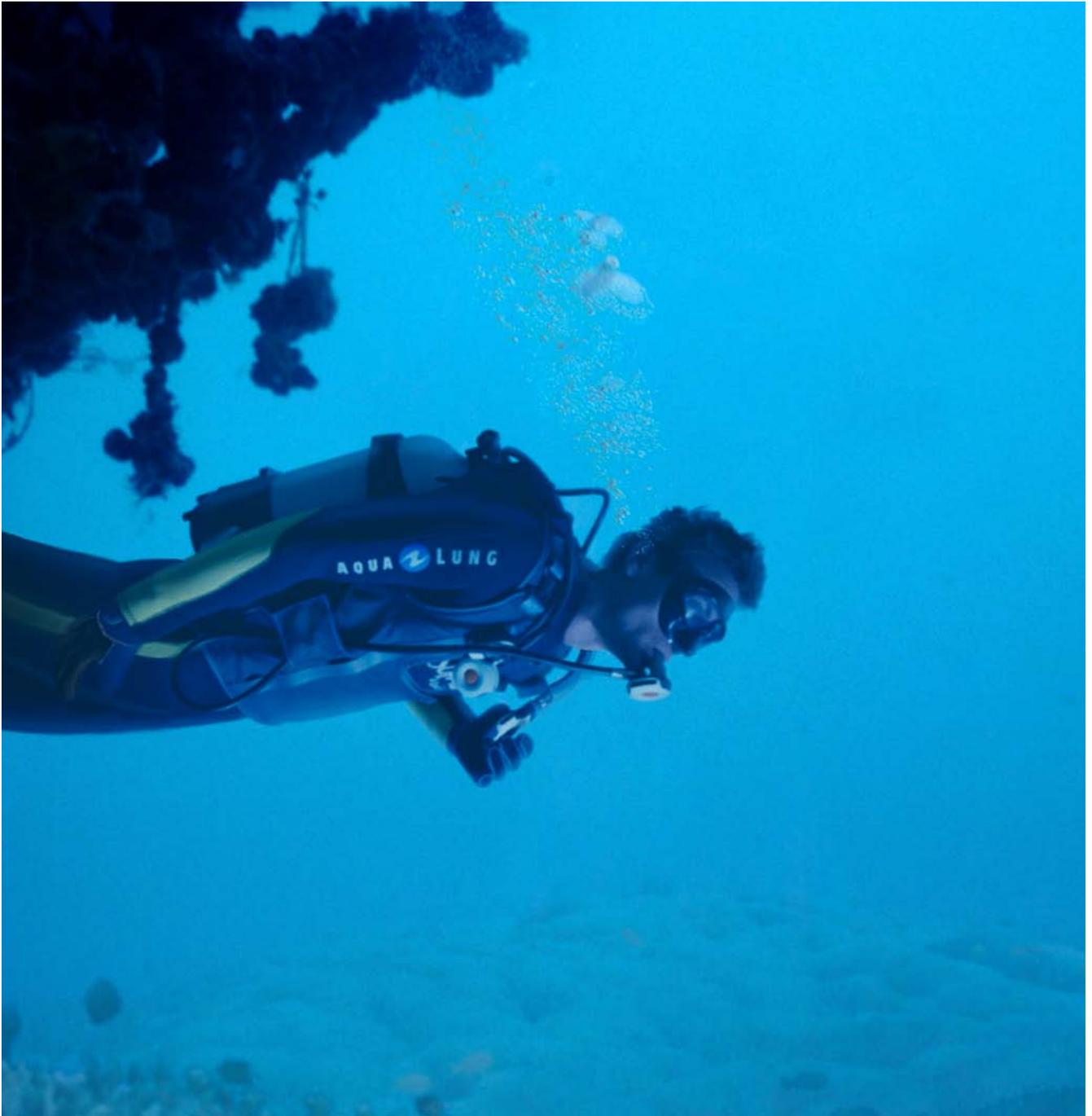
Everything that is marked in orange should be checked before the dive.



Weight locks and release handles are checked.



String to the air dump valve.





6.3 *Materials*

Especially since I chose white on a product that would be subjected to rough use and hard environments, it was important for me to consider the wear and tear of the product.

For visibility and marketing reasons, I chose hard contrasts on the iconic shapes of the hard parts of the equipment. But since black is often very quickly bleached and matted by sun and wear, I chose a dark grey on the fabrics. The white parts are powder coated sheet metal, which of course is quite sturdy, but will eventually get dented and worn. Hopefully, the users would agree with me that this is something that actually will increase the value of the product.

1. Injection moulded rubber with a flexible plastic skeleton.
2. Injection moulded ABS plastic.
3. Deep drawn, powdercoated sheet steel.
4. Injection moulded ABS plastic.
5. Cordura®



Visualization of how the product could look after years of use.

7. Discussion

The brief stated “Investigate whether a BC can facilitate intuitive use and improve dive safety for the non-experienced diver. Through its simple use the BC should attract new divers, but it should also be their first choice as they grow more experienced.”

As the brief says, I regard this project as an investigation into a possible product. The end result is by no means a concept ready for the market, instead it can be regarded as inspiration for how any scuba diving brand easily could create new products without using new technology or even take any large economical risks. From this point of view, I believe my project is very successful. The three main points were Safety, Market and Use and I believe all three aspects has been properly addressed in the final result.

I would of course have liked to be able to test my ideas more, especially the parts that are very hard to test in theory, such as the center of gravity, and whether the hose of the secondary stage will pull the mouthpiece too much when the diver moves. Things like this would of course require actual dives with the a functional prototype, which is really far into the product development for a four month master project.

I would also have liked to work more closely

with experts in the business, but since Sweden’s only scuba diving company were unwilling to cooperate, I still believe the right decision was made, to only work with the feedback and point of view from the end users and expert divers.



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Appendix

Appendix I - Research survey

Icke-dykarformulär

Jag är:

- Man
 Kvinna

Ålder:

Jag gillar att:

- Simma
 Snorkla
 Fridyka (dykning utan lufttuber)

Jag har:

- Gjort ett eller flera provdyk med lufttuber
 Påbörjat men avbrutit en dykutbildning

Jag hade börjat dyka om det inte varit/verkat så:

- Komplicerat
 Dyrt
 Färligt
 Fysiskt påfrestande
 Kallt
 Blött
 Mansdominerat

Andra anledningar:

Men jag har ändå funderat på att börja på grund av:

- Naturupplevelsen
 Lugnet
 Äventyrligheten
 Frihetskänslan
 Viktlösheten

Andra anledningar:

Övriga kommentarer:

Om du är intresserad av att veta mer om arbetet, och kan tänka dig att svara på fler frågor, skriv in din mailadress nedan.

Skicka

Dykarformulär

Jag är:

- Man
- Kvinna

Ålder:

Dykt sedan år:

Antal dyk:

Utbildningsnivå: (ungefärlig om du inte är PADI/NAUI dykare)

- Open Water
- Advanced
- Rescue Diver
- Divemaster
- Instructor

Jag gillar även att:

- Snorkla
- Fridyka

Jag dyker oftast i:

- Kalla vatten (<15 grader)
- Varma vatten (>15 grader)

Jag dyker oftast med:

- Vätträkt
- Torrträkt
-
- Luft
- Blandgas (nitrox el dyl)

- Parfina

Under ett *genomsnittligt* dyk är mitt medeldjup ungefär:

- < 15 m
- 15-20 m
- 20-30 m
- 30-40 m
- > 40 m

Min *genomsnittliga* dyktid är ungefär:

- < 20 min
- 20-30 min
- 30-40 min
- 40-50 min
- > 50 min

Under dyk har jag ofta problem med:

- Ryggsmärtor
- Dåligt synfält (svårt att se instrument osv)
- Hitta instrument (snabbt få tag i inflatorslang osv)
- Tung utrustning
- Dålig rörlighet i vattnet (kumpig utrustning)
- Kommunikationen med min parkamrat
- Avvägning
- Julgranseffekt - för mycket utrustning och inget bra sätt att fästa den

Andra problem:

Jag gillar dykningen på grund av:

- Naturupplevelsen
- Lugnet
- Äventyrligheten
- Frihetskänslan
- Viktlösheten

Andra anledningar:

Om du har tankar om vad som hade förbättrat dykupplevelsen, eller om du har idéer om dykprodukt framtiden, skriv dem här:

Om du är intresserad av att veta mer om arbetet, och kan tänka dig att svara på fler frågor, skriv in di

Skicka

Appendix II - Research survey answers

Answers, non-divers

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9										
Male	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	63																			
Female	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	37																			
Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	22-35	125.71								
Likes:																																																																					
Swimming	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	51																			
Snorkeling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	46																			
Free diving																																																		12																			
Tried scuba diving																																																		16																			
Started a scuba course	X																																																	2																			
Would have been diving if it didn't seem so:																																																																					
Complicated	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21																			
Expensive	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	40																			
Dangerous																																																		11																			
Physically demanding																																																		0																			
Cold																																																		13																			
Wet																																																		3																			
Male dominated																																																		0																			
Other reasons (I)	1	3	5	6						8	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	2																		
Has considered starting because of the:																																																																					
Nature experience	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	52																			
Calmness	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	23																			
Adventure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	44																			
Freedom	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	33																			
Weightlessness																																																		20																			
Other reasons (II)																																																																					
Comments (III)	7	4	5							7	8									12	15									19	11									15	16									17	20																		

	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	
Male	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	93		
Female																													77		
																													16		
Age	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	16-49 [30,9]			
Certified since:	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1976-2008			
No. of dives:	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4-4000 [301]			
Level																															
OW																												22			
Adv	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	26			
Resc	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	18			
DM																												10			
Instr	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	17			
Also like																															
Snorkeling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	64			
Free diving	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	37			
Mostly dives in																															
Cold water < 15°C	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	55			
Warm water > 15°C																												38			
Dives with																															
Wetsuit	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	40			
Drysuit	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	53			
Air	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	66			
Mixed air																												27			
Buddy line	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	6			

	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	
Average depth																																
< 15 m	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	17			
15-20 m	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	46			
20-30 m	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	21			
30-40 m																													9			
> 40 m																													0			
Average dive time																																
< 20 min																													3			
20-30 min																													10			
30-40 min	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	33				
40-50 min	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	28				
> 50 min																													19			
Recurring problems:																																
Back pains																													2			
Poor field of vision																													12			
Hard to find instruments																													11			
Heavy equipment	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	7				
Poor mobility																													7			
Buddy communication																													20			
Bouyancy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	10				
Christmastree effect																													2			
Other problems [I]																																
Like diving because of the:																																
Nature experience	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	81			
Calmness	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	74			
Adventure	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	73			
Freedom	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	70			
Weightlessness	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	49			
Other reasons [II]																																
Comments [III]																																

Appendix III - Research survey comments

Comments from divers - problems

- Fel storlek på utrustningen.
- Dyker på natten har man ingenstans att hålla ficklampan.
- Känns lite ansträngt att alltid söka sin parkamrat
- Linser, alltid ett orosmoment om man inte har slipat cyklop
- Komma ihåg alla delar att kontrollera före dyk
- Om det är djupt- minns att jag fick svårt att orientera mig. Upp/ned/fram tillbaka, tappade normala referensramar om botten är ganska lika överallt, svårt m avståndsbedömning osv.
- Hur kan man förbättra lukten?
- Kan man förbättra fästningen snorkel/mask? Där brukar jag få lite panik för att det är för mycket felmarginal. allt går att röra på och flytta på och snurra på och så vidare, precis i ytterkanten av mitt synfält och mer eller mindre ovanpå örat
- Specifikt luftvandring i torrdräkt, dålig passform
- Tung utrustning är jobbigt på land men inte i vattnet
- Bränner mig på manettrådar.
- Hål i torrhandske
- Måste släppa in kallt vatten i huvan för att tryckutjämna.
- Lättare att ta på och av utrustning. mina händer blir svaga när de blir kalla, jag behöver t.ex ofta ta hjälp av någon annan att ta av fenor innan jag ska upp i båten.
- Före dyk: total klaustrofobi i dräkten, illamående (på allvar) för att dräkten stinker. utrustningen drar o sliter i halsen. allt detta är saker som jag kanske skulle bli av med om jag dök oftare. likväl jobbigt när jag dyker.

Comments from divers - ideas

- Dykarklocka med "radio"sändare som håller koll på var ens polare är (gärna avstånd i meter).
- En dykarklocka som är kopplad till regulatorn och den andra utrustningen och därmed kan avgöra per 20sek intervall om hur länge man har kvar att dyka innan man måste stiga upp exkl 'reserven'.
- Utveckla hörselupplevelsen
- Man håller på att utveckla arificiella gälar som utviner syret ur vattnet, det verkar spännande
- En liten långsmal öppning i ovansidan av cyklopet som låter vatten sippra in och ta bort dimman samtidigt som man kan ta ut regulatorn och ta en liten slang i munnen och suga ut vattnet (och sen spotta) innan man sätter regulatorn på plats igen. ser väl det eg inte som ett problem, men det är nog en produkt som skulle sälja :)
- Undervattensgps
- Effektivt navigeringssystem, enkelt vrakbojningssystem
- Dykparker! finns utomlands, med skyltar under vattnet och dagsutflykter med guide! bra sätt att tillgängliggöra exempelvis känsliga vrak och natur
- Billigare och mer tillgängliga rebreathers
- Lättare flaskor, d12 väger en del
- Smidigare utrustning, mindre för- och efterjobb för dykningen. kort sagt, mer dykning mindre arbete.

Comments from non-divers - reasons not to dive

- Konstigt nog får jag ibland en känsla av instängdhet när jag är under vattnet...
- Har ingen i min omgivning som har intresset och att dela upplevelserna med..
- Drog hem för tidigt från asien och missade chansen.
- Har inte tid
- Har inte riktigt blivit tillfälle. Svårt att hinna med allt man vill, konkurrerar med andra fritidsaktiviteter.
- Avlägset till bra platser,
- Att jag ofta är förkyld och då ska man inte dyka.
- Jag är nog mest bara lat och ligga och sova på stranden är kul det också
- Om jag inte hade haft astma!!
- Om jag haft tid
- Om jag haft tid och möjlighet...
- Tidskrävande
- Om jag haft mer tid
- Haft mera tid, hoppas få det
- Tiden räcker inte riktigt till
- Otrevligt vatten i Sverige
- Har inte funnits något tillfälle
- Tidskrävande
- Det är helt enkelt för dyrt och meckigt att dyka. dessutom ska man ju ha en utbildning. utbildningen i sig är nog det största hindret för mig förutom kostnaden. sen eftersom jag är så van i vattnet ser jag snorkling som ett väldigt bra alternativ...
- Ska börja, har bara inte kommit igång
- Har inte tid och om jag vetat att jag skulle åka utomlands. i Sverige anser jag att man inte får någon direkt upplevelse när man dyker.
- Jag har inte tagit något dykcertifikat pga att jag inte varit utomlands. Att ta det i Sverige i en pool verkar tråkigt och onödigt när man kan göra det billigare utomlands plus få en härligare naturupplevelse.
- Har aldrig fått chansen att testa, har inte kollat upp det själv och tror inte att sverige är ett kul land att dyka i.
- Finns det nåt kul att titta på i svenska vatten? och var? sälj in den svenska dykningen till den med lite pengar på ett attraktivt sätt, så kanske jag hakar på en tur!!

- Att det känns lite farligt är på ett sätt tjuvningen med det hela, men det känns som man alltid skulle ha ett proffs i närheten så att inget kan gå fel... djupet kan jag tro är en av "skrämselfaktorerna".
- Otillgängligt och icke spontant
- Jag tränade fridykning men hade problem med att tryckutjämna, så det blev ingen karriär! ;)