Concept Generation

Several tools and exercises were utilized to generate creative ideas and concepts. To ensure that bodily and mental elements of cognition were incorporated in the design thinking process, each team member dressed themselves in a wetsuit, fastened on the buoyancy compensator, regulator, and tank and brainstormed raw concepts. In class, we applied biomimicking, performed the “Dice Roll”, and “Devil’s Advocate” exercises to come up with raw ideas. These tools aided us in producing combinations of people, activities, and resources involved in product design that had not been previously considered. After accumulating over 30 rough concepts, 7 concepts were further developed based on customer needs and targets. The following 4 concepts were chosen as the optimal concepts, which satisfy most, if not all, of the functions and targets. The last 3 were chosen as secondary concepts. For Concepts 2, 3 and 4 a 3mm neoprene wetsuit seen in Figure 2.0 can be integrated into the design.

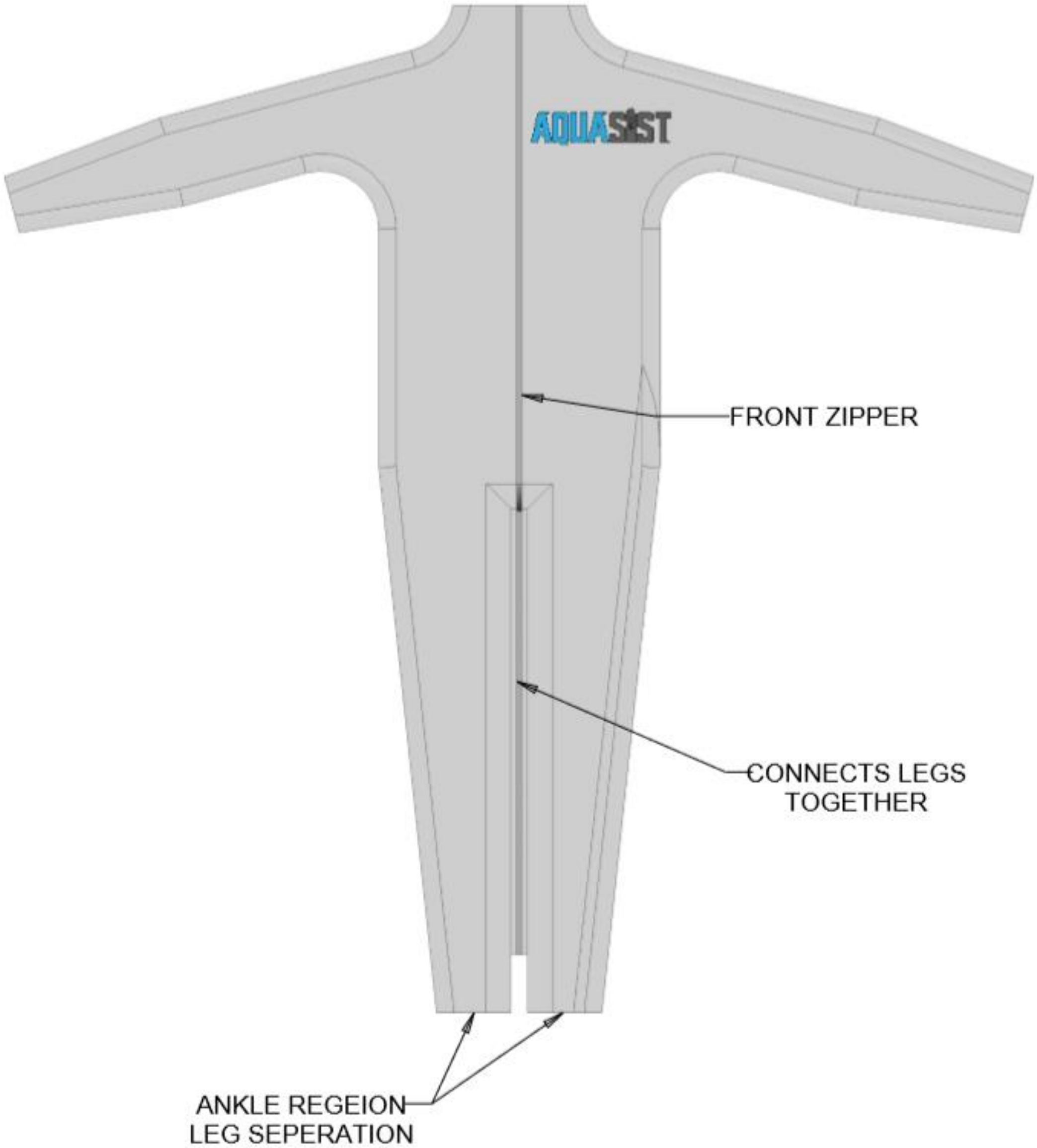


Figure 2.0, Integrated Wetsuit

Figure 2.0 shows some changes that the AQUASIST wetsuit offers. The zipper is moved from the back of the diver to the front of the diver to provide easy access. The zipper also starts from the ankles of a diver and goes to their neck, instead of starting at the lower back and going to the neck. The zipper starts at the ankles for two reasons. One being the wetsuit is like a pillow case prior to being zipped up. By making the wetsuit open like a pillow case, the wetsuit is easier for paraplegic divers to get their legs in and out of the wetsuit. When the zipper is zipped up the diver's legs are separated, and the wetsuit material is pulled close to the diver's skin. By separating the diver's legs, the amount of water that the diver's body needs to warm to provide an insulating warm water layer is minimized. The other reason the zipper starts at the ankles is to connect the legs together. The wetsuit region by the ankles remains separated like traditional wetsuits to provide a tight seal for the wetsuit to trap the hot water provided by the body's heat. The wetsuit seen in Figure 2.0 can also provide a mounting location for additional attachments needed for Concepts 2,3, and 4 to operate. Disclaimer: Concepts 2,3, and 4 could be attached to the diver by other means than through the wetsuit if deemed a superior design.

Concept 1. Secondary Buoyancy Compensator

In this concept, the device attaches to a scuba tank, directly across from the mount for the buoyancy compensator (BC). This location was chosen because there are many different styles of scuba gear, but the location of the tank remains constant in most scuba gear styles. Thus, by attaching the device to the scuba tank, it would ensure compatibility with the majority of the dive equipment that the potential customers would have access to. A drawing of the concept can be seen in Figure 3.0.

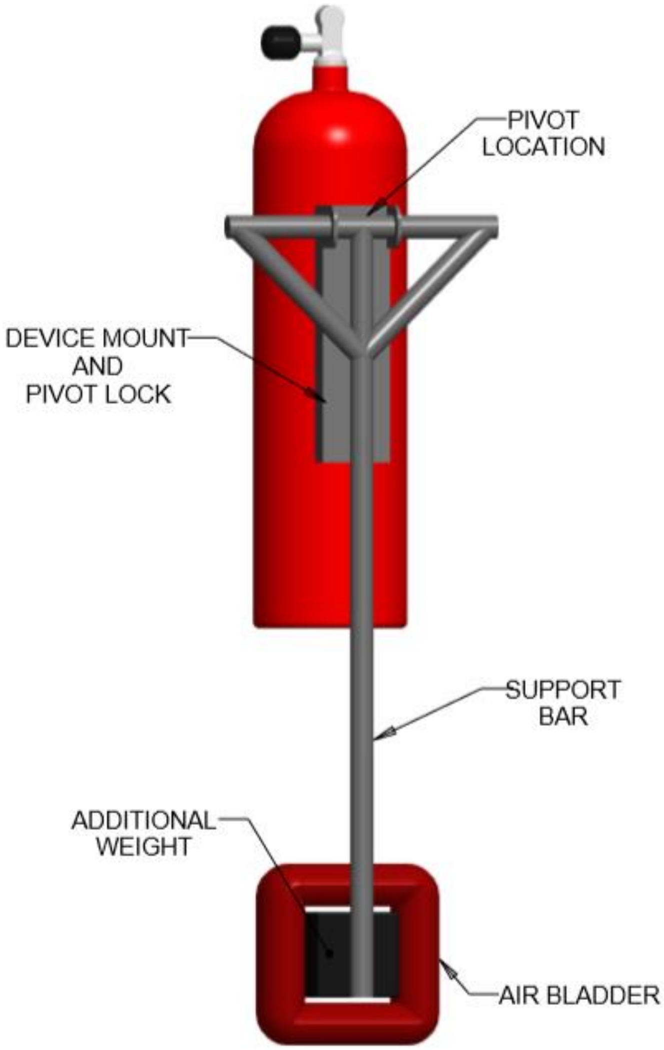


Figure 3.0, Concept 1, Secondary Buoyancy Compensator

The device mount is fixed to tank similarly to a traditional BC mounts, it uses two cam-band straps around the tank. The device mount also has a pivoting location that a support bar rotates about. The support bar provides a means to secure the paraplegic diver's legs and a mount for a secondary BC. The support bar has the pivots to make the transition in and out of the water user friendly. The support bar would be in the position seen in Figure 3.0 when the diver is in the water and would be locked in place. The support bar rotates about the pivot location 180^{o} towards the scuba tank valve during transitioning in and out of the water. The air bladder's receives air from a lowpressure port on the scuba diver's regulator. The method of controlling the amount of air that is supplied to the air bladder is similar to standard BC controls. The air bladder is wrapped in elastic material, so when diver releases through the relief valve the air will always be forced out of the air bladder.

Concept 2. Buoyancy Sticks

In concept 2 the diver could add buoyancy or weight sticks to themselves. The sticks are stored in pouches and can be seen in Figure 4.0.

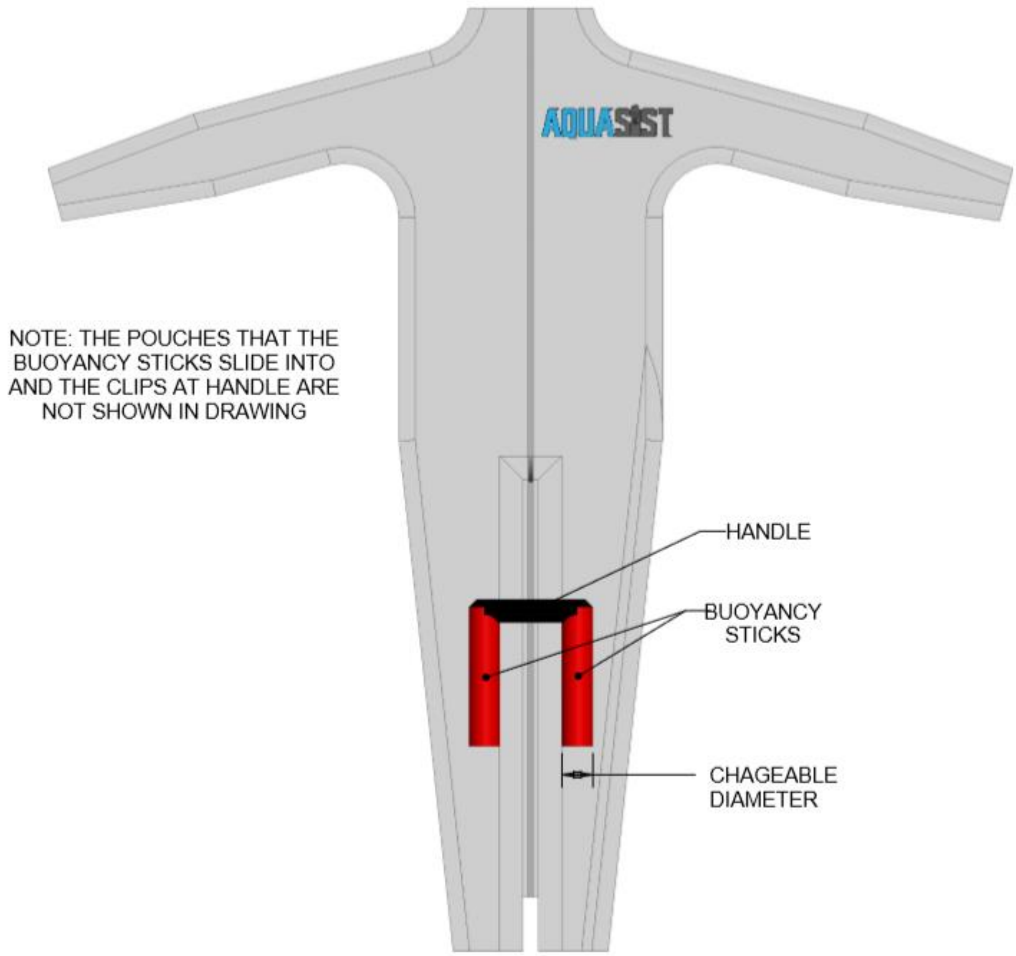


Figure 4.0, Concept 2, Buoyancy Sticks

The paraplegic diver could place buoyancy sticks into pouches on the wetsuit in or out of the water. Once placed in pouch the diver can clip the handle of the buoyancy sticks to the wetsuit to keep it in place. Different diameter buoyancy sticks will be available for purchase, because the amount of lift that each diver needs to correct their trim depends on their body composition. The difference in diameter of the buoyancy stick will control the amount of lift the stick provides. Each diver will have to determine how much lift they need through a trial and error process but once the correct amount of lift is found for the diver, the diver can just use the same buoyance stick for similar dives. The pouch for the buoyancy stick is located at the knee region of the diver. By placing the ridged buoyancy stick into the pouch over the knee joint, the diver's knees will not be able to bend when the buoyancy stick is inserted. The diver will become more streamlined and have better control of their leg's location by isolating the knee joint.

Concept 3. Air Tube

An air tube concept was inspired by a self-making bed comforter design which can be seen in Figure 5.0.

Figure 5.0, Self-making Bed

When air is added to the air tubes the in left portion of Figure 4.0 the air tubes become ridged and cause the comforter to lie flat, as seen in the right portion of Figure 4.0. In concept 3, an air tube is placed along the inside of the diver's legs which can be seen in Figure 5.0.

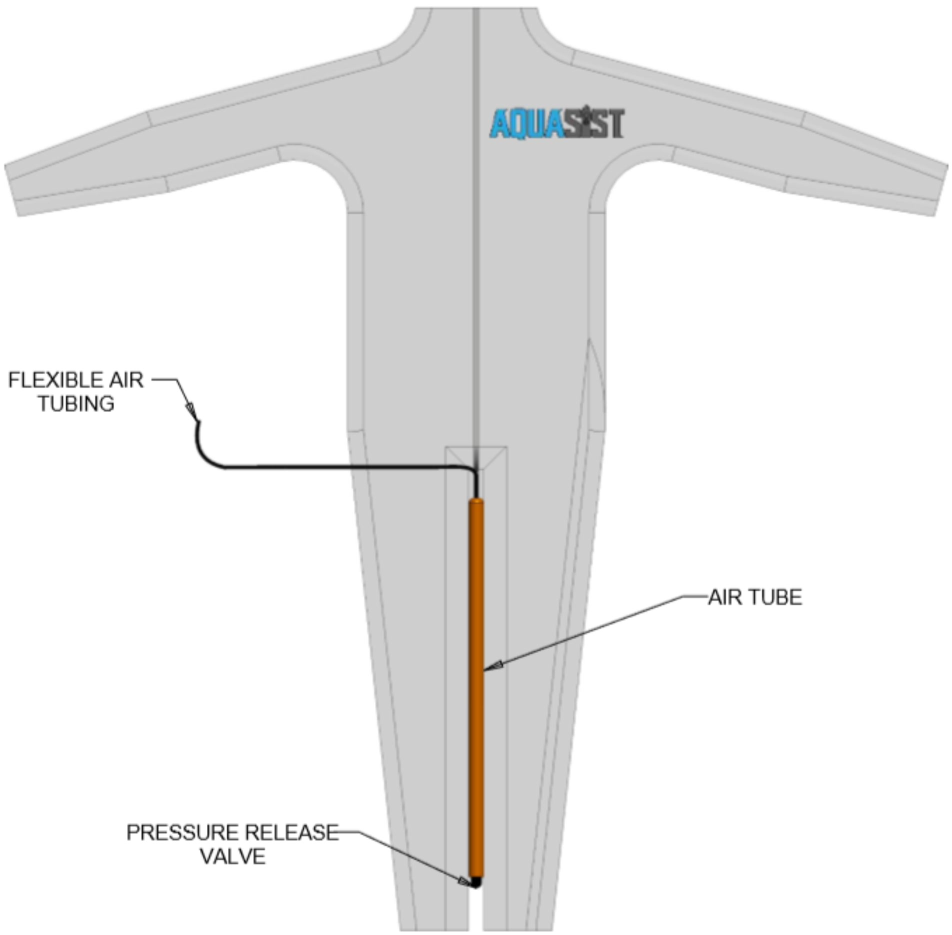


Figure 6.0, Concept 3, Air Tube

The diver could add or release air to the air tubes in the same way they control their standard BC but the controls would be independent of each other. The pressure release valve has an automatic blow-off safety feature, so tube cannot burst from over inflation. Pressure can also be released manually by pulling a cord with hands to open the valve. The air tube can be inflated by sending air from scuba tank through the flexible airline. The flexible airline will rui8n through loops on the wetsuit to an area easily accessible by the diver’s hands. When the diver inflates the air tube it provides lift and their legs are straightened out by the increased rigidity of the air tube. While the diver is getting assistance transitioning in and out of the water, or at the water's surface the air tube would not be inflated. When the air tube is not inflated the device doesn't provide a lift force and the device is bendable.

Concept 4. Adjustable Lift Location

Concept 4 allows the paraplegic diver to manually move the location of a buoyant force on their body. The diver can move a float anywhere from their ankles to their waste. An image of Concept 4 can be seen in Figure 7.0

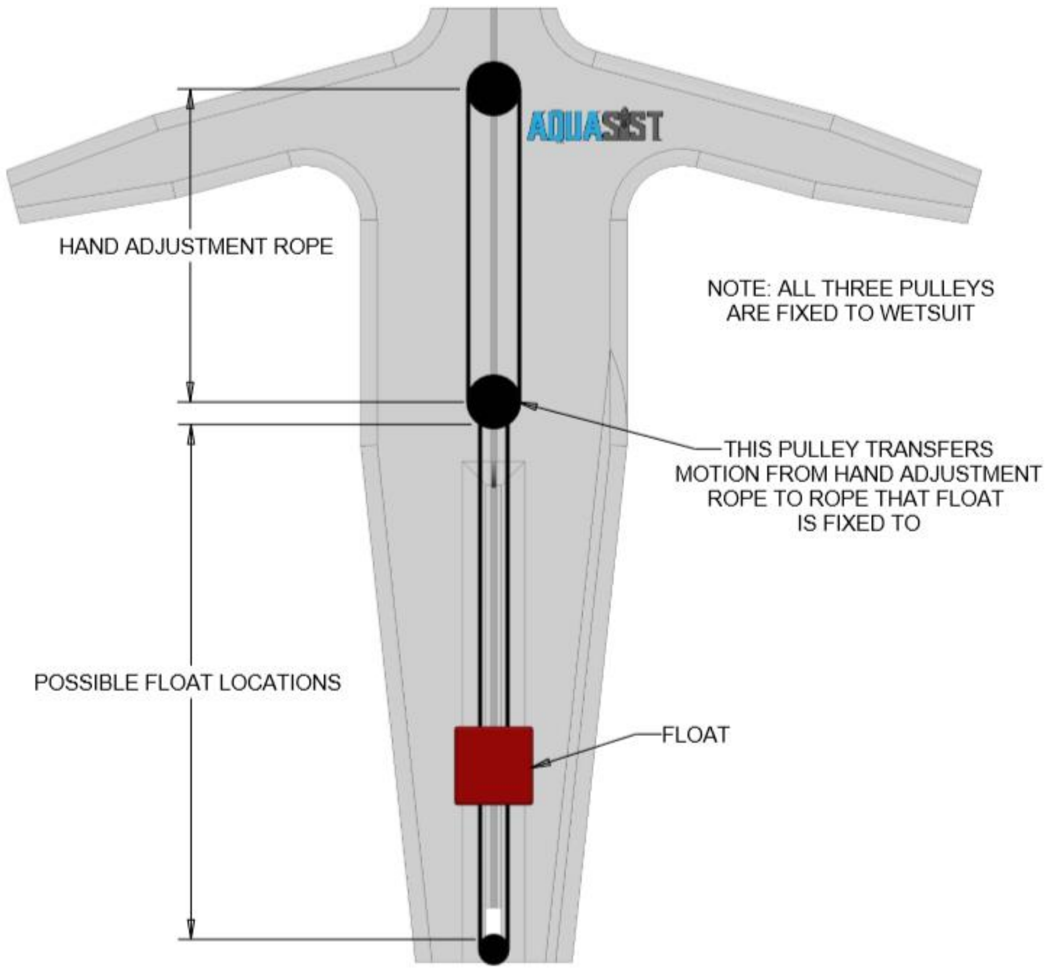
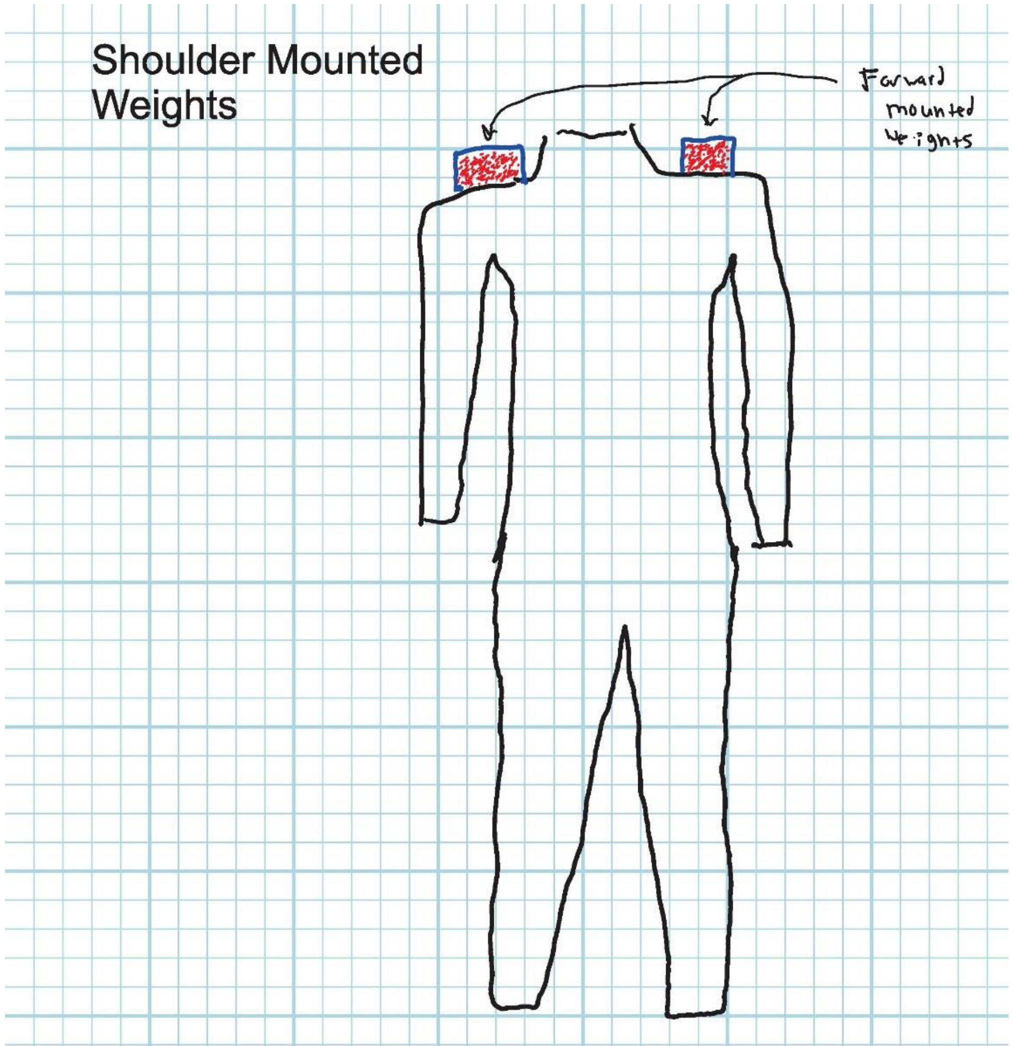


Figure 7.0, Concept 4, Adjustable Lift Location

The diver simply pulls the hand adjustment rope, seen in Figure 7.0, to adjust the location of the float. The diver would move the float to their waste at the water's surface. By shifting the diver's center of buoyancy towards their waste it aids the diver in holding their head out of the water and remain in vertical orientation to the water's surface. The float can then be moved to any location desired by the diver. The float supplies more torque about the diver's axis of rotation the closer it is to the diver's feet. This torque aids the diver in controlling their trim. The diver's axis of rotation is the imaginary intersection of the diver's center of buoyancy and center of gravity. The location of the diver's axis of rotation depends on the position the diver is in, the type of gear the diver has on, the diver's body composition, the amount of air the diver has in their lungs, and many other factors. Since there are many factors that control the location of the diver's axis of rotation, an adjustable float location will aid a many different body compositions and dive styles without having to customize a new device for each diver.

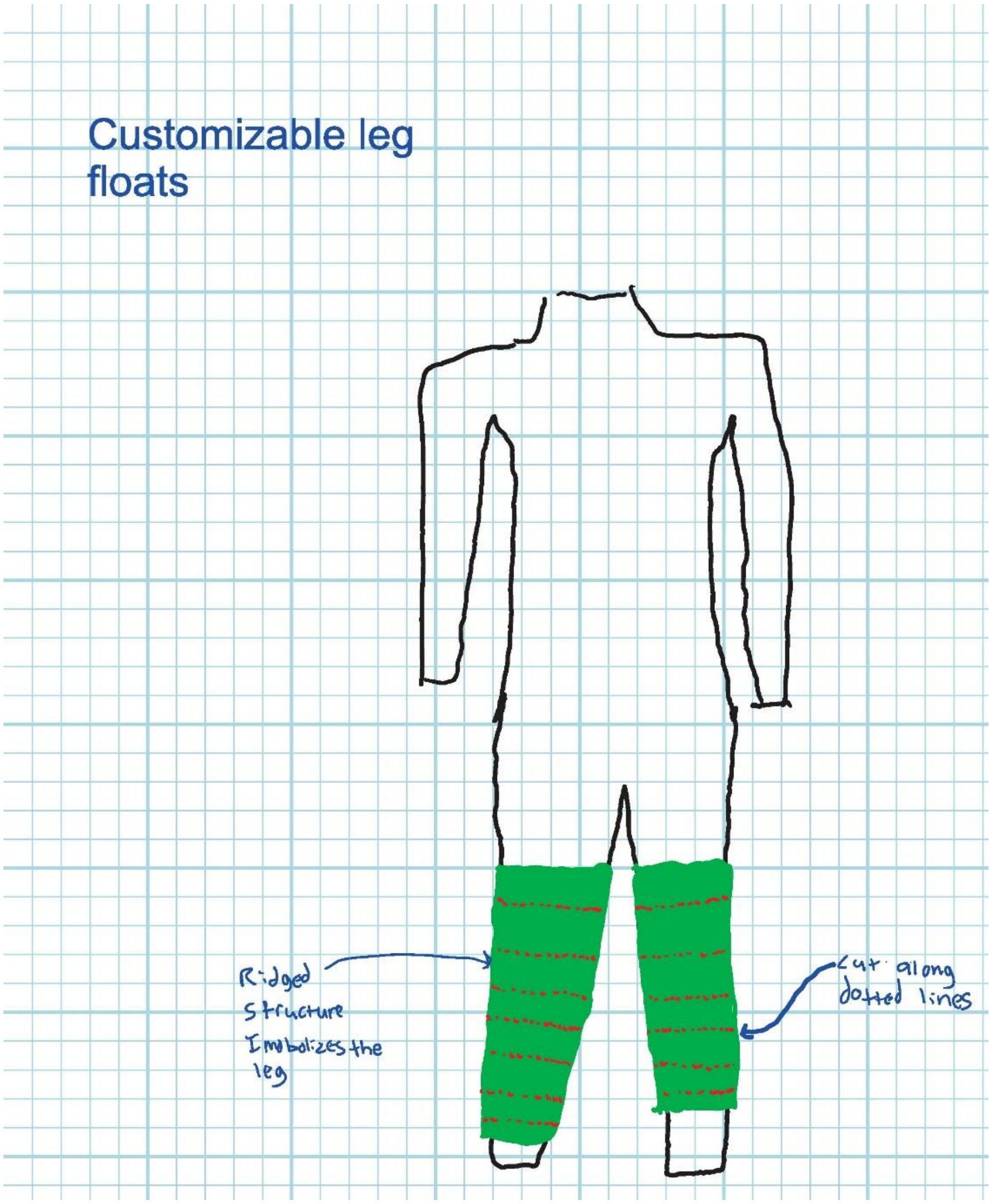
The following four concepts made it past the initial generation phase and into more serious concept selection but were ultimately decided against whether it be due to performance ability or design complexity.

Concept 5. Weighted shoulder pads



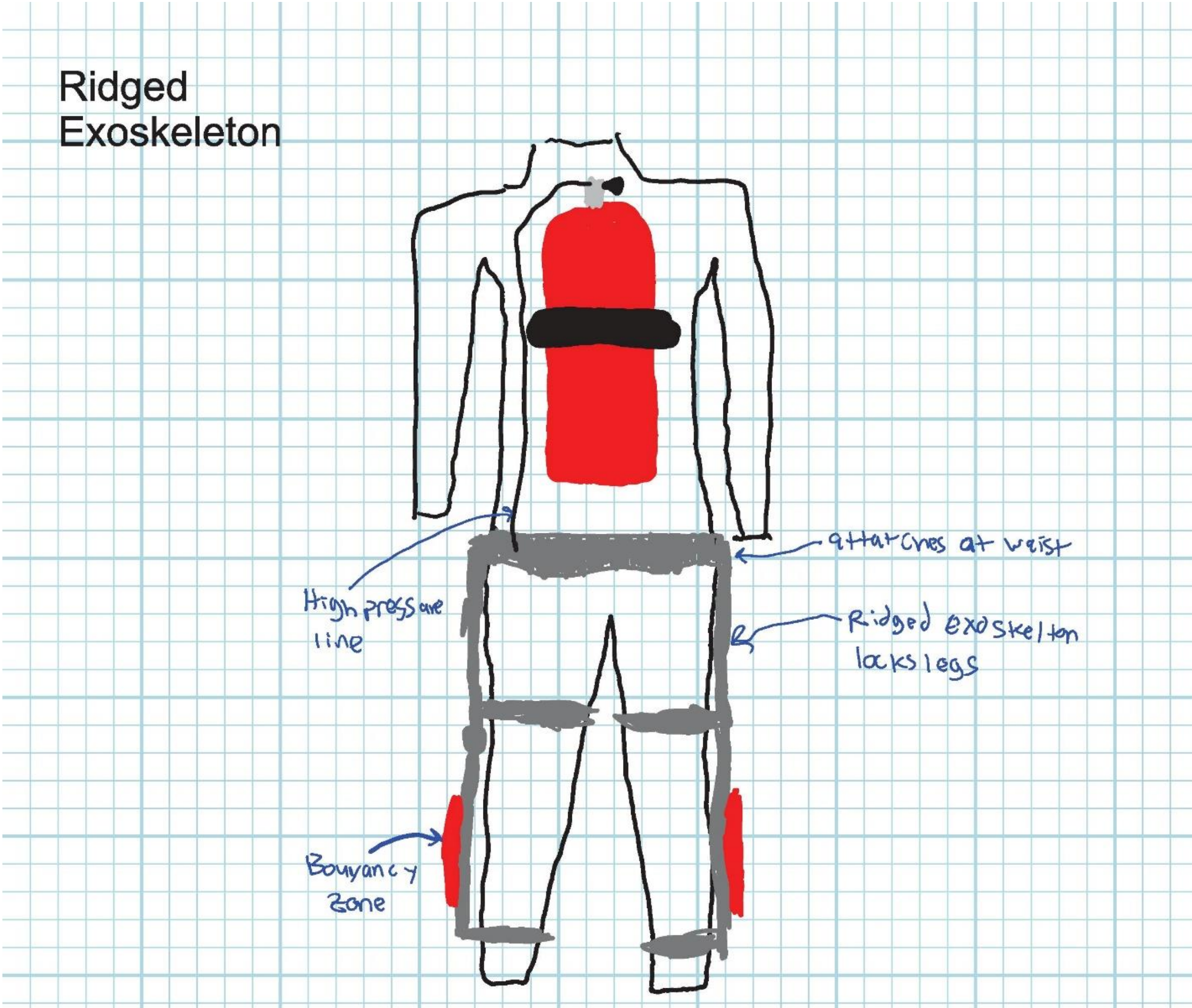
With weights mounted forward on the shoulders, the divers center of buoyancy would be shifted towards the front of his body and therefore provide more control of his profile in the water. This still affords no control to his legs and was therefore decided against.

Concept 6. Customizable Leg Floats



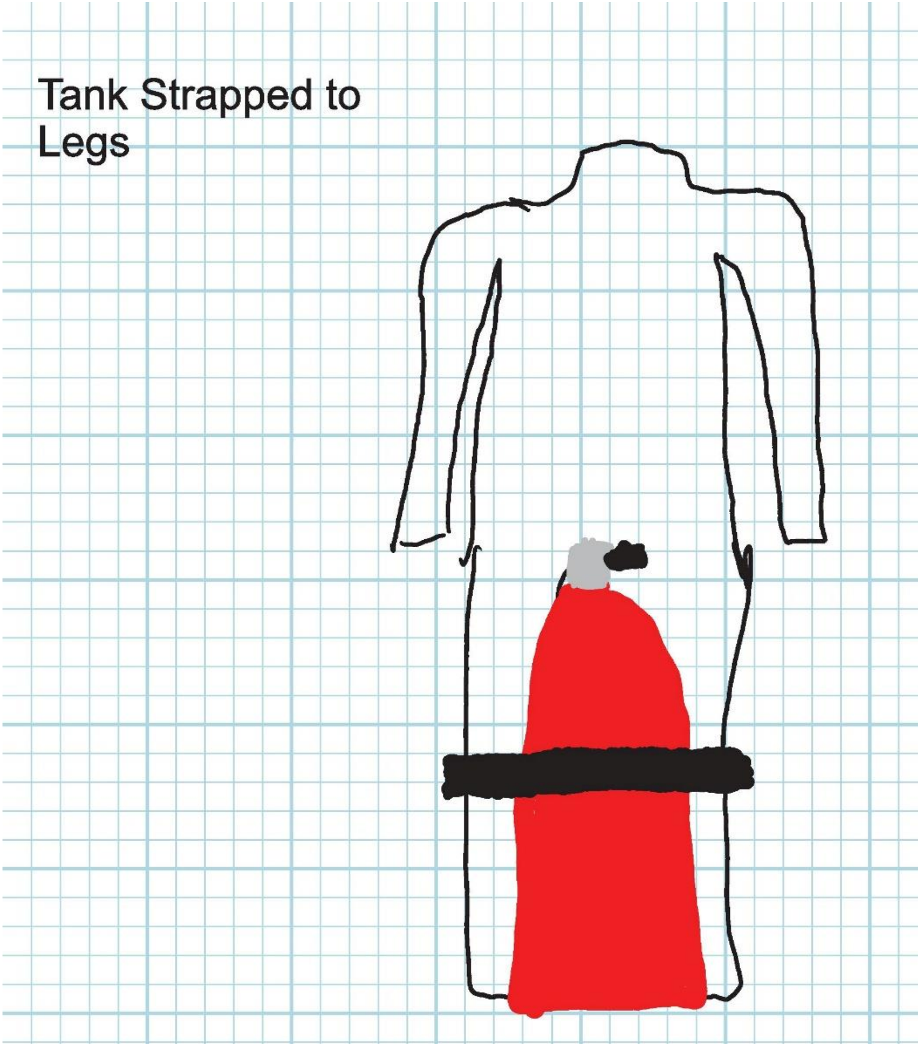
The customizable leg floats act similar to water wings but instead for the legs. They can be cut down to size making sure they fit many different individuals and have a rigid internal structure making sure the legs stay immobilized. This design was ultimately decided against as the floats would have to be bulky, affording the diver a more difficult experience underwater.

Concept 7. Rigid Exoskeleton



The rigid exoskeleton affords the diver a high level of control over his streamlined profile by immobilizing his legs. With an attached high pressure hose the diver can inflate two separate buoyance zones allowing control of his trim in the water. This design was ultimately decided against as it would be bulky and difficult for the diver to use underwater. In effect, we see it may hinder his or her dive more than help it.

Concept 8. Tank Between Legs



With the tank shifted from the back to between the legs, the legs can be immobilized, and buoyancy can be controlled in groups of smaller buoyancy compensators around the body. This idea was decided against because it is completely incompatible with all currently existing scuba equipment and would also require specialist training and instruction to use.