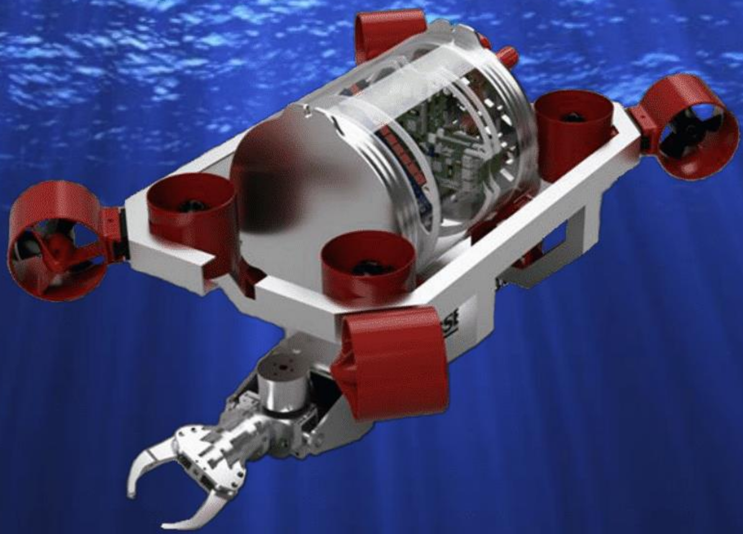
ÆGIR



TEAM MEMBERS		
Martin Evensen	Project Manager	President
Tolunay Metli	Mechanical Engineer	Vice President
Simen Norheim Pedersen	Mechanical Engineer	Chief Mechanical
Rein Åsmund Torsvik	Software Engineer	Chief Electrical & Topside Control System
Terje Haga Stavnem	Software Engineer	Topside Control System
Vivian Salanto	Mechanical Engineer	Manipulator Control
Maria Dahl	Mechanical Engineer	Manipulator Control
Sondre Nordbotn	Mechanical Engineer	Thruster Design
Robel Amar	Mechanical Engineer	Thruster Design

MENTORS	FIELD
Hirpa Gelgele Lemu	Mechanical Engineering
Terje Kårstad	Software Engineering

UiS Subsea

University of Stavanger
Stavanger, Norway

Contents

1.1 Abstract

UiS Subsea’s latest addition, Ægir, is a purpose-built underwater vehicle designed to perform challenges tasks in the Port of Long Beach. As such, Ægir is very small and light weight. In the 2017 MATE ROV Competition, the company will demonstrate Ægir’s ability to do a selection of tasks in a timely and reliable manner. The competition is set to simulate confined and precarious conditions of the port and waterfront, Port cities of the future.

This year the company had problems recruiting engineers, specifically electrical engineers. The lack of electrical engineers made it impossible to construct and produce a new ROV. Since the company was very satisfied with their 2016 ROV, Ægir, the company chose to modify it, as the tasks allowed the company to use the same ROV by improving and adding some new tools.

As a company, UiS Subsea’s main goal is to provide an environment where students can use their knowledge from their studies, while gaining experience as subsea engineers. Participating in the MATE ROV competition is therefore a great way to combine theory and practise to achieve a common goal. This year’s ROV-team consists of seven bachelor students from mechanical- and computer engineering studies. The team that will be traveling to Long Beach, California, consists of seven of the previously mentioned bachelor students along with two fourth year students. Since the beginning of the project, the students have worked together to accomplish the goals set for the project.

Figur 1: UiS Subsea team, 2017.

1.2 Acknowledgements

We are grateful for the support and funding given to UiS Subsea from the University of Stavanger and its institutes in the Faculty of Science and Technology. Thank you Terje Kaarstad and Hirpa Lemu for supervising the bachelor theses at the 2017 ROV team.

Without our sponsors in the industry, UiS Subsea would not exist. Thank you for having faith in our work and seeing the value of this project. A special thanks to the MATE Center for hosting the competition at Long Beach City College.

MATE Center	Competition Host
The University of Stavanger	Funding, materials, equipment and lab space
FFU	Funding and expertise
Oceaneering	Funding and expertise
Subsea 7	Funding and expertise
MacArtney	Equipment (connectors) and expertise
Elfa Distrelec	Equipment (discounts) and expertise
Envirex	Funding and expertise
Gassco	Funding and expertise
Deepocean	Funding and expertise
Smed T. Kristiansen AS	Water jet cutting and expertise
Stinger	Funding and expertise
SKF	Equipment (bearings) and expertise
Innova AS	Equipment and expertise
Statoil	Funding

Figure 2: Sponsors of the 2017 UiS Subsea ROV project.

2 Design Rationale

2.1 Design Process

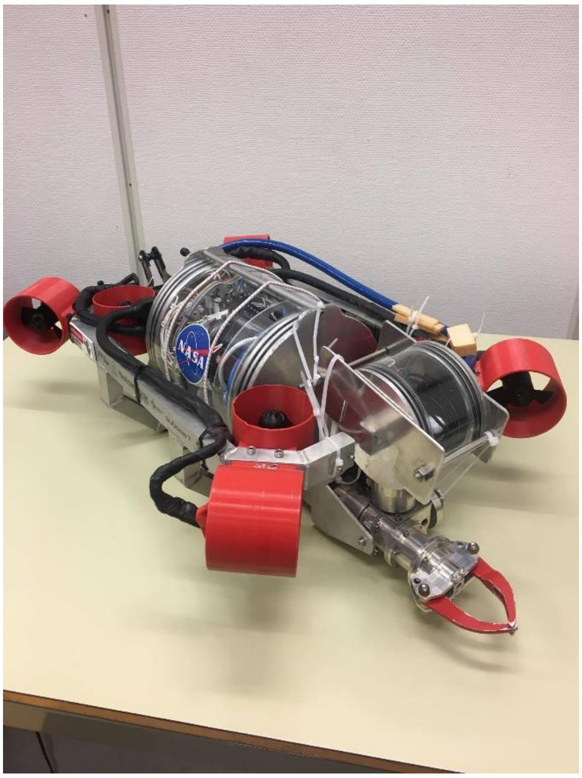


Figure 3: Ægir.

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 apartment. 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 Ægir. 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 this 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.


Figure 4: Length of the pod.

It was decided that Ægir would only have one electronics housing with specified dimensions to minimize weight and size. And 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 Solid works. 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.

2.2 Frame

Ægir'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 DOF 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.

2.3 Tools

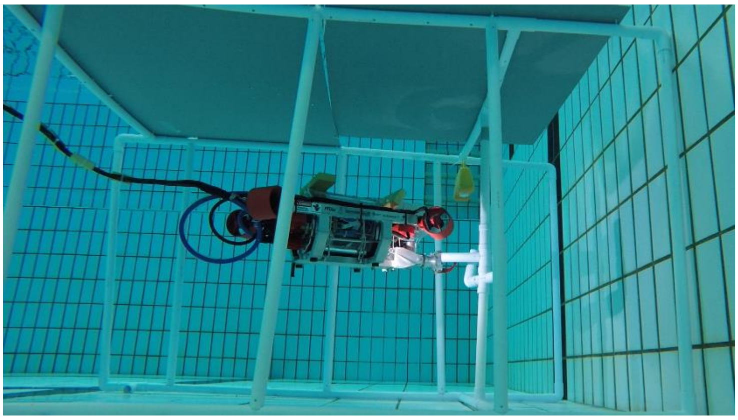
This year, as opposed to previous years, the company decided to develop task specific tools to enable the ROV to complete some of the tasks in a more precise and efficient manner. This was also necessary for some of the specific tasks that require more than the standard grabber tool, such as reading RFID of containers and collecting sediment samples simulated by agar. (MATE COMPETITION MANUAL 2017)

a) Sensors

Interface to the sensors

A circuit board, based on a STM32F3DISCOVERY microcontroller development board, has been designed to realize an interface to the various sensors used on Ægir. The circuit board design is focused on flexibility and low susceptibility to electromagnetic interference(EMI). This is because all electronics are in the same housing, and thus are exposed for EMI caused by the nearby voltage converters and the rapidly changing thruster current consumption.

Depth sensor



Figur 4: In order to operate underwater, ÆGIR uses it's depth sensor.

Ægir is provided with a digital pressure sensor in order to measure the depths with an accuracy of +/- 1 cm. The digital pressure sensor has been epoxy-cast into a stainless M12 bolt on the end cap, that leaves only the measuring membrane exposed. The pressure sensor resolve pressure down to 40 meters' depth. Calibration of the sensor to atmospheric pressure can be done at any time from the surface control system. The pressure measurement is converted from a digital pressure value into depth in mm, and transmitted to the surface control system. The depth measurement is also used to enable automatic control of depth.

Safety Sensor

Ægir is equipped with an internal temperature measurement and leakage detection on the inside the electronics housing. The leakage detector works in the way that if a leakage occurs, water will create an electrical connection between two partially exposed wires placed in the electronics housing, the sensor will then transmit the data to the surface. The internal temperature sensor is monitored to ensure that the Ægir 's maximum recommended operating temperature of 60°C is not exceeded. Both the leakage detector and the temperature sensor ensures early warnings in case of water-leakage or overheating, this is an important factor to ensure the vessels safety under different forms of harsh conditions.

Attitude Sensors

To assure accurate estimates of the attitude, the vessels angular position, Ægir has been equipped with a custom sensor fusion algorithm, that combines the state variables and the sensor measurements. This algorithm uses variable weights to produce optimal combination of accelerometer and gyroscope state estimates. This enables both precise and stable automatic attitude control.

b) 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 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.

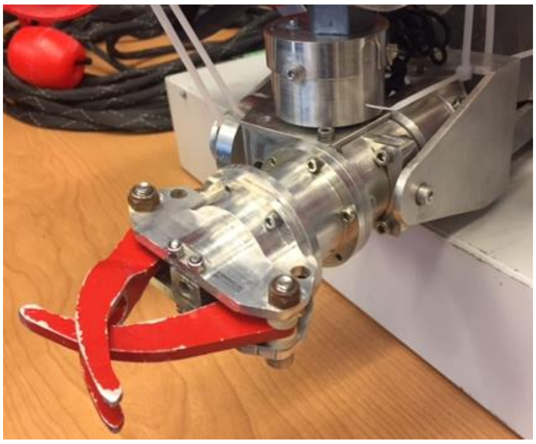
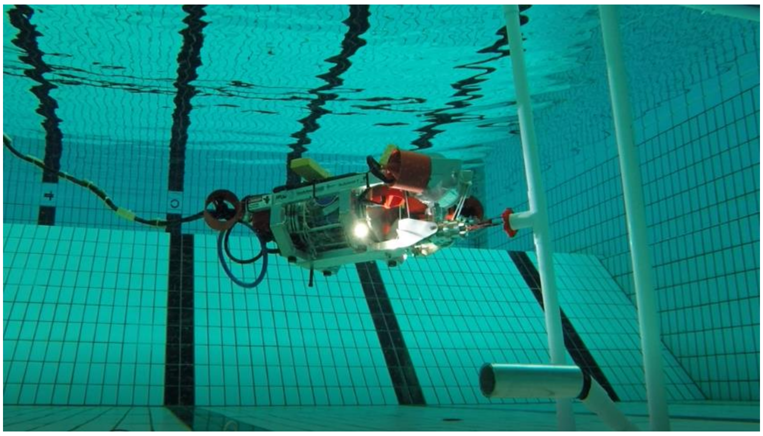


Figure 5: The manipulator.

Ægir's manipulator system consists of 3 functions, which are; a wrist with pitch and roll and an end effector equipped with an intermeshing 3-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 Ægir and on the seabed, move objects around and turn valves. The manipulator is controlled by the surface control system.



Figur 6: Manipulator performing it's roll feature.

c) Camera

Ægir 's camera system consists of two cameras: the main camera and a camera mounted inside the electronics housing. The main camera is mounted at the front and gives the pilot a view of 97 degrees in horizontal direction. The main camera is the operators main view for navigation and operating the manipulator. It is mounted inside its own housing and has a tilt function to get a wider working area. The housing is more compact than the past versions and is constructed from easily replaceable parts.

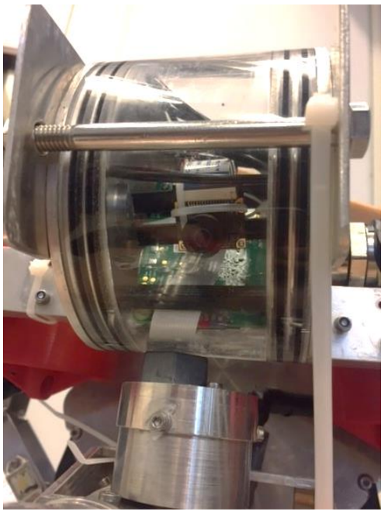
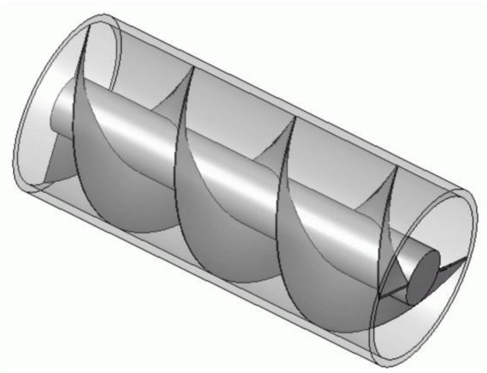


Figure 7: The camera.

Video streams can be started and stopped by buttons in the graphical user interface. There are also buttons to grab still images for each camera. The audio feedback helps the operator in navigating the vessel by relaying the thruster power in an intuitive way.

d) Agar collector tool

The agar collector tool uses an Archimedes' screw to collect agar into a cup that is later transported to the surface for inspection. As the volume of the screw chamber is known, we can also know how much agar is collected for each full rotation of the screw.



Figur 8: Model of Arcimedes' scew.

e) RFID reader and "Raman spectrometer" tool

The RFID scanner tool is designet to stab the light sensor port. This enables the ROV to quickly align with both the RFID activation light sensor and the ID transmitter. At the end of the tool is a RGB LED that is used to activate the sensor. The radio transceiver to read the ID is located inside the tool right behind the red alignment end of the tool, such that it comes as close as possible to the ID transmitter when the tool is stabbed. The tool has its own tether that is separated from the ROV's tether. The tool is also used as a Raman spectrometer using the RGB LED in front as the scanner.

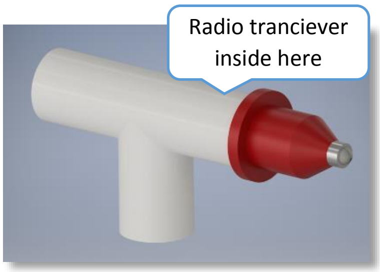


Figure 9: RFID reader

2.4 Thrusters

Ægir uses eight thrusters, where the design of the propellers, and the shrouding are self-made. The shrouds 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.

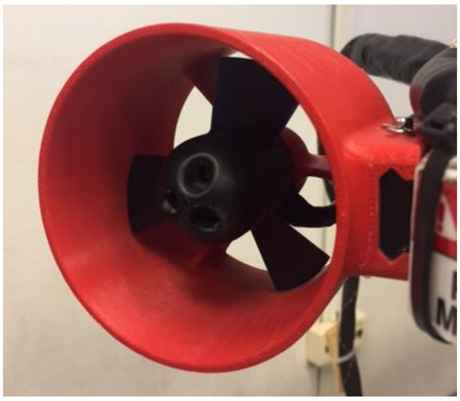


Figure 10: Thrusters.

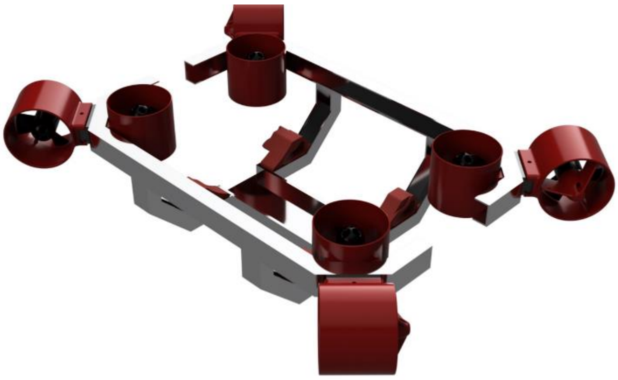


Figure 11: Frame and thrusters.

For vertical control of *Ægir*, 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.
Given *Ægir's* design, the horizontal thrusters led to a diameter exceeding 58 cm, size requirement. 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 a maximum of 34 N. To avoid overloading the DC/DC-converter, the software sets a hard limit to 50 % of the maximum possible thrust. This gives the thrusters a more practical maximum operating thrust of 18 N, using approximately 5.5 A.
Since the company chose to produce the thrusters themselves, the stators and copper winding in the motors had to be electrically isolated. After the isolation, an insulation test showed that after soaking in water for 24 hours, the motor was still giving a resistance of over 100 MΩ at 250 V DC, testing with a MΩ meter.

2.5 Electronics housing

Ægir's main electronics are housed inside an acrylic tube sealed with a custom CNC milled aluminum endcap at each end of the tube. If the electronics overheat and expands the air volume inside, the endcaps will be held in place by three rods fixed on the outside of the house. The rods also help prevent the house from rotating within the frame. Acrylic were chosen for the tube over aluminum because of its light-weight, and high-strength properties. This helps reduce the weight of *Ægir*, and therefor helps meet the strict weight requirement. Having a cylindrical shape on the electronics housing allows *Ægir* to move efficiently in water because of its low drag coefficient. Since acrylic is transparent, it makes it easier to visually inspect different components and the electronics via status indicator LED's which is a part of the prelaunch safety checklist and post-mission structural inspection. The main purpose of an electronics housing is to keep the electronics dry, safe, and serviceable, but due to *Ægir's* low weight, the electronics housing also doubles as the primary buoyancy.

2.6 Electrical Systems

a) Tether

Ægir's new tether contains power and communication cables neatly bundled into a flexible protective sleeve with strain relief on both ends. In this way, the cables will prevent to be tangled and will be more organized.

The tether contains a 2∗2.5mm² flexible single stranded tinned core for power transfer, which are sized for minimal weight and are calculated to be sufficient for the maximal power needed by Ægir. The maximum voltage drop over the 24-meter tether is calculated to a maximum of ≈ 6.7 V, which means the minimal operating voltage will be 41.3 V assuming the nominal 48 V from the power supply. The cut-off voltage of the on-board power converters is 36 V, which gives us a 5.3 V margin for fluctuations and inaccuracies in the power supply. It's been used a CAT5e UTP flexible cord for communication to the IP-camera. CAT5e was chosen due to its cost, flexibility and high ability to transfer data; which was necessary for streaming the IP-camera video feed. (Delta Electronics u.d.) (Huang 2003)

b) Power Distribution

The power in Ægir is delivered through a circuit board, as in Figure 12, specifically designed for this ROV. The inlet cable is connected to the board and main fuse 17 cm from the power supply attachment point. The inlet power is converted to 5 and 12 Volt via 3 DC/DC converters. All subsystems have individual fuses. The fuse for each component is calculated after the components maximum current draw as in Table 1.

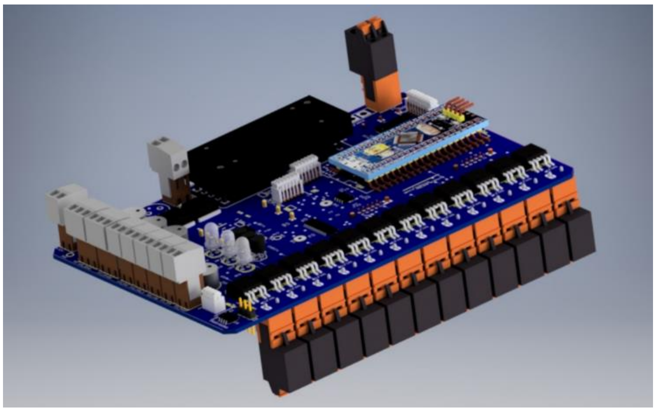


Figure 12: Power distribution circuit board

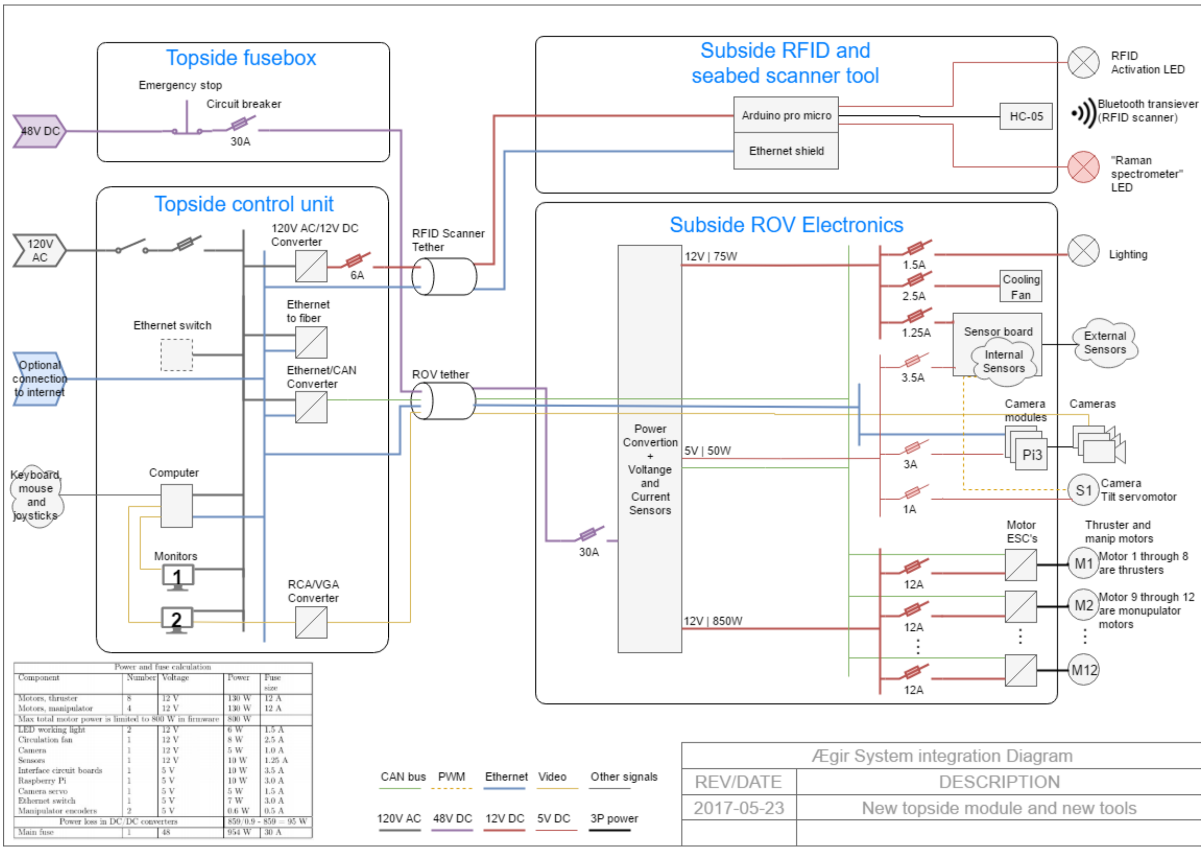
Table 1: Overview over the different fuses used for subsystems in Ægir

Power and fuse calculation				
Component	Number	Voltage	Power	Fuse size
Motors, thruster	8	12 V	130 W	12 A
Motors, manipulator	4	12 V	130 W	12 A
Max total motor power is limited to 800 W in firmware			800 W	
LED working light	2	12 V	6 W	1.5 A
Circulation fan	1	12 V	8 W	2.5 A
Camera	1	12 V	5 W	1.0 A
Sensors	1	12 V	10 W	1.25 A
Interface circuit boards	1	5 V	10 W	3.5 A
Raspberry Pi	1	5 V	10 W	3.0 A
Camera servo	1	5 V	5 W	1.5 A
Ethernet switch	1	5 V	7 W	3.0 A
Manipulator encoders	2	5 V	0.6 W	0.5 A
Power loss in DC/DC converters			859/0.9 - 859 = 95 W	
Main fuse	1	48	954 W	30 A

c) Communications

The communication, except for the camera video-feed, has been realized by using the CAN-bus standard that is based on broadcasting messages. Subsystems on the network then use a hardware filter to sort out the identifiers relevant to that specific subsystem. This type of communication makes it possible to easily connect and disconnect subsystems while the system is running. Controller output from the Xbox-controller at the surface is routed over to the CAN-bus network. Similarly, all sensor data sent up via CAN-bus is transmitted over Ethernet to the surface system where the values are displayed for the operator. The communication system is shown in Table 2.

Table 2: System integration diagram (SID)



Power and fuse calculation				
Component	Number	Voltage	Power	Fuse size
Motors, thruster	8	12 V	130 W	12 A
Motors, manipulator	4	12 V	130 W	12 A
Max total motor power is limited to 800 W in firmware			800 W	
LED working light	2	12 V	6 W	1.5 A
Circulation fan	1	12 V	8 W	2.5 A
Camera	1	12 V	5 W	1.0 A
Sensors	1	12 V	10 W	1.25 A
Interface circuit boards	1	5 V	10 W	3.5 A
Raspberry Pi	1	5 V	10 W	3.0 A
Camera servo	1	5 V	5 W	1.5 A
Ethernet switch	1	5 V	7 W	3.0 A
Manipulator encoders	2	5 V	0.6 W	0.5 A
Power loss in DC/DC converters			859/0.9 - 859 = 95 W	
Main fuse	1	48	954 W	30 A

d) Testing and trouble shooting

The team started the process for troubleshooting by identify the problem and divide it into subproblems for the different components. On background of the weight- and size-requirements from the competition manual, the team discussed different materials and did strength calculations for the different materials.

It was made changes on several components to meet the challenges of «port cities of the future». To avoid problems that could occur, new components like pod, camera house, thrusters were exposed for tests to determine their behavior in water, stability and its functionality.

In addition to Ægir being small and have a low weight, it was desirable to get the highest performance out of the thrusters. This included proper testing of different types of 3D printed thrusters, where the propellers had different blades and pitch. It was also done tests for the shrouding on a self-made test bench to find the propellers that gave the best thrust.

The electronic housing was vacuum tested on a depth of 4 meter in a pool, to create a simulated pressure. In addition to this, both pod and camera house were tested through simulation.

3. Safety

3.1 Safety philosophy

At UiS Subsea, safety is top priority. This company follows a zero tolerance approach when it comes to serious 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.

3.2 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.

3.3 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.

Electrical

The electrical components are protected with fuses. These are dimensioned according to operating currents. 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.

Figur 13: Strain-relief to protect the tether.

3.4 Safety checklists

Pre-launch

1. Personal safety equipment ON

2. Ensure that all O-rings are in place, undamaged and properly greased

3. Ensure that no bulkhead connectors are loose

4. Check that all locking sleeves are tightened in place

5. Ensure that the blind plug is fastened tight

6. Check that the electronics housing is fastened

7. Check that all horizontal thrusters are properly fastened with clevis pins

8. Check that all propellers are fastened in place

9. Hands ROV before turning power ON

10. Control voltage level and current limiting of power supply if applicable

11. Control status indicator LED's

12. 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

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 Ægir
5. Keep Ægir calmly under water for 10s, check for bubbles
6. Pull Ægir up from water. Inspect waterproof housings for leakages
7. Tether assistance ready
8. Slowly launch Ægir

Post-launch

1. Power OFF and wait for 5 seconds
2. Pull Ægir up
3. Check for major damages
4. Rinse ROV with fresh water

4 Project Management

4.1 Scheduling

A Gantt chart was created at the beginning of the project with start and deadline of each process. A Gantt chart, such as the one illustrated in Figure X1, gave the team a simple way to record their progress. More detailed Gantt charts for each project processes, i.e. Production of Parts, were also created. The initial project plan illustrated in Figure 14 were produced by the project manager in close collaboration with the department chiefs. This to secure a viable estimation of the project duration.

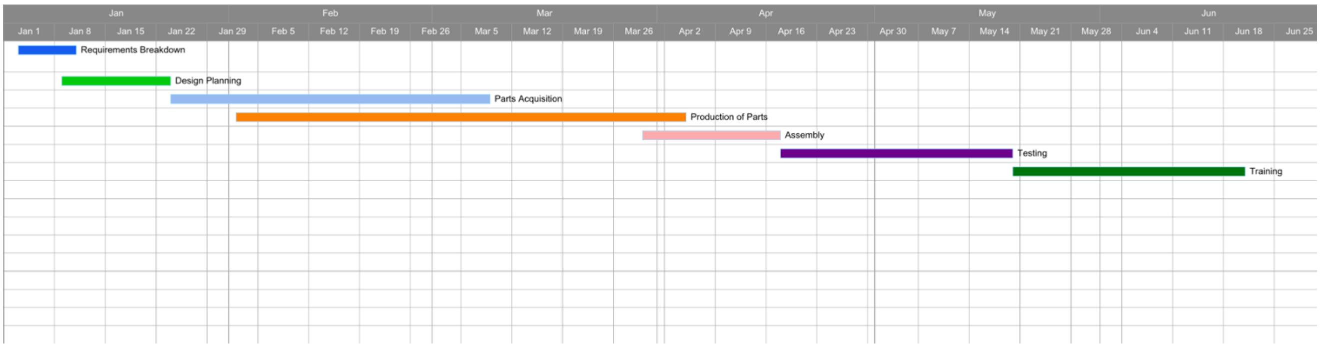


Figure 14: Gantt chart of main UiS Subsea Project Processes

To ensure that project progress was according to the initial plan, project manager arranged meetings every Monday. These meetings summed up the previous week and stated what had to be done in the coming week. If there had to be done changes to the initial plan in Figure 14, new deadlines were added. However, UiS Subsea maintained their initial plan and had a successful unveiling in late April.

4.2 Organizational structure

UiS Subsea as an organization is divided into departments including Senior Management, Project Management, Mechanical Engineering, Electrical Engineering and Computer Science. The organizational structure is illustrated in Figure 15. The project manager act as a link between Senior Management and the ROV team. Each sub-department within the ROV team has a functional leader who are reporting to the project manager.

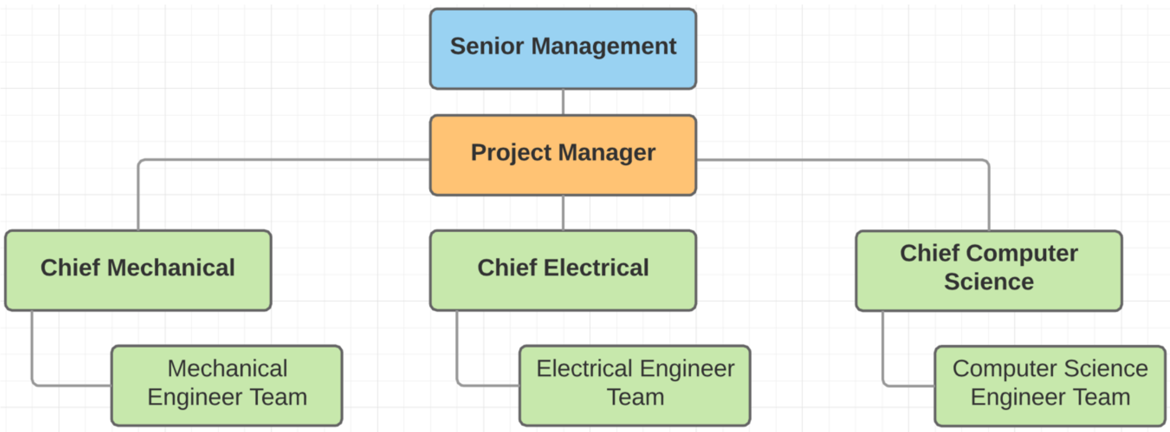


Figure 15: UiS Subsea Organizational Structure

In addition to maintaining the project relative to the schedule in Figure X1, project manager had close collaboration with the chief of economics in the senior management. In this way, the ROV project held its expenditures within budget.

However, it is important to emphasize that the UiS Subsea ROV team do not possess a strong hierarchically organizational structure. To ensure project improvement and cross-functional collaboration all team members were located in the same room for the entire project duration. In this way, UiS Subsea could ensure a flow of knowledge and experiences across departments through communication in an innovative environment. This would again increase the overall skills of team members and lead to continuous improvement of future UiS Subsea projects as they will be able to contribute with knowledge and experience to future ROV teams. Without continuous improvement and flow of experience and knowledge, a project like UiS Subsea is not sustainable.

4.3 Budget and project costing

The management prepared an estimated project cost based on last year's performance. The team looked at what could be improved and added to adapt to the new mission tasks. Travel expenses have a tendency to fluxuate from year to year, and it is often not possible calculate later in the development. With this year's travel expenses being about $3'600 lower, the team prioritized spending more on the ROV. This year's team focused more on upgrading the cameras and adding an overall more sophisticated electrical equipment to the vehicle.

The budget was estimated based on the donations from the University of Stavanger and the official sponsors. See Table 3 for the complete budget list. The spending was kept track by entering the receipts on a Project Costing sheet, see Table 4. The result is a better ROV while staying within the budget.

Table 3: Budget for Ægir

Budget ROV 2017 (1 NOK = 0.12 USD)	$22 386,60
Budget ROV 2017 (NOK)	**kr 186 555,00**
Manipulator	
Description	**Estimated cost (NOK)**
Motors	kr 1 245,00
Gears	kr 1 500,00
ESC	kr 1 500,00
Housing	kr 800,00
Sum	**kr 5 045,00**
Electronics	
Description	**Estimated cost (NOK)**
Microcontrollers	kr 2 000,00
Sensors	kr 1 500,00
DC/DC main	kr 3 520,00
Power distribution	kr 1 500,00
Cameras	kr 3 000,00
PCB production	kr 5 000,00
CAN-converter	kr 1 500,00
Sum	**kr 18 020,00**
Thrusters	
Description	**Estimated cost (NOK)**
ESC	kr 7 490,00
Motors	kr 4 150,00
Sum	**kr 11 640,00**
Travel	
Description	**Estimated cost (NOK)**
Air fare	kr 110 000,00
Hotel	kr 20 000,00
Transport, ROV	kr 5 000,00
Sum	**kr 135 000,00**
Production	
Description	**Estimated cost (NOK)**
Coffee	kr 1 000,00
Frame-materials	kr 1 500,00
Electronics Housing	kr 1 250,00
O-rings	kr 1 500,00
Buoyancy	kr 2 500,00
Sum	**kr 7 750,00**
TCU	
Description	**Estimated cost (NOK)**
PC	kr 7 000,00
Tether	kr 1 000,00
TCU-case	kr 1 100,00
Sum	**kr 9 100,00**

Table 4: Project Budget and Costing UiS Subsea 2017

Field	Item	Description	Type	Qty	Cost (NOK)	Total (NOK)
Mechanical	O-rings	Connectors and housings	Purchased	1	kr 1 000,00	kr 1 000,00
	Connectors	Subconn Connectors	Donated	24	kr 1 500,00	kr 36 000,00
	Bearings	Stainless SKF W-series bearings	Donated	31	kr 150,00	kr 4 650,00
	Picatinny rails		Purchased	4	kr 50,00	kr 200,00
	Gears	Delrin: Worm and spur	Purchased	10	kr 100,00	kr 1 000,00
	Timing pulley and belt	Syncroflex belt, aluminium pulley	Purchased	3	kr 75,00	kr 225,00
	Leadscrew	Tr8x1.5 Screw, Flanged nut	Purchased	2	kr 300,00	kr 600,00
	Linear rail	Low profile, lubrication free	Purchased	2	kr 210,00	kr 420,00
	Thruster duct	3D-printed	Donated	8	kr 250,00	kr 2 000,00
	Propellers	3D-printed	Purchased	8	kr 200,00	kr 1 600,00
	Supports	3D-printed	Donated	6	kr 80,00	kr 480,00
	Clear Epoxy	Loctite 3430	Purchased	1	kr 285,00	kr 285,00
	Thermal Conductive Epoxy	MG Chemicals 832TC	Purchased	1	kr 1 500,00	kr 1 500,00
	Fasteners	Stainless A4: Nuts, Bolts, Clevis pins	Purchased	1	kr 500,00	kr 500,00
	O-ring grease	Molykote 44 Medium	Purchased	1	kr 400,00	kr 400,00
	Strain relief	Aramid	Purchased	2	kr 200,00	kr 400,00
	Tether sleeving	PVC 30m	Purchased	1	kr 300,00	kr 300,00
Materials	Aluminum	6082-T6 Channel, Billet, Sheet	Purchased	1	kr 1 800,00	kr 1 800,00
	Acryl tube	Ø200, Ø120, Ø24	Purchased	3	kr 150,00	kr 450,00
Labour	Welding		Donated	1	kr 1 000,00	kr 1 000,00
	Water-jet cutting		Donated	1	kr 500,00	kr 500,00
Electronics	Custom PCB		Purchased	2	kr 400,00	kr 800,00
	DC/DC converters		Purchased	4	kr 700,00	kr 2 800,00
	STM32 microcontroller		Purchased	2	kr 80,00	kr 160,00
	LED Diodes		Purchased	2	kr 55,00	kr 110,00
	Tether cables		Purchased	25	kr 40,00	kr 1 000,00
	Raspberry Pi +PiCam		Purchased	1	kr 450,00	kr 450,00
	Electronic Speed Controllers		Purchased	12	kr 1 000,00	kr 12 000,00
	Misc. parts for custom PCB		Purchased	1	kr 2 500,00	kr 2 500,00
	Motors for thrusters		Purchased	8	kr 120,00	kr 960,00
	Motors for manipulator		Purchased	4	kr 360,00	kr 1 440,00
	Encoders for manipulator		Purchased	2	kr 430,00	kr 860,00
	Ethernet switch		Purchased	1	kr 920,00	kr 920,00
	Cables and cable assembly		Purchased	1	kr 500,00	kr 500,00
	Cooling fans		Purchased	2	kr 110,00	kr 220,00
Topside	Computer		Re-used	1	kr 4 000,00	kr 4 000,00
	Xbox Controller		Re-used	2	kr 350,00	kr 700,00
	Monitor		Re-used	1	kr 920,00	kr 920,00
	CAN-bus converter		Donated	1	kr 800,00	kr 800,00
	Ethernet switch		Re-used	1	kr 500,00	kr 500,00
	TCU-case		Re-used	1	kr 500,00	kr 500,00
Total	Vehicle expenses					kr 87 450,00
Total ROV	Vehicle expenses	USD (1 NOK = 0.12 USD)		0,1	kr 87 450,00	**$10 494,00**
Travel	Airplane tickets (9 persons)					kr 82 040,00
	Shipping ROV	Estimated				kr 5 000,00
	Lodging					kr 11 000,00
Total						kr 98 040,00
Total Travel		USD (1 NOK = 0.12 USD)		0,1	kr 98 040,00	**$11 764,80**
Total Cost						**$22 258,80**

5. Conclusion

5.1. Challenges

Technical

During the MATE competition in 2016 there was an issue with Ægir where the camera connection was lost. This occurred because one of the leads in the ethernet cable had a bad connection. All cameras were connected through this ethernet cable. This led to a position where the pilot was unable to see any of the camera feeds. The solution to this problem was to replace the ethernet cable, and as a safety measure, add a backup camera for redundancy, where the camera feed is fed through a separate cable in the tether. This was done such that the company has a working plan to work around this problem if it occurs again.

Non-technical

Every year UiS Subsea creates a new ROV for the annual MATE competition, since 2014. This requires a team of software, mechanical and electrical engineers. This year the company were unable to attract enough new people which made us lack electrical engineering students. Without any such students, the possibility to create a new ROV was not reasonable. After failing to engage enough electrical engineering students, the company decided to focus on and improve last year's ROV, Ægir, for this year's competition.

5.2. Lessons learned and skills gained

The UiS Subsea company learned how important to have some redundancy in the system, especially around the critical parts. This makes the team able to continue working through some non-fatal problems. It is more time consuming to try and fix a problem while doing a job, rather than using a backup and then fixing the problem after the job is finished.

The team also gained valuable experience working and cooperating with engineering students from other fields. This experience has given the company great teamwork, and made us good at distributing the workload evenly.

5.3. Future improvements

During the testing of the work for the contract, it showed the necessity to increase Ægir's front camera FOV. This became apparent for turning of Ægir as it got difficult to see what was coming while turning. For the manipulator, it is planned to add a third DOF where it can turn downwards. This will be hindered by the camera FOV which will make the pilot unable to see where the manipulator is pointed. To fix this issue the company can use a wide-angle lens on the front camera, which will distort the view and increase the FOV. The company can also use an aspheric lens on the front camera to only distort the outermost part of the camera feed. Lastly the company can add movement functionality for the camera to be able to control the direction of the camera.

UiS Subsea should see this opportunity to create a ROV for the MATE competition as more than creating technology just for the competition. The focus from UiS Subsea should be more focused on developing new technology for a real-world application.

5.4 Reflection

UiS Subsea's number one goal is to promote knowledge and experience about underwater robotics at the University of Stavanger. Since our first participation four years ago, UiS Subsea have facilitated interdisciplinary collaboration through exciting and innovative working environments for its members. This year's ROV project has been different compared to earlier projects, demanding another way of problem solving. For the first time in UiS Subsea's history we had the possibility to improve a ROV from one year to another.

“First of all I would like to thank MATE for hosting the competition which allows us to compete in such a challenging and educational environment. This is my second year as mechanical chief at UiS Subsea, and the challenges faced during this project has been quite different compared to last year. For the last six months, I have worked as a mentor for the newest members at UiS Subsea. This includes training in the mechanical features of the robot and how to build the new tools necessary for this year’s competition. As a mentor I have gained knowledge in how to motivate and encourage team members. And how to organize project processes according to plan.”

Simen Pedersen, Chief Mechanical UiS Subsea 2017

“This is my first year at UiS Subsea, and after intense work the last six months there is no doubt that this is an experience that will be beneficial in the future. Skills within engineering, product development, team work and interpersonal collaboration are all thanks to this project. I hope that UiS Subsea will continue to give students the possibility to engage in projects like this as it is such a remarkable experience.”

Maria Dahl, team member UiS Subsea 2017

6 References

Delta Electronics. n.d. "Delphi Series." Accessed 03 15, 2017. http://www.deltaww.com/filecenter/Products/download/01/0102/DS_V36SE05010_03032011.pdf.

Huang, Han-Way. 2003. *MC68HC12 an Introduction: Software and Hardware Interfacing.* United States.

MATE COMPETITION MANUAL. 2017. "marinetech." Accessed 2017. marinetech.org.

7 Appendix

A. Software

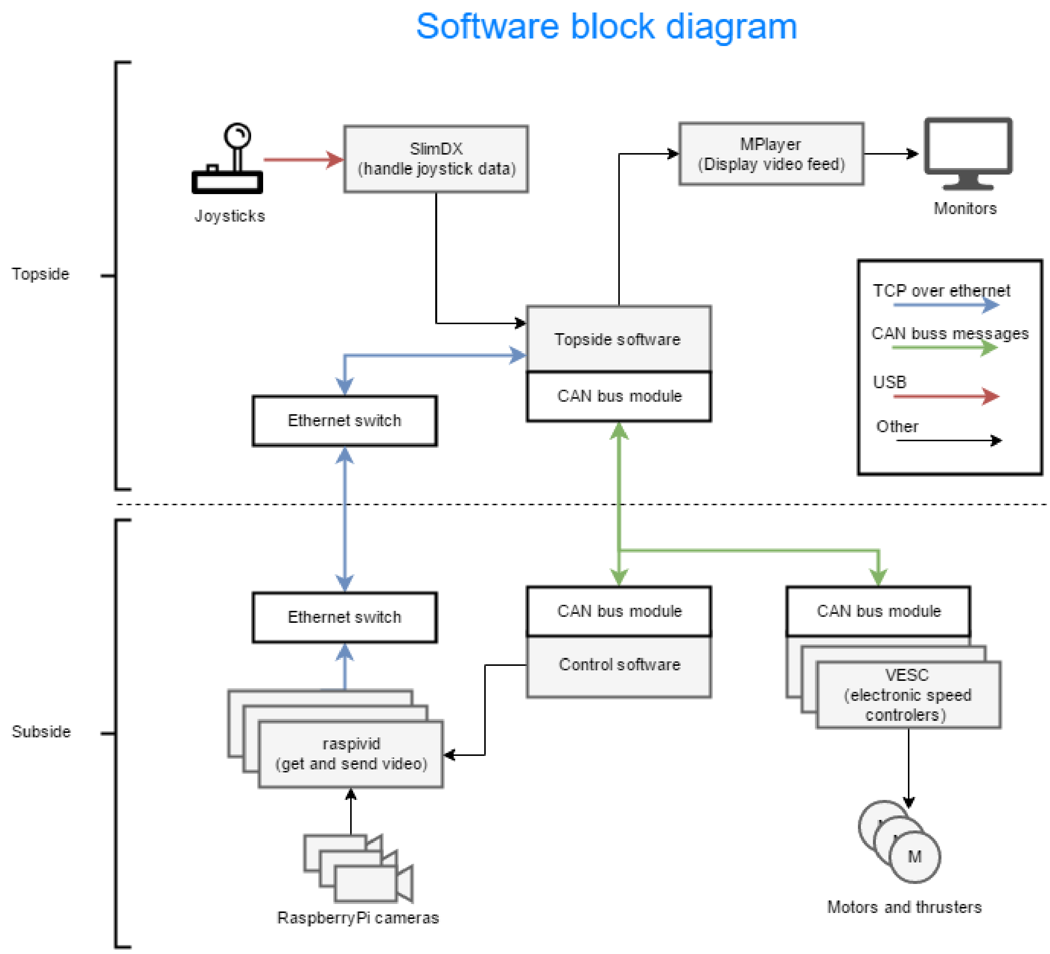


Figure 10: Software Block Diagram

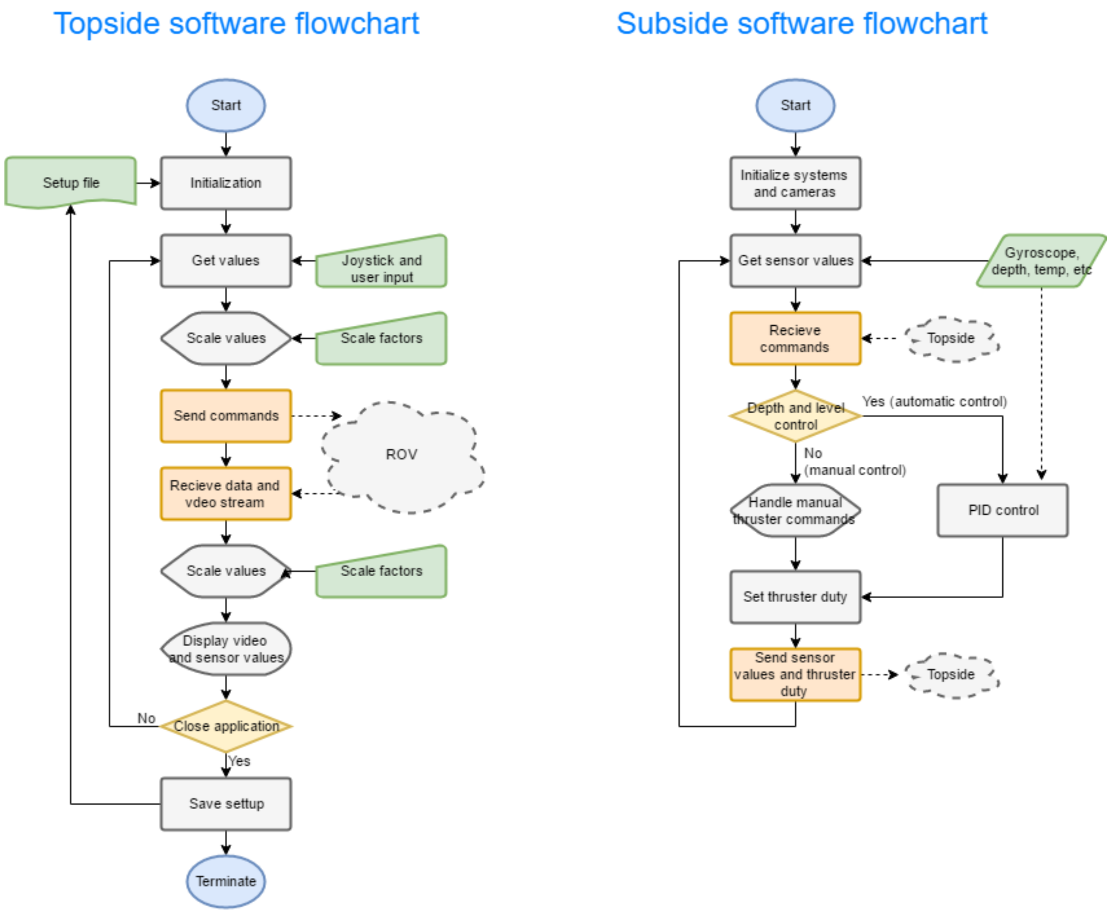


Figure 11: Software flowcharts