UiS Subsea

VONA

University Of Stavanger
Stavanger, Norway
MATE 2018

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I. Introduction

A.Abstract

UIS Subsea has through 2018 developed the ROV, Vona to perform a variety of tasks in this year's competition in Seattle. The project group consists of ten hard working bachelor students from the University in Stavanger, with diverse backgrounds. Our vision for Vona has been to build a small and versatile ROV which can perform the challenges in the competition fast.

UIS Subsea is a student organisation under the University in Stavanger which yearly develops a new ROV. The organisations goal is to give bachelor students an opportunity to acquire knowledge about underwater engineering projects and to use theory in practice. This years ROV-team consists of eight electrical engineering students and two mechanical engineering students. Vona is designed to be as small as possible to be fast and easy to navigate. The electrical housing is designed so that all the custom printed circuit boards, motor controllers and cameras have enough room to allow air circulation to prevent high temperatures. The frame is made of aluminium to be light and strong enough to carry the eight thrusters, electrical housing and the manipulator.

Figure 1: Picture of UIS Subsea´s team members

II. Safety

A. Safety Philosophy

At UiS Subsea, safety is top priority. This company follows a zero tolerance approach when it comes to safety risks. The company and the University of Stavanger have numerous guidelines to mitigate damage or serious illness to the people in the working environment. UiS Subsea utilizes working JSAs for both operating and producing. To accommodate our HSE protocols, we have our own designated HSE coordinator with many years of working experience as a safety representative. All our electrical – engineers (Bachelor students) who are working on and constructing Vona are certified electricians with many years of experience and attention to workmanship. Therefore since they were used to handling tools and filling out JSAs it became natural for them to oversee and advise work done by others.

B. Lab Safety Protocol

Everyone involved in manufacturing has undergone lab-safety courses during the fall semester. As a result the team can operate any machines necessary for their work in a safely and functionally manner. This corresponds with the company's and the University's zero tolerance approach to safety risks. Different safety equipment are mandatory for the different work environments. Safety goggles are required at all times, and ear protections are required for noisy environments. Proper ventilation and use of respiratory equipment are mandatory in environments involving dust and microparticles.

C. Vehicle Safety Features

Mechanical

The tether has been equipped with a strain-relief made out of aramid to prevent any damages to the connectors if the tether is exposed to strain. The tether is also sleeved to prevent any damage to the cables. All sharp edges have been deburred to ensure safe operation and handling. All the thruster has been fitted with thruster guards that holds IP 20, to ensure that no particles less than 12.5 mm (typically a finger) will be shredded by the propeller.

Electrical

The electrical components are protected with fuses. These are dimensioned according to operating currents. There is one main fuse for the ROV, resettable fuses for the motors and ordinary fuses for the rest. The vehicle is equipped with a button that shuts of the power to the motors manually. Additionally, if the communication is lost, all power to the motors will shut off.

Figure 2: Development of the motorcontroller housing

III. Design Rationale

A. Design Proscess

The company began the product development phase by brainstorming the team's ideas and designs. We did this by breaking down the competition manual to see what the tasks demanded from both the mechanical- and electro/data department. The company used brainstorming in between the different groups of engineering students to come up with good solutions. We did this to discover things that could not be done, e.g. that the mechanical engineering had a design that wouldn't be possible to accomplish, because of the electrical parts that had to be adopted into the robot.

The company looked for ways to improve our previously ROVs, along with the future goals for Vona. After the requirements for the mission was released, the main factors for the design were identified, which was weight and size. To meet the specifications, it was necessary to discuss the materials and designs out of what we thought was most appropriate for the competition. With these new requirements and target specifications defined, different concepts were generated in order, by using a concept scoring matrix with respect to the requirements.

The scores were added and the best concept was selected for further development. It was decided that Vona would only have one electronics housing with specified dimensions to minimize weight and size. In addition, we decided to improve the previous design by implementing a dome at the front of the housing. From this approach the team had a starting point for the rest of the ROV. It was then possible for the team to work in parallel, ensuring a rapid development. Precautions were taken regarding electromagnetic interference that occurred from choosing one housing. To minimize this problem, circuit boards and connectors were placed in ways that high and low power electronics could be separated as much as possible. This concept would require few connectors, which lead to a less total volume and a reduced production cost. Next, with the help of different CAD tools and FEA-simulations we got a physical understanding on how the final design would look like. The different components were generated digitally into CAD files using Autodesk Inventor. The CAD files were then prepared for machining by making a program for fabricating in the CNC machine. For components made in the 3D printer, the format was converted to a stl file.

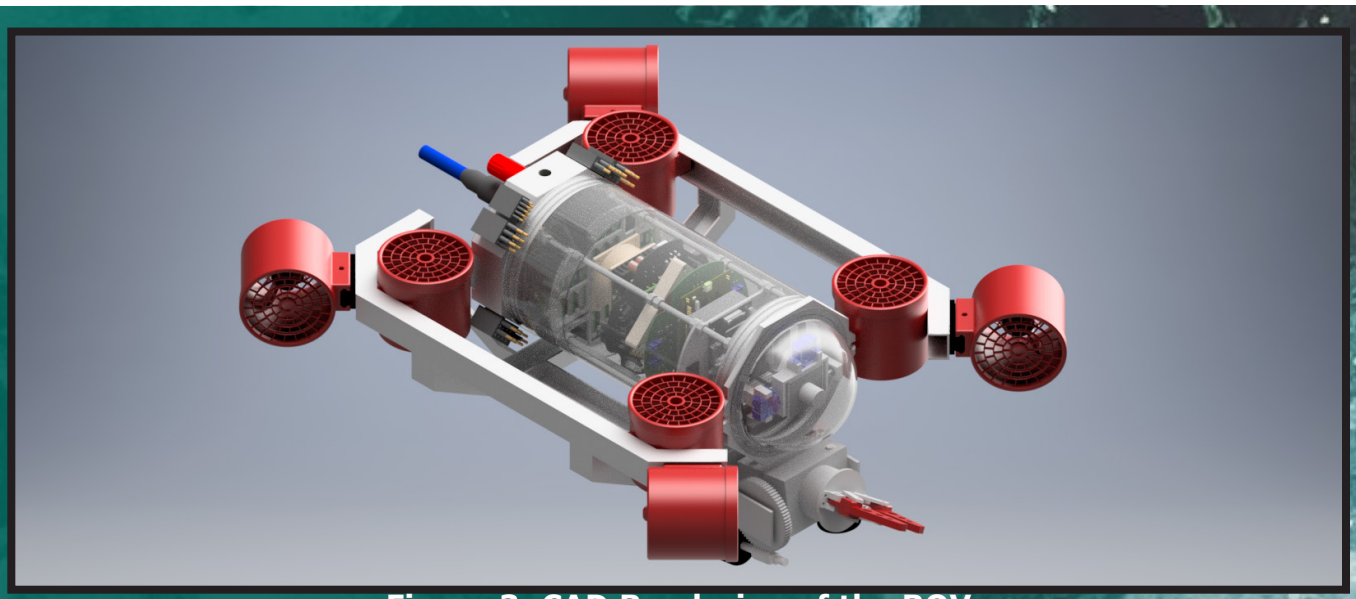


Figure 3: CAD Rendering of the ROV

B. Power Distribution

All the subsystems in Vona is powered through a power distribution board, shown in figure 4 & 5. The power distribution board has been specially designed for this ROV and contains all the voltage regulators and safety features required for normal operation.

The inlet cable is connected to the bard 15 cm from the power supply attachment point. The inlet power (40-65V) is converted to 5 V and 12 V via three DC/DC-converters. The board inlet and each subsystem have individual fuses. Each thruster motor is designed to deliver up to 120W of power, and the manipulator motors 140W. For a total of 1340W of power, its total power consumption is limited by software to accommodate a power supply of 800W.

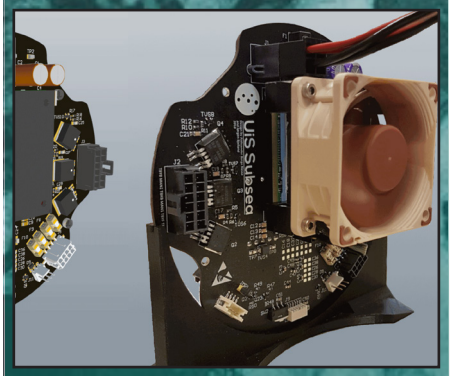


Figure 4: The power distribution board from the front with the fan mounted

C. Sensor Board

Vona is equipped with a tailor-made sensor board, designed with intent of easy expansion and compatibility. It has spare ports with the possibility of connecting extra sensor if needed. When it comes to navigating in deep and sludgy oceans with little to no visibility, the ROV is dependent on its many sensors.
Vona is therefore equipped with the following sensors to help her guide through the water.

- Pressure sensor used to calculate the depth from the surface.
- Sensors for information about the ROVs orientation
- Leakage sensors in case of water breaking through the housing
- Temperature sensor to keep an eye on the temperature inside
- Power usage sensors on all motors to identify errors, and distributing the power in the most efficient way

Together, all these sensors ensures a robust and reliable ROV, and making it possible to lock the ROV in any desirable orientation.

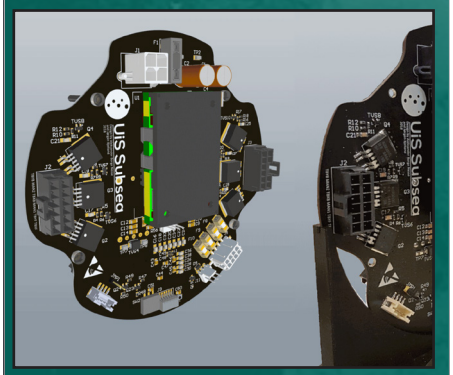


Figure 5: The backside of the power distribution without the fan

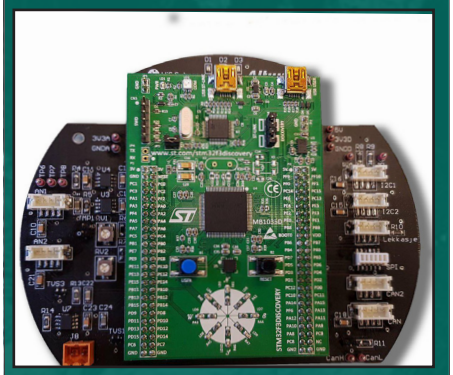


Figure 6: Photo of the sensor board

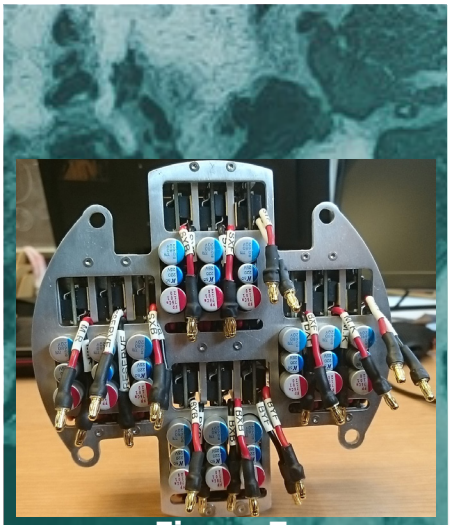


Figure 7: 12 motorcontrollers mounted together

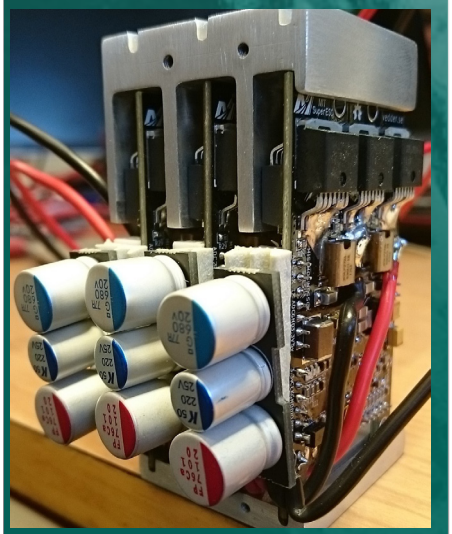


Figure 8: Motorcontrollers with capacitors mounted on circuitboardholders

Figure 9: Photo of the thruster

D. Motor Controllers

The fitting for the motorcontrollers were designed with free airflow and optimal use of space in mind. To ensure optimal performance by the motors and motorcontrolleres, there is used high – end capacitor with very low ESR. This allows the DC/DC converter to maintain a very stable voltage at startup as well as during operation. For each motorcontroller there is mounted plugs on the wires for the supply voltage and for the motors to ensure easy decoupling incase of replacement and troubleshooting. The cicuitboardholders in figure 7 are designed with a heatsink, so that the MOSFETs at the motorcontrollers, will have a large surface to get rid of heat.

E. Thrusters

Vona uses eight thrusters, where the design of the propellers, and the shrouding with thruster guards are self-made. The shrouds and thruster guards were produced using the additive manufacturing process known as fused deposition modelling, FDM. Having unlimited access to the university's 3D-printer during this process, the shrouds were cost-effective and easily produced. For vertical control of Vona, four thrusters were mounted in the corners, on the inside of the frame. As for the horizontal control, the four remaining thrusters were also mounted in the corners, but on the outside. To make it easier to achieve 6 degrees of freedom, the horizontal thrusters were mounted at 45-degree angles. The company therefore decided to implement picatinny rails into the thruster system design. Picatinny rails allows for quick detachment and reattachment.

All eight thrusters use the motor, *Series 28-30A* from NTM Prop Drive. At maximum thrust, the motor use 20 A at 12 V and each thruster could produce over 34 N. Since the chose to produce the thrusters themselves, the stators and copper winding in the motors had to be electrically isolated. This was done by making an aluminum mold where the stator was placed and then filled with epoxy. The mold was then put in a sealed container with a vacuum pump to remove air pockets in the mold and in the epoxy, itself. After this process it was left in an oven to cure. After the isolation, an insulation test showed that after soaking in water for 24 hours, the motor was still giving a resistance of over 50 MΩ at 250 VDC, testing with a megger(SK3012).

F. Frame

Vona's frame is built to be light and to help make the ROV easy to maneuver. The placement of the electronics house is set to be in the center of the ROV. The frame therefore consists of four aluminum U-profiles, two under and one on each side, designed to surround half of the electronics housing. The U-profiles were chosen due to their low weight, low cost, availability, and easy processing. They also serve as cushioning for the electronics house. The thrusters are integrated into the frame, both on the outside and the inside of the frame, and are therefore placed far from the center. This gives better maneuverability and provides sufficient torque when the ROV has eccentric loads. Having the electronics house in the center along with the increased torque, makes the frame ideal for the 6 degrees of freedom navigation system.
The headlights are potted in optically clear epoxy, using a mold made from aluminum to mount the headlights in place. This solution requires minimal space and weight and offers a large improvement from previous designs.

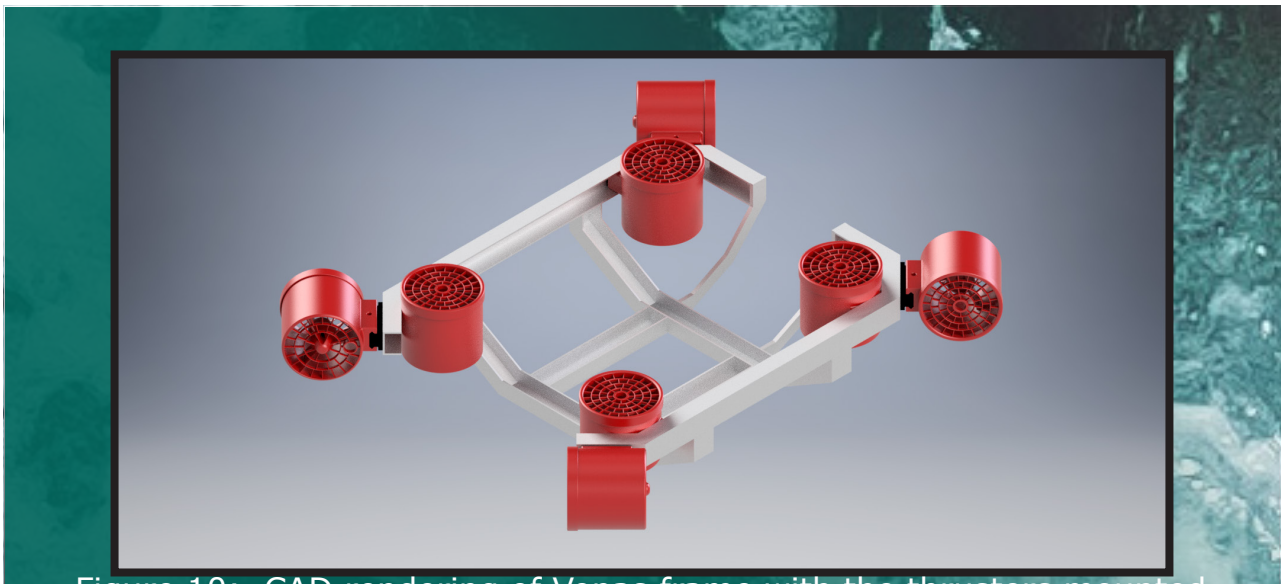


Figure 10: CAD rendering of Vonas frame with the thrusters mounted

G. Camera

Camera Mount
This years ROV concept has been mounted with a dome in the front. This improvement from last years design has the benefit of placing the main camera inside the dome, giving a better viewing angle. The main camera will be mounted in a 3D modelled camera housing made out of Polyactic Acid(PLA), with the smart functionality of 360 degree free rotation. Two servomotors will be directly mounted on the camera housing providing the tilting and the panning of the camera inside the dome. The benefits of using servomotors is the programmable interface that can prevent the camera from being rotated beyond components that blocks the view for the camera (Manipulator, frame,etc.).

The camera and the camera house will be mounted on a plate made out of aluminium inside the pod of the ROV. This type of solution will give an easy manoeuvring of the camera, and the structural strength, holding everything in place.

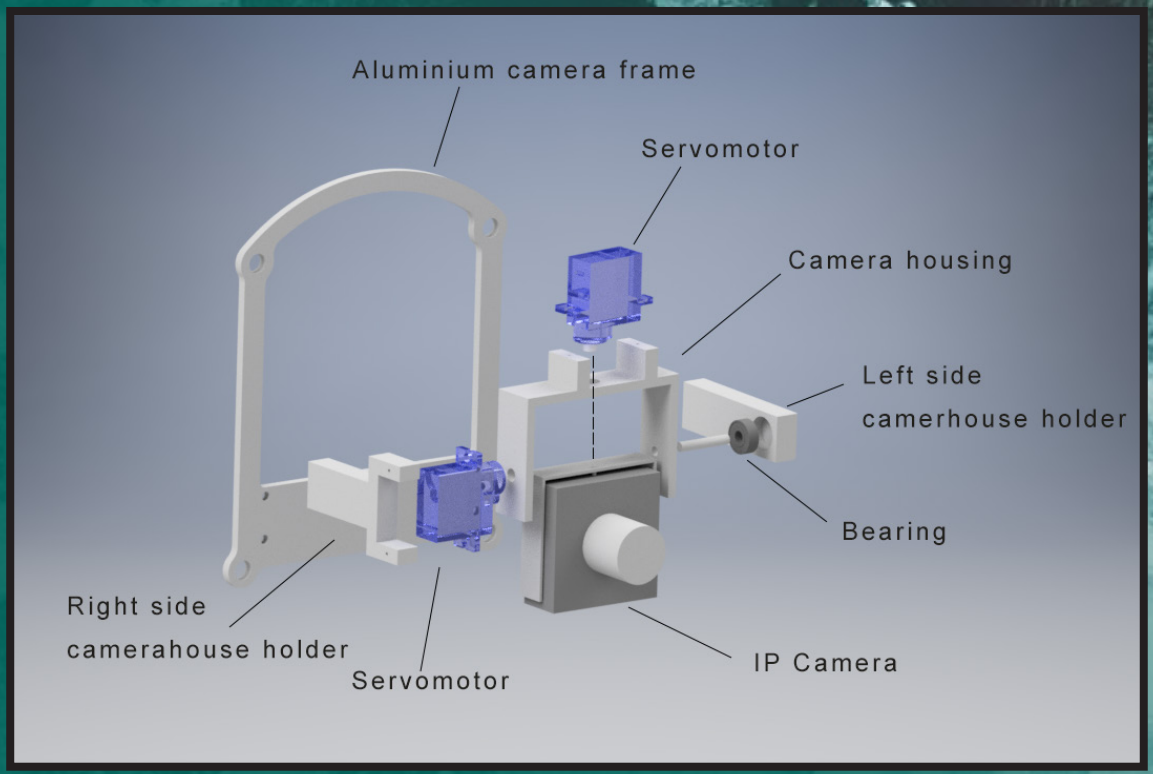


Figure 11. Camera mount

Seconday Camera

A secondary camera has been strategically placed under the ROVs manipulator giving the most crucial viewing angle, as most of the task will be performed by the manipulator, furthermore the tools that will be used solving the task given by the pilot are also occupying the same area as the manipulator, namely, in the front of the ROV.

By placing a camera with a slightly wider lens, such the manipulator and the tools are in sight has proven us that this is just what's needed in case the main camera is not enough. Choosing an analog FPV camera will give the least error sources, since the transmission cables will go uninterrupted from the ROV to topside computers through the tether

Additional Cameras

Vona has been mounted with additional cameras for a better functionality. An USB camera will monitor the tether in the back of the ROV, and one in the front as an overall tool camera. They will be connected to the ASUS Tinkerboard inside the pod, giving us the option to mount even more cameras where it will be essentially needed.

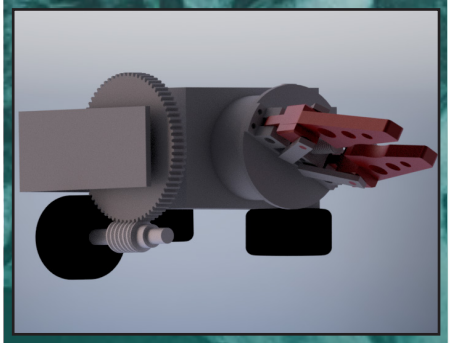


Figure 12: Manipulator

H. Manipulator

The manipulator was designed with focus on weight, durability and modularity. To reduce weight, the manipulator and end effector is powered by 3 brushless DC motors, *Multistar Elite 3508-268KV,* potted in epoxy instead of stepper motors. This solution avoids the need for waterproof housings, but introduces the need for gearing, as the RPM of the motors is relatively high. Vona's manipulator system consists of 3 functions, which are; a wrist with pitch and roll and an end effector equipped with an intermeshing 2-finger gripper. The different functions can be locked in place manually in the event of failure. The 3-function gripper enables the ROV to grab and place objects, both in front of Vona and on the seabed, move objects around and turn handles on each corner of the OBS. The manipulator is controlled by the surface control system.

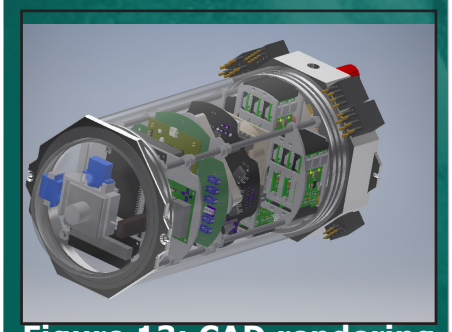


Figure 13: CAD rendering og the electronic housing

I. Electronic Housing

All the main electronics for Vona are located inside an acrylic tube sealed with a custom CNC milled aluminium endcap and frontcap. The main purpose of the electronic housing is to keep the electronics dry, safe and easy accessible.

A dome is placed on the frontcap for the camera to see trough. The tube is held in place by two rods connected to the aluminium frame. For construction of the tube, acrylic material where chosen because of its light-weight and high-strength properties. It is also an advantage that the electronics housing is transparent when driving Vona, so its possible to inspect the status LED indicators on the circuit boards and wiring without
opening the housing.

The housings shape makes it hydrodynamic wich makes it easier for the pilot to maneuver in water. The air volume gives buoyance to the ROV system reducing the need of extra floating .

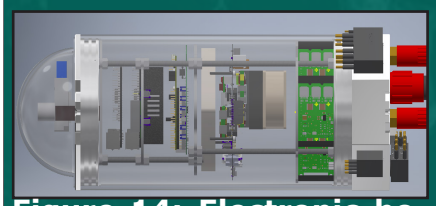


Figure 14: Electronic housing from the side

J. Tether

Vona's tether contains power and communication cables neatly bundled into a flexible, protective sleeve with strain relief on both ends.
The tether contains:

- 2*2.5mm2 flexible single stranded tinned core for power transfer. The
power cables are sized for minimal weight and are calculated to be sufficient for the maximal power needed by Vona.

- CAT6 for Ethernet communication to the IP-camera. CAT6 was chosen due to its cost, flexibility and ability to transfer data with a bandwidth of Gbit/sec; which was necessary for streaming the IP-camera video feed.

- 2*24 AWG for CAN-bus communication; calculated from bus length and number of nodes. [1]

- Air hose for supplying air for the lift bag.

IV. Mission Tools

A.Overview

For sending an release activation signal to the lift bag and to receive the OBS level and seismic data there has been created a combined tool.

B.Lift Bag Tool

By using a microcontroller together with a piezoelectrical element there will be created an acoustic signal. This signal will be received and correctly identified by the microcontroller on the lift bag and activate the release mechanism. This gived a completely wireless release of the lift bag and requires no mechanical contact for releasing the bag.

C. Tool to Level the OBS

The same microcontroller, now together with a WiFi receiver is designed to receive the level and seismic data from the ocean bottom seismograph. When the ROV pilot is performing the task of leveling the platform, the level data will be transferred to the microcontroller.

Both the lift bag signal and the leveling data will be transferred from or to the control system by use of CAN-communication. For this, the tool is also equipped with a dedicated CAN-driver module. The microcontroller can then receive a 'release' command from the ROV pilot via the control system over CAN-bus. The pilot will also be able to read the level data and display the seismic data graphically.

C. Inductive Power

An inductive power coupling have been designed to deliver 5V, 1A, 5W power to power an Ocean Bottom Seismometer. The unit will be powered by two 9V alkaline batteries with an inline 2A fuse less than 5 cm from the positive battery terminal. The inductive coil is covered with epoxy. The endcap is pressed in place and waterproofed with a gasket. This assures that any pressure created due to water or electrical damage will be released without the need of a valve.

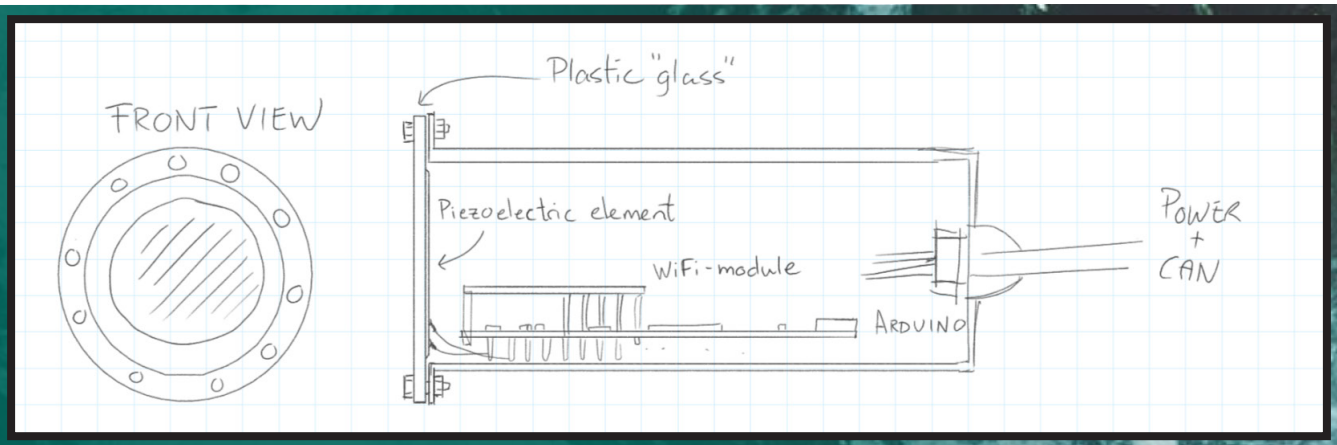


Figure 15: Sketch of the combined tool

V. Software Design

A. Overview

We wanted to build an architecture that would to it's full extent utilize the strengths available in current technology, while simultaneously maintaining the possibility to easily debug or add extensions to facilitate new requirements or ideas. Going with this mindset we were able to build a system that's tailored to the task at hand,
but still easy to adapt to other projects. By utilizing Git and GitHub this system was built quickly by multiple developers working on different parts of the project, while the entire history of the software was recorded.

B.Control Station

This is the surface-side software. From this graphical user interface the pilot is able to control the ROV using a game-style controller of their own choice. Information about the server, tool readings, and warnings are displayed in near real time, and all the ROV's settings and configurations are easily accessible. This year the entire user interface was built using HTML, JavaScript and CSS, along with the React JS framework. This made it possible to package the entire user interface within a single webpage, meaning that the user only needs a computer with a working web browser to control the ROV.

Whenever the user generate some data - i.e. change some settings or press a button on the controller - an event is triggered. This event will immediately send information about the event to the server over established WebSockets. This results in a very low latency transmission which only consumes strictly necessary resources, as opposed to continuously sending information - that may not contain any changes - with predetermined intervals.

Different pilots may have different preferences as to what assignments buttons on the game controller should have. In the controller settings menu it is therefore possible to configure every button and axis on the controller in whatever way suits the pilot best. Such configurations may then be given a name and stored on the server. Stored configurations will immediately be accessible to all clients.

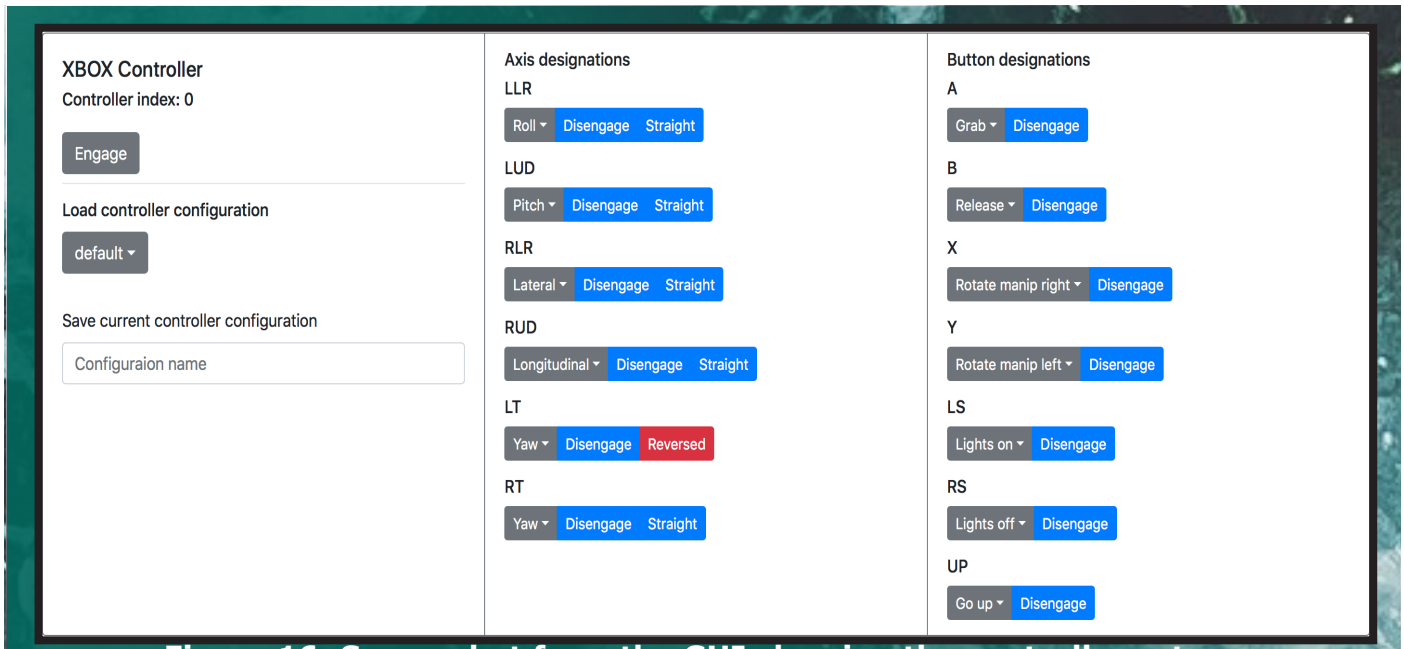


Figure 16: Screenshot from the GUI showing the controller set-up

C. Tether Communication

Communication through the tether is made possible by a CAT6 ethernet cable, enabling gigabit bandwidth. To better utilize this feature there is a gigabit ethernet switch inside the ROV to which both Tinkerboards and multiple IP-cameras are connected. Video streams from cameras connected to the Tinkerboards are suspended and resumed whenever they are needed. The IP-cameras do this automatically. Data about user controls or sensors in the ROV is packaged with the popular JSON-format and communicated between server and clients using WebSockets.

D.Internal Communication

There are two Tinkerboards inside the ROV. The first one is serving as the main server from which the web-page with the user interface is hosted. This Tinkerboard is also responsible for communicating with motor controllers over CAN-bus. The other Tinkerboard is utilizing the I^2C-protocol to communicate with the power supply board and the sensors board. Onboard GPIO (General Purpose Input Output) pins on this Tinkerboard are used to control lights and servo motors for the main camera by generating PWM-signals.

E. Movement Controls

The ROV can be controlled by a range of different game controllers. The button and axis layouts for different controllers can easily be encoded using the JSON-format, which in turn the graphical user interface is able to visualize and manipulate (see figure 17). By default the only such configuration available is one for the XBOX 360 controller.
Torque vectors from the controller are transformed individually to make them less sensitive to user input close to extreme points, i.e. close to -100%, 0% or 100%.
The data from these raw sources are then mapped to torque around and along all spatial axes. At this point the torque vector is six-dimensional, and it is here that regulator algorithms for depth and angles contribute their own torques. This vector is then transformed to the responding torque on each thruster, resulting in an eight-dimensional vector which is normalized on the interval (-1, 1).

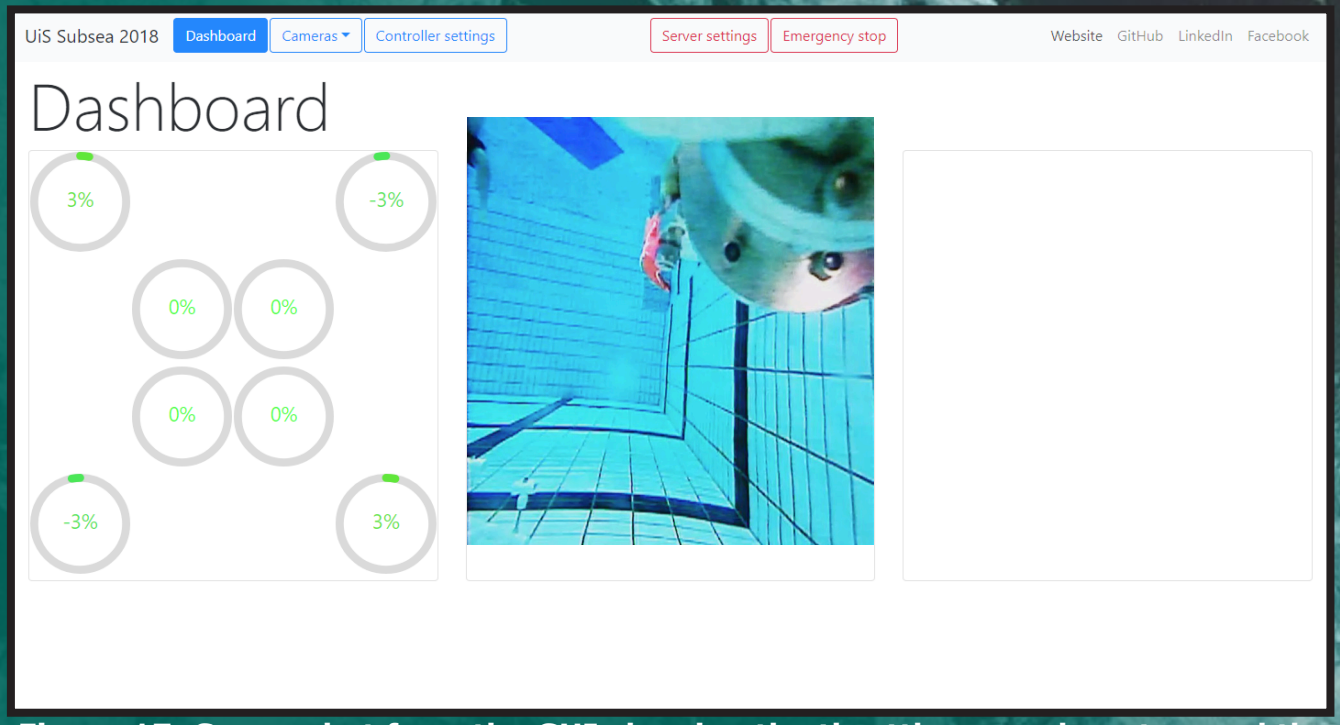


Figure 17: Screenshot from the GUI showing the throttle on each motor, and the camerafeeds

VI. Logistics

A. Company Organization

UIS Subsea consists of 16 students, all with different backgrounds from STEM-fields. On the top of the hierarchy, a board of students with and without experience from earlier participation in the competition monitors the economic aspects and the overall health of the company. The project manager is responsible for the daily management, and to oversee that the project is consistently moving forward towards the intermediate objectives. The project manager is also in charge of the two manufacturing and design groups divided into an electrical and a mechanical department. Both groups are again divided into subgroups as shown in figure 18. The chief of each department reports to the project manager who reports to the board.

Project manager and chief executive officer (CEO) also work closely with the chief financial officer (CFO). This is so the projects spending is kept within the budget. You can see the budget in the figure on next page.
Throughout our time in UiS Subsea, we have not kept a strong hierarchically organizational structure. Because UiS Subsea consists of a relatively small team and everyone can participate in other divisions of the company as we see fit. This especially true for the project manager and the senior department.

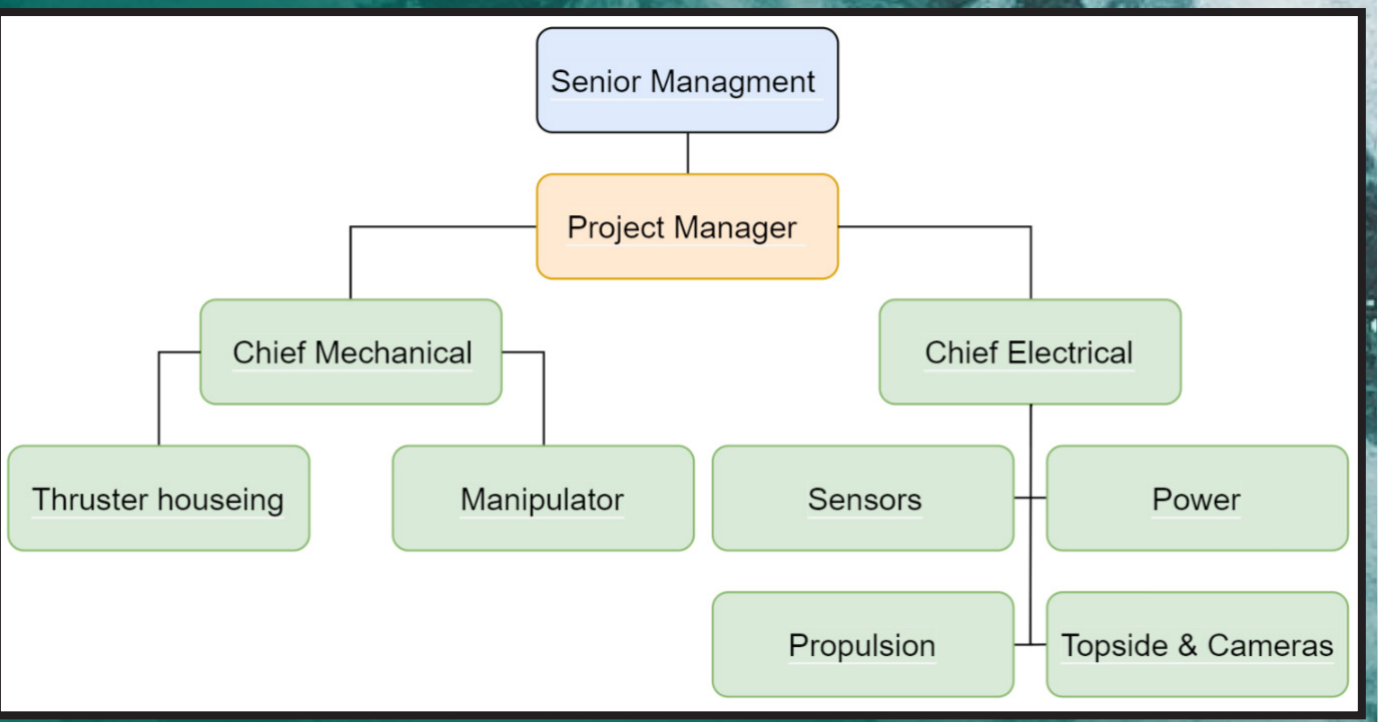


Figure 18: The companys hierarchy

B.Project management

To ensure that the project keeps up with its internal and external deadlines, weekly meetings have been held by the project manager with the whole project team and (a Gantt chart has been followed. In the meetings each group have presented its progress and had a chance to ask questions. The Gantt chart makes it easy to follow the projects state and to give an overlook on objectives that needs to be done in near and far future.) All of the employees were located in the same room, which paved the way for cross-functional collaboration. This made sure that both the senior department and the rest of the company had a constant flow of knowledge and experience across all

the departments. This way, the newest members of the company can quickly get accustomed to working in this company while also learning about the management aspect of the company, which they in turn can bring this knowledge to new students next year. This way of transferring knowledge is a tried and tested methodology and has worked excellently throughout the years. It increases overall skill of the company with each iteration of vehicle.

C. Budget and Project Costing

The team based its new design principle on last year's design, hence it was sensible for management to base this year's budget on last year's result and donated funds and leftover capital. The goal was to make more efficient use of funds as previous expertise could help reveal areas where costs could be cut while still maintaining optimal quality. As all research is based on cumulative knowledge, the team looked at ways to improve the previous design principle to increase performance. The budget of 2018 is given in table to the right. From previous experience, travel costs tend to vary drastically depending on the destination of the competition, hence a fair amount of funds were reserved especially for this. We are very grateful for the support of our sponsors; the University of Stavanger, Tekna, FFU, Gassco and Oceaneering for their monetary donations, as well as Altium, SKF, Nordic Steel, Årdal maskinering, Elprint and Nexans for their software and material contribution. The table below shows the sponsors and the corresponding values they provided. The spending was strictly controlled and recorded by logging receipts in a spreadsheet as shown in the table below. This ensured to keep the project within budget.

Sponsors	Description	Value (NOK)	Value (USD)
University of Stavanger	Monetary donation	kr 100 000,00	$ 12 000,00
Tekna	Monetary donation	kr 10 000,00	$ 1 200,00
FFU	Monetary donation	kr 25 000,00	$ 3 000,00
Oceaneering	Monetary donation	kr 20 000,00	$ 2 400,00
Gassco	Monetary donation	kr 25 000,00	$ 3 000,00
Nexans	Cables (estimated)	kr 1 500,00	$ 180,00
Elprint	Circuit boards (estimated)	kr 3 000,00	$ 360,00
Årdal maskinering	Material cutting (estimated)	kr 1 000,00	$ 120,00
Nordic Steel	Material cutting (estimated)	kr 10 000,00	$ 1 200,00
Altium	Software (1 year license)	kr 400 000,00	$ 48 000,00
Total (Monetary)		**kr 180 000,00**	**$ 21 600,00**
Total (Production)		**kr 415 500,00**	**$ 49 860,00**
Total		**kr 595 500,00**	**$ 71 460,00**

Budget 2018

Manipulator		
Description	**Estimated Cost (NOK)**	
Motors	kr	1 245,00
Gears	kr	1 200,00
ESC	kr	1 200,00
Housing	kr	500,00
Sum	kr	4 145,00
Electronics		
Description	**Estimated Cost (NOK)**	
Microcontrollers	kr	1 000,00
Sensors	kr	1 500,00
DC/DC converter	kr	3 500,00
Powerdistribution	kr	1 500,00
Camera	kr	3 000,00
Connectors	kr	10 000,00
Custom PCB	kr	5 000,00
Sum	kr	25 500,00
Thrusters		
Description	**Estimated Cost (NOK)**	
ESC	kr	7 500,00
Motors	kr	4 200,00
3D-Printing	kr	2 000,00
Sum	kr	13 700,00
TCU		
Description	**Estiamted Cost (NOK)**	
Computer	kr	7 000,00
Umbilical	kr	1 000,00
Umbilical connector	kr	1 000,00
Fusebox	kr	700,00
Sum	kr	9 700,00
Production		
Description	**Estimated Cost (NOK)**	
Coffee	kr	1 500,00
Framematerials	kr	1 000,00
Electronics housing	kr	1 250,00
O-rings	kr	900,00
Buoyancy	kr	2 500,00
Sum	kr	7 150,00
Travel		
Description	**Estimated Cost (NOK)**	
Plane tickets	kr	117 000,00
Lodging	kr	20 000,00
Transport	kr	5 000,00
Transport of ROV	kr	5 000,00
Sum	kr	147 000,00
Total ROV	kr	60 195,00
Total Travel	kr	147 000,00
Total Cost (NOK)	**kr**	**207 195,00**
Total Cost (USD)	**$**	**24 863,40**

Field	Item	Description	Type	Qty	Cost	Total
Materials	Aluminum		Purchased	1	kr 1 125,00	kr 1 125,00
	Acryl tube		Purchased	1	kr 300,00	kr 300,00
	Dome		Purchased	2	kr 280,00	kr 560,00
Mechanical	Tether sleeving		Purchased	1	kr 300,00	kr 300,00
	Strain relief		Purchased	2	kr 200,00	kr 400,00
	Epoxy		Purchased	1	kr 730,00	kr 730,00
	Fasteners		Purchased	1	kr 800,00	kr 800,00
	Propellers		Purchased	8	kr 580,00	kr 4 640,00
	Thruster duct		Donated	8	kr 250,00	kr 2 000,00
	Picatinny rails		Re-used	4	kr 50,00	kr 200,00
	O-rings		Purchased	1	kr 1 000,00	kr 1 000,00
	Connectors		Re-used	8	kr 1 500,00	kr 12 000,00
	Gears		Purchased	5	kr 425,00	kr 2 125,00
	Bearings		Donated	50	kr 150,00	kr 7 500,00
	Supports		Donated	6	kr 80,00	kr 480,00
	Leadscrew		Purchased	2	kr 300,00	kr 600,00
Electronics	Thruster motors		Purchased	8	kr 120,00	kr 960,00
	Manipulator motors		Purchased	4	kr 400,00	kr 1 600,00
	Electronic Speed Controller		Purchased	12	kr 900,00	kr 10 800,00
	Tinkerboard		Purchased	2	kr 560,00	kr 1 120,00
	Cooling fans		Purchased	3	kr 160,00	kr 480,00
	Ethernet switch		Purchased	1	kr 810,00	kr 810,00
	LED diode		Purchased	2	kr 175,00	kr 350,00
	DC/DC converters		Purchased	4	kr 750,00	kr 3 000,00
	LED drivers		Purchased	1	kr 660,00	kr 660,00
	Microcontroller		Purchased	2	kr 100,00	kr 200,00
	Tether cable + Misc.		Purchased	1	kr 2 175,00	kr 2 175,00
	Camera		Purchased	1	kr 660,00	kr 660,00
	Custom PCB + Misc.		Purchased	1	kr 5 100,00	kr 5 100,00
	Sensors		Purchased	3	kr 470,00	kr 1 410,00
	Sensor board + Misc.		Purchased	1	kr 4 770,00	kr 4 770,00
	Cables and cable assembly		Donated	1	kr 1 500,00	kr 1 500,00
Topside	Computer		Purchased	1	kr 4 400,00	kr 4 400,00
	TSU-case		Re-used	1	kr 500,00	kr 500,00
	Monitor		Re-used	1	kr 920,00	kr 920,00
	Joystick		Re-used	2	kr 350,00	kr 700,00
Labour	Welding		Donated	1	kr 1 000,00	kr 1 000,00
Total	Vehicle expenses					kr 77 875,00
Total ROV	Vehicle expenses	USD (1 NOK = 0,12 USD)			kr 77 875,00	**$ 9 345,00**
Travel	Airplane tickets					kr 44 070,00
	Shipping ROV	Estimated				kr 5 000,00
	Lodging					kr 20 170,00
Total						kr 69 240,00
Total Travel		USD (1 NOK = 0,12 USD)			kr 69 240,00	**$ 8 308,80**
Total Cost						**$ 17 653,80**

From this, we were able to reduce the total spending on the ROV by $1000 compared to last year's, while keeping at least the same level of quality and performance. The total cost was drastically reduced due to much lower travel costs.

VII. Conclusion

A. Testing and Troubleshooting

Testing and troubleshooting has been a crucial part in the whole process of creating a brand new ROV. The system functionality is verified through testing of individual components, circuits, and by overall integration. Before entering the water, basic checks and functionality tests were performed by powering the ROV outside the water. After successfully ensuring proper thruster and tool operation and no leakage in to the electrical housing, the ROV and equipment were transported to the pool for in-water testing. At the pool, the launch procedure consisted of very careful inspection to verify waterproofing, tether strain relief and buoyancy. Initially when the ROV is entering the water the waterproofing test consists of carefully looking for air bubbles coming from the electronic housing and leakage into the pod. Finally, when the ROV was ready, the further testing consisted of mission simulation, getting driving experience and gathering data for further vehicle development.

B. Challenges

Throughout the design and build process, many challenges were faced by employees at UiS Subsea. One of the biggest non-technical challenge was the management and collaborating between electrical and mechanical department in both the design and build process. This year there was decided that the size of the electrical housing should be smaller in diameter. That has given a lot of challenges that requires very good communicating and collaborating skill between the departments. Another challenge has been lack of mechanical employees and for that reason some of the electrical crew has also been working with mechanical tasks. To make sure all parts fits ass it should and results in good solutions with great details there has been organized weekly meetings to ensure good planning and communications between the departments.

The main technical challenge faced was also the fact mentioned that the size of the electrical housing should be smaller in diameter. To do so the design needed to be more compact than ever before, and that has led to many challenges. One of the biggest was the design of the circuit board for power distribution and the result from this challenge was some very interesting PCB designs.

Another huge challenge was that our DC/DC converter for the motor controllers shut down due to overcurrent in the startup moment. Countless hours were spent debugging the power circuits and every single part of the circuit was taking apart until the root cause and solution were identified. The cause of the problem was found to be the large capacitors with very low ESR which allows very large current to flow when they are charging up. The solution was to create our own soft start circuit to control the current flowing in the startup moment.

C. Lessons Learned and Skills Gained

Each employee of UiS Subsea learned a variety of technical skills. The electrical department employees learned how to start with technical requirements, devise the needed circuit, create a test circuit, and then design the schematic and board layout in Altium. This cumulated in learning how to populate and test the circuit boards. Both mechanical and electrical departments learned the features of Autodesk Inventor, and correct design for manufacturability. Employees also gained skills in manufacturing methods by making their own parts in-house. The software department learned how to make the whole system more portable, making it less dependent on a specific rig, and rather making it possible to connect to any device with an internet connection and

an ethernet port. They also learned how to make the software more module based, making it far easier to changes in Vona , or to match any individual preferences. This is a pioneering design for UisSubsea, making troubleshooting, debugging and redesigning the whole system an easy step in the future.

In addition to technical skills, many lessons were learned and employees from every department learned how to work together and communicate with eyes towards a common goal. For the management some of the challenges have been to coordinate the task such that the workload is shared evenly, and to maintain good communication between the departments. During weekly meetings between department leads and project group heads, the previous week's progress, outstanding tasks, and any new tasks were discussed. This was discovered to have an impact on ensuring appropriate progress was being made in a timely manner and to ensure communications between the departments.

D.Future Improvements

This year saw many improvements from previous year, but there are still many areas to improve.

One of our biggest issues this year was lack of employees with mechanical background and for that reason the frame design is about the same as before. Therefor one of the future improvements for the next year will be a new and more compact frame design.

Also, one of our future goals is to use sonar system to collect data about ROVs position on the horizontal plane.

E. Reflections

UiS Subsea's number one goal is to promote knowledge and experience about underwater robotics at the University of Stavanger. Since our first participation five years ago, UiS Subsea have facilitated interdisciplinary collaboration through exciting and innovative working environments for its members.

"Being a part of UiS Subsea has been one of the most valuable experiences of my graduate program at the University of Stavanger. The reason for this, is the opportunity to learn how to use theoretical experience in a practical manner. To experience the whole process between technical requirements to the finished product. Not only was I able to gain critical electrical engineering experience in the areas of PCB design, but I have gotten basic skills in the areas of CAD design and manufacturing. The learning curve has been steep and as much important as technical skill is the experience of working in a team."

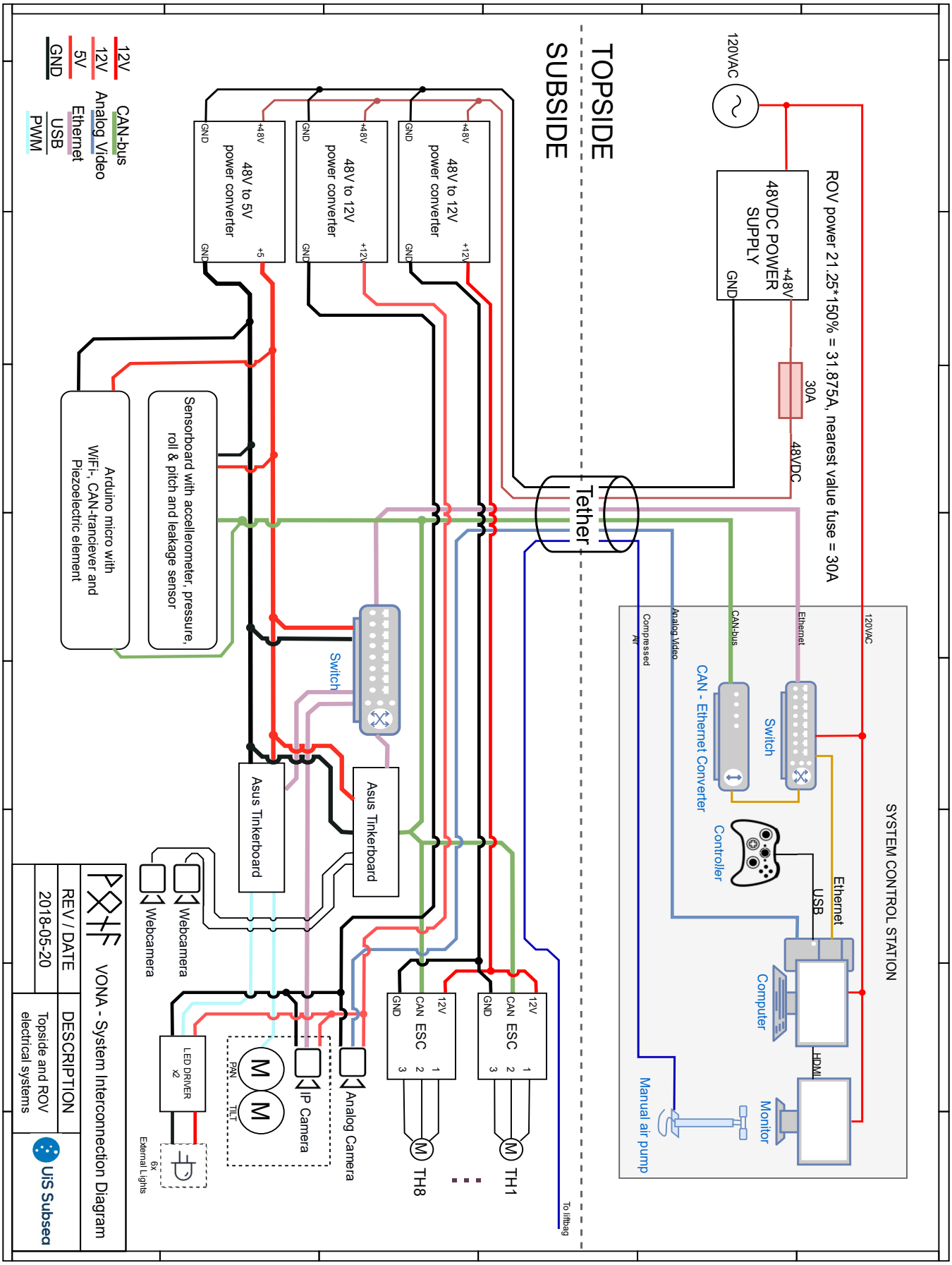
- Jørgen Bjelland (Electrical Department)

"This is my first year at UiS Subsea, I became a member of the organization when I were going to write my thesis. First of all I am very grateful that so many sponsors and the University of Stavanger helped us economically and with expertise, the projected couldn't have been realized without their help. At first one of our problems was in fact the lack of mechanical – engineering students who could aid us building the ROV. It became upon us that we had to compensate for the lack of these by expanding our knowledge toward manufacturing parts at the workshop. Great opportunities came out of this as we had to learn how to use CAD as well as using different machines at the workshop. My work as an HSE coordinator has at times been very challenging, but in the end also very rewarding since there has been no damage to employees or property. These experiences is something I am proud of to apply further on I my career."

- Daniel André Kommedal Hille (Electrical Department, HSE coordinator)

VIII. Appendix

A. Systems Interconnect Diagram (SID)



B.Safety Checklist

Pre – launch

1. Make sure that the designated working and deployment area is tidy and suited as a proper working environment in accordance with the company's HSE protocols
2. Ensure that the SJA is filled out and approved by the HSE - coordinator
3. Personal safety equipment ON
4. Ensure that all O-rings are in place, undamaged and properly greased
5. Ensure that no bulkhead connectors are loose
6. Check that all locking sleeves are tightened in place
7. Ensure that the blind plug is fastened tight
8. Check that the electronics housing is fastened
9. Check that all horizontal thrusters are properly fastened with clevis pins
10. Check that all propellers are fastened and in place
11. Ensure that all thruster guards are in place, properly fastened and undamaged
12. Check all exterior cables and connection points for damage, and make sure that they are properly fastened and not in contact with any sharp edges
13. Make sure that all components in the electronic house are properly fastened with no exposed wires or visible damages
14. Make sure that all visible wires and plugs inside the electronic house are properly connected or terminated
15. Keep hands of the ROV before turning power ON
16. Control voltage level and current limiting of power supply if applicable
17. Control status indicator LED's
18. Do not let the electronics house be closed with power ON above water for a long period of time due to heat accumulation inside the electronic housing
19. Do not run motors in open air for a longer period of time due to possible overheating

Launch

1. Keep hands away from thrusters
2. No hands on control system
3. A minimum of two people launching the ROV
4. Slowly launch Vona
5. Keep Vona calmly under water for 10s, check for bubbles
6. Pull Vona up from water. Inspect waterproof housings for leakages
7. Tether assistance ready
8. Slowly launch Vona

Post – launch

1. Power OFF and wait for 5 seconds
2. Pull Vona up
3. Check for major damages
4. Rinse ROV with fresh water, especially underneath propellers and in places where pool – water is accumulated.

C. Acknowledgments

UIS Subsea would like to thank everyone who has helped us during the project. A special thanks to our sponsors, mentors and MATE for hosting the competition.

D. References

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