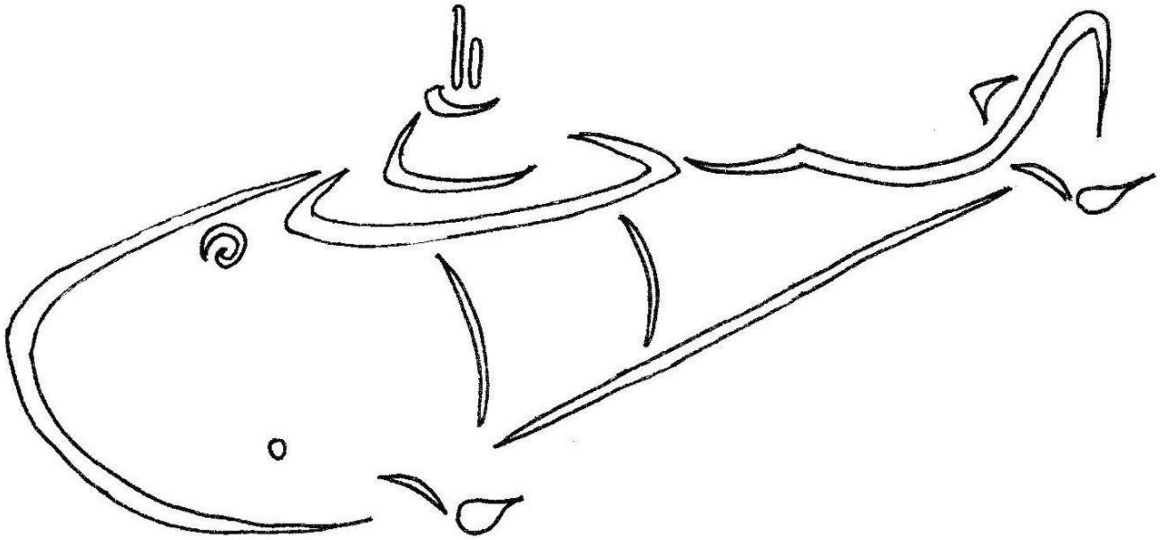

The River Shark

Final Design Report – ISR #12

HOCHSCHULE RHEIN-WAAL
Rhine-Waal University of Applied Sciences

The Submarine Team:

David Zakharia	**Sena Çankaya**	**Clemens Natusch**	**Roland Grichnik**
Christian Becker	**Christian Moll**	**Olimjon Ibragimov**	**Christopher Kick**
Frank Veenstra	**Cora Klockenbusch**	**Oliver Kahrmann**	**Purnima Sharma**
Christian Meurer	**Janina Zierul**	**Felix Weigand**	**Prof. William Megill**

Table of Contents

1.0 INTRODUCTION:

For our first attempt at the International Submarine Races, the team opted to recycle a hull previously used by the UK's BATH team. The "Sea bomb" itself was designed with hydrodynamics in mind, and due to certain circumstances we, the Rhein Waal Sub Team from Germany, have been given ownership of this hull in order to compete at the 2013 ISR. The hull will undergo drastic changes, including a complete redesign of the drive mechanism, changes to the navigation system, pilot positioning and orientation, as well as general hull re-modifications all of which will be explained in further detail throughout this report. The previous "Sea bomb" model incorporated a front end drive mechanism with square fins on the left and right of the nose; these fins had a left to right motion that generated the overall thrust. For our newly designed "River shark" and due to our high interest in bio-mimicry, multiple teams were dispatched to create an overall mechanism inspired by fish. The most crucial elements for efficiency are the design of the fins and the conversion of the pilot's muscular output to the fin mechanism input. The easiest and perhaps most efficient drive, for a human, would be a rotary system such as that of a bicycle; yet before designing this component it was necessary to know what this rotary energy was going to be converted into, and thus preliminary fin research began.

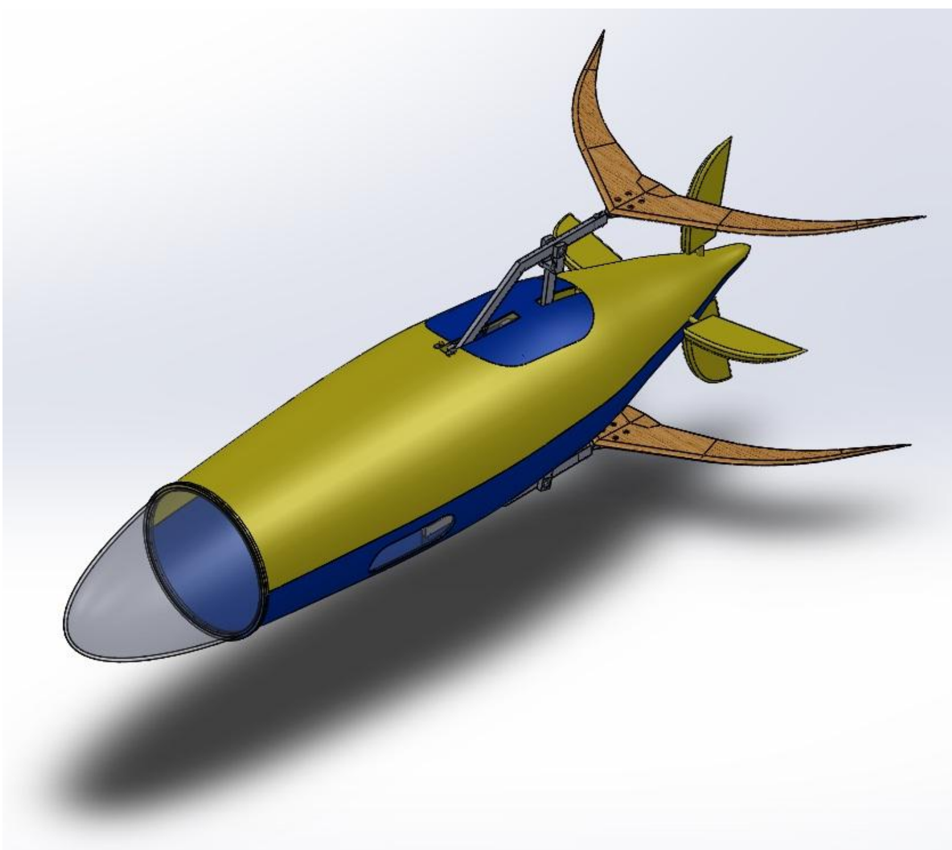

Figure 01: The Rhein-Waal University
human powered submarine design.

2.0 THE BIOMIMETIC FINS:

The team members, Frank Veenstra and Christian Meurer, tasked to the design of the fin are students pursuing their Masters degree in Bionics and Biomimetics, and for that reason chosen to find a bionic/biomimetic fin design capable of attaining superior speeds in comparison to previous submarines.

2.1 Biomimicry:

Figure 02: Sailfish (genus Istiophorus) with the typical lunate shaped caudal fin. (Image via: www.arkive.org)

For designing the fin we were inspired by the shape of the caudal fin of the Sailfish. Sailfish are generally known for their fast speeds and great jumps and can swim a remarkable distance of 100 meter in 4.8 seconds which means they can reach speeds of up to 20 m/s or 40 knots. In Figure 02, shows an image of an Indo-Pacific Sailfish (*Istiophorus platypterus*); they have been clocked at approximately 109 km/h or 30 m/s and can be categorized as one of the fastest fish underwater.

Figure 03: Design of the sailfish inspired fin.

By studying the caudal fin of the sailfish the team was able to design a replica with a span of 160 cm and a chord of 20 cm. This design gives the fin an aspect ratio of 8:1 allowing the fin, according to literature, to reach higher speeds. The overall thickness of the fin varies from the edges to the center, yet at its thickest point in the middle, the fin will be no more than 25 mm thick. The profile of the fin is inspired by the NACA 0020 airfoil which has a lift coefficient between 1.89 -3.08 for an angle of attack between 15°-25°; this design will provides confident thrust results even at angles as high as 25 degrees. Finally, the rudders will also be designed based on the research of the fin, using the same profile, yet the overall shape is to be based on the dorsal fin of a shark. The design of the rudders has not been finalized and more research will be put into it prior to the race. Figure 04 below shows the fin as it has been modeled for the submarine; please note that the material will not be wood, even though that was considered.

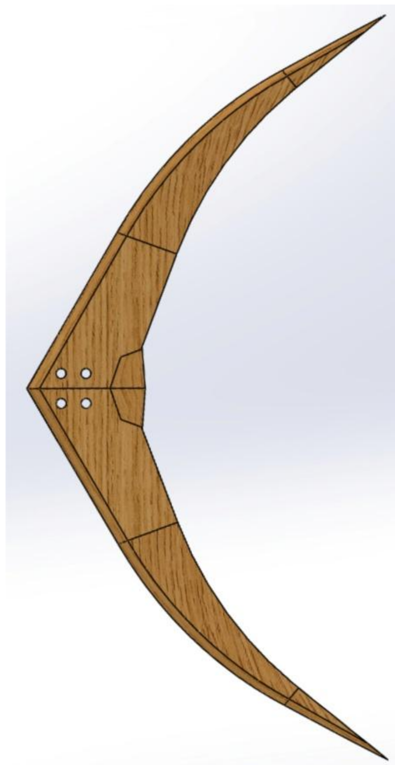

Figure 04: A model of the finalized fin design.

2.2 Fin Material:

A crucial design decision in any device is the material to be used; for the fins we wanted a strong but flexible material capable of handling high forces while still providing a natural flexibility to the motion. The material decided upon is glass fiber reinforced polyurethane foam (Coosa nautical 20 / COOSA Composites LLC). This foam is applied mainly in various parts of boats like stringers, decks and walls. The foam has a high strength to weight ratio, in fact 45% lighter than plywood, and has a density of 320 kg/m^3. Further benefits of this foam are its low water absorption and the fact that it is dimensionally stable, yet the team opted to apply a waterproof coating onto the finalized fin in order to make it watertight as well as to provide further smoothing to aid in decreasing surface drag. To further reinforce the fin a fiberglass sheet will be added to the midsection of the fin, this will provide a framework for the foam as well as a convenient attachment point to connect the fin to the drive mechanism to be used. During production the fiberglass and polyurethane foam are cut out of blocks using a CNC machine.

2.3 Number of Fins:

The fins required a more linear approach in order to oscillate like the caudal fin of a fish. The first step would be to decide on the position and direction of motion of the fin or fins in order to design a mechanism capable of accommodating such a system. Naturally, fish have a single caudal fin that generates the forward thrust, yet this design would have serious consequences in a mechanical system that does not appear to affect the overall performance of fish. Due to Newton's third law of motion, as the fin moves from side to side, the body and head will move in the opposite direction; fish are very flexible and have the capacity to at least attempt to overcome these forces, yet in a hard shell, such as that of the hull of a submarine, such forces will be noticed and very difficult to overcome. It is important to note, that the speed of the fin as well as the relative size of the fin to the body both play a major role in the effect of this force; logically, the larger the body and the smaller the fin the less effect the motion of the fin would have on the body of the submarine, yet the designed submarine is roughly 3 meters long and the fin is expected to be about 1.6 meters, which in essence will exert large forces on the hull. Furthermore, the cross-section of a fish is vertically linear which makes it more difficult to have a side to side motion, yet the submarine hull has a circular cross-section making it even easier to move side to side. After analysis of this problem, the team came to the conclusion that having two fins moving in synchronous motion (with opposing starting points) would counteract any rotational forces that would be exerted onto the hull and thus allow for smoother motion with less navigational input required; also, this would allow for double the thrust (in theory).

2.4 Fin Positioning:

Once the decision was finalized and having two fins on either side of the hull, proved to be a better choice than one fin at the tail, the team proceeded to discuss the optimum undulatory motion for the fins; Basically, a discussion about whether the fins move up and down or side to side. In most fish, such as tuna, salmon, and sharks, it is obvious that nature chose the side to side motion, yet in mammals of the sea such as whales, dolphins, and sea lions, we notice a top to bottom motion. It is true that evolution played the deciding role in this phenomenon, yet for a submersible with dual rear ended fins, what would be the optimum design? By further investigating the issue, multiple arguments were made for each concept. Yet, eventually, the complexity of implementing each design was the deciding factor. Since we have previously decided on a circular, bicycle-like, mechanism converting that motion into a horizontally linear motion proved to be a much more difficult, time consuming, and weight increasing solution; therefore having the rotational motion converted into a vertically linear motion was the chosen solution forcing the fins to undulate from top to bottom. Perhaps for the team's future model a side to side double fin solution would prove more efficient (the team shall take its chances and experiment with this design at this year's ISR).

3.0 THE DRIVE MECHANISM:

Knowing that the drive mechanism required a rotational input, such as that of a bicycle, as well as a top to bottom undulatory output on both sides of the submarine, the concepts to be applied had diminished greatly leaving one solution capable of accommodating all the restrictions, and keeping complexity and weight to a minimum.

3.1 Overall Design:

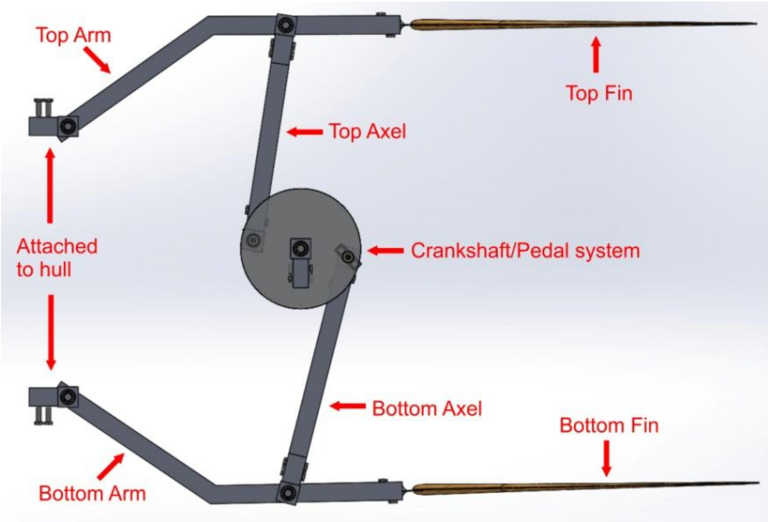

Figure 05: A side view model showing the drive mechanism.

The proposed design was to use a crankshaft system with conventional bicycle pedals as an input method for the pilot, and have two drive axels moving upward and downwards from the center of the crankshaft, much like how a piston works. On the top side and bottom of the hull, discussions and research of converting and amplifying the vertically linear motion generated by the crankshaft into a precise undulatory motion optimized for the fins was in motion. As can be seen in Figure 05, the concept is simple and requires minimal space to implement.

3.2 Arm Design

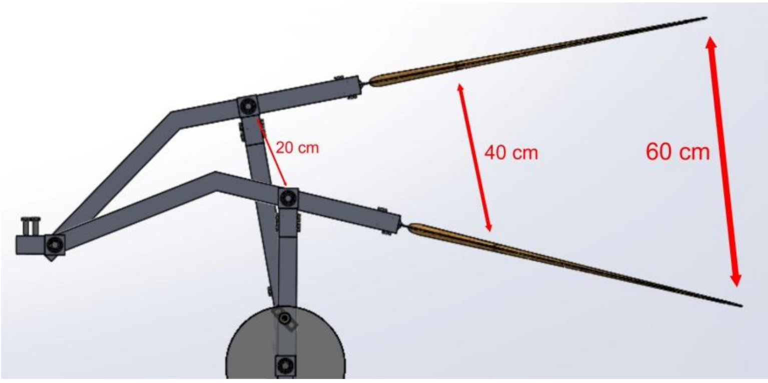

Figure 06: A side view model of the top side of the drive mechanism.

As can be seen in Figure 06, preliminary research showed that the optimum amplitude of the oscillating fin from the top of the stroke to the bottom of the stroke is roughly 40 to 50 centimeters. As can be seen in the figure an output of roughly 40 cm at the inner part of the fin is achieved while achieving a 60 cm span at the tips of the fin. The proposed crankshaft would provide approximately 20 cm of vertical linear motion, therefore by using an arm attached to the hull at one end, and to the fin at the other end, with the vertical axleconnected to the center of it, would double the output of the crankshaft as well as add a small rotation into the previously proposed linear motion of the fin. The center as described here is the midpoint between the point of connection to the hull and the outer end of the midsection of the fin; that being roughly 20 cm inwards from the attachment point of the fin. The arm itself would need to have a certain bend into it in order to keep the fin as close to the hull as possible to minimize drag as well as to optimize the angle at which the fin is oscillating; attempting to have the fin horizontal with the hull at mid stroke, and have an approximate 15 degree angle of attack at either end of the stroke. Furthermore, the design architecture of the crankshaft would need to be compact and precise, thus all parts shall be manufactured from scratch to a specific design that should allow for easy replacements and adjustments to take place. Finally, the size of the mechanism may be compact, yet for the pilot to perform the rotary motion, extra knee space may be required and the hull of the submarine may need to be enlarged in the vertical direction, this will be further discussed in this report in the section regarding the hull changes.

3.3 Crankshaft Design:

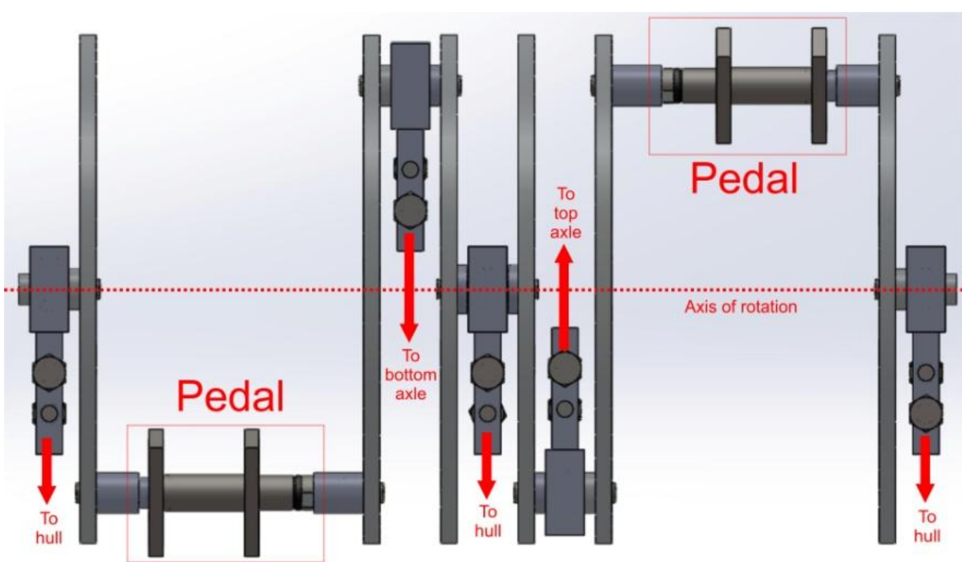

Figure 07: A model of the crankshaft design.

As can be seen in Figure 07, the crankshaft is composed of numerous parts, to discuss the assembly process part by part would require many pages, for simplicity in explanation, the basic concept will be described. The crankshaft is built mostly out of aluminum and will rely on 5 ball bearings to keep the motion as frictionless as possible. A total of 13 unique parts were custom designed to create this crankshaft, most complex of which is the axis along the middle of the crankshaft; this was necessary to provide rigidity to the entire structure otherwise the crankshaft would only be held from two opposing ends and not stable for exhaustive pedaling. The crankshaft is divided into 5 slots; the outermost two are for pedaling and provide a comfortable 15 cm for any pilot's feet to fit. The innermost slot, is the center slot and is essential to the functioning of the entire crankshaft, as previously discussed this was an exceptionally difficult part to design in order to be able to easily assemble and disassemble it if need be, but also, and most importantly, its task is to keep the plates on its left and right rotating in synchrony. The last two slots of the crankshaft are simply used to connect the crankshaft to the arm on the top and bottom side of the hull. The team is confident that this crankshaft design will produce excellent results at the races.

3.4 Other issues:

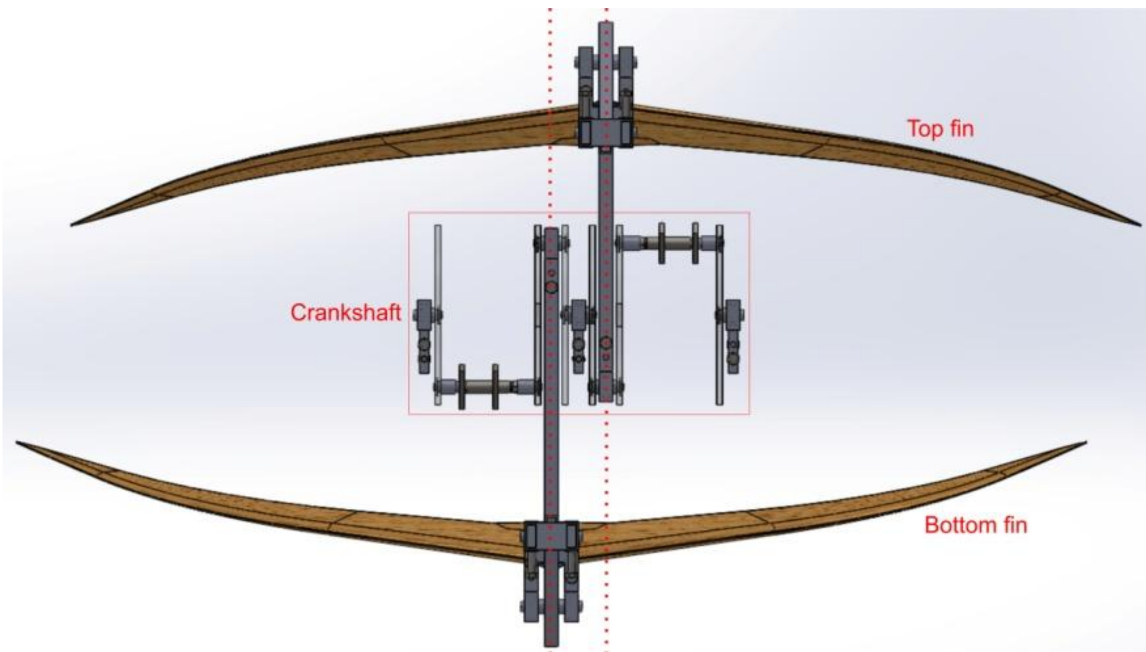

Figure 08: A model of the front view of the drive mechanism.

One final issue faced by the team in designing the crankshaft, is the connection to the arms. As can be seen in Figure 08, the center of the top fin and the bottom fin are not aligned; this may seem like an error, yet it was considered and accepted as such. In order to ensure the rigidity of the crankshaft, the center of the fins needed to be above their axle as it comes off of the crankshaft; to offset the centerline would result in side forces propagating through the crankshaft and would have undesired consequences. After careful analysis, the difference in centers was found to be roughly 7.5 cm and thus was considered irrelevant when dealing with 160 cm span fins, furthermore upon realization of the model, if any roll effects seem to be taking place, they can be adjusted using the initial position of the pitch rudders. In general, it can be said that the design has been well modeled and designed to allow for easy access, tuning, assembly, and disassembly. We are confident in its abilities.

4.0 THE PITCH LIMITER:

Before moving onwards, there is a design element that had not been researched in great detail at the time of submitting this report, yet through discussions has proven to be an essential addition to maximize the efficiency of the fins and mechanism. This part is being referred to as a "pitch limiter" and will connect the arm of the crankshaft mechanism to the fin.

4.1 Standard Fin Motion:

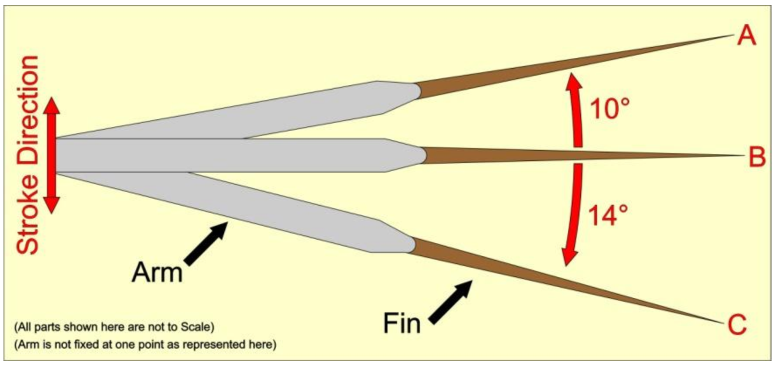

Figure 09: A representation of the angle of motion of the top side arm and fin prior to attaching the pitch limiter.

As can be seen in Figure 09, the arm and top side fin are normally to be attached directly to one another producing a 10° angle of motion upwards (A) from the horizontal (B) and a 14° angle of motion downwards (C) from the horizontal (B). This figure represents the state of the top side fin in an upward or downward stroke. The disadvantage in this system is that the fin at its position B is perfectly parallel with the direction of motion of the submarine, and thus the motion of the water, and therefore produces no thrust. A further disadvantage, which could be overcome by adjusting the arm mechanism, is the angle of the fin at position A, being at 10°, and 5° short of the optimum angle for the designed fin. It is possible to calculate the average angle at which the fin hits the water relative to the horizontal. By adding the top and bottom maximum angels of +10° and -14° and dividing by 2 we get a shocking result of -2°; this is the average, or the midpoint, of the motion and is a very weak angle. The overall thrust is diminished due to the fact that the submarine attains the most thrust when the fins are at an angle closer to 15° and the average point of this design is at -2°. To overcome these disadvantages, the pitch limiter concept was introduced. The device is expected to serve two purposes, the first is to allow further flexibility for the fin and adjust the angle of attack beyond what the arm would be capable of achieving; this concept is based on OMER's design to maximize efficiency. The top side arm itself, mathematically, is expected to oscillate between +9.98° and -14.34°; by using the pitch limiter these numbers could be adjusted to reach the optimum 15°, and slightly beyond, in either direction to provide the best overall angle of attack for the fin.

4.2 Fin Angle Control:

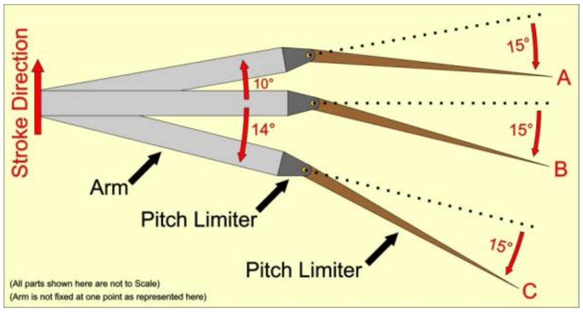

Figure 10: A representation of the expected motion of the fin during an optimized upward stroke of the top side arm.

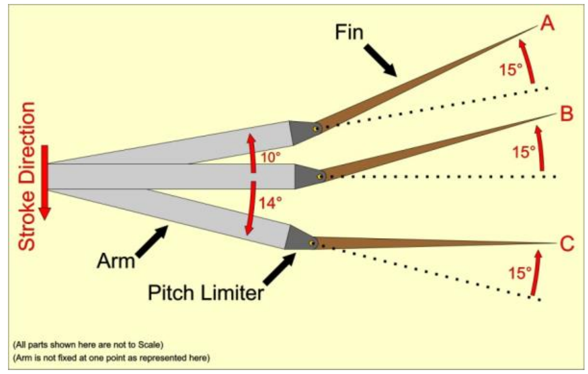

Figure 11: A representation of the expected motion of the fin during an optimized downward stroke of the top side arm.

By observing Figure 10 and Figure 11 during an upward and downward stroke respectively, it is now obvious that the fin itself is always at an angle. It is possible to calculate the average angle to be expected of the fin by calculating the angle of the fin relative to the horizontal at the top and bottom of each stoke. In Figure 10, at the top of the stroke the arm is at +10° and the fin at -15° relatively, therefore the angle with the horizontal at that point is roughly -5°. At the bottom of the stroke, the arm is at -14° and the fin at an additional -15° resulting in an overall angle of -29° with the horizontal. The average angle for the upward stroke is therefore: (-5 + -29) / 2 = -17°; the negative sign is clearly irrelevant in this number, as the thrust is generated as a result of the angle between the fin and the direction of motion of water across it; in this case we have an average of -17°. As previously mentioned this part is still theoretical and has not been properly studied to be realized, adjusting the pitch limiter's design could bring us closer to a more perfected design. We now proceed to calculate the average in the downward stroke of Figure 11; at the top of the stroke, we notice the arm at a +10° angle and the fin at an additional +15° resulting in a +25° angle from the horizontal. At the bottom of the stroke the arm is at -14° while the fin is at +15° relatively and therefore is at +1° from the horizontal. The average for the overall downward stroke is therefore: (25 + 1) / 2 = +13°; this result is a bit shy of the optimum 15 degrees, but is rather astounding when compared to a downward stroke without a pitch limiter. It can be seen that by adjusting the pitch limiter angle to approximately 14° instead of 15°, the average upward and downward strokes become -15° and +15° respectively; Exactly where they need to be. Further study and experimentation will be needed to test the efficiency of the pitch limiter in general.

4.3 Disadvantages:

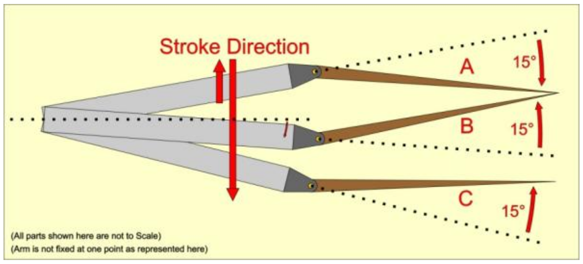

Figure 12: A representation of a more realistic downward stroke.

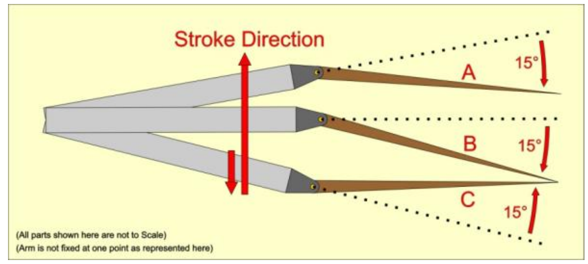

Figure 13: A representation of a more realistic upward stroke.

The previously discussed figures represented an optimized upward and downward stroke, where the initial position was optimized to test the pitch limiter's limits. In a more realistic thought experiment, it can be seen in Figure 12 and Figure 13 that the amplitude of the entire system is greatly decreased. By looking at Figure 12 we see that at the top of an upward stroke, the fin is now at position A; as the downward stroke begins, the pitch limiter needs to switch the angle from a -15° to a +15° as can be seen in this example, this switch is semi-autonomous with the downward stroke of the arm. It is said to be semi-autonomous because of the water below the fin that will push it upwards as the arm pushes downwards due to the freedom of rotation of the pitch limiter. As can be seen on Figure 12, at position B the pitch limiter has reached its opposing limit yet the arm is now more than halfway through its stroke. This is a great loss in amplitude; recall that in the optimized study the fin at position A would be at the dotted line of position A rather than its current position as shown in Figure 12; This amounts to a loss of approximately 50% in amplitude, which is mirrored in Figure 13 during an upward stroke.

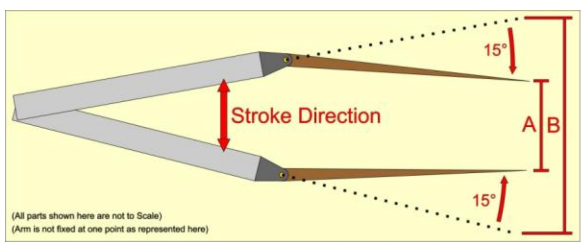

Figure 14: A representation of the realistic loss in amplitude during an upward and downward stroke.

As can be seen in Figure 14, the effective distance between the fins at the top and bottom of the stroke is approximately half when including a pitch limiter (A) as opposed to having no pitch limiter (B). The overall gain in thrust due to the optimized angle of the fins is effectively being diminished by decreasing the amplitude of the fin's motion. To overcome this loss the team has devised a new concept for the pitch limiter which has not been previously implemented at the ISR, as far the research shows. The concept involves spring loading the pitch limiter providing an advantage by attempting to recover the amplitude originally lost by the addition of the pitch limiter. The spring system would consist of dual spring coils forcing the fin into a 0° angle relative to the arm when at rest, and attempting to keep the fin at that position. As the arm moves up and down, the added force of the water being pushed would push the fin off center and into a maximum of 15°, in either way. At the top or bottom of the stroke, where the force applied on the water is essentially nullified, the springs would theoretically reorient the fin to be collinear with the arm again, and thus adding roughly 10 centimeters to the next stroke.

4.4 Spring Loading:

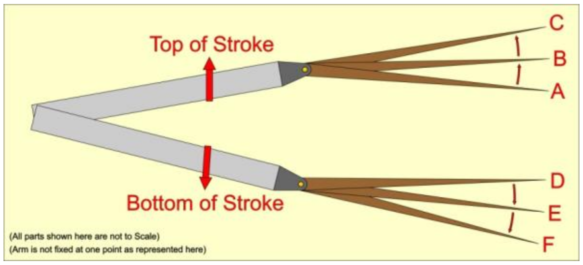

Figure 15: A representation of the effect of a spring system within the pitch limiter at the top or bottom of a stroke.

Normally as we have previously seen, in a realistic up stroke the fin reaches position A, at which point the arm begin its down stroke and the fin's efficiency drops greatly as it switches to the opposite angle. The addition of the pitch limiter's spring system, would more rapidly aid in the reorientation of the fin and aligning it to the arm as fast as possible in order to maximize the distance available for the down stroke to follow. By moving the fin from position A to position C, it is clear that a great amount of distance was added to the amplitude at the tip of the fin. This effect is mirrored at the bottom of the stroke, where the fin's original position of D is spring pushed back to the 0° angle (F).

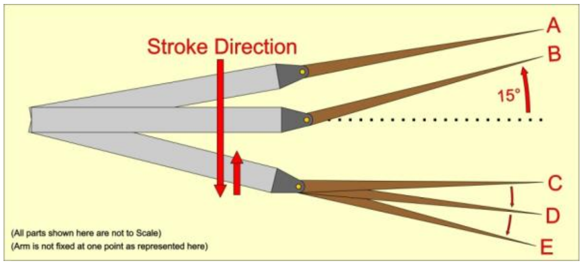

Figure 16: A representation of the downward stroke with a spring loaded pitch limiter.

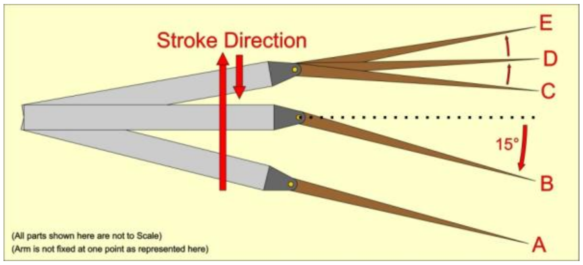

Figure 17: A representation of the upward stroke with a spring loaded pitch limiter.

As can be seen in Figure 16 and Figure 17, the upward and downward strokes are now adjusted to gain maximum amplitude at the controlled angles. In either stroke, you notice the beginning of the stroke at position A, collinear with the arm and adheres to our initial study of the optimized pitch limiter angles, and as the stroke pushes the fin it pushes to reach the maximum of 15 degrees roughly as it reaches the horizontal, thus providing maximum thrust at a point which was previously producing no thrust at all. As the stroke continues towards position C, some of the thrust being produced is lost, yet the springs take action when the arm reaches the end of its stroke and stops exerting a force on the fin, allowing it to re-orient to position E in preparation for the next stroke. This system seems to be extremely efficient, yet as previously mentioned, this device design has not been implemented at the time of submission of this report, yet it off course will be further studied prior to the race.

5.0 NAVIGATION:

In order to navigate the submarine underwater, the team decided to implement a system similar to the system used by the “Sea bomb”, yet we imposed drastic changes. The controller will consist of two independent joysticks; one for each hand of the pilot. Also the cable system previously used is complex and un-modernized, the team has agreed on developing a simpler system that uses push-pull cables; this would reduce number of cables required down to two; from a previous 4. The joystick decision came down to a simple feat of simplicity and comfort for the pilot. By having one joystick to control all degrees of motion, the pilot would need more fine tuned motions to control the overall direction of the submarine; by having two joysticks, each hand is now capable of performing independent adjustments to the yaw and pitch of the submarine. Furthermore constructing two joystick apparatuses is far simpler, and less prone to malfunctions, than constructing a single 2-axis joystick. After multiple tests it was decided that a joystick length of 90 mm would be sufficient for any pilot to use and would be un-invasive to overall comfort. The rather difficult tests involved determining the angle of rotation of the pilot’s wrist in regards to yaw and pitch control; with the added difficulty of the pilot being compacted and having minimal space to move his arms. Yet after many tests a motion of +/-20° was found to be sufficient for any user to control the rudders. Knowing the angle of the wrist’s of the pilot was not enough, the next task was to determine the effect this motion was intended to provide. After analyzing the “Sea bomb” navigational system for the rudders found at the tail of the submarine, the team concluded that a push-pull cable would require a motion of approximately 40 mm to achieve the desired angles on the rudders.

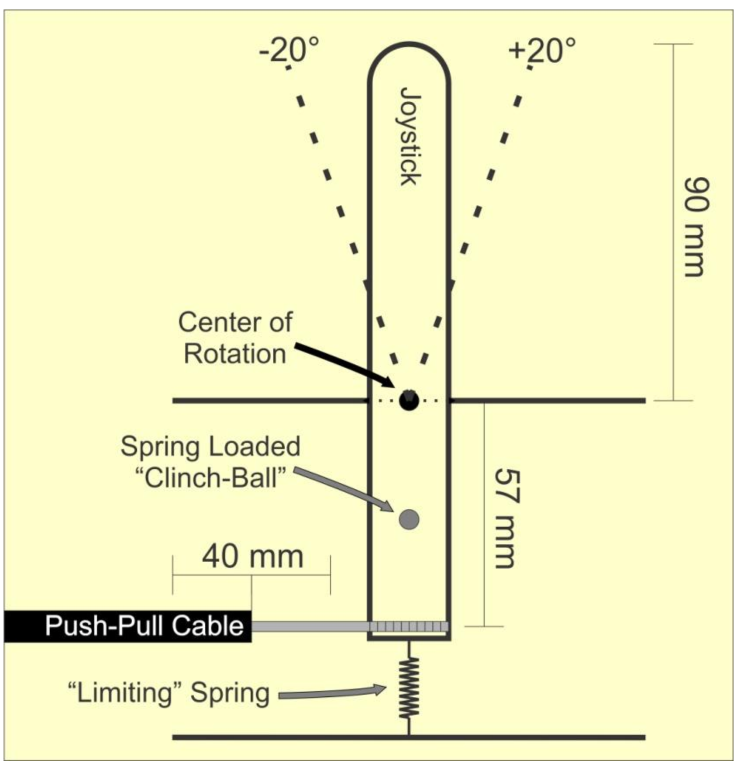

Figure 18: A representation of the mechanics of the joystick.

Knowing all the required data, it is possible to calculate how far from the center of rotation of the joystick does the push pull cable need to be attached in order to output a 40 mm control distance.

$$Circumference_{40\ mm} = \frac{40°}{360°} 2\pi r$$
$$r = (\frac{\pi}{180\ mm})^{-1} \approx 57.14\ mm$$

The distance to the push-pull cable is now known and further analysis of the joystick can be made. It turns out that if you apply a force at the top of the joystick in a certain direction it only requires 0.63 times that force to move the push pull cable in the opposite direction; due to the flip of directions at the center of rotation. By looking at Figure 18, it can be said that a force to the right on the top of the joystick would produce a motion to the left at the bottom of the joystick; and the push-pull cable.

The rudders have a theoretical limit of 18°, and any increase in angle above that limit would cause undesired effects as well as a loss of control over the heading of the submarine. For this reason a “Limiting” spring was added to the bottom of the controller. The string properties still need to be calculated, yet the effect is simple, as the joystick approaches to the 20° limit, the spring should reach its maximum stretching point with normal human force, and thus stop the pilot from over angling. This would keep the pilot in check, as well as keep the rudder fins within the tolerable region. An added advantage, and necessary portion of the navigational control system, is to be able to return the rudders to their zero positions in order to navigate straight ahead when necessary; the spring forces the joystick back to the vertical zero position. This action is further aided by a spring loaded “clinch-ball” that holds the joystick at the zero position and requires extra force to move the joystick out of that position. The overall design of the navigational controller has not been realized as of this report, yet it will require some testing and fine tuning for the finalized race-ready model.

6.0 THE HULL:

In the previous “Sea bomb” model, the pilot was lying on his back and manipulating the mechanism at the nose of the submarine with his feet. In our new model, the pilot will be lying on his stomach and manipulating the mechanism with his feet at the rear end of the submarine. The drastic change in pilot orientation opened the way for major hull renovations. Since the pilot’s head would be at the front end of the submarine, the team has decided to create a plexi-glass nose dome for the submarine and place that at the front section of the submarine; this would require cutting the previous nose of the “Sea bomb”. Having this change also disturbs the buoyancy of the overall hull and the team will therefore be required to re-level the hull for the new design. The see-through nose cone, will serve to provide a large viewing angle of the water ahead and allow the pilot to judge depth and other in-water orientation aspects required to maneuver the submarine. As previously mentioned, in the drive mechanism section, the hull’s height may be increased to allow more room for the pilot’s knees in order to create optimum thrust. This height increase will not be too large, perhaps no more than 10 centimeters, yet it proposed many questions as far as how to implement such a change. The solution was simple, and fit well into other safety solutions the team had been discussing. The old “Sea bomb” hull consisted of two parts, the top half and the bottom half, which were closed using specific lock mechanisms; this was not an efficient underwater assembly technique. For the new redesigned model, the two halves of the hull will be permanently attached to one another forming a single part; this change would allow the team to simply add a strip of a fiberglass composite with the desired width in between the two hull halves, prior to gluing, and have the desired new height of the hull. Furthermore, the transparent nose would now act as the entry and exit point of the submarine, allowing for a more hydrodynamic design for the nose as well as an easier and more reliable exit point for emergencies.

7.0 SAFETY:

The only subject left to discuss, the most important aspect of any device, is safety. Every aspect previously discussed was designed with extra care and attention to provide optimum safety for the pilot.

- Obstacles: Beginning with the drive mechanism, having it moved to the back of the hull, would ensure that it is out of the way of the pilot as well as the rescue divers. The hull redesigns, are at the core of the safety features.
- Dimensions: The hull dimensions are 3 meters long with a diameter of 70 cm at its widest. The fins are 160 cm long and will extrude roughly 80 cm off the center line in both directions, horizontally.
- Coloring: The submarine’s top side is colored yellow and the bottom side is blue; seeing as the bottom is of no consequence, the inherited yellow top side from the “Sea bomb” is excellent for spotting the submarine from above the water surface.
- Egress: Having the pilot head first and the nose as the point of egress, in the unlikely and unfortunate event of an emergency, the pilot can easily unlatch the nose and push with his or her feet, which are already at an angle at the knees, to propel his or her body out of the submarine; in other words, it does not get easier or faster than that.
- Cylinder & Comfort: Also, in regards to the pilot, the oxygen tank will be attached to the bottom portion of the hull, providing the pilot with over 40 centimeters of space for his torso to fit comfortably and be able to move comfortably if need be with no obstruction but the top of the hull.
- Markings & Strobe Light: In regard to the safety standards required by the ISR committee, all latches and other essential parts will be properly marked for rescue divers, as well as the underwater emergency strobe light shinning in the 360 degree horizontal plane.
- Pop-Up Buoy: The final safety feature, and the most essential for locating the submarine in distress, is the emergency buoy. The design of the new buoy is very similar to that of the design used by the “Sea bomb”. The design will have a bicycle brake handle attached to one of the navigation joysticks and will act as a dead-man switch. The buoy itself will be cylindrical in shape with a 3/8” orange line wrapped around it. At the bottom of the buoy will be a groove with a lever arm inside of it positioned in a way such that when the lever unlatches the buoy is released and floats to the surface with an upward force of 500g. The wire from the handle (dead-man switch) will enter the device and connect to the lever arm holding the buoy in place; a spring will also be attached to the lever in a way such that when the spring expands the lever unhooks. The wire to the handle will act to keep the spring compressed, until the handle is released and the spring expands, unhooks the lever, and deploys the buoy.

8.0 CONCLUSION:

In conclusion, the team would like to thank ISR for giving us the opportunity to compete and are confident that our submarine design will prove to be an interesting and hopefully successful variation to its predecessor. The careful design steps of the new drive mechanism and biomimetic fins set this human powered underwater submarine at a league of its own in regards to design and inspiration, we can only hope that as the models become a reality, the testing will prove to be equally as rewarding.

9.0 APPENDIX:

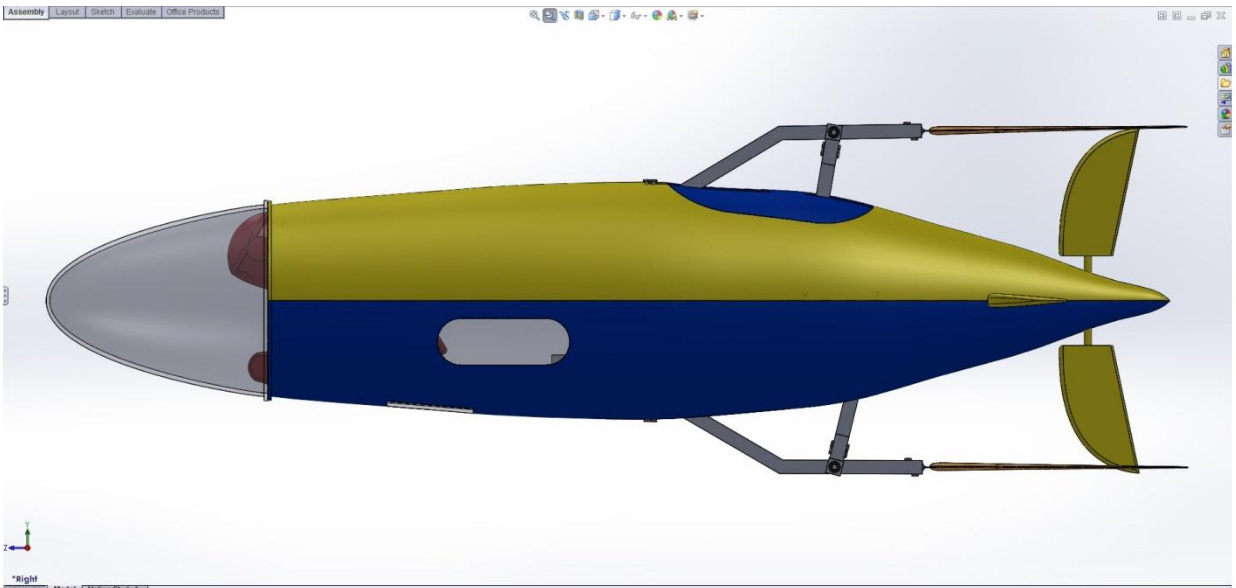

Figure 19: A side view of the entire model.

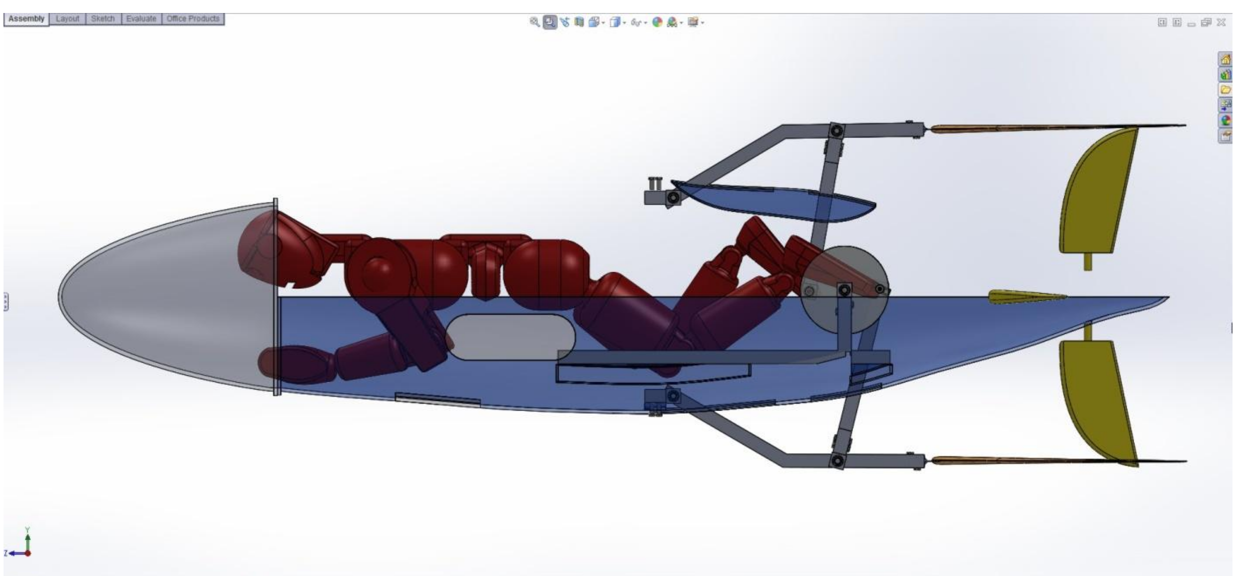

Figure 20: A see-through and cut out side view of the entire model.

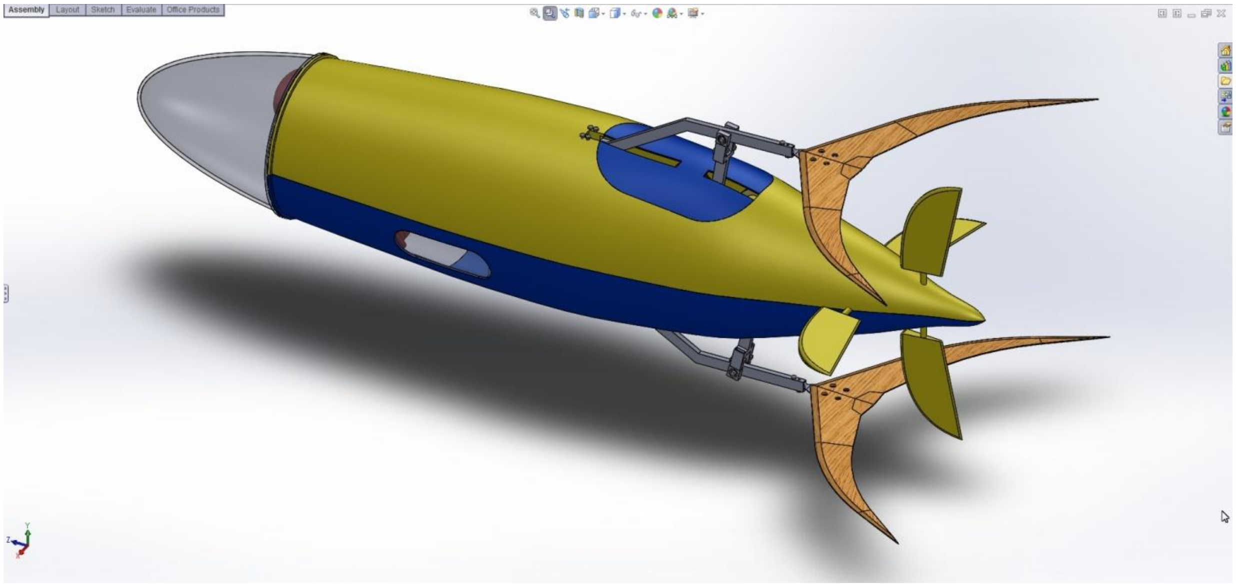

Figure 21: A 3D view of the entire.

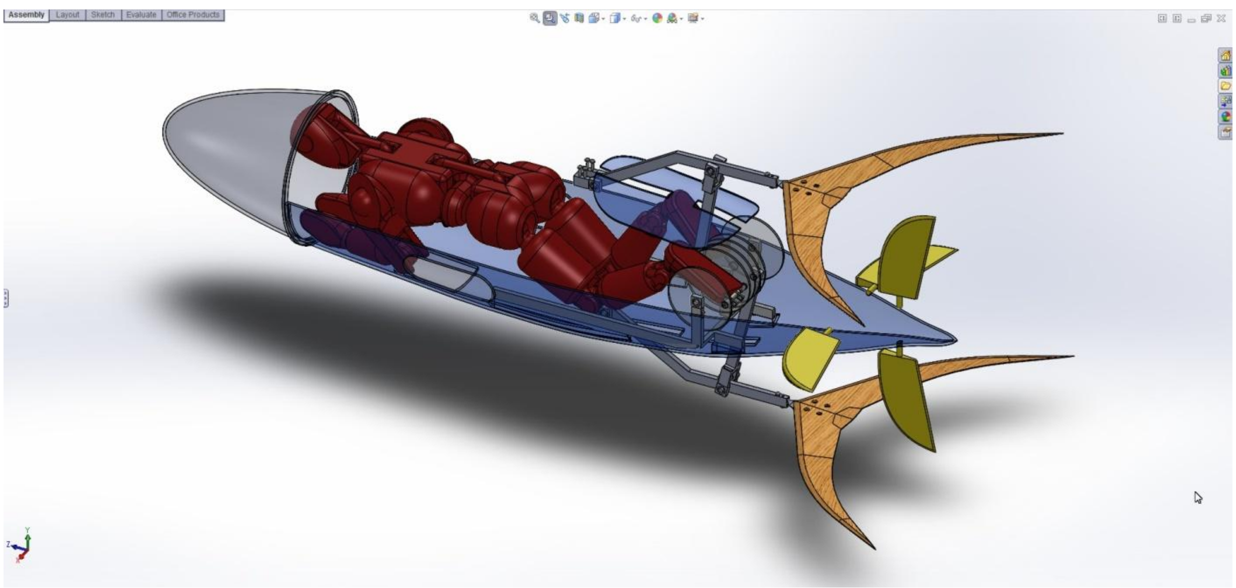

Figure 22: A see-through and cut out 3D view of the entire model.

Thank you.