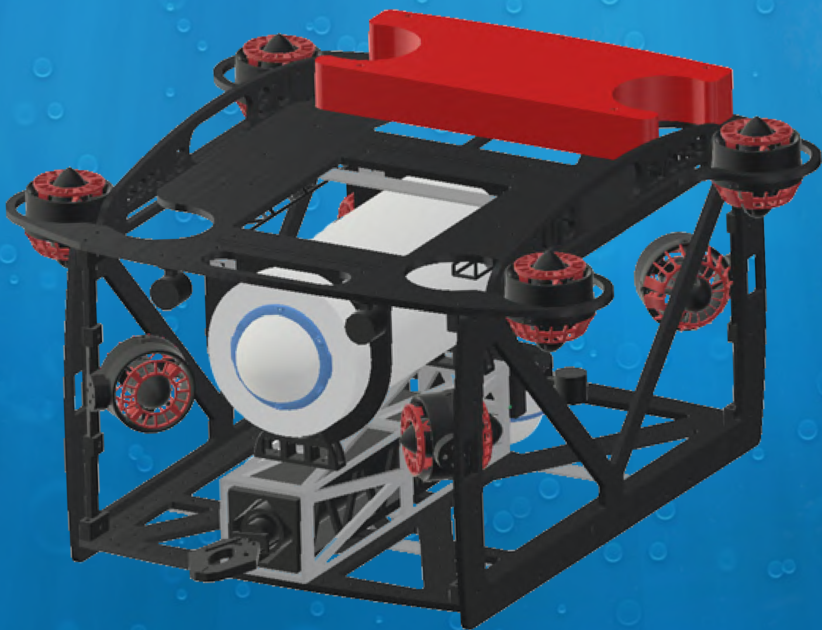
FENRIS



MATE ROV COMPETITION 2022

Technical Documentation

University of Stavanger

Stavanger, Norway

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Abstract

UiS Subsea is an organization based in Norway with development of subsea vessels as its main focus. The organization was founded in 2013 under University of Stavanger, and has a main purpose to motivate students into the subsea field, by creating an innovative and independently working environment. By working closely to the subsea industry located in and around Stavanger, the students are being well prepared to face real world challenges they may face when finishing their studies.

The organisation has participated in the MATE ROV Competition on four previous occasions, first in 2015 and most recently in 2019. During these years, the organization has engaged students writing their bachelor thesis, and challenged them to build an ROV in this time period. Using the knowledge and experiences acquired over the years of studying, this years team has developed a new ROV with the main intent of creating a vessel which is both modular and environmentally friendly. The vessel is modular with further development in mind, to increase engagement from students in earlier part of their bachelor programs, and students from other fields of study.

To realize the goals of a modular and environmentally friendly ROV, the vessel is designed with the possibility of interchangable PCB's in the electrical housing. The ROV has a large frame designed with a focus on environmental impact, where multiple new attachments can be implemented. As an example, the manipulator arm is easy to detach and replace with another tool of choice. To support this, the ROV features excess use of connectors, allowing for expansion of external components. The solutions for the overall ROV is described more in depth in this document.

This years team includes 21 students and two former bachelor students. They are divided into ten teams, where the two former bachelor students serves as mentors of the team. The other 21 students make up nine different teams, working on separate tasks to achieve the common goal of designing an ROV and a float for the MATE ROV Competition. The members of UiS Subsea are shown in figure 1.

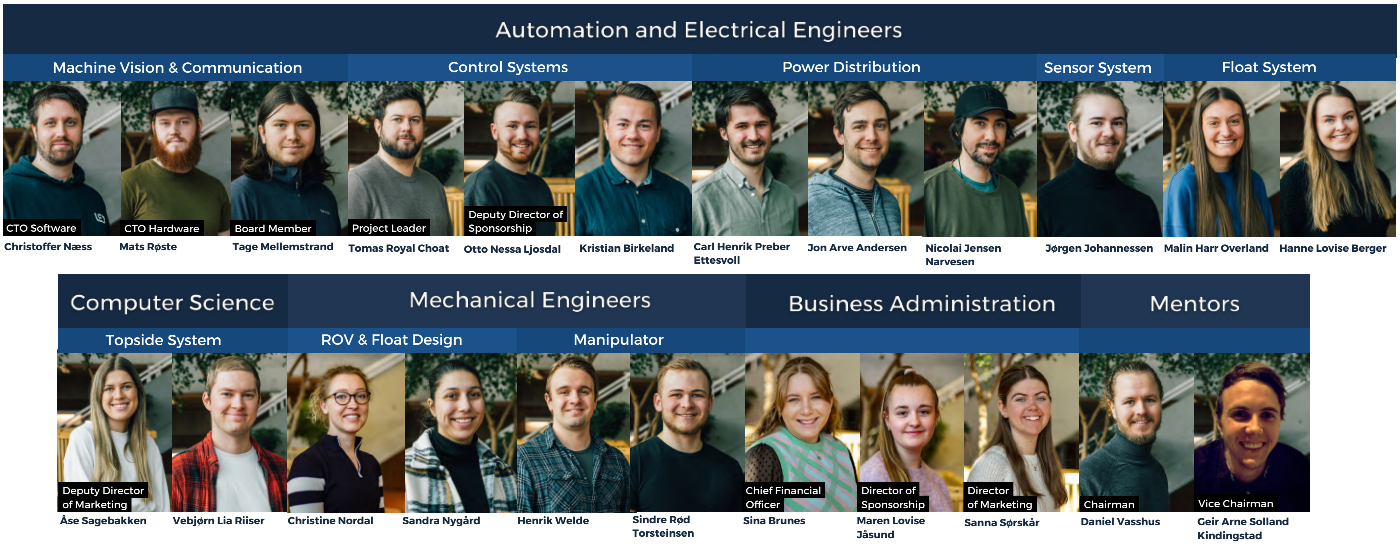

Figure 1: The UiS Subsea team.

Contents

Mechanical design

In this chapter, the mechanical design of our ROV, Fenris, shown in figure 2, is presented.

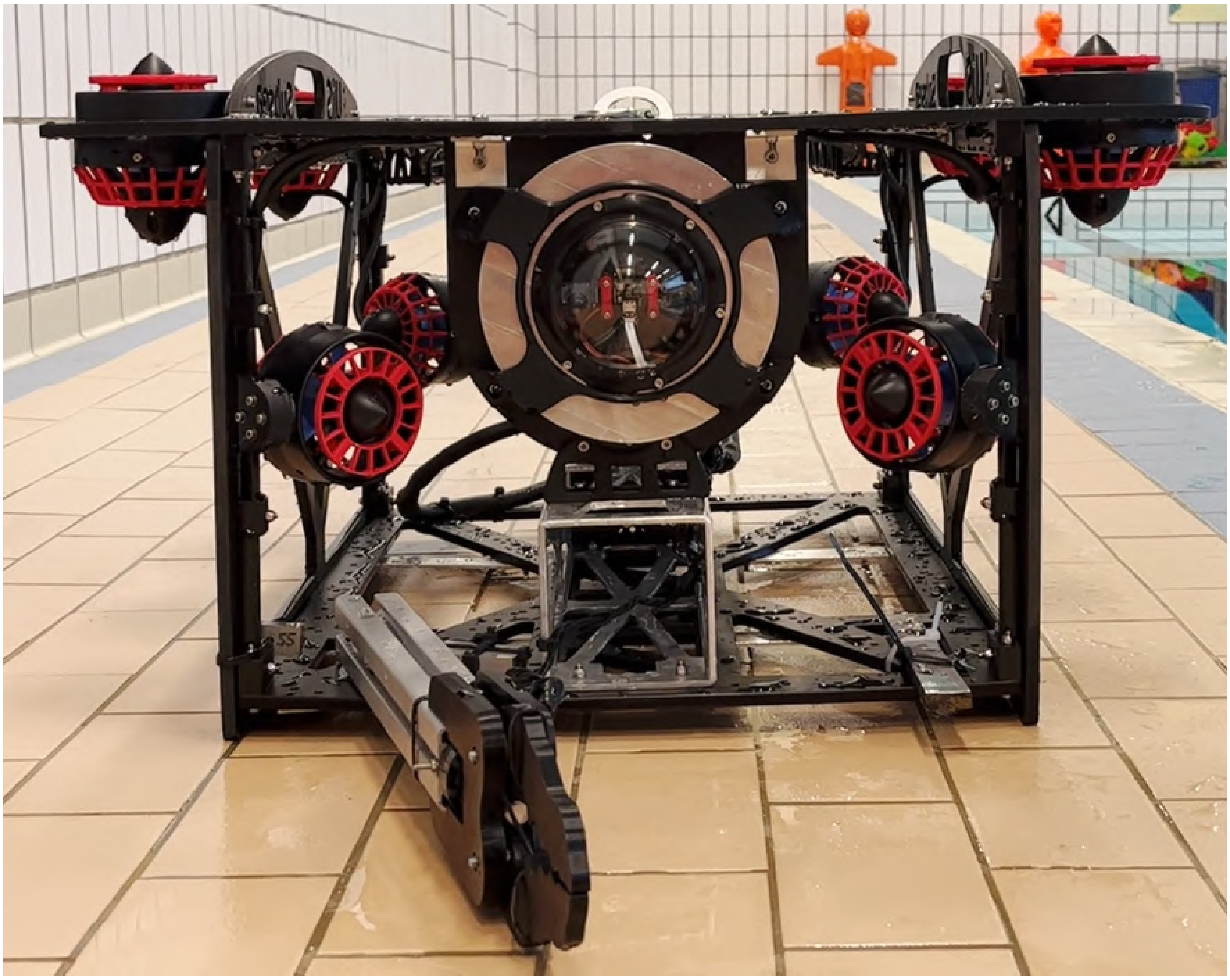

Figure 2: Fenris shown from the front with the spare manipulator arm mounted.

Because of complications during productions of the main manipulator, the backup manipulator was used during testing. The main manipulator is shown in the CAD model on the front page.

Frame

In the development process, the frame was designed with focus on the **D**esign **F**or **E**nvironment (DFE) concept. The goal was to minimize the environmental impact in the product's life cycle. There was also a focus on the functionality of the ROV, especially including:

- Easy assembly and disassembly
- Minimal maintenance needed
- Low weight
- Natural water stability
- Free water flow through the frame and the thrusters
- Low interference between thrusters

During the material selection, there was a significant focus on the environmental impact and recyclability. It was considered important to find local suppliers for the materials and production to limit the environmental footprint due to transportation. The frame had to be as light as possible while simultaneously having the strength to endure all the equipment. PEHD was chosen for the frame since it is an easily recyclable thermoplastic. In addition, it has good mechanical properties, such as low water absorption, good impact strength, ductility, low density, and corrosion resistance.

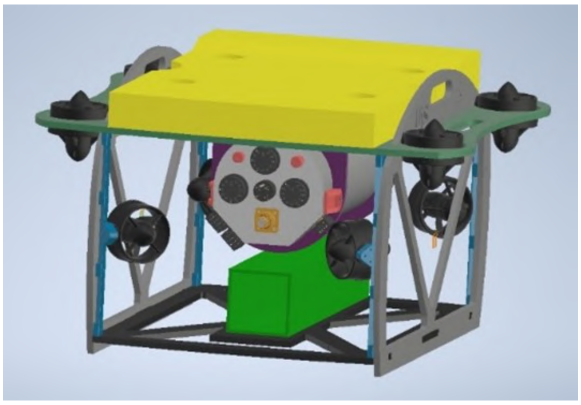

Figure 3: CAD model of the frame.

The frame is designed for the top plate to slide onto the side plates to ease the assembly. The design is open and simple, and extra components can be attached easily after the product is finished. This makes it possible for the frame to be reused in the future as a base with alterations. The open design also minimizes the drag, and reduces the overall weight and the quantity of material being used. Rounded edges were formed on the plates both for reducing drag, and for increasing safety while handling the material. The side plates have a v-structure in the middle to strengthen and stiffen the plates. This is important due to the weight of the electronics housing and the manipulator, which could have created instability in the frame if not strengthened. Holes for the four vertical thrusters were created in the top plate to protect them against impacts. The electronics housing is placed underneath the top plate for easy assembly and disassembly, and to obtain a lower center of gravity. Retainers under the top plate, shown in figure 3 (purple), are designed to keep the electronics housing in place. In addition, two brackets, shown in figure 3 (pink), are being used to fasten the housing. The brackets for the electronic housing are fastened to the top plate using aluminum angles. A metal bracket is attached to the ROV frame to prevent the tether connectors from being pulled off the electronic housing, and the tether is secured to the frame by a carabiner hook. The length, width, and height of the ROV are 674x698x408 mm, and the thickness of the plates is 8 mm.

Herman Miller's DFE assessment tool evaluated the ROV and checked whether it was a cradle-to-cradle product. The DFE assessment tool used the material chemistry, amount of recycled content, disassembly, and recyclability to assess how successful the DFE concept had been. A product being truly cradle-to-cradle would have had a score of 100 % when rated. The assessment of the ROV is illustrated in figure 4, with the scores for the assessment factors, their factored weights, and weighted scores. The recycled content only had a factored weight of 10 % since there was little focus on this factor compared to the other factors during the production process. The reason for this was the limit on time and resources. The three other factors were weighted equally since they had been given an equal amount of focus and time. The weighted scores were calculated by multiplying the frame score by the factor weight of that score. When adding up all the weighted scores, the ROV frame attained a rating of 88.22 %. This was relatively high, and the product was satisfying in terms of DFE and when it comes to being a cradle-to-cradle product. The frame is satisfying with regards to disassembly, material chemistry, and recyclability.

DFE Assement Factor	Frame Score [%]	Factor Weight [%]	Weighted Score [%]
Material Chemistry	94.47	30	28.34
Resycled content	15.36	10	1.54
Disassembly	100.00	30	30.00
Recyclability	94.47	30	28.34
Overall Score		100	88.22

Figure 4: DFE assesment of the ROV frame.

Thrusters

Because of their simplicity and ease of implementation, the T200 thrusters from Blue Robotics were selected for the ROV. These can easily be controlled by the motor controller basic ESC from Blue Robotics, and is powered at 12 VDC. At 12 VDC the maximum power provided by each thuster is approximately 36 N. This gives powerful and simple to use thrusters that only needs to be fitted with proper thruster guards to comply with the competition manual (MECH-006). For the back side of the thruster, we found a 3D-model of a thruster guard that was a perfect fit for the thrusters. The thruster guard on the front side is modelled in Autodesk Fusion 360. Both guards are 3D-printed in ABS plastic, and figure 5 shows the front side of a thruster fitted with a thruster guard.

Figure 5: Front side of T200 thruster with thrust guards.

To make an easily controllable ROV, eight thrusters are utilized. Four of these are mounted horizontally with an angle of 45° relative to the frame. These are used to control the horizontal movement of the ROV. The horizontal thrusters are mounted close to the electrical housing in order to minimize tilting under translational motion. In addition, there has been made an effort to place the thrusters such that the center of mass is located in the center of the thruster configuration. This will minimize rotation while moving, and keep the ROV in place while yawing. The other four thrusters are mounted vertically in each corner of the ROV, and are used to control the stability and depth of the ROV. These thrusters are placed with as much spacing between them as possible to obtain an effective stability control. The thruster configuration is shown in figure 6.

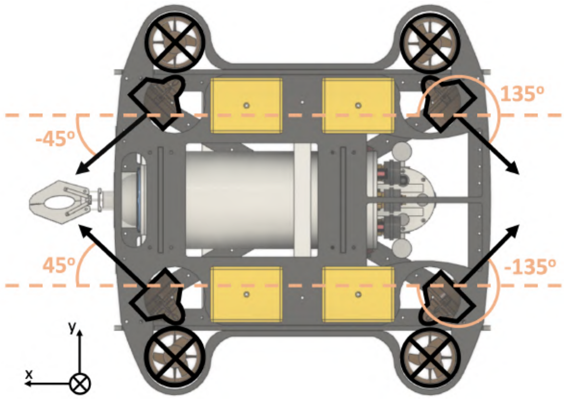

Figure 6: Thruster configuration.

Electronics housing

The electronics housing is designed to contain the relevant electronics needed for the ROV to function while also keeping it relatively easy to manufacture. The housing consists of four main parts, the front piece, the main body, the rear piece and the back plate, all of them shown in figure 7. A back plate is mounted on the rear piece to make assembly of the electronics easier. A tubular design in aluminium is used to keep the weight down while also providing enough structural integrity to withstand pressure down to an operating depth of 50 meters. With the connectors disregarded, the housing is 473.6 mm long with an outer diameter of 175 mm.

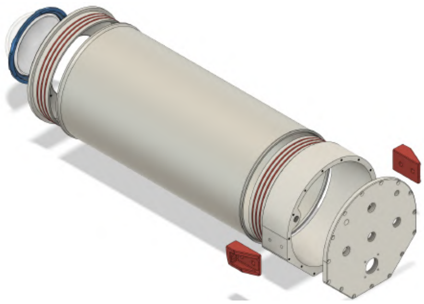

Figure 7: Exploded view of the electronics housing.

The front part has a clear acrylic dome mounted to it to provide a window for the front facing camera. Some of the connectors used on the ROV are 90° low profile connectors. Because of the way the tether is mounted and interfaced, the 90 degree connectors has to be mounted on the outside of the housing, parallel with the main body. To make sure the electronics housing still keeps the water out, the rear piece has five flat sides, where three of them are being used to mount the 90 degree connectors. The front and the rear piece is attached to the main piece using o-rings. Mounting of the electronics housing is done with two brackets mounted on each side of the rear piece. Aluminium is used because it excels at multiple different areas simultaneously, those being thermal conductivity, corrosion resistance, weight reduction and machinability.

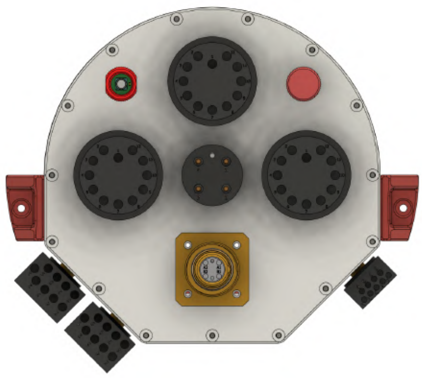

Figure 8: All connectors that are used one the ROV. Mounting brackets are also shown.

Buoyancy

For optimal stability and maneuverability of the ROV, it was desired to keep the ROV close to neutral buoyancy. The frame was stable in the roll direction due to the focus on symmetric components and symmetric placement of components, shown in figure 9. As expected, due to the volume and buoyancy of the electronics housing, the righting moment caused some tilt in the pitch direction, causing the front to tip upwards. The righting moment was corrected for by ensuring that the COB and COG[1] were on the same vertical axis. This was done by adding ballast in front on the bottom plate and buoyancy elements in the back on the top plate. Lead is often used as ballast due to its high density, but was discarded since it is toxic and may affect the entire ecosystem. The ballast needed to be corrosion-resistant, durable, and have high density. Stainless steel was therefore chosen as ballast. Waste material was found in the boxes for recycling at the workshop at the university, and ballast of different sizes were produced.

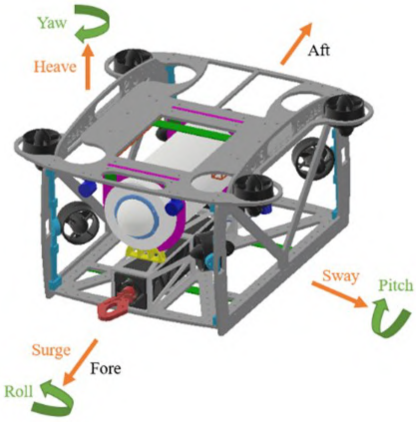

Figure 9: The six degrees of freedom for an ROV.

Manipulator arm

The designed manipulator arm for the ROV includes two degrees of freedom, being rotation and extrusion. Along with this, it also includes a pitch mechanism. To realise the extrusion, a lead screw is rotated, moving the manipulator arm in and out. The movement is restricted by attaching the arm in an aluminium cage. To support the arm, supportwalls with bearings, shown in figure 10, is used on each side of the arm in the aluminum cage.

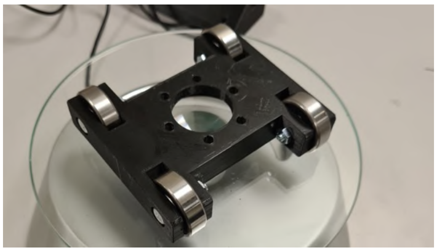

Figure 10: Supportwall for the manipulator arm.

To rotate the gripper on the manipulator arm, a worm wheel is mounted to the outer part of the arm, shown to the left in figure 11. This is rotated by driving the worm gear, mounted on top of the worm wheel, as shown to the right in figure 11. Both parts are comprised into a box, protecting the mechanical parts from outside debris.

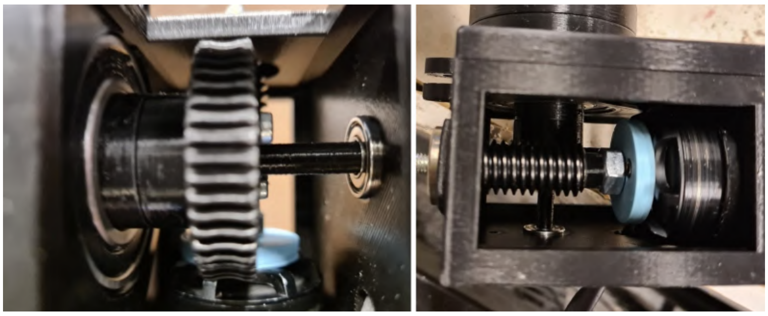

Figure 11: Worm wheel (left) and worm gear (right) to rotate the gripper.

[1]**C**enter **O**f **B**uoyancy and **C**enter **O**f **G**ravity

The pinching mechanism is realized using the principle of bicycle breaks. By using a Bowden cable actuated by a motor. The front piece, shown in figure 12, is compressed, mechanically closing the gripper. The front piece is spring loaded, opening the claw when the force from the Bowden cable is decreased.

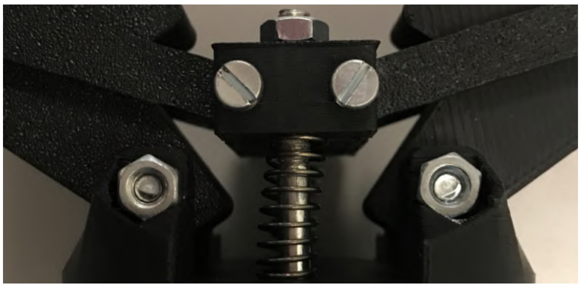

Figure 12: Front piece on the gripper.

Along with the above described manipulator arm, a spare manipulator arm has been designed. This arm includes pitching, which is realized using a worm gear actuated by a motor, shown in figure 13. The worm gear further actuates two worm wheels on each piece of the gripper. The gripper is mechanically one directional, meaning that it cannot open itself, ensuring pinching with low power consumption, since the motors don't have to run to keep the pitching.

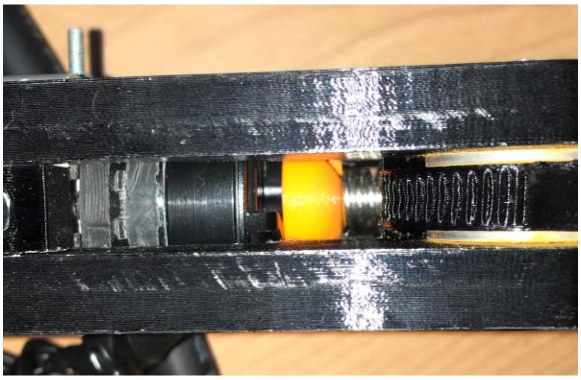

Figure 13: Worm gear, motor and worm wheel on the gripper.

To actuate the manipulator arms, the BLDC motor *Eaglepower 3508 390KV*, shown in figure 14, is used for each degree of freedom. This is a motor that is actually intended to drive the propellers for flying drones, but has worked well for the manipulator arm on the ROV as well. The greatest advantage of the motor is that it is light, with a stated weight by the supplier of 88 grams.

Figure 14: Eaglepower 3508 390KV.

To meet the requirements of the competition manual (ELEC-018E), the motors' stators are sealed with thermal epoxy. The electrical resistance was measured afterwards with an insulation tester as the procedure, *MATE Technical Bulletin - Sealing Brushless Motors*, suggested. The resistance was measured to be greater than 200 MΩ. The results after the sealing process is shown in figure 15.

Figure 15: Waterproof Eaglepower 3508 390KV.

Electrical system

The overall electrical system for the ROV is shown in figure 16. Each part of the system is explained in detail in the subsections that follows.

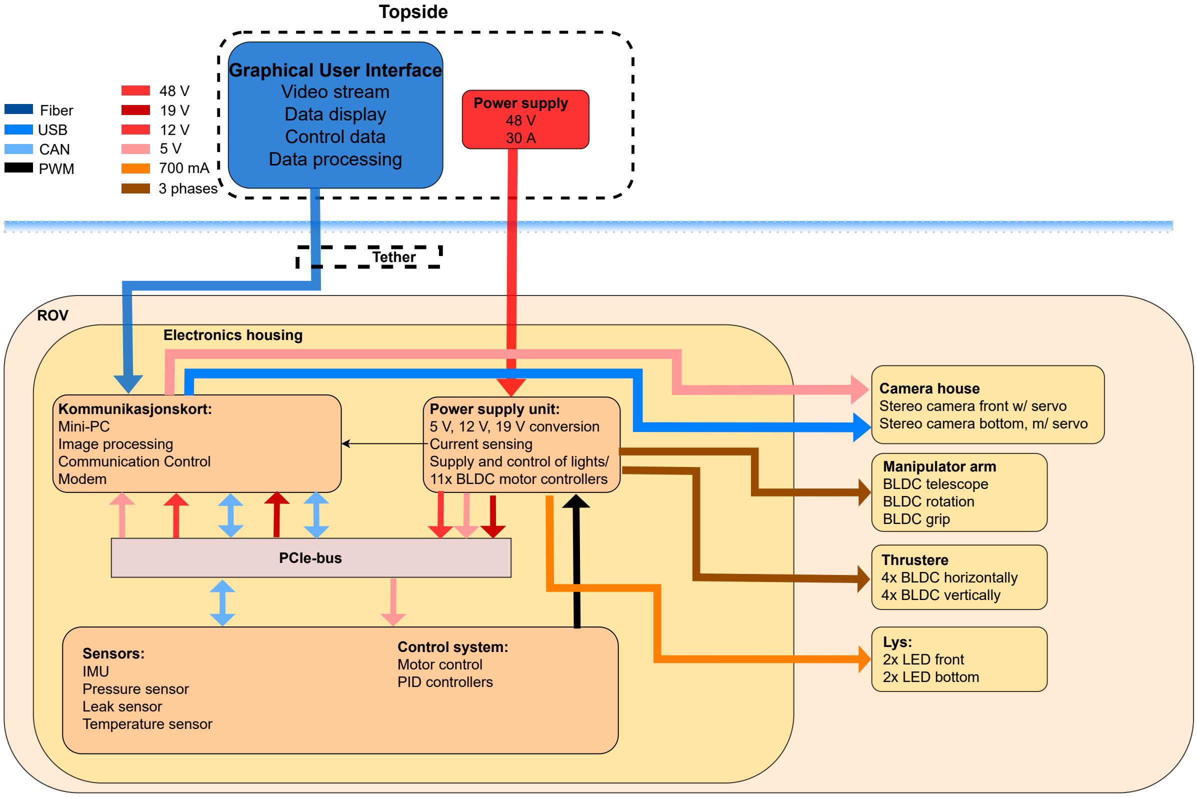

Figure 16: Simplified block diagram of the ROV.

Tether

To supply the ROV, a tether previously designed by the organisation is used, illustrated in figure 17. It consists of two main parts, being the cables supplying power to the ROV, and cables allowing for communication between the ROV and topside. To supply the ROV with power, stranded 12 AWG cables are used, reducing power loss, along with a flexible cable with minimal effect on the mobility of the ROV. To allow for communication between the ROV and topside, a fiber cable is used, so that the designed ROV is made in such a way that the design can be utilized in a greater scale, where the distances are longer. A pair of single mode 9/125 µm fibers are used for the communication between topside and the ROV. They are connected to 1310 nm SFP gigabit transceivers in both ends to convert the fiber into

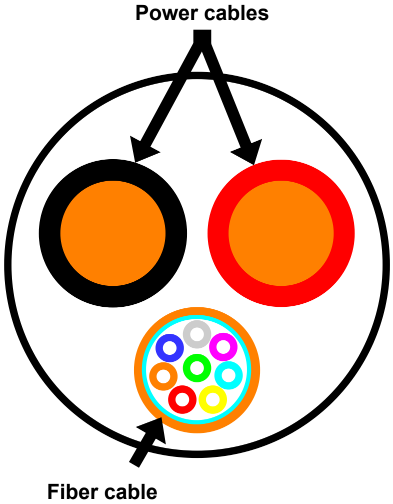

Figure 17: Illustration of the tether used.

ethernet. The tether is filled with cellular plastic to make it neutrally buoyant. The cellular plastic used is low moisture absorbing, flexible and robust, making the overall tether durable.

Connectors

All power supply and communications go through connectors, shown in figure 18. These connectors are delivered by *MacArtney Underwater Technlogies* and is rated to depths of up to 8000 meters. The connectors are connected to the thrusters, the motors in the manipulator arm and an external camera. The connectors are also used to connect the tether to the electrical housing, supplying power to the ROV, and communication over fiber. An ethernet connector is also included, as a backup solution to the fiber connector. There is also used a penetrator from Blue Robotics to mount a pressure sensor, which is potted with hard epoxy in the penetrator. To release pressure, the backplate includes a manually adjustable valve.

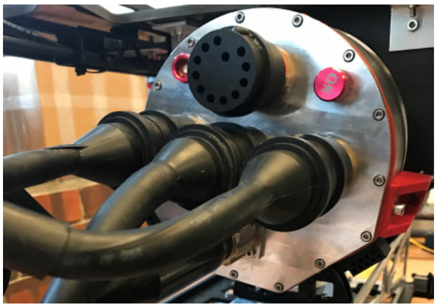

Figure 18: Connectors used to supply power to and data from external electronics.

Cameras

Two sets of stereo cameras are mounted on the ROV, one set facing forward, and one set facing downwards. The housing containing the downward facing cameras are shown in figure 19, while the other camera is mounted inside the electrical housing. Using synced and calibrated stereo cameras makes it possible to calculate distances to objects, which in turn enables the possibility to calculate objects' widths and heights. Both cameras are mounted on a pivot with a servomotor, and can therefore be tilted $\pm$ 30° from the GUI to give the pilot access to a larger field of vision. The cameras are connected to a mini-PC mounted inside the electronics housing using USB.

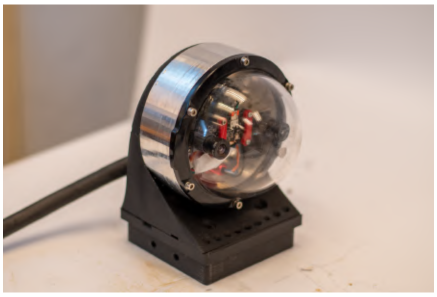

Figure 19: External camera house with stereo camera. Camera type: ELP960p. Maximum resolution: 2560x960. Camera sensor: OV9750.

Lighting

On the outside of the ROV, two pairs of external light sources are used. The light sources used are *MKRAWT-H2* LEDs mounted on aluminum PCBs, shown in figure 20. They make a strong light source, able to light up objects at a distance of 1 m from the ROV, with no external non-ROV lighting. This makes the ROV compatible for usage in other situations which does not include external non-ROV light sources, such as operations in sea water. The lighting from the LEDs are controlled

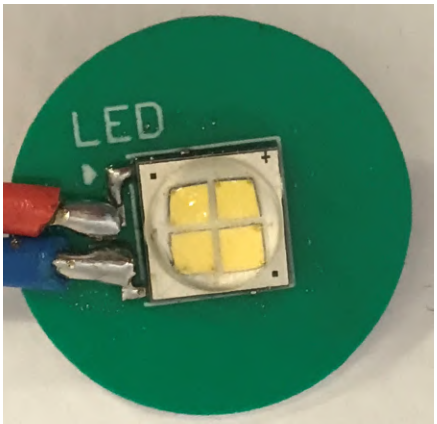

Figure 20: LEDs making the external light sources on the ROV.

using a LED driver, so that optimal lighting of objects can be achieved at different distances. The driver is current-controlled, mitigating instances of thermal runaway.

Onboard Electronics

Onboard the ROV, there are three subsystems consisting of a sensor and control system, a power supply system and a communication and vision system. Each system are comprised onto separate PCBs, reducing electrical interference from the power system to the more delicate sensor and communication systems.

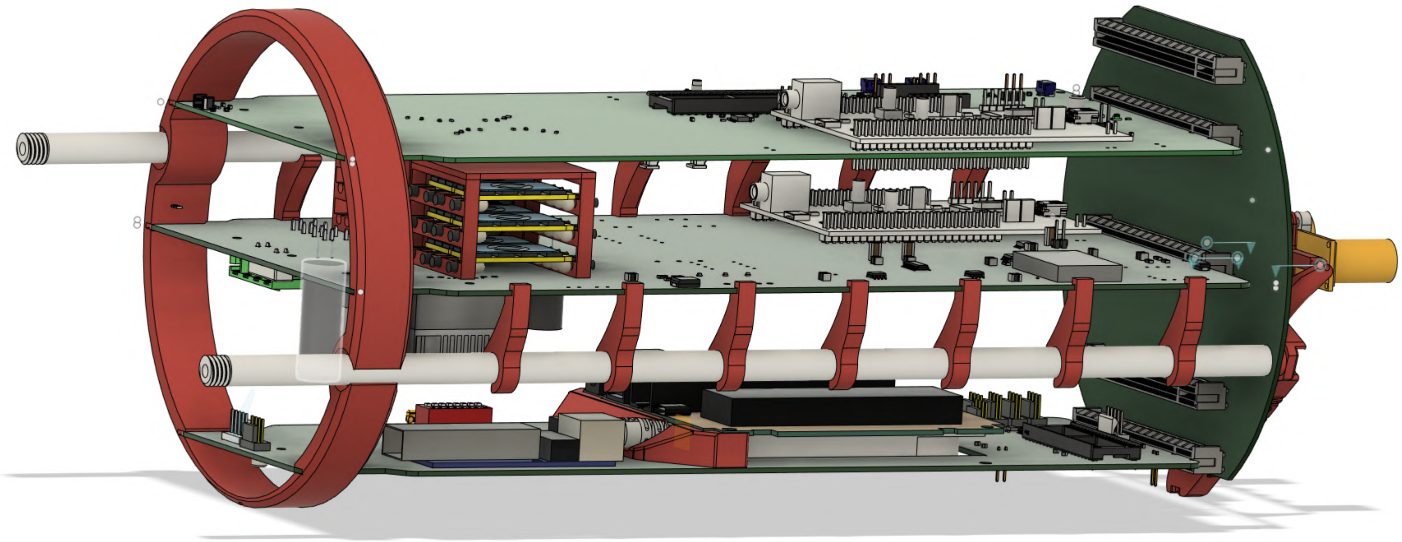

Figure 21: Onboard electronics in the electrical housing.

To mount the different PCBs, a separate circuit board is used, shown on the right hand side of figure 21. Each PCB is fitted with a PCIe connector, which creates a multibus interface between the circuit boards. The PCIe is used to both supply the onboard electronics with power, and forms the communication-bus between the different PCBs. This means that circuit board can easily be swapped and only require to have the same setup on the PCIe contact, making the system on the ROV scalable.

Power supply unit

The power supply unit is designed in-house using off-the-shelf DC/DC-converters to convert the mainline 48 V into the voltages needed on the ROV. The structure of the unit is illustrated in figure 22.

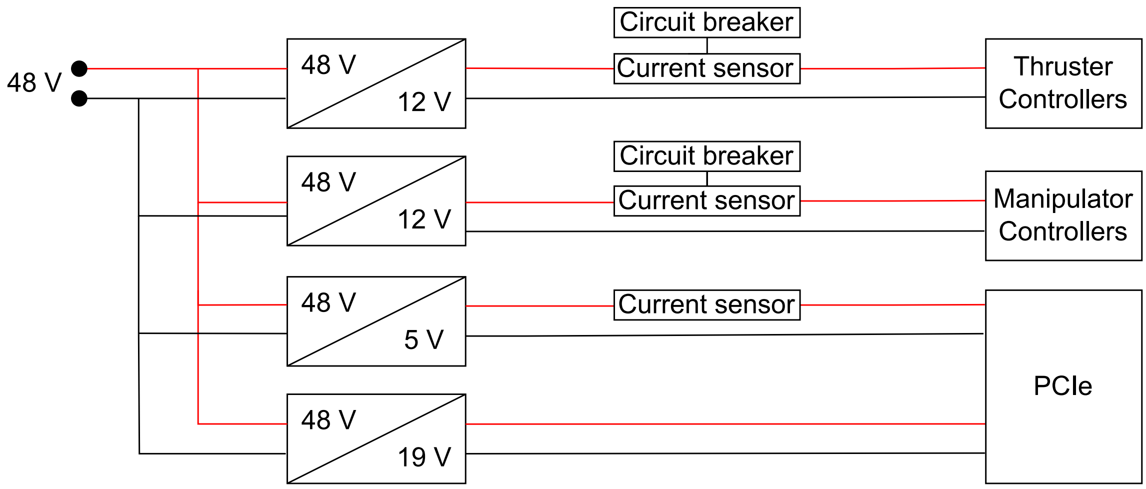

Figure 22: Block diagram of the power supply unit.

Power for the thrusters and motors in the manipulator arm is supplied using two separate quarter brick 48/12 V DC/DC converters. These converters are chosen due to their high power density and nominal efficiency rating of 97.1 % for the converter supplying the thrusters, and 93 % for the converter to motors in the manipulator arm. This allows for conversion with minimal power loss and occupied space. Alongside this, due to to the standardised size of the converters, high quality heatsinks are used, allowing for great heat conduction. With the heatsinks, attachment for fans to each converter have been designed and 3D printed, further increasing the heat conduction of each converter.

The other converters are used to step down 48 V to 19 V and 5 V, to supply the mini-PC on the ROV, as well as the microcontrollers for the separate subsystems. These are converters with low voltage ripple, to reduce the risk of overvoltage for the most critical electronics in the ROV.

Alongside the converters, the power supply unit includes three current sensors for the circuits with the most variable current draw. This allows for visual inspection of the power consumption on the ROV, whom the data is used to improve the overall system and reduce the sources of error when troubleshooting.

At the same time, two of the current sensors are part of fast analog triggered circuit breakers designed in-house. The circuit breakers also have a digitally controlled reset signal, which is controlled from the topside. This is done to avoid instances where the ROV has be to retrieved from water because a physical circuit break has been triggered, mitigating suspension of operations due to overcurrent. The complete power supply unit with motor controllers mounted on the board is shown in figure 23.

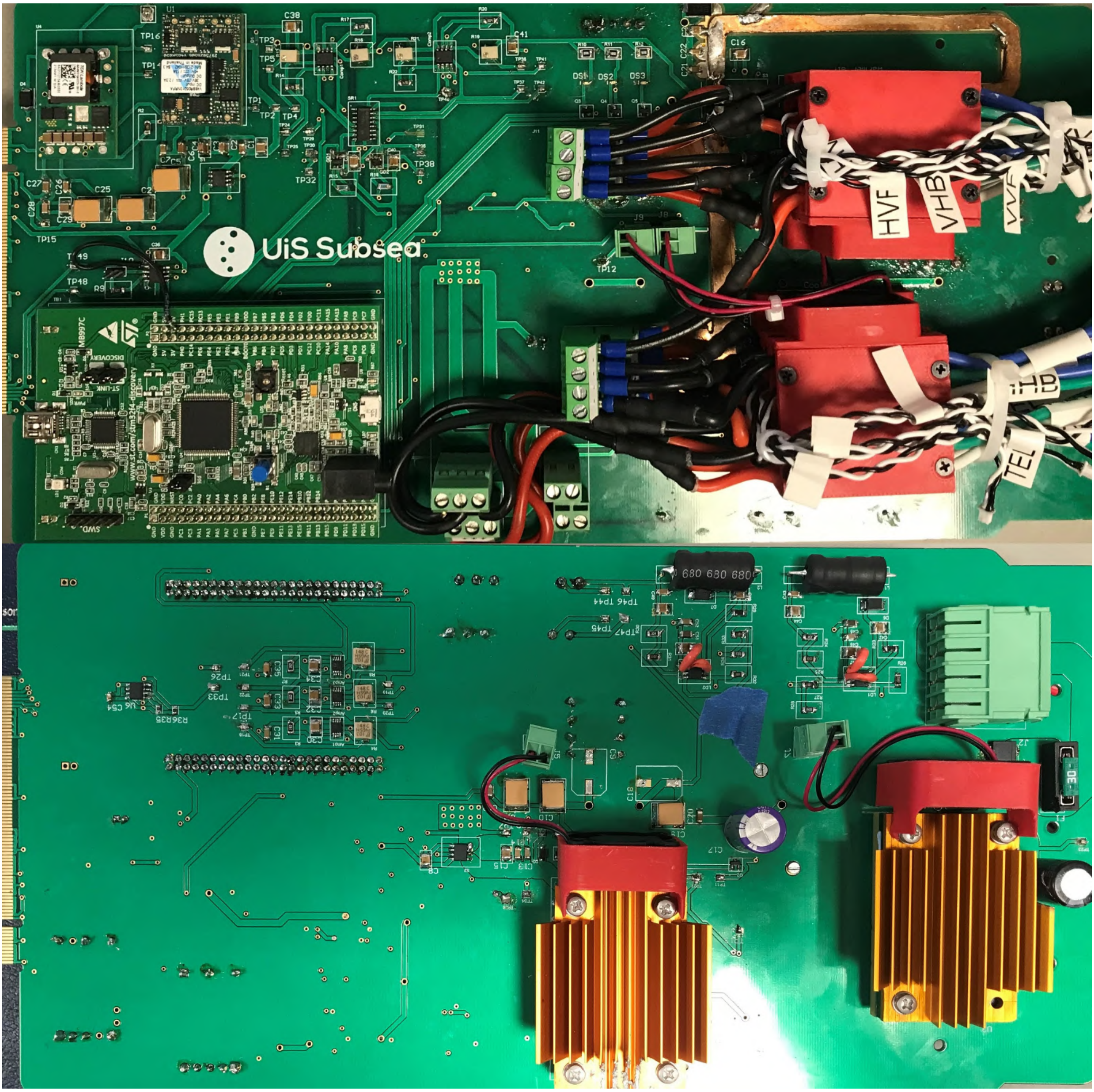

Figure 23: Power supply unit PCB.

Communication unit

The communication unit consists of an Asus PN51 mini-PC stripped from its housing, with the bare PCB mounted on a carrier PCB for connection to the PCIe connector and an STM32F415 microcontroller. Figure 24 shows this carrier board. The microcontroller is connected to the PC with USB and is used to translate the signals coming from topside into CAN bus packages to be distributed over the CAN bus to the other units inside the ROV.

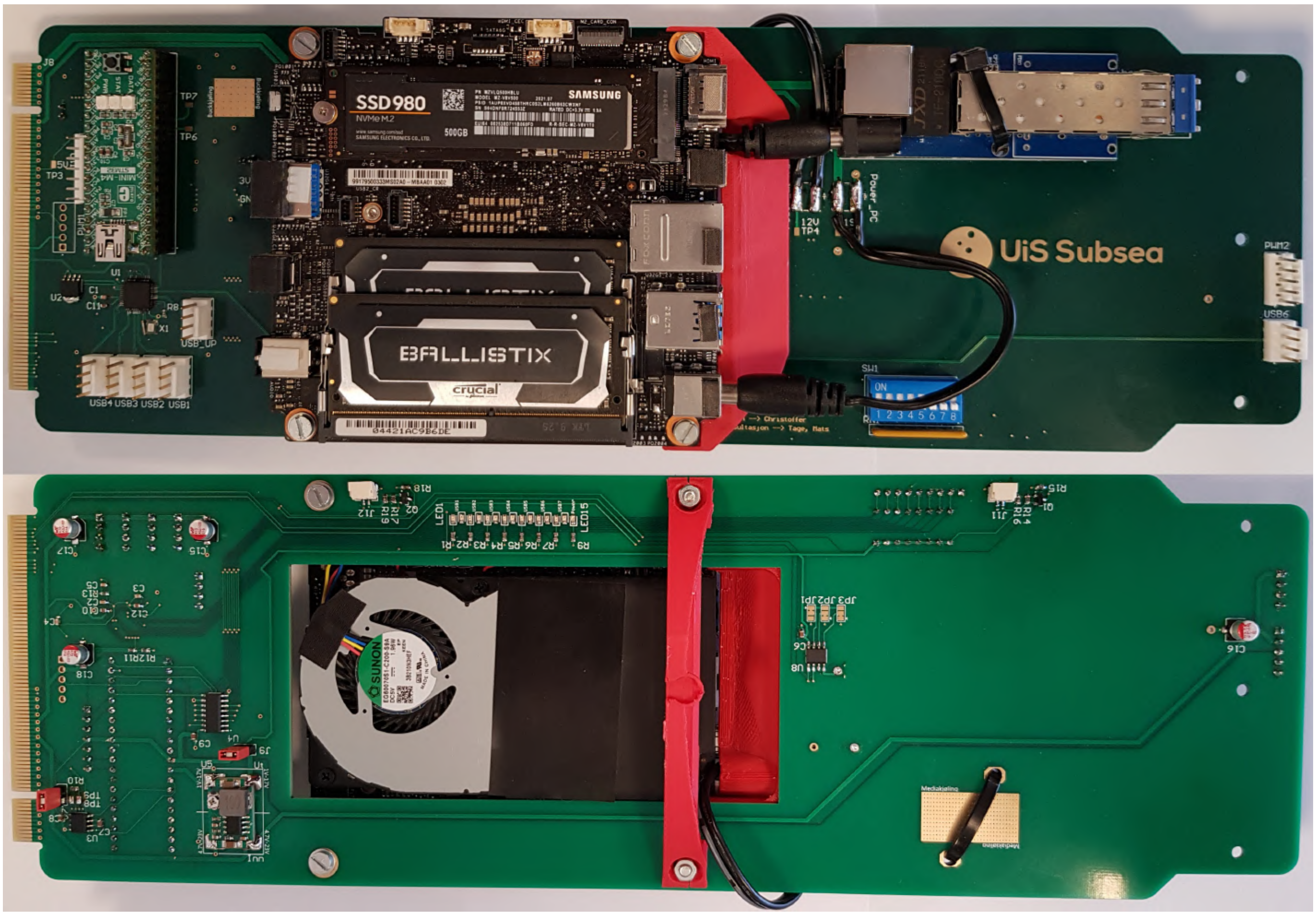

Figure 24: Communication unit PCB.

To connect the PC to the topside a media converter is mounted on the carrier PCB (blue PCB with metal cage on the right side) to house the fiber transceiver. The media converter then connects to the PC with a short network cable, and the fiber plugs into the transceiver. The topside PC can then communicate with the onboard PC over this fiber link.

To simplify the USB connections (3, one for each camera module and one for the microcontroller), a USB hub has been designed into the carrier PCB so that only one USB cable needs to be plugged into the PC itself.

Sensors

The sensor system of the ROV is able to measure depth, roll and pitch angle, temperature and moisture. The sensor system is built in-house with simplicity in mind, where only the most necessary measurements are implemented. With these measurements, orientation of the ROV is easily controlled with PID controllers, and safe operation under water is assured. The sensor system shares space together with the control system, and is located on the top PCB mounted in the electronics housing as shown in figure 21. The complete PCB is shown in figure 25.

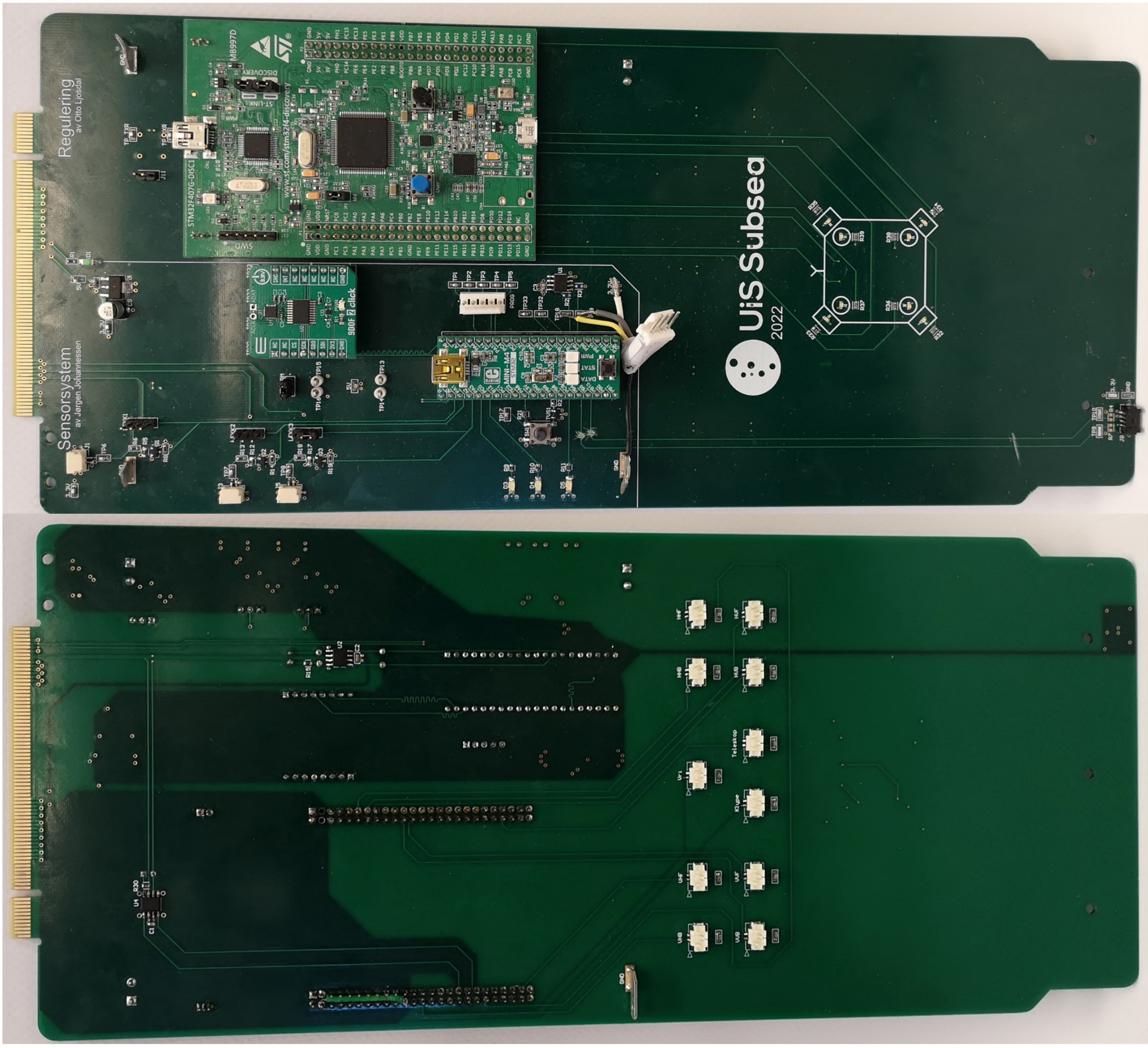

Figure 25: Sensor and control system.

The sensor system is built around the *MikroElektronika MIKROE-1367*, which is a development board using the *STM32F415RG* microcontroller. The *STM32F415* provides quick data processing with an FPU module and CPU capable of operating at a maximum frequency up to 168 MHz, and is able to communicate with the rest of the ROV using its onboard CAN module. The sensor system sends processed data from the four sensor measurements at a frequency of 20 Hz, which are connected to the microcontroller by using the SPI and I2C protocols, as well as direct inputs using the GPIO module. The sensor system consists exclusively of sensors requiring 3.3 VDC supply voltage. Therefore, an onboard voltage regulator is required, converting the supplied 5 VDC to 3.3 VDC.

Moisture detection is implemented on three different locations in the electronic housing within the ROV, and covers the front of the housing where the front stereo camera is located, the back of the housing where the connectors are located, and the middle bottom of the housing where the communication unit is located. This provides an overview of where the leakage occurs if the ROV were to leak. The moisture detection system is based on the *Blue Robotics SOS Leak Sensor*, but modified in a way that provides several connection points across the electronics housing.

The sensor system uses three temperature sensors to measure temperatures across the three PCBs inside the ROV, which ensures a good estimate of the ambient temperature inside of the electronics housing by calculating the average temperature across the three sensors. The temperature sensor used is the *STMicroelectronics STTS75*, which provides a measurement range of -55°C to 125°C, and an accuracy of ±0.5°C.

Depth measurement is fulfilled by measuring the pressure around the ROV when submerged in water. By first measuring the pressure at surface level when the ROV first gets submerged, depth can be calculated by subtracting the surface water pressure from the current pressure of the water around the ROV when it dives deeper. The sensor system uses the *TE Connectivity MS5803-05ba* pressure sensor for depth measurement, which has a maximum range of 5 *bar* and an accuracy of ±80 *mbar* when submerged in water with a temperature of 20°C.

Roll and pitch angles are calculated using a combination of a gyroscope and an accelerometer implemented on an IMU unit. By combining the precision of the gyroscope and the accuracy of the accelerometer using a complementary filter, measurement of roll and pitch angles are reliable and forms the basis of excellent PID controlling. The IMU unit being used is the *TDK InvenSense ICM-20948*, which includes a gyroscope with a measurement range of ±250 *dps* and a sensitivity of 131 LSB/dps, and an accelerometer with a measurement range of ±2 g and a sensitivity of 16.384 LSB/g.

Control system

The ROV has two main control systems, one is completely manual and the other is automatic. These control systems are implemented on a STM32F4Discovery development board[2] which is mounted on the topmost PCB shown in figure 21. This board also houses the sensor system and has connectors on the underside to allow the motor controllers' PWM-signals to be connected to the development board. The PCB allows the development board to connect to the remaining system via a CAN bus transceiver connected to the PCIe connector.

The manual control system lets the pilot control the motion of the ROV by using an Xbox controller. The microcontroller on the development board receives a value from -100 to 100, in both the x-axis and the y-axis, from the Xbox controller. The x-axis runs along the length of the ROV and the y-axis along the width. These values are used to calculate the throttle needed on each of the thrusters to move the ROV in the direction given by the values. The pilot is also able to manually control the yaw and heave of the ROV. The horizontal thrusters are exclusively controlled manually by the pilot, but the vertical ones are also controlled automatically. The control system also allows the pilot to control the manipulator. The system only allows one of the motors on the manipulator arm to be moved at once to not overload the voltage converter.

Three PID controllers are implemented on the control unit in order to realise the stability control of the ROV. The purpose of the stability control system is to ease the pilots task of manual operation by automatically counteract rolling, pitching and depth drifting. Therefore, the three PID controllers are controlling one degree of freedom each: rolling, pitching and heaving. The PIDs are realised through a feedback loop from the sensor system, which contains an IMU for reading the roll and pitch angles, and a pressure sensor for reading the depth. The controller parameters were found through mathematical modelling of the system in the first place, and after the first water test, they were fine-tuned in order to obtain a more optimal stability control. One of the main advantages of the stability control, is to prevent the ROV from pitching while holding heavy objects with the manipulator arm.

As previously stated, the pilot has the ability to control the depth of the ROV manually. This is done by pausing the PID controller responsible for the heave control. When the pilot stops adjusting the depth of the ROV, the PID controller automatically resumes operation with the new depth being set as the new reference point.

The use of 8 thrusters with 12 VDC creates a need to limit the amount of power used, such that the ROV never exceeds the maximum allowed current of 30 A (ELEC-008E). This is done in the microcontroller by giving the PID controllers limited amount of power and also by limiting some of the movement controlled manually.

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[2]With an STM32F407 microcontroller.

Topside System

The topside system consists of a laptop, an Xbox One controller and two portable screens as can be seen in figure 26. Due to the compact design of the control station, the whole system, excluding the power supply, can be carried inside a backpack. Communication between topside and the ROV goes through the fiber cable. After the control station is set up, only power and fiber communication to the ROV needs to be connected.

Figure 26: Topside system setup.

The program is easily installable on any Windows computer and the Xbox controller has a sufficient amount of buttons in order to feel natural and not overwhelming, when controlling the ROV.

The topside program is comprised of 4 parts. The graphical user interface, the program that collects information from the controller, the network handler and the main program which integrates the other parts together. The topside program is made in Python with the Qt framework.

The GUI is made to best visualize information to the operator. It features:

- Two camera streams with a short delay
- Buttons to tilt the camera streams
- Buttons to turn of the converters for thrusters and motors in the manipulator arm
- Information in the form of depth, power consumption, temperature and thruster actuation
- 3D model to see the ROV's orientation in the water

One of the screens shown in figure 26 is a touch screen which means that the GUI can be used without having to use the trackpad nor the mouse.

The controls for the ROV can be seen in figure 27.

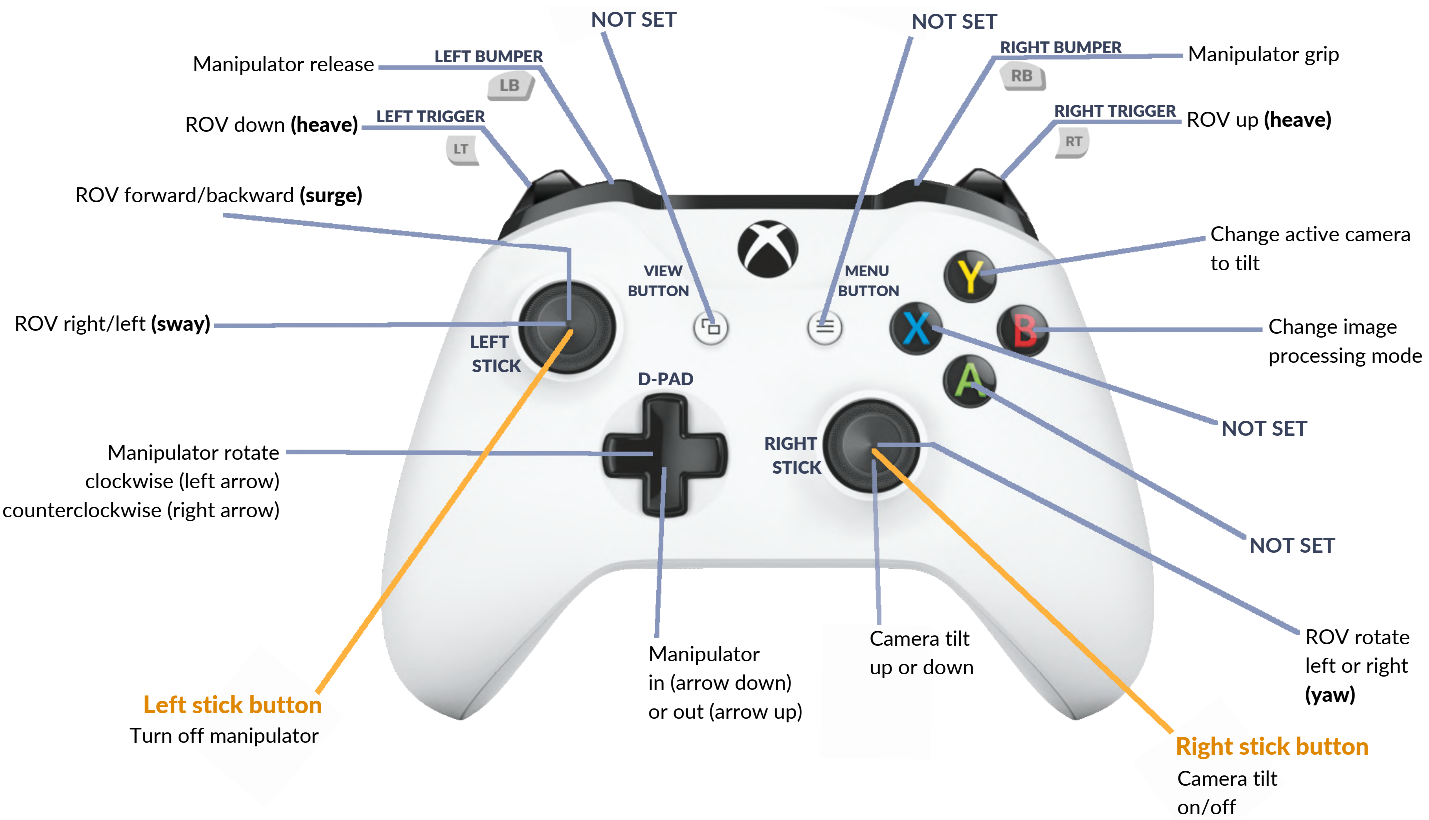


Figure 27: Controller functions.

Image processing

There are several tasks which need image processing in some form. All image processing is done with OpenCV in Python on the Asus mini PC, which is a part of the communication unit.

Automatic photomosaic

Pictures are taken using the GUI. The pictures are stitched together and processed on the ROV. The result of a test of this stiching algorithm is shown in figure 28.

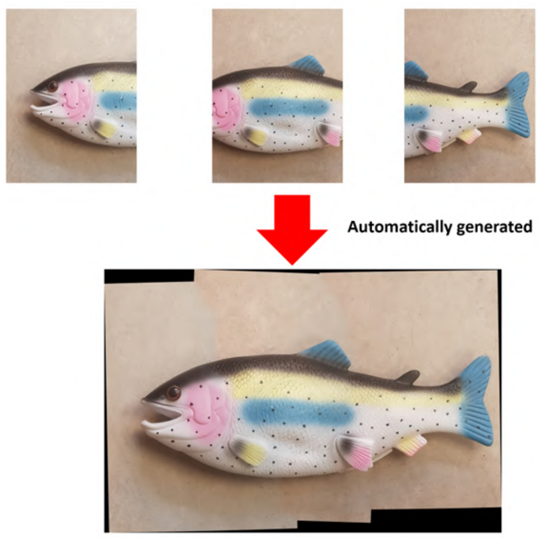


Figure 28: Automatic photomosaic generation.

Distinguishing between living and dead fish

The program, used to distinguish between living and dead fish, is using a model made with YOLO[3]. The model has been trained on pictures of both dead and alive fish.

Some screenshots of a test of the training is shown in figure 29a and figure 29b. The video used to verify the trained model is not used in the training itself, this is done to verify that the training will work on videos and pictures outside the training sets.

(a) Program found fish, labeled and marked them. **(b)** Program found dead fish, labeled and marked them.

Figure 29: Training results

HUD

A **H**ead **U**p **D**isplay that displays depth, pitch and roll is shown in figure 30, and is used to give the pilot immediate feedback to make controlling the ROV easier without visual overview. This HUD is drawn on top of the camera feed for the front camera.

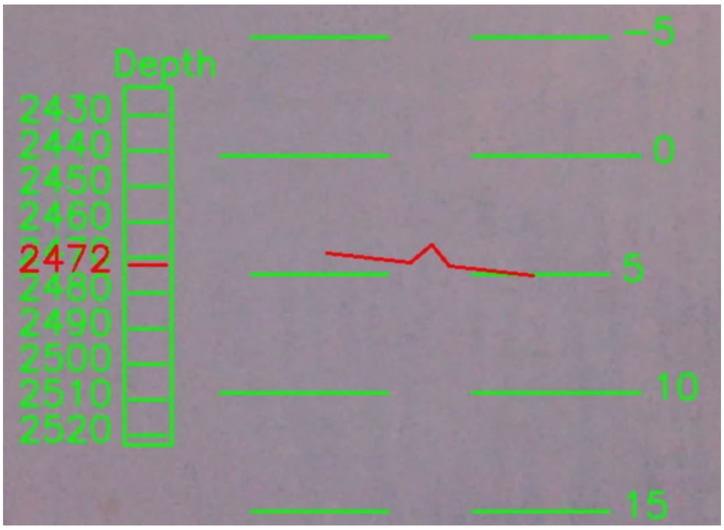


Figure 30: The HUD for the operator of the ROV.

[3] YOLO: **Y**ou **O**nly **L**ook **O**nce, an efficient machine learning algorithm used to detect objects.

Safety

During the development process of the ROV and the float, there are several instances of danger that must always be taken into account, and kept in mind by all participants of the project. For the organization UiS Subsea, it is crucial that no damage is caused to, first and foremost, our own members and other people, but also not to equipment and facilities. In particular, a lot of potential hazards may arise during the production in the electrical lab and in the mechanical workshop, and during the testing phase by the pool. All the facilities that has been made use of by the members of UiS Subsea are provided by the University of Stavanger, and the university has established strict guidelines on conduct during work in certain areas. UiS Subsea demands compliance from all members that these guidelines are followed, and that everyone strives to reduce potential hazards as much as possible.

Electrical laboratory

The initial testing of the separate electrical units and the overall system was done in an electrical laboratory. Accompanying this, the University of Stavanger demands that all personnel using the laboratory has gone through a HSE course, before allowing them to operate on the lab. This makes sure that all work in the electrical lab is done in a safe manner, and that all members of the organisation knows the risks of operating in the laboratory, as well as means of mitigating the risks. Among the safety measures practiced, the use of a solder fume extractor, eye protection and ESD wrist bands, are some of the most important examples.

Mechanical workshop

To make sure every member of the organisation operates in a safe manner in the workshop at the campus, the University of Stavanger demands that all personnel using the workshop has to have an approved safety course issued by the operators of the workshop. Any work done with heavy machinery or dangerous tools has to be done under supervision of the operators of the workshop until they are satisfied that you are able to use the machinery by yourself. Safety measures in the workshop includes the use of standard work wear and eye protection, which is demanded, and provided, by the university.

Pool

Water testing of the ROV was done in a pool. Along with this, UiS Subsea demands that all members follows the safety routines during operations. This includes removing all equipment which is not vital for the operation, taking off shoes and verifying that connectors and strain relief has been attached correctly. This is done to prevent injures caused by stumbling, slipping and electrocution. In addition at least one of the personnel at the poolside has to have completed a Norwegian lifeguard course. There is also developed a JSA, which is submitted to MATE, in conjunction with this kind of work.

Project management

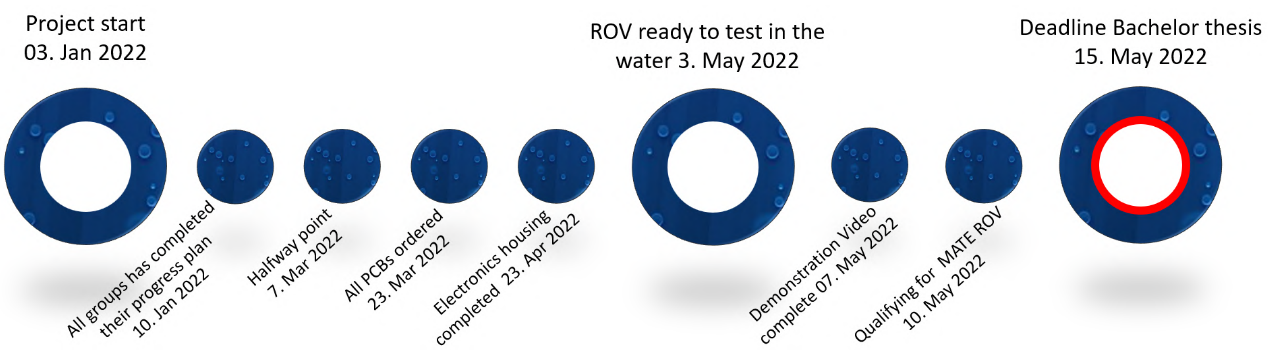
The management of UiS Subsea is divided into two different parts. One part consists of a team of eight students whom are responsible for the daily operation of the organization. This team is responsible for staying in contact with sponsors, attracting new sponsors, accounting, budgeting, expense reimbursement and managing social media accounts.

The other part of the management includes three students. These student are responsible for the project itself, where the roles are divided into project leader, CTO Software and CTO Hardware. By splitting the organisation in this way, the daily operation needed for running UiS Subsea are independent from the project. This makes sure that the progress of the project are not halted by daily operations.

The need for students from different fields of study in the project, has demanded cooperation beyond the usual amount for a standard study program. Each group are developing their own subsystem for the project, but the key for completing the vessels is managing to put all the subsystems together. To accomplish this, the project management have arranged meetings with representatives from all groups, every Monday since the project started. In addition, UiS Subsea are assigned an office at the University of Stavanger dedicated to the members of the organization. Throughout the entire project, every group, or at least members from every group, have been present at the office on a daily basis. This has proved to be a decisive factor in order to complete the vessels.

Since every member of the organization are writing their bachelor thesis based on the project, and the students were busy with other subjects last semester, the development process didn't start before the beginning of January 2022. The late start has proven to be a challenge throughout the whole project. Vital components of the ROV took a long time to complete, and the deadlines that was set before starting, were difficult to comply fully with. The most critical delay experienced was the latency of the water test of the vessels, which was initially planned to be the 15th of April, but ended up being the 3rd of May. Despite the time difficulties, the project was successfully completed, sending the qualification video before the deadline. Some components, such as the manipulator arm, was not completely finished at this point, but final adjustments are to be made before the competition.

The main milestones related to the project with the associated dates of completion are shown in the figure below.



Cost planning

UiS Subsea has a tradition of leaving about 100 000,- NOK for the next years project. This means that next years project already has the funding needed to start building a ROV before additional funding is needed. The biggest cost involved in the project is the cost of travelling and competing in the US.

Since the ROV is already funded and the University of Stavanger, which is our biggest contributor, yearly donates more than what is needed to build the next ROV, the remaining cost to cover is the travel expenses. Through different local companies, some of the travel expenses are covered, but every student who travels to the US will have to pay some of the cost themselves.

Therefore, any expenses exceeding the 100 000,- NOK in the original budget increases the amount every student will have to pay to travel, but do not put the company at any risk.

Since the team is divided into nine different teams, working on separate tasks in designing and building an ROV, every group has an initial budget to complete their part. If a group should need to use more money than allocated, they would need approval from the chief financial officer. In figure 31, the budget for each team and the amount used is shown.

Group:	Budget	Amount used	Remaining
ROV og float-design (mec)	kr 10 000,00	kr 8 562,51	kr 1 437,49
Manipulators (mec)	kr 7 000,00	kr 4 427,39	kr 2 572,61
Graphical User Interface (comp)	kr 5 000,00	kr -	kr 5 000,00
Sensors (el)	kr 7 000,00	kr 5 843,96	kr 1 156,04
Power supply unit (el)	kr 10 000,00	kr 11 394,09	kr -1 394,09
Control system (el)	kr 3 000,00	kr 1 213,07	kr 1 786,93
Image processing and communication (el)	kr 10 000,00	kr 11 398,47	kr -1 398,47
Float (el)	kr 8 000,00	kr 9 998,15	kr -1 998,15
General components for ROV	kr 25 000,00	kr 36 112,39	kr -11 112,39
Organization and social	kr 15 000,00	kr 11 255,11	kr 3 744,89
Sum (NOK)	kr 100 000,00	kr 100 205,14	kr -205,14
Sum (USD)	$ 10 417,00	$ 10 438,00	$ -21,00

Figure 31: Overview of costs. Currency in NOK. Sums given in NOK and USD. mec indicates Mechanial engineers, comp indicates Computer Science and el indicates Electrical engineers.

Just above the budgeted 100 000,- NOK were used on the project. Most of the groups used about as much money as the budget allowed them to. The general components budget was not as big as it needed to be, because of the cost of thrusters and connectors. Luckily, the remaining groups in average needed less than were allocated to them, and the total cost ended up being satisfying regarding the overall budget.

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