# SYNCHRO

**- Core 77 design award -**

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# Phase 1 : Problem Recognition

## Introduction

The first phase began by questioning the reasons behind divers' deaths and tried to think of a better way to solve the issue. These were the initial objectives of this project and they suggested the rough concept. This phase has the purpose of creating awareness among people of the problem and encouraging them to consider this important issue.

## 1-1. About this project

This project is about how to efficiently prevent divers' deaths through a consideration of the relevant factors and a redesign of scuba equipment. Every year, many incidents related to underwater activity have been happening. Among them, the statistic of casualties regarding scuba diver's deaths is indicated as 0.03% out of 50 million divers.

The origin of diving supposedly goes back to 500BC, when a Greek solider is said to have dived off of a ship and used a hollow reed to breath underwater for hours. Then, after the 1940s, a rebreathing device was invented by Jacques Cousteau and engineer Emilie Gagnan, and this was the trigger that led to recreational scuba dives. It has been more than 70 years since the recreational dive was appeared. However, the number of casualties and fatalities has not been dramatically decreased when you compare it to the technological development. Every year, cutting edge scuba equipment has come out but nobody can be sure that it can guarantee your safe leisure activity. Actually, when you see the incident data, you can clearly see the number of fatality has only slightly decreased over the last decade.

There are a number of unexpected situations that can occur when you have an experience to explore submarine areas. In particular, panic attack or panic disorder is quite a common situation in our real life. Even when you have a presentation in front of a client, you might get into a slight panic. Or sometimes when panic is serious, you cannot control yourself and you might need someone's help. There are a few prescriptions or descriptions arou¬nd to help us deal

with panic in various situations. For example, we can call an ambulance when it is serious, and we can ask others to help us. However, what about underwater situations? Imagine that you are stuck in an unexpected situation and feel anxious about the uncertainty of the underwater environment. What would you do to overcome it?

## 1-2. Objective

* Preventing diver's death through searching for relevant factors in order to redesign scuba equipment.
* Finding effective ways to make divers calm down, if they get into a panic due to inexperience in scuba diving.
* To suggest efficient new equipment for preventing panic situations which can provide new ways of educating in the diver training process.

The main purpose of this project is not only to save life but also to encourage scuba diving beginners to overcome their fear and anxiety to allow them to enjoy underwater activity.

## 1-3. Concept

My concept in this project is to analyze divers' breathing patterns and so give feedback to them during the dive to prevent serious potential incidents and it also makes it easier to get synchronized with their buddy's breathing, in time of emergency.

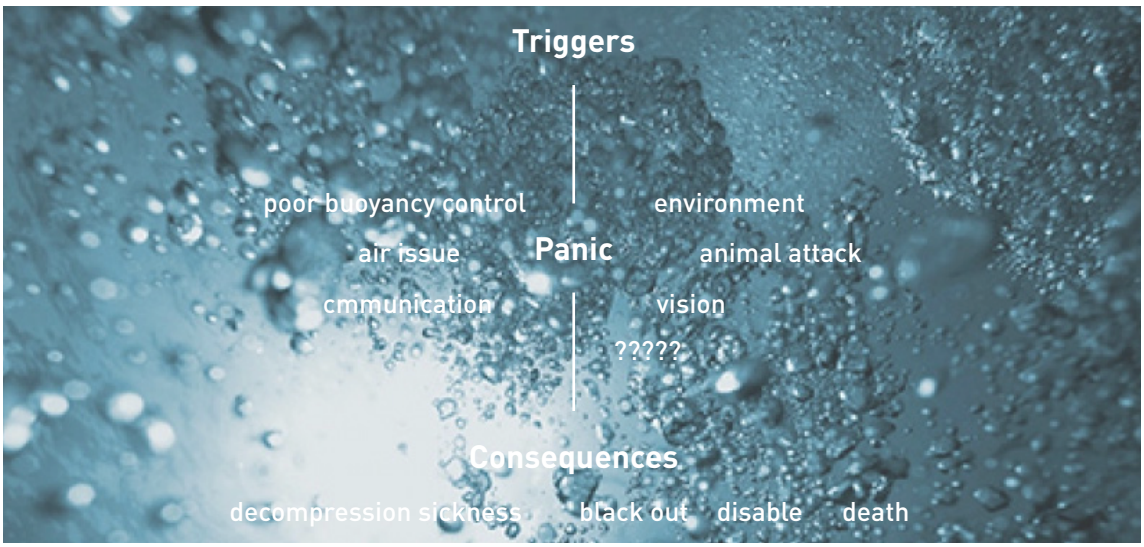


Figure 1 - Diagram of incident sequence.

# Phase 2 : Background Research

## Introduction

This phase will be mainly concerned with describing the general research for incidents, reasons for accidents, the basic system of scuba diving, its pros and cons, etc, and will locate the key issues of diving activity. And the clues from that information will be the important ingredients for generating ideas.

## 2-1. Why divers death?

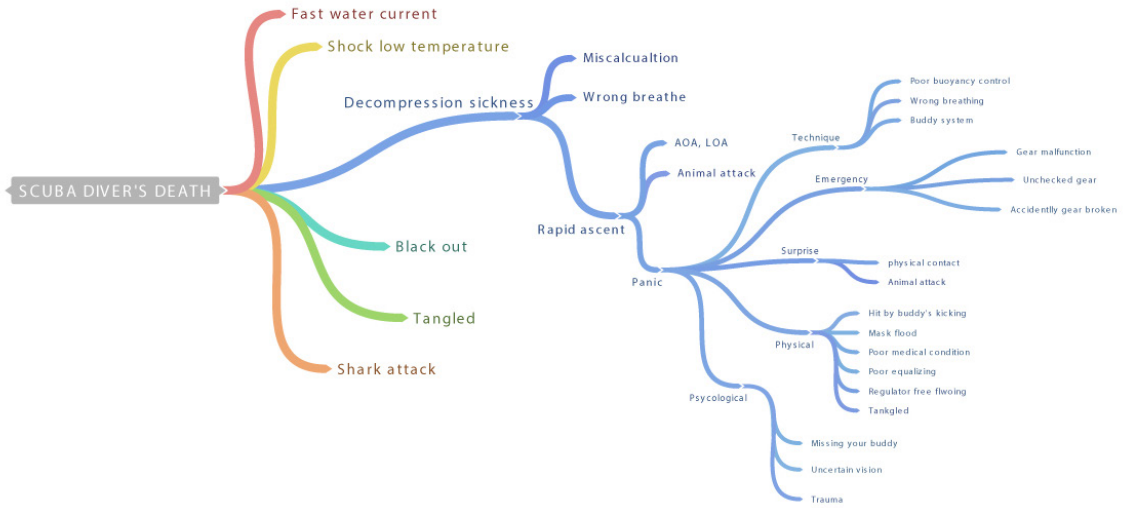


Figure 2 - Reasons for diver's death

There are a lot of reasons for divers' death. As you can see from figure 2, the diagram shows the general reasons behind diver accidents leading to death. By chasing the causes of each situation threatening a diver's life, I found the most common and serious cause, which is decompression sickness. Decompression sickness – also known as the bends – describes a condition arising from dissolved gases coming out of solution into bubbles inside the body on depressurisation. This disease also has several causes such as gear malfunction, wrong breathing and rapid ascent. Rapid rising to the surface is quite dangerous to divers because it may result in serious physical and psychological problems and it mostly arises in a panic situation.

There are so many unexpected situations in underwater areas, so the reason of panic is massively hard to be defined in one sentence. It can be categorized into 5 reasons which are: technique issues, emergency situations, surprise, physical and psychological problem. And each category has several multiple reasons behind it as well.

## Rapid ascent

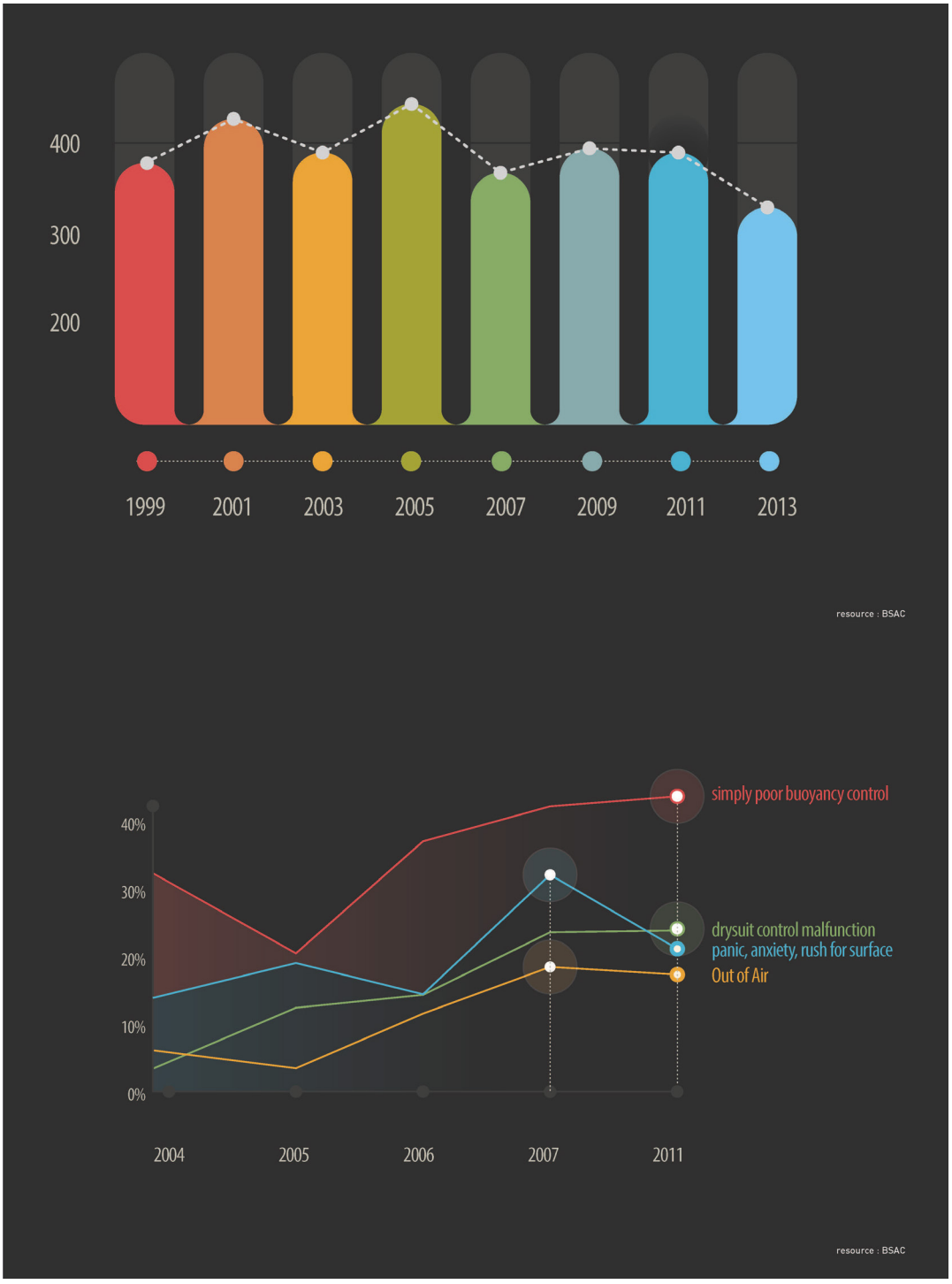


Figure 3 - Incident repetition rate
Figure 4 - Incidents related to rapid ascent

The figure 3 shows how often incidents occurred every two years in UK from 1999 to 2013. According to this diagram, I could find an interesting fact which is that it seems that incidents have been in decline recently but, actually, it is still high when you consider the development of technology in that time.

Figure 4 shows the main reasons for the accidents regarding rapid scent. The largest feature of rapid ascent incidents is poor buoyancy control. And fear, anxiety and panic, which is second largest part, has been chasing this issue of poor buoyancy control except for 2011. Buoyancy is a matter of skill level, but the fear and panic is an uncontrollable problem associated with human will. Thus, it seems reasonable to look into this aspect to prevent serious accident related to panic situation for scuba divers.

## 2-2. Why divers panic?

It is a fact that one fifth of all diver deaths can be directly attributed to panic, according to the National Underwater Accident Data Center. Another 22 percent of fatalities remain a mystery. Considering the number of divers who are recovered with working equipment, plenty of air, and their weight belts firmly in place, most experts believe that death due to panic is far more common than reported.

Panic can kill in any number of ways. Rapid, shallow breathing can cause hypoxia and a buildup of carbon dioxide, causing the diver to act irrationally, breathing faster, expelling the regulator or bolting to the surface. These panic responses can make you pass out, or even have a heart attack if you have a weak heart. Panicking also hinders your ability to solve problems and get to safety when your equipment malfunctions.

These are the following recommended ways to deal with it.
1. Practice makes poised.
2. Hatch emergency plans.
3. Stop. Breathe. Think. Act.
4. Know the sign.

Knowing the relevant signs would be really helpful to prevent a serious panic situation. You should be aware of these symptoms and should communicate with your buddy constantly.

• Rapid breathing or feeling like you can't get enough air.
• Rapid heart rate, palpitations or heaviness in the chest.
• Gastrointestinal distress, "butterflies," nausea, vomiting or diarrhea.
• Muscle tension, headache or tremors.
• Trembling voice or inability to speak.
• Sweating, chills or hot flashes, an out-of-control feeling or a feeling of impending doom.

However, the problem is you can't really react to those things automatically when you are in panic, since fear and anxiety makes you forget all the knowledge you have learnt. There is thus a demand for new products or systems to prevent and deal with an unexpected panic situation. The following description is what normally panicked divers do according to PADI diver manual book.

"Panicked divers, fearing drowning, typically struggle to hold their heads high above the water, expanding tremendous energy, they usually fail to establish positive buoyancy, and spit out their regulators and shove their masks up to their foreheads, requiring them to fight even harder to breathe. Panicked divers will generally be anxious and breathe rapidly and shallowly. They pay no attention to their buddy or others and make quick, jerky movements. Their eyes are wide and unseeing, and they don't usually respond to direction. Divers exhibiting these signs need immediate help, because they will continue to struggle until completely exhausted and unable to remain afloat." [2]

## 2-3. Breathing

Looking at the description from the PADI diver manual book, we see that the panicked divers seem to be really uncontrollable by themselves. Maybe it is almost impossible to stop their panic disorder when it has started to occur. Then, what if we can detect our dangerous situation and pre-panic in advance? If it is possible, maybe we can prevent and reduce some potential serious situations

caused by panic. To do so, the key factor that causes panic would need to be identified.

When you look through the cause of panic, it is not difficult to find a common factor that is very important through the whole sequence from preventative procedures to after the panic itself. The issue of breathing is mentioned in all descriptions regarding panic and death in this report. Breathing in underwater diving is really as important as when you are on land, indeed, even more crucial. Because of this, if we have some problem in breathing in our daily life, we can take a step quickly in many other ways. However, it is totally different in underwater situations. Imagine you have only limited air, which comes from only one regulator with a hose, and there is no other air around you except for your own. You probably would be in chaos when you feel you have some problem in breathing or find you have no more air. Actually, there are a lot of practices to cope with this kind of situation, but you can't do all the practices every day to prevent unexpected scenarios. And once you meet this kind of unprepared situation, you will be in a panic, as can happen to most beginner divers.

At least, however, it is not difficult to guess and measure our physical condition when you are about to get into a panic while you are diving. Then, how can we measure our personal physical condition, specifically: how much stress I am in or how nervous I am at a certain situation, in submarine conditions? There is an interesting story regarding astronauts which is about how they are monitored to check their stress. Their eye blinking is consistently monitored in order to determine their stress levels. People tend to blink more quickly when they are experiencing stress, so checking eye blinking can let you know of slight changes of your bodily and mental condition. Then, what factor can be the equivalent to 'eye-blinking' in underwater conditions? I believe it is respiration.

One cannot overemphasize how important correct breathing is for a scuba diver. Most beginner divers are instructed just to breath normally, but actually it is not easy to be 'normal'. Thus, how can dive beginners learn the right breathing techniques even though they are not familiar with this new environment? Currently, the only way is just to practice breathing and to get used to it. There are manuals regarding correct breathing techniques, but there are not many people

who know exactly what it is, and although they know about it, they often forget this while they are diving because there are so many things to consider underwater. Thus, I strongly believe that there should be some equipment, which would control and monitor their manner of breathing in order to recognize an individual's unique breathing pattern.

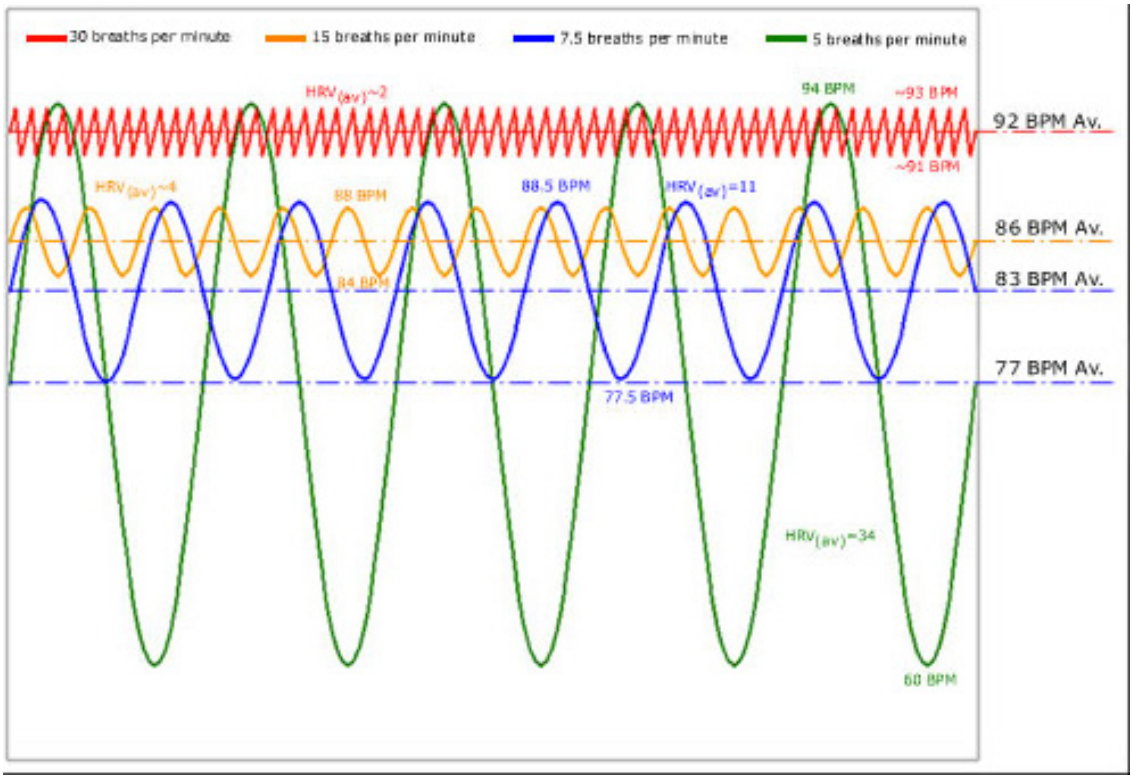


Figure 5 - Graph of Breathing Cycles Per Minute

## 2-4. Buddy system

There is a unique system for scuba divers to prevent small or big problems. It is called the buddy system. Buddy diving is the use of the buddy system by scuba divers and is a set of safety procedures that are intended to improve divers' chances of avoiding or surviving accidents in or under water by diving in a group of two or three divers. When using the buddy system, the group dives together and everyone co-operates with each other, so that they can help or rescue each other in the event of an emergency.

Figure 6 - Buddy Diving

# Phase 3 : Solution

## Introduction

This phrase is the idea generating stage. I will lay out the detailed concept of my idea based on research above, and provide designs for new scuba diving equipment and systems for a safer dive. This project has focused on a public need and I try to provide an innovative and vital design response to it.

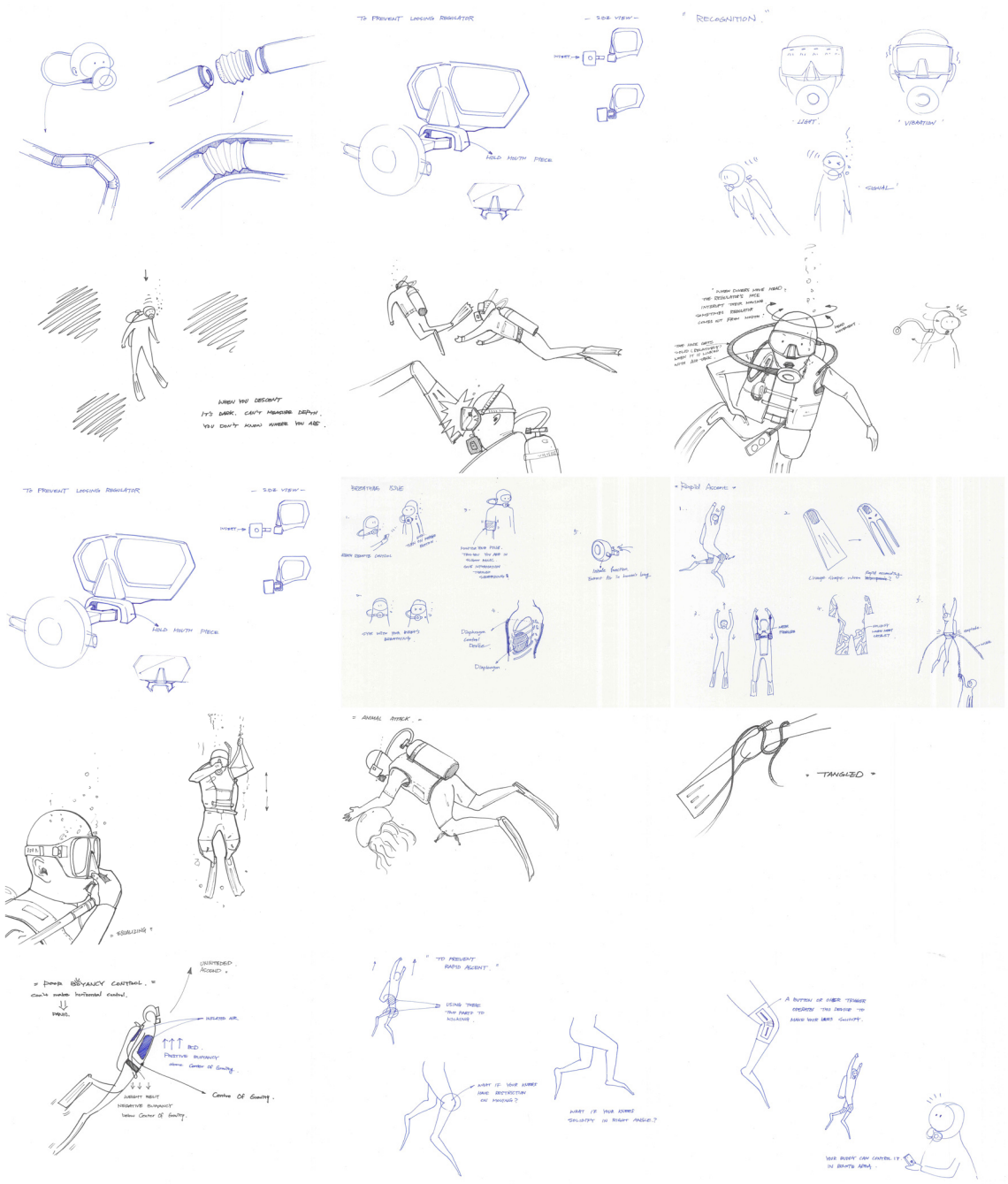


Figure 6 - Idea Generation

## 3-1. Approach

After continuous background research and idea generation, I decided to redesign the regulator, because I found a huge potential aspect in this device since it is closely related to the essential factor, which is breathing. As is obvious, we cannot live without air and it is not simply a crucial matter on land, but also in underwater environments. Thus, I tried to figure out solutions to diver's death by redesigning this equipment.

**Regulator**

Divers put their lives in the hands of the small regulator, so this gear needs to be carefully checked before you dive. The basic mechanism is shown in the pictures, below. It contains a really complicated mechanism inside of the regulator but it is not difficult to figure out the pattern of whether you are breathing in or out though just simply checking a membrane in between the outer shell and inside space where the air goes in and out.

When you inhale the air, the membrane made of silicone goes into the inside space because of the pressure difference between inside and outside. If you exhale, it reverses the opposite sequence of inhaling. Thus, it might be easily deployed to detect your breathing pattern when a switch or sensor is installed on the surface of the membrane.

Going back to the beginning of this report, my approach is to prevent divers' death and so to redesign equipment – the regulator – to monitor the breathing pattern for each diver. Then, what can we do through measuring breathing patterns?

Knowing individual breathing patterns for divers can deliver huge advantages to them in terms of preventing pre-panic situations as well as ensuring safer dives in future. People have different physical conditions, such as lung capacity and exercise ability, so they have different air consumption rates. Therefore, it might be somewhat dangerous just to refer to a manual or online description which would be a generalized, average value. Even it is the same person, it might be possible to have different breathing patterns because he/she has different

physical and psychological conditions from day to day. The breathing pattern is affected by these kinds of small differences.

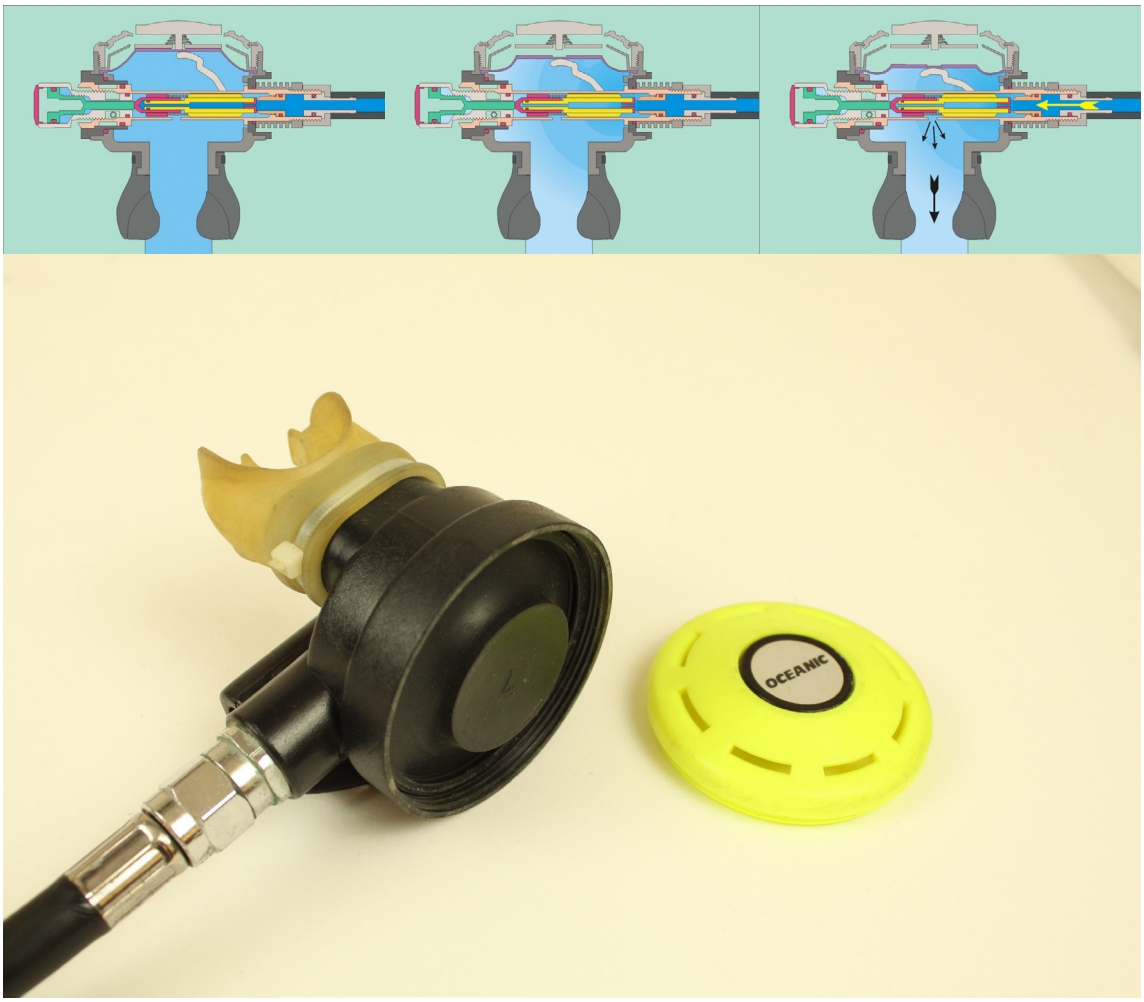


Figure 7,8,9,10 - Mechanism of Reculator

## 3-2. Solution

My solution for preventing diver's death started from an analysis of individual breathing patterns. And the analysed pattern will be applied to diverse situations. Basically, the main concept of this design is to give feedback to divers to let them know their current condition as comparing with standard and current breath patterns.

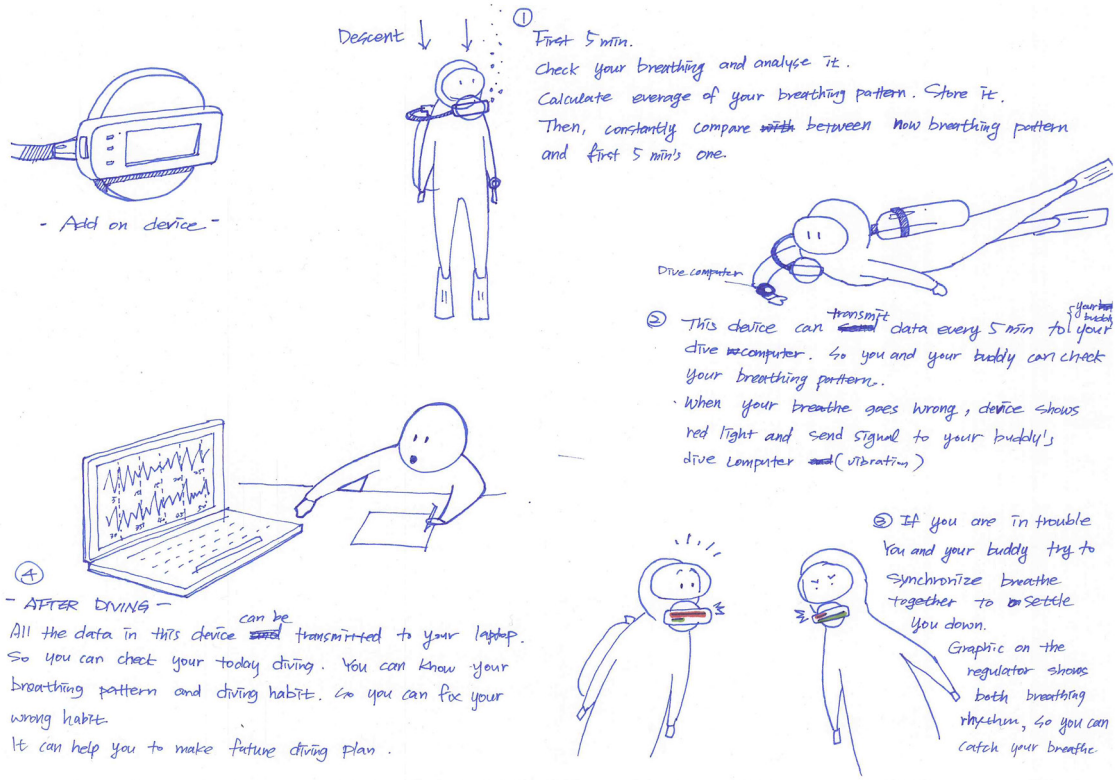


Figure 11- Scenario 1

### Scenario

Here is a scenario. Let's say you are about to dive with your friend. You have this new regulator and your buddy has it as well. As soon as you enter the water the device starts to measure your breath for the first 5 minutes. It checks your daily breath pattern because humans are in different conditions each day, so you might have today's unique breath pattern corresponding to your current condition. After collecting the data for 5 minutes, it now starts to analyse your average pattern of breathing and store it. Once the device is set up, it compares your updated breathing pattern with the designated one, and gives you feedback if something is wrong. For example, if your interval of breath-in and breath-out time is faster compared to the first 5 minutes' data, this device shows you in different colours which you can notice. Or this device can transmit some data to your dive computer, which looks like watch on the wrist. For instance, you have

breathed averagely 7 times in a minute for the first 5 minutes. After that, the device is consistently comparing your latest breathing for every minute. If the updated breathing is around six to nine times, it should be ok. However, when it goes below 5 or exceeds 10 times, there must be something wrong. Then, the device transmits a warning signal to both of you and your buddy. If you can realize that something is different in your body in advance, you and your buddy might be able to deal with it more easily, before the situation becomes more serious, and you can recover your breathing rhythm quickly, once you recognise it. This is the recognition stage.

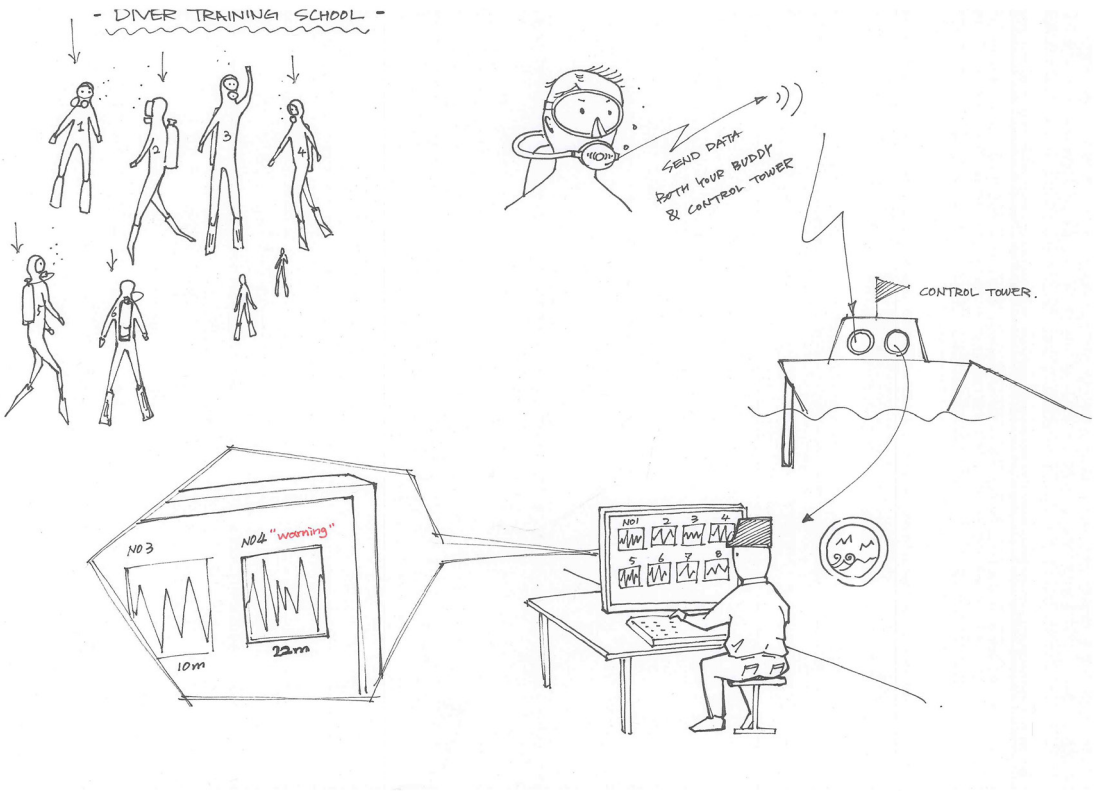


Figure 12- Scenario 2

## Scenario

Here is the second scenario. This is for the group diving in a certain association such as a diving school or submarine military troops. All the stages are exactly the same as the first scenario except for one thing. The different aspect in the second story is that there is a control tower where a director can supervise all divers to confirm every diver's safety. This device transmits not only to both of you and your buddy, but also to the control tower on the surface of the ocean. If once this system is settled, the groups, which are using this device, can monitor their divers' conditions more effectively and can handle any emergency situation more quickly. It is useful for them to collect a number of divers' data in order to compare each person and produce statistics. Once these statistics have been collected to some degree, divers can easily realize their own breathing pattern

and habits. It will be the good standard of your diving.

The next step concerns the moment after diving. As I mentioned in the above paragraph, divers can review their diving through the data collected. Actually, every diver fills out his or her daily diving summary in a logbook after finishing a dive. It is easy to understand as a kind of diver's diary. They write down quite specific information such as in and out time, temperature, maximum depth, visibility, objective, and observations of animals, etc. What I suggest is to add breathing patterns to the logbook contents so they can see their diving story more specifically. For example, my breathing was unstable after 30 minutes from the start in 18 metre deep water, I can guess what was happening at that time and would be able to catch small problem. Also, you can see your equalizing time and number, or buoyancy control through reviewing the breath differences. Then, you would probably recognise your wrong habits when you look at your breathing history. And this will be useful for planning your future diving plan. Because of this, if you know your air consumption rate regarding depth or some situation, you can consider these kind of situations and be ready for it in advance, to prevent potential dangerous situations by reviewing your diving history.

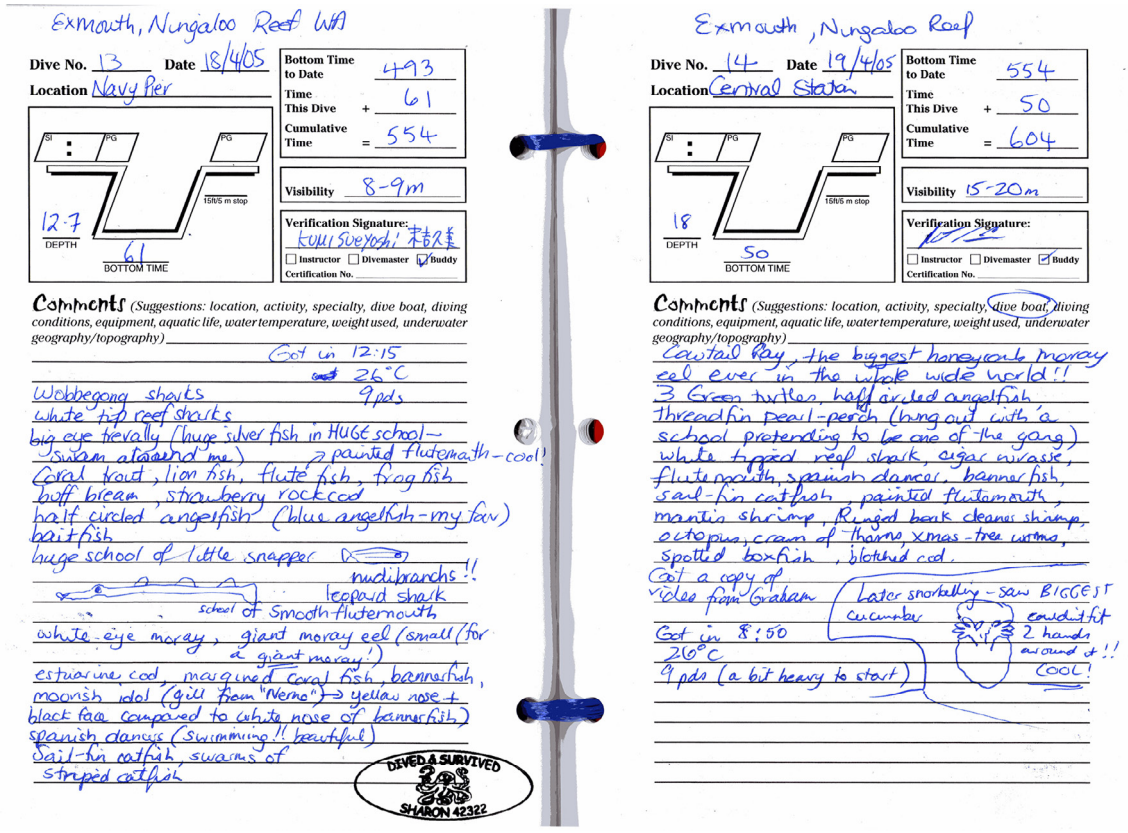


Figure 13- Contents of Logbook

**Sync**

The next stage is synchronization. When one of the buddies has a problem with their respiration, both of them can get information in a real time.  Maybe the guy who has started to have difficulties in breathing cannot easily readjust his breathing technique. So the idea to help the diver to have regular breathing is for him or her to synchronize his breathing with his buddy. To explain more specifically: there is a display on the surface of the regulator and it shows the breathing patterns of the two guys. When the warning signal has been received, you and your buddy's breathing rhythm is displayed on the regulator at the same time. Then you can easily compare your breathing rhythm with your buddy's and you will try to imitate your buddy's respiration because your friend has a relatively more normal breathe rate than you. It needs practice for this kind of situation. This step is the 'Sync' stage.

However, what if you are in a real panic, so you can't control yourself due to respiration problems? If you ascend rapidly from below 10 meters after 20 minutes of diving, you are likely to risk huge injury, even death. Therefore, rapid ascending has to be stopped. However, you might feel you have no choice, when you are in panic or feel it is hard to breath, but to escape the water. Thus, this third step is the idea for the extreme emergency situation.

Let's have a look what is going on when a panicking diver is trying to soar to the surface. Firstly, a normal diver tries to grab a panicked diver's fins or legs to stop them from rapidly ascending. Then, the panicked diver must be very confused so they sometimes can't breath well even though they have the regulator in their mouth. After that, the panicked diver starts to drink salt water and it makes them panic even more. This makes them violent wriggle but the normal diver can't release his buddy's legs. He has to wait until his buddy gets exhausted, and then he can supply air through pushing  the 'purge' button in the middle of the regulator's outer surface to his panicked buddy. The purge button is the part of a diving regulator that may be depressed manually to force the regulator to deliver air. This is either a separate part mounted on the front cover or the cover may be made flexible and serves as the purge button.  Of course it would be wonderful if the diver, who got a panic attack, can stop it before he or she

loses their reason, but any unexpected situation can happen in an underwater environment which is unfamiliar.  Thus, we need to prepare for every potential danger that can lead to death, especially in relation to air supply.

Therefore, this stage is only for the extreme situations, such as those mentioned above. This shows more forcibility than the first synchronised method of air breathing. This is the handling method to cope with extreme scenarios. First of all, when your buddy has a panic attack, cannot breathe well, and so tries to ascend rapidly to the surface, you operate the trigger for forced synchronising. Then, your regulator and buddy's one are synced as one device. After that, if one of you pulls the trigger, the purge button is moved exactly the same with the person's one who generates it first. Thus, you and your buddy can have exactly the same breathing pattern while this system is operating. It has the advantage that, during the emergency situation, you can have relatively free hands because you don't need to push your buddy's purge button with your own hand. Rather than this, you can stop your friends' soaring and supply air simultaneously. It is good for your buddy as well as you because you can deal with both problems at once, and so can concentrate on only the one task, which is that of preventing rapid ascent.

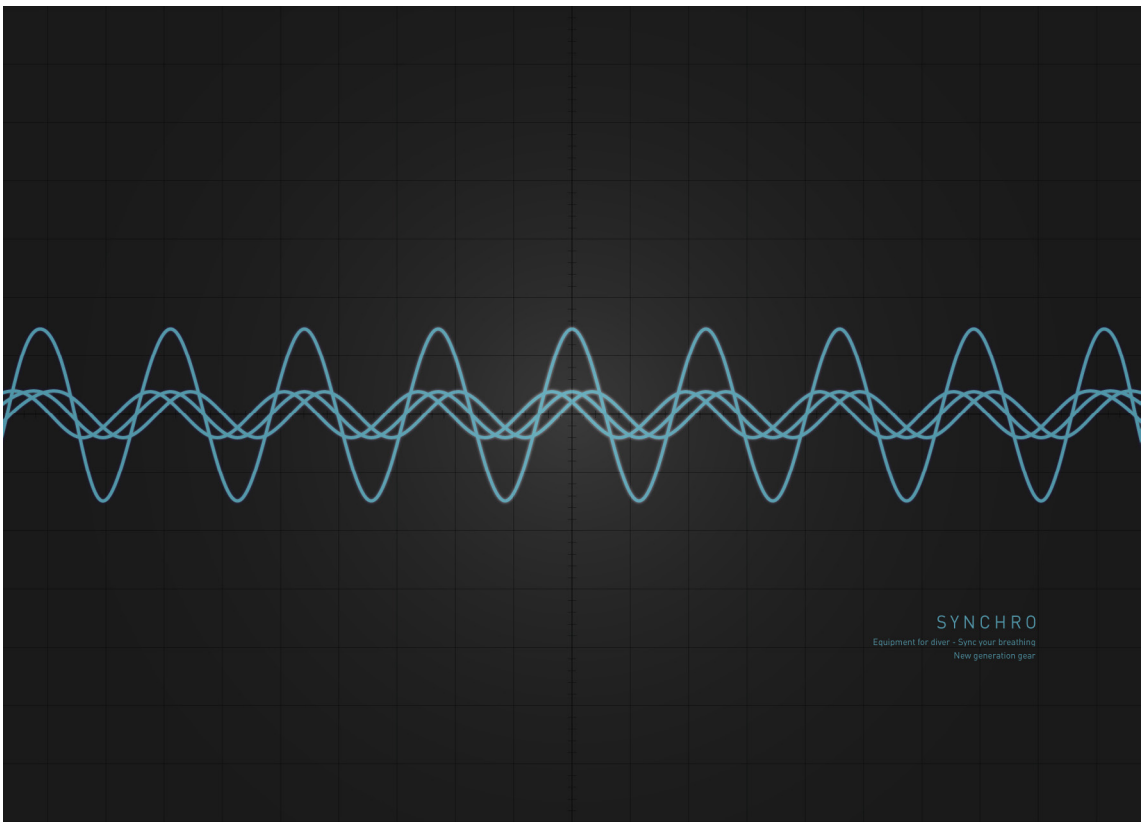


Figure 16 - Imagination Graphic of Synchronising

## 3-3. Benchmarking

There are a lot of sports/leisure products related to monitoring the user's condition and giving feedback. You can easily find them in commercial and sports equipment shops. The picture below is of a device for monitoring your body condition.

Figure 8 shows a product named 'Fitbit' which is a wristband that contains a small device called the Flex Tracker. The tracker is the brain of the outfit. This device has a series of functions which are tracks steps, distance, calories burned and active minutes, which monitor how long and well you sleep, that wakes you (and not your partner) with a silent wake alarm, and LED lights show how your day is stacking up against your goal. The next picture's product is a heart rate monitoring device. This device helps runners to measure the intensity of their workout more easily and effectively. Also both devices can transmit to you mobile or computer to provide more detail information to monitor. Nowadays, the more people want specific data of their exercise and life pattern, the more devices are needed for satisfying users. My device is designed for users who have the same kinds of requirements.


Figure 17 - Fitbit

Figure 18 - Heart Rate Monitoring Band

## 3-4. Target user

One of the most important things in designing products is target setting. Thus, what kind of people can be users of this product? As mentioned before, some people, who have interest in their systematic exercise and well-being, might need this product. But apart for them, we can expect many potential users. First of all, beginner divers such as taste or open water divers who are unfamiliar with the uncertain underwater world could be our users. This device allows new divers to feel more comfortable since they remind the user that they are constantly being monitored by someone – whether their buddy and/or the control tower – and that faith allows the user to be more confident. Secondly, instructors also need it because the people who they are teaching are mostly beginners or are unaccustomed to diving. Thus, naturally instructors need it for their student's safety. The next target users would be those who have difficulty in breathing in underwater or who have a fear of water, for some reason.

## Technology

To properly operate the functions mentioned above, the device needs some technology specialized for use under water. Especially, the way of transmitting data is more complex than it might be for land use. Because of this, it is relatively difficult to use telephone or cable connections to send data. Instead of that, for instance, a submarine relies on sound to send and receive digital data.


Figure 19 - Acoustic modem

Acoustic modems offer the possibility of wireless communication under water. For those who have dealt with cables in unfavorable ocean environments, this is an elegant solution for communication. Typical applications for acoustic modems are real time systems or previously deployed systems where data needs to be periodically downloaded.

As only sound signals can be transmitted in water environments, the way of transmitting is slightly different. There is a simple diagram that illustrates the procedure of transmitting data underwater. Let's say there are two 'Synchro' devices. My device analyzes my breathing pattern and the digital signal, which is the analyzed information, is sent to an acoustic modem. Then it transfers to the sound signal and transmits to the other device. The acoustic modem of the second device receives the sound signal and transfers it into digital data.

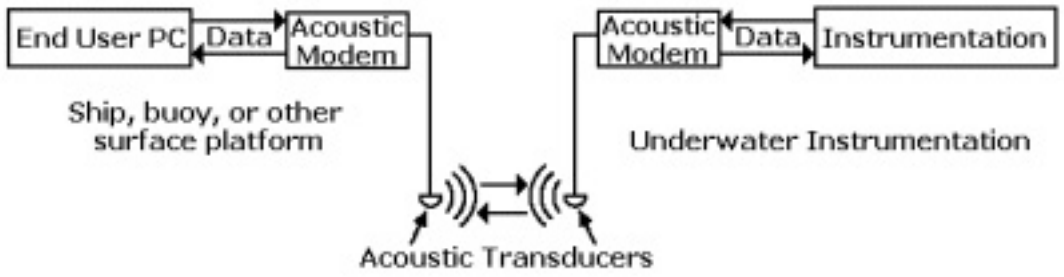


Figure 20 - A diagram of Basic Acoustic Communication Model.

## Display

Showing a diver's condition on the display is one of the most important things in this product. Care should be taken in choosing the method for display, because there are a few things that need to be carefully considered. The reason is that, divers are equipped so much gear and the display has to be definitely clear but not too much be an eyesore. It would be best if the device can deliver correct information without any electronic displays. However, it is almost impossible to perform the functions that I generated as key concepts, so it seems that there is choice but to use electronics.

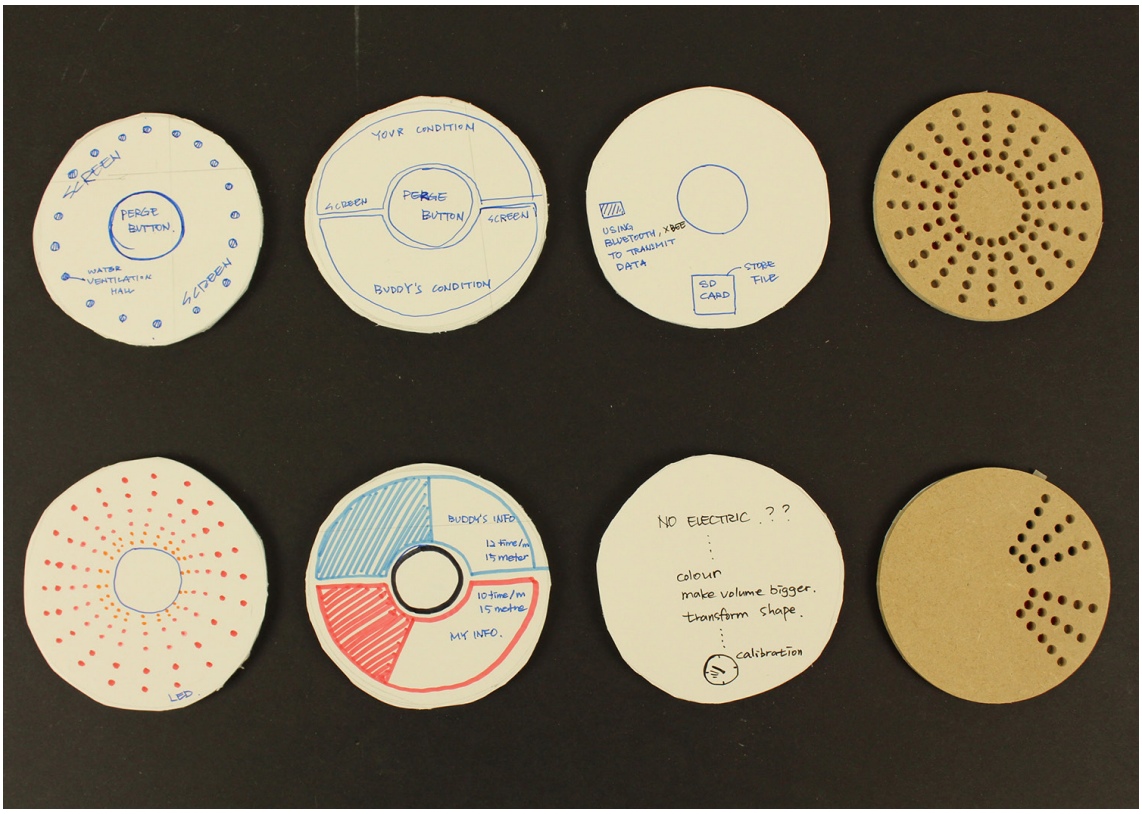


Figure 21 - Display part mock up

The most ideal idea for display would be the screen monitor such as LCD or OLED. This display would allow for the delivery of more accurate information than any other method. It can show beautiful graphics and text for better understanding, but it has low brightness so there is a possibility that divers cannot receive the information clearly.

The next way is to make a display out of LEDs. The light called RGB LED can make any other colour in one light source, so it can be used extensively in many areas. This light is especially useful for this project because NeoPixel light is quite small, so it can be installed in a small surface such as a regulator. And it is relatively bright compared to an OLED panel, so people can perceive this signal more easily. Furthermore, there is a single data line with a very timing-specific protocol. Since the protocol is very sensitive to timing, it requires a real-time microcontroller such as an AVR, Arduino, PIC, mbed, etc.

These are the two options for display and both ways are quite appropriate for application to the new regulator. To me, the latter seems more reasonable in terms of its strong visibility.

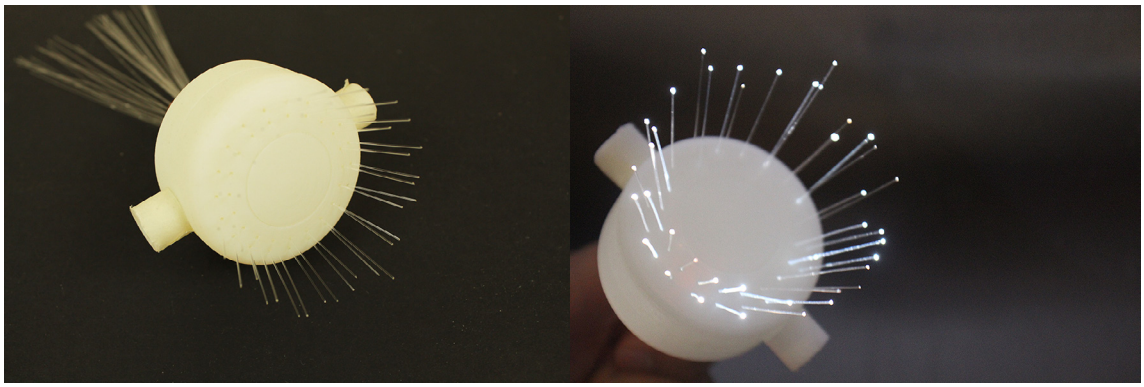

Figure 22, 23 - Regulator & fibre optics with light

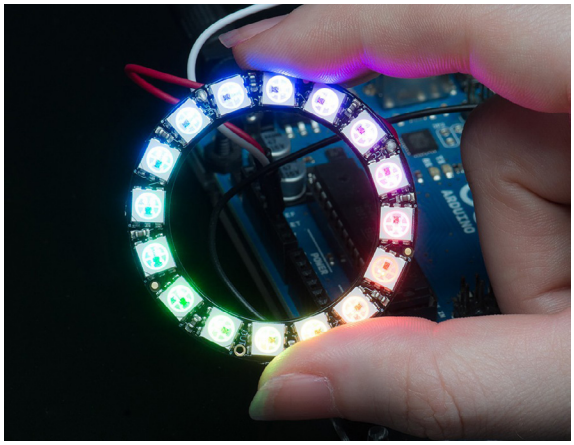

Figure 23 - NeoPixel RGB Ring

# Phase 4 : Conclusion

My project has been driven to find the ways to reduce incidents of divers' accident and prevent death during scuba dives. My intention was to approach people's psychological aspect, which is to enable the beginner diver to feel more confident and to allow them to be more comfortable. I believed the solution would be simple,  even though it had not yet been discovered, so I kept researching to find the possible trigger which leads divers to dangerous situations. Thus, I finally decided to look into respiration related issues.

This problem recognition seemed quite reasonable because the majority of incidents are quite closely related to air problems. Divers could not enjoy their experience freely without a smooth air supply, because they might feel mentally unstable, being worried about serious future accidents, for example. Once they have confidence in their apparatus and environment, via the interface of breathing techniques, they no longer feel threatened by air issues, and so can enjoy scuba diving. Incidents related to air problems are more common under water, of course, than on land, and accidents underwater are more serious and harder to handle. But the issue goes beyond the smooth supply of air, since there is another reason why we need to alleviate inexperienced diver's anxiety. Because of this, you should remember that even a slight, unusual thing could lead to a serious problem in an underwater environment.

Thus, I suggest a new generation of scuba equipment, which is able to help users to maintain a correct breathing pattern. In ordinary time while diving, this device constantly analyses your breathing pattern and gives feedback not only to you but also to your buddy and control tower (if there is one). This stage makes you aware of keeping to the right breathing pattern and gives you comfort as you can feel that you are securely monitored by someone. And analysed data can be used in review after diving and the collected data applied in the next diving plan. In emergency situations, the regulator can also assist in dealing with them since it allows for synchronization of you and your buddy. This product is good not only for preventing potential small problems that might arise from breathing issues, which could trigger a series of increasingly dangerous consequences, but it also helps to deal with emergency situations.

As more people are concerned about their better life quality, many products relating to safety and healthy life have been pouring on to the market. Some devices monitor your every physical condition while you are sleeping. And some devices check your heart beat while you are running and give you feedback. Like this, products oriented around healthy life styles have given rise to particular needs and demands. Then, why not also underwater activity? There must be a demand for more interesting and safe activity among people who like to dive.

I strongly believe that this product will affect the existing market and make an impact on the current scuba diving system. Nowadays, scuba systems need to be more customized to each individual and analyzed individually for better experience and safer activity. This device is the new generation of scuba equipment which will be able to satisfy those people's needs; because there is nothing more important than safety in any human activity.

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**Picture**

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