NEWCASTLE UNIVERSITY
ENGINEERING PROJECTS SOCIETY

Newcastle University

MATE INTERNATIONAL ROV COMPETITION 2019
EXPLORER CLASS

NEWCASTLE UNIVERSITY
NEWCASTLE UPON TYNE, UNITED KINGDOM

NUROVERS PRESENTS
GRU+STUART
A TECHNICAL REPORT

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1. ABSTRACT

NUROVers is a small emerging company, established as a corporate spin-off of the Newcastle University Engineering Projects Society. As a society comprising enterprising engineers and computer scientists of varying disciplines, this arm was set up to cater to the increasing demand for underwater vehicles. Facing competition from well-established enterprises across the globe, the company embraces the challenges of breaking into the market – relishing the spirit of adventure in the quest to enter the field. This work ethos and resilient spirit is the very embodiment of NUROVers, reflecting the new yet driven team.

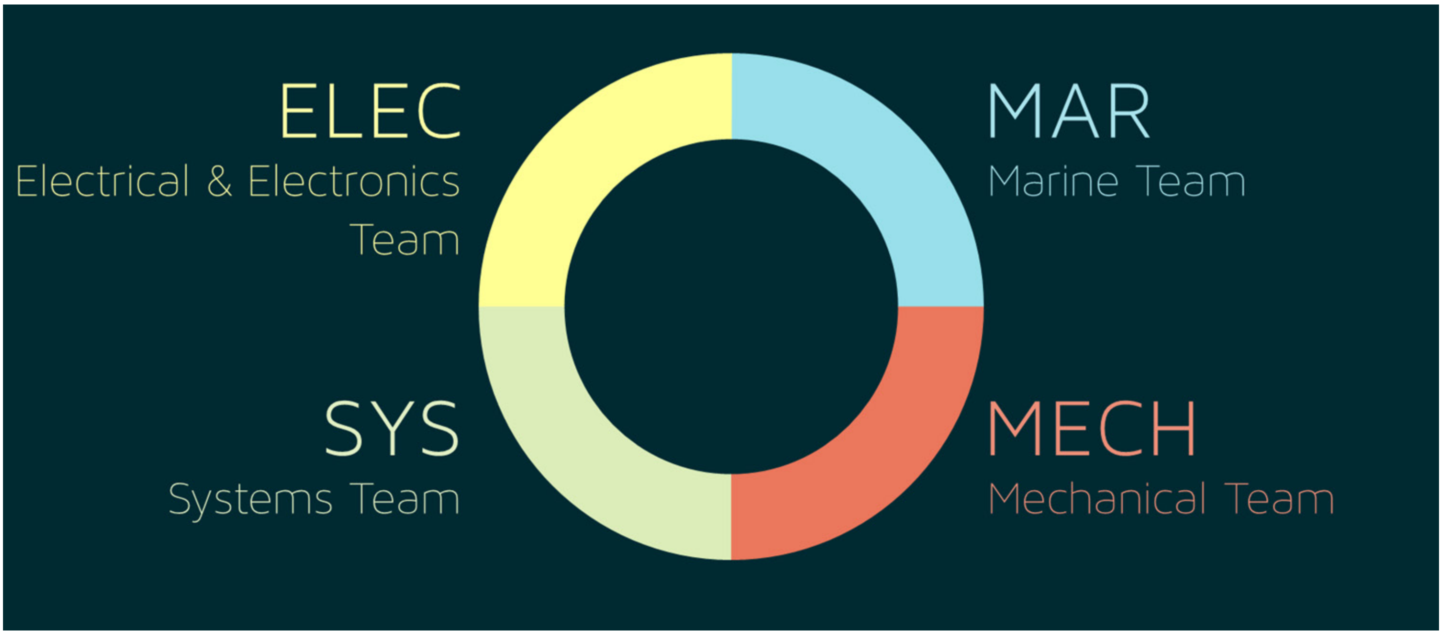
In the first operating year, NUROVers has decided to respond to Eastman's Request for Proposals (RFP) to design and build a Remotely Operated Vehicle (ROV), intended for freshwater operations within Tennessee. The team's work has culminated in the production of GRU+STUART, an ROV coupled with a Micro-ROV capable of a series of tasks such as the inspection & repair of dams, maintaining healthy waterways, as well as preserving history by lifting a cannon.

This document will outline details of the NUROVer's efforts, the design philosophy as well as the rationale behind decisions made.

2. COMPANY OVERVIEW

2.1 ROLES & STRUCTURE

NUROVers comprises 4 divisions – Electrical, Marine, Mechanical, and Systems – with each sub-team leading the design on their respective area of the ROV. All divisions report to the executive branch: responsible for managing the overall project timeline and budget. To help with project control, divisional decisions - including but not limited to design and component procurement - are approved by the executive before proceeding with the build. Working independently yet in unison allows the respective units to concentrate on relevant tasks, bringing the vehicle design to a higher level while allowing for effective management.



2.2 PROJECT MANAGEMENT

With four separate teams to work on the different aspects of the ROV, inter-team coordination would be vital. In order to achieve this, regular meetings were held between the executive committee and the team captains to discuss updates, issues, as well as how the team should move forward in order to stay on track with deadlines. At a lower level, members of different teams would attend each other's meetings where their knowledge would be paramount in the design of an effective ROV as often certain parameters of one team would put constraints on another, for instance choosing an arm motor which would provide the required torque to complete the task but not be too heavy or require too much power to operate.

2.3 SUB-TEAM MANAGEMENT (CASE STUDY: SYSTEMS)

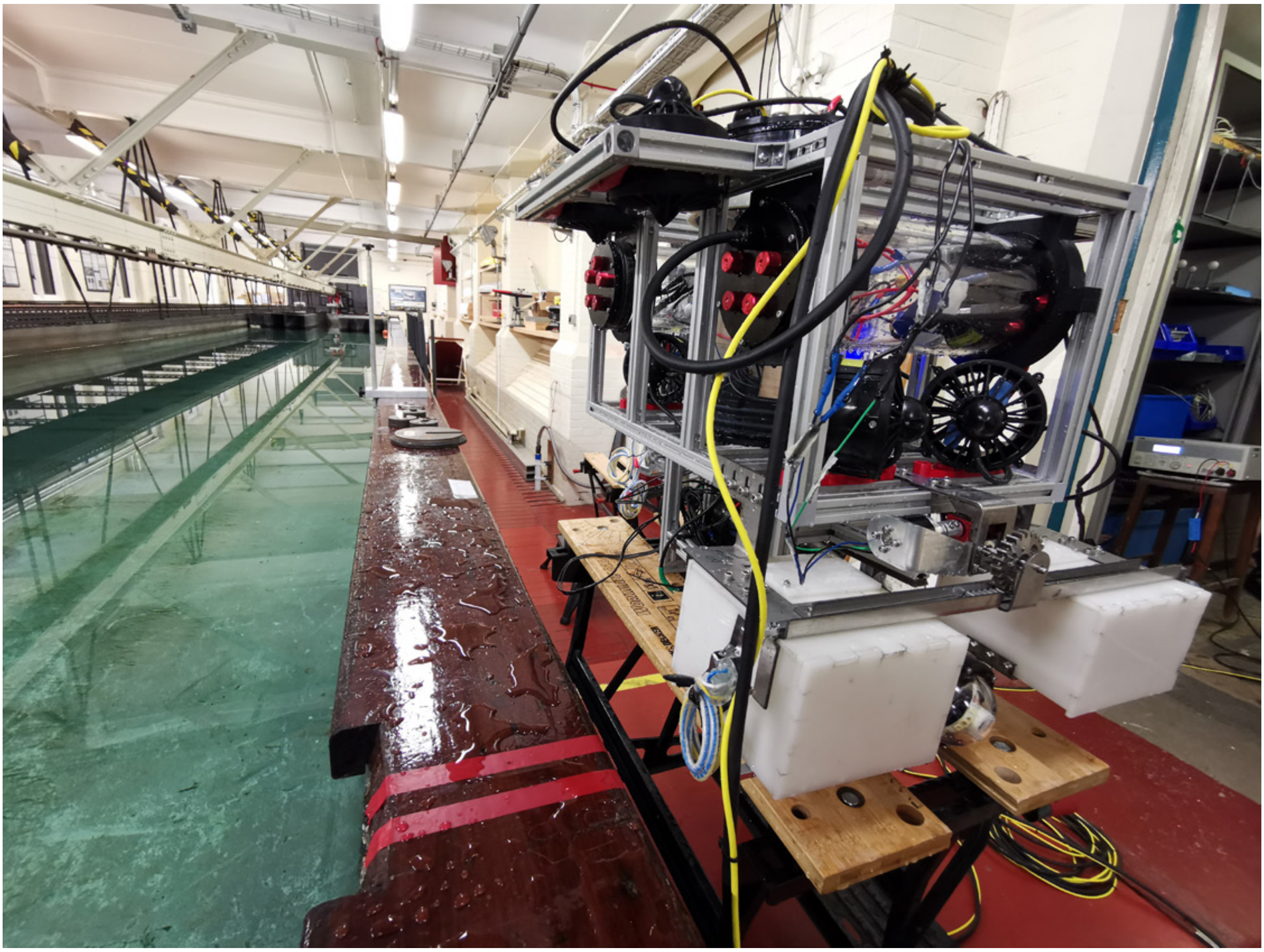
There was a strong organisation element to the project management level of the Systems team. When organising the team, it was decided that the Vice- Captain of the Systems team would arrange meetings, distribute tasks, and keep team morale high, so everyone could work to the best of their ability.
There was a spread of skills within the Systems team. As many members brought previous knowledge and interests to the team, they joined a Sub-Team using their particular skills. Each member was given the choice of which Sub-Team to join, and they chose the one they felt most suited to. Some examples of the sub teams were: Low level, High level, and Graphical User Interface (GUI). Each Sub-Team had its own tasks that were set using Trello (a web based, list making application) and team members could document what they were doing and when. New tasks were set to members based on these teams, although if a team member believed they could complete a task outside of their Sub-Team they were encouraged to complete it for the team. The team communicated via Microsoft Teams, a Microsoft app that allows the creation of groups of people, with the possibility of members posting and commenting on these posts. Meetings were arranged weekly, to allow all members to contribute, with the times and locations posted on Microsoft teams. The agenda was created by the Captain and minutes were taken by the Vice-Captain. These meetings allowed all members to discuss that week's tasks, any issues they were having, and what needed to be done in the future, along with any discussions with other teams that were needed. These meetings were positive as they allowed an open communication between all Sub-Teams. Any questions or issues between meetings were to be directed at either the Captain or Vice-Captain.

3. DESIGN RATIONALE

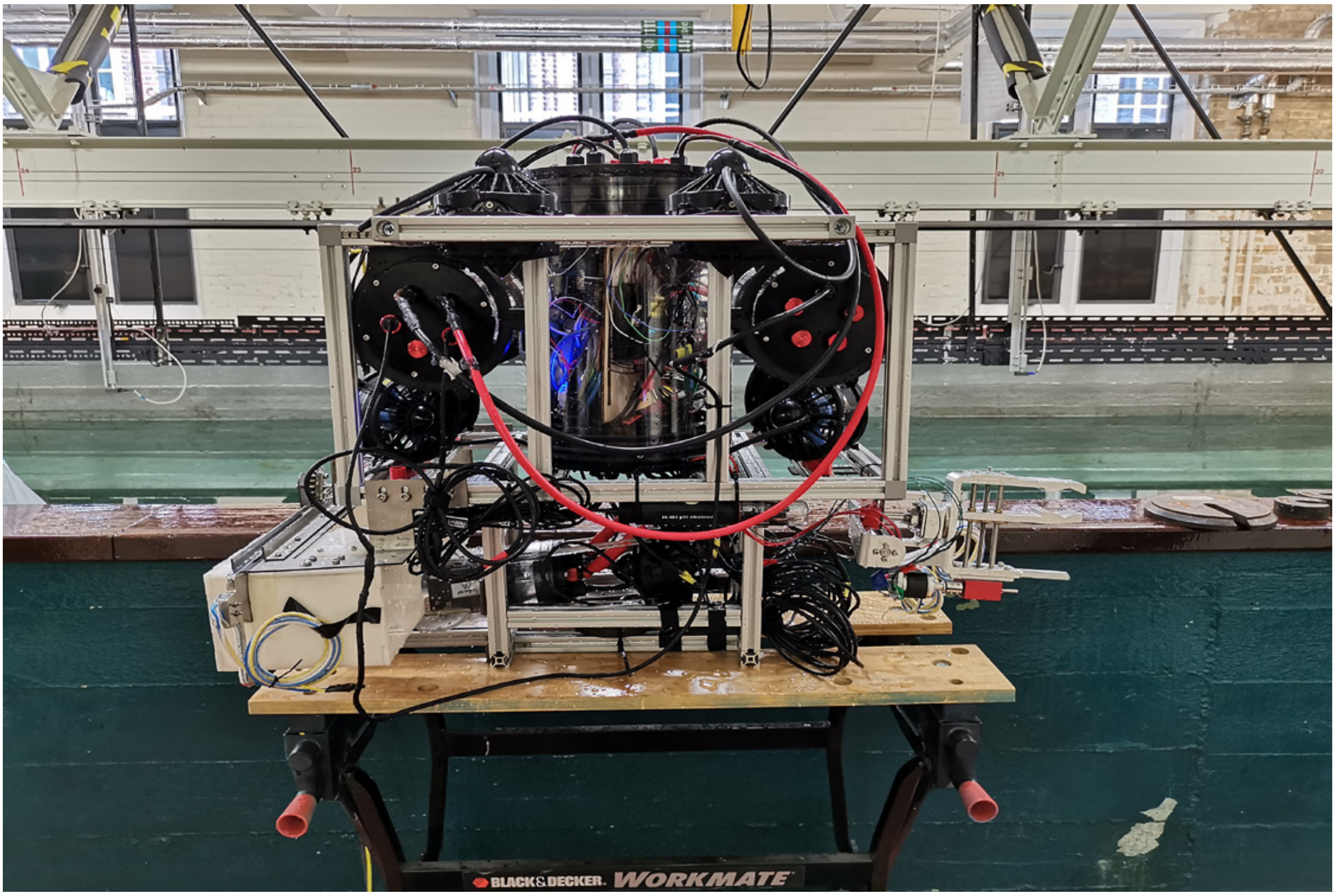
The primary challenge in settling on a design rationale was the dilemma of buy vs make. As a fresh start-up, NUROVers sees itself as a systems integrater. An evaluation was conducted and it was determined to be significantly more cost-effective (in terms of both monetary and man-hours) to procure parts from specialist manufacturers. This allows for significantly cheaper parts to be obtained (as compared to the effort required to self-design efficient components such as thrusters) while also ensuring the overall effectiveness of the ROV. This is in line with the modus operandi of many shipyards worldwide, functioning as systems integration firms whom bring together parts from various suppliers to produce a vessel. However, to effectively tackle the unique challenges posed, NUROVers has also adopted a policy to custom build and design in-house solutions - where commercial Off-The-Shelf alternatives are not easily available - such as for the ROV frame and the power converter

3.1 FLEXIBILITY

Another point of the NUROVers design rationale is to keep the ROV as adaptable as



possible in to overcome challenges as they arise with ease, be it during the competition or even during the design phase. One example of this was the central cylinder which houses the bulk of our electronics turning out to be too small to practically hold all of the electronics and so a larger one was bought. Since the team opted to have a frame base for our ROV , it was a simple case of altering the frame slightly to accommodate the larger cylinder so no major redesign was required. An effort was also made to keep components as standard as possible. For instance, the motors that are used in the mechanical gripper are the same motors that drive the thrusters, allowing for fewer spares and hence reducing costs. Keeping the ROV adaptable also allows for easy modification to take on new tasks and challenges without the need for a complete redesign. Throughout the design process, the team kept referring to the hydrostatics of the ROV - ensuring that the components used are not too heavy resulting in the ROV being negatively buoyant, nor too light such that the ROV becomes positively buoyant; both of which would provide significant issues during operation.



4. ELECTRICAL DESIGN

This section covers systems for power transmission, conversion and distribution, actuators, control and sensors.

4.1 POWER SYSTEM

The power system is designed to deliver near the maximum permissible power of the competition rules. For conversion and distribution at 12 VDC this suggests 120A rating in the most demanding case. A short run of 16mm cable delivers to a 12 branch distribution board. This board has 12 fused branches, 11 of which support a thruster Electronic Speed Controller (ESC) rated at 25 A.

The convertor itself is an isolated, unregulated Vicor BCM3814V60E15A3C02 module, its output is rated at 130 A, with at peak efficiency of 96%. Still the module itself has substantial power dissipation and thickness of the outputs wires means it installed in its own enclosure. Its PMbus permits current, voltage and temperature, monitoring as well as limiting. This is performed while offline for diagnostic and fault checking. Additionally as this bus is unregulated with several back feeding loads in the form of thrusters, an externally mounted braking resistor allows control the bus voltage should it rise above desired outputs.

The distribution board has 11 Blue Robotics ESCv3 connected, supplying 8 T200 Thrusters and 3 M100 Motors. The ESCs at the comparatively low voltage of 12 V, have ample current to draw upon so do not lack power output. For the actuating motors, a holding gearbox is used to develop the required torque. The thrusters are used as manufactured with power management implemented in software.

Control of the numerous loads is performed by a supervisory Raspberry Pi and a pair of controlling Arduino Megas. The Raspberry Pi communicates via single twisted pair tether to the surface and via USB UART to its Arduino Mega. The choice of Arduino Megas is primarily due to their ease of programming and large array of outputs. The final branch supplies power via a point of load DC-DC regulator. Sensing is performed by a variety of appropriate sensors, some have self-supporting circuits which are accessed via bus or analogue inputs, others require interfaces built onto the shield present atop one of the Arduinos.

Connection and mounting is performed within a cylindrical enclosure. A mounting board holds larger structures in place while ESCs are routed towards their pre-planned penetrators.

4.2 FUSE SELECTION

The maximum power draw from the distribution board is calculated at: 2460W (calculations detailed in table below), the current at 48 V DC is 51A DC. SInce the competition limit is 30A, a 30 A tether fuse is hence selected.

Load	Voltage (V DC)	Current (A DC	Quantity ()	Load consumption (W)
Thruster + ARM motors	12	25	8	2400
Embedded	12	5	1	60
	Total			**2460**

5. MARINE DESIGN

5.1 BUOYANCY

The buoyancy of the main ROV is neutral with no loads attached. This is because maintaining the depth when trying to pick up items from the bed of the pool is quite a challenge, hence the neutral buoyancy. It also reduces the strain on the electronics since the thrusters do not need to be constantly operating to maintain a certain depth, instead they just need to propel the ROV to the required depth and stop afterwards. The buoyancy of the ROV comes from the three enclosures installed. The mini-ROV is positively buoyant, thus providing a situational positive buoyancy to the main ROV when docked. This is helpful in case the main ROV is unable to surface due to unforeseen circumstances, thus making the main ROV easier to salvage.

5.2 FRAME

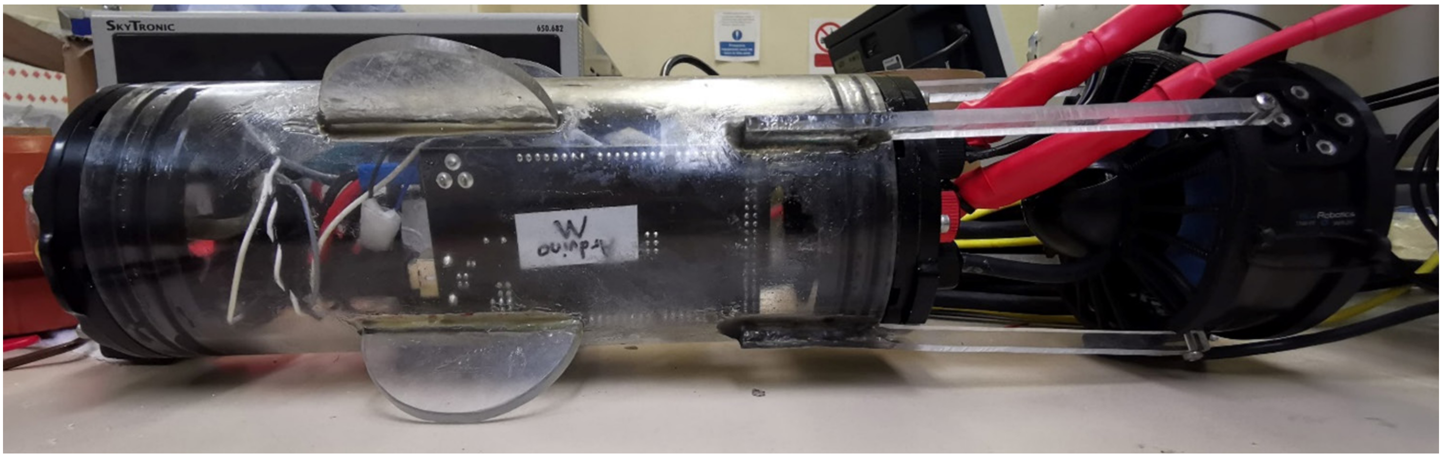
The main aim of the frame was to emphasise on a modular system, as well as the longevity of the frame. Thus, aluminium profile bars were utilised to build the entire frame. These had a mass of 0.4kg per metre length, as well as a density of 2.7g per cubic metre, making them rather lightweight. The bars were then fitted in a box like structure to maximise internal space, allowing for the installation of 3 watertight enclosures inside. As the profile bars were cross bars in nature, it allowed for the installation of multiple connectors and brackets along the bars. This meant that the frame can be fitted with various components such as the arm, 3D-printed parts, and various sensors. These components can be easily moved around as well, making the position of the loadout adjustable, thus making the frame easily customisable for various purposes, hence the modular aspect. The thrusters are mounted on the outside of the frame to form ‘wings’, allowing for more internal space. At the bottom of the frame, there is also a docking area for the mini-ROV.

5.3 THRUSTERS

There are 8 thrusters mounted on the main ROV in total, with 4 being used for vertical propulsion, and the remaining 4 for horizontal propulsion. The T200 model Blue Robotic thrusters were used for the vertical thrusters, while the T100 model Blue robotic thrusters were used for the horizontal thrusters. This is because the T200 models are more powerful compared to the T100 models, capable of generating 3.55 kg of forward force at 12 volts, compared to the 2.36 kg of force generated by the

T100 models. Vertical propulsion is placed at a higher level of importance since the ROV needs to lift and move various items around the pool area, most notably the cannon which would be the heaviest item since any item being carried by the ROV would impact its buoyancy negatively. The horizontal thrusters are each mounted at a 45-degree angle. This gives the main ROV the ability to rotate on its axis and in conjunction with all the other thrusters, the main ROV gets a full 6-degree freedom of movement. All thrusters are also covered with guards to prevent any injuries from occurring.

5.4 MICRO-ROV (STUART)



The mini-ROV comprises of an enclosure cylinder, fitted with a camera, lights, and a single T100 thruster. As the only objective required of the mini-ROV would be to explore a 6-inch diameter pipe for any defects, there is no need for any vertical propulsion and controls, since it just needs to be capable of moving forwards and backwards. It is fitted with 4 semi-circle bumpers placed in the 4 cardinal directions with respect to the cylinder. These allow for a smooth transition along the pipe, since the enclosure cylinder’s diameter is 3-inch, making it prone to getting stuck or misaligned without the bumpers.

5.5 LIFT BAG

A lift bag is strapped on the main ROV for additional buoyancy when lifting up the cannon. It has a lift capacity of 25kg, thus making it easier to lift the cannon. Air would be supplied to the lift bag via a surface pump through a pipe. As the lift bag is self-sealing there would be no leakages when pumping air in.

5.6 ENCLOSURES

There are 3 Blue Robotics enclosures installed in the main ROV, 2 of 4-inch diameter, and 1 8-inch diameter. The 4-inch diameter enclosures are used for housing the forward and rear cameras, as well as the power conversion system, whereas the 8-inch diameter enclosure is used to house all the electronics required to power the main ROV and its systems. Circular enclosures were chosen as they are able to distribute stresses and forces evenly over their surfaces. Each enclosure is composed of a few components: acrylic cylinder, 2 aluminium flanges, 2 seals for each flange, 1 O-ring for each flange, and 2 aluminium end caps. The seals and O-rings are used to prevent any water from leaking into the enclosure. Aluminium is used for the flanges and end caps in order to facilitate better heat transfer from the enclosure to the surrounding waters to create an efficient cooling system.

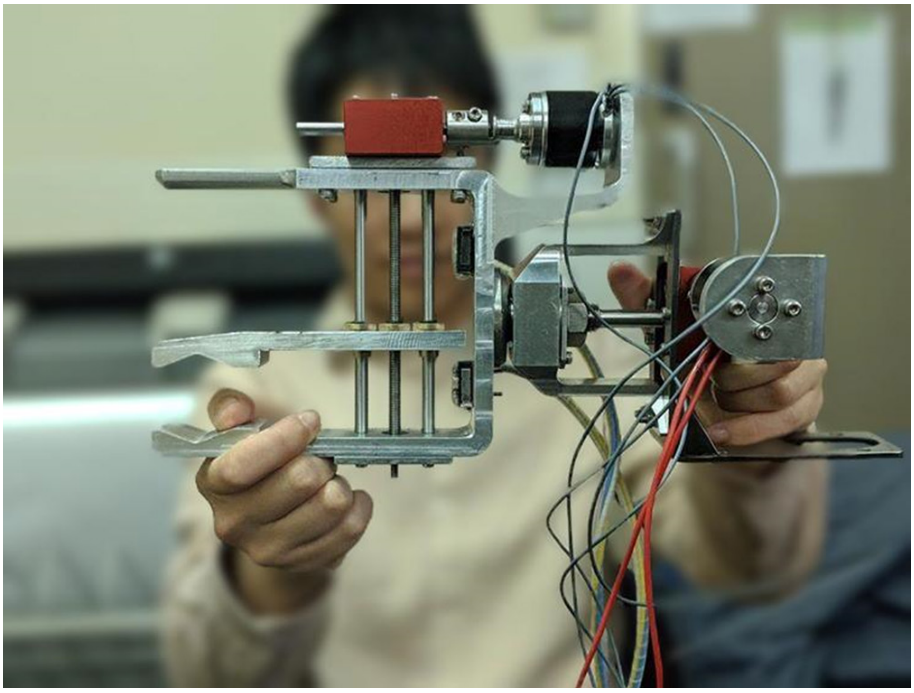
5.7 TETHER

2 types of cables are attached from the ROV to the surface, a yellow cable for data transfer, and a black cable for power. They have a length of 15m each in order to give the main ROV the freedom to roam about in the water. A strain relief device is added onto the cables in order to mitigate any strain that would occur on the cables when pulling on it. Both cables use copper inside.

6. MECHANICAL DESIGN

6.1 ACTUATOR

All the mechanisms use waterproof brushless motors, which are the same motors used in the thrusters. These motors are capable of reaching high RPMs with fair amount of torque, making them the ideal choice for their application. This choice also made the assembly, testing, troubleshooting and replacements easier. The motors are also rated to function well under extreme pressure and depth, therefore not limiting the depths the ROV can safely operate in. As this is a DC motor there is no control over its precise positions, therefore the user is incapable of having full control over its exact location and movements. To rectify this, a self holding actuation mechanism was developed, which consists of a high gear-ratio gearbox that is installed in each mechanism. Speed modulators were also installed to limit the amount of current being provided to the motors allowing them to spin at lower rpms. Limit switches were fitted in each mechanism, wherever moving parts had limiting boundaries, to make sure the operator does not damage the equipment in operation.



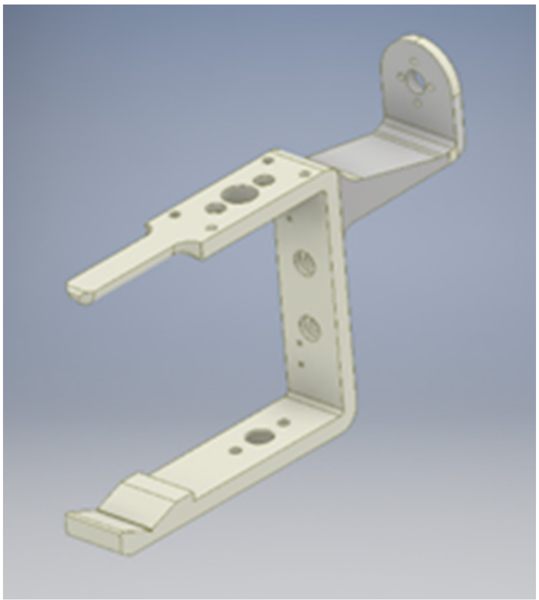
6.2 ARM AND GRIPPER

Gripper is fitted on a 1 axis robotic arm to allow rotation. For this axis, the same actuator mechanism is used. Therefore, a very slow and manageable motion of the of the gripper is possible. The gripper can hold a payload with a force of 150 N using the lead screw mechanism. The gripper and the axis mechanism can also sustain weight far greater than the ROV thrusters can lift, therefore leaving a large margin of safety. Furthermore, it is capable of holding pipes ranging from ½ inch to 3 inches and U-bolt, due to its specialized geometries. The gripper is designed to be simple, rigid, and light-weight. To make it simple and rigid, most of the joints were fused into one reducing the weight of fasteners and inaccuracies during assembly. These points are elaborated below:

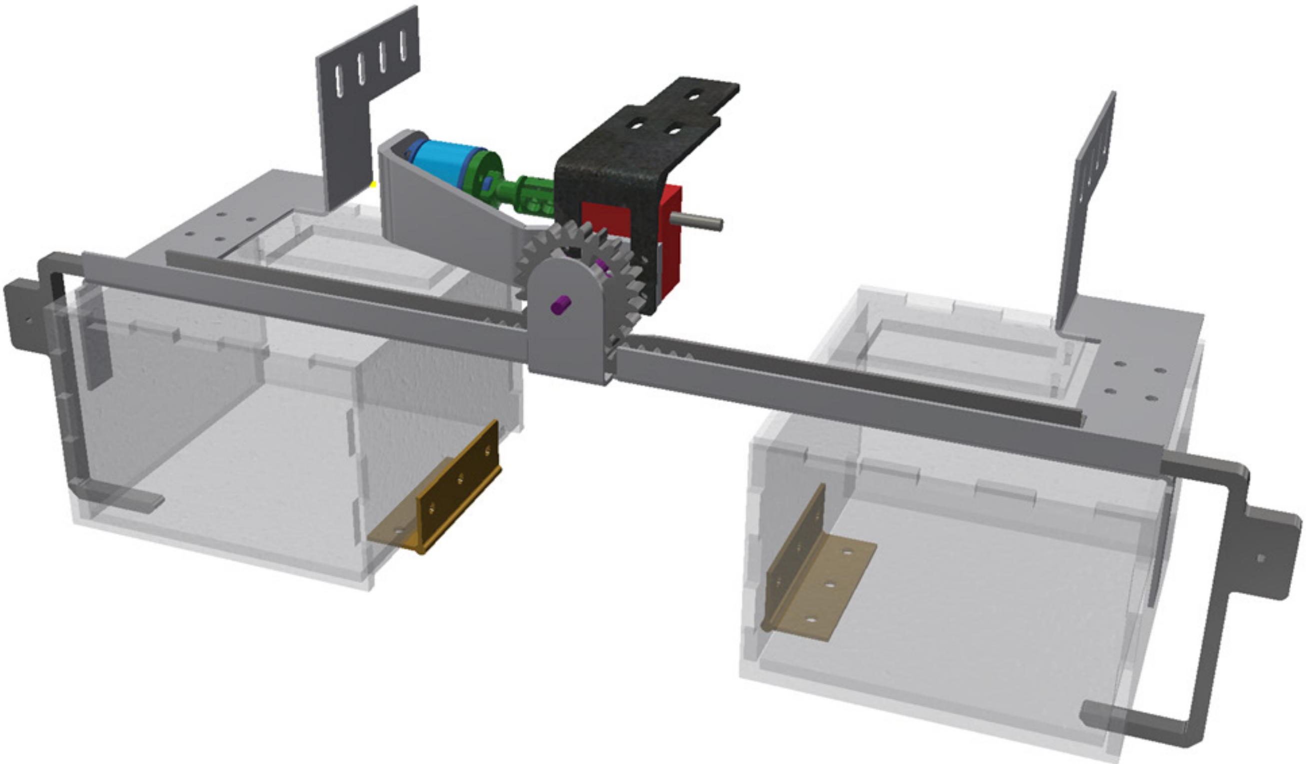
Light-weight - In the design phase of this project, special care was taken into the selection of materials, ensuring that lightweight yet high strength materials were chosen in order to minimize the gripper's effect on the ROV's centre of gravity and buoyancy. Further efforts were put in towards the design in order to remove any surfaces or sections which did not contribute to the structural integrity of the gripper.

High Strength / Rigid - The arm and the gripper were manufactured using materials like aluminium, steel and brass to increase strength. The actuator mechanism makes it possible to remove the bending stresses from the motor shaft, increasing the life of the motor and decreasing the chances of failure. This actuator mechanism also increases the strength of all the mechanisms.

Simple - The main aim for the gripper was to make it as simple as possible by reducing the amount of parts necessary, to in turn decrease the chances of failure. This was done through making the gripper mostly out of one solid part via a CNC milling machine ensuring all our dimensions were accurate and reliable. Necessary tolerances were taken into consideration throughout the design phase.



6.3 RELEASE MECHANISM



Similar to the gripper, the release mechanism was designed to be simple, yet reliable. This release mechanism is operated by a rack and pinion gear set, which can be moved in one direction to release the trout fish and then in the other direction to release the grout. This mechanism was chosen as it can independently operate 2 release boxes using only one actuator to reduce weight.

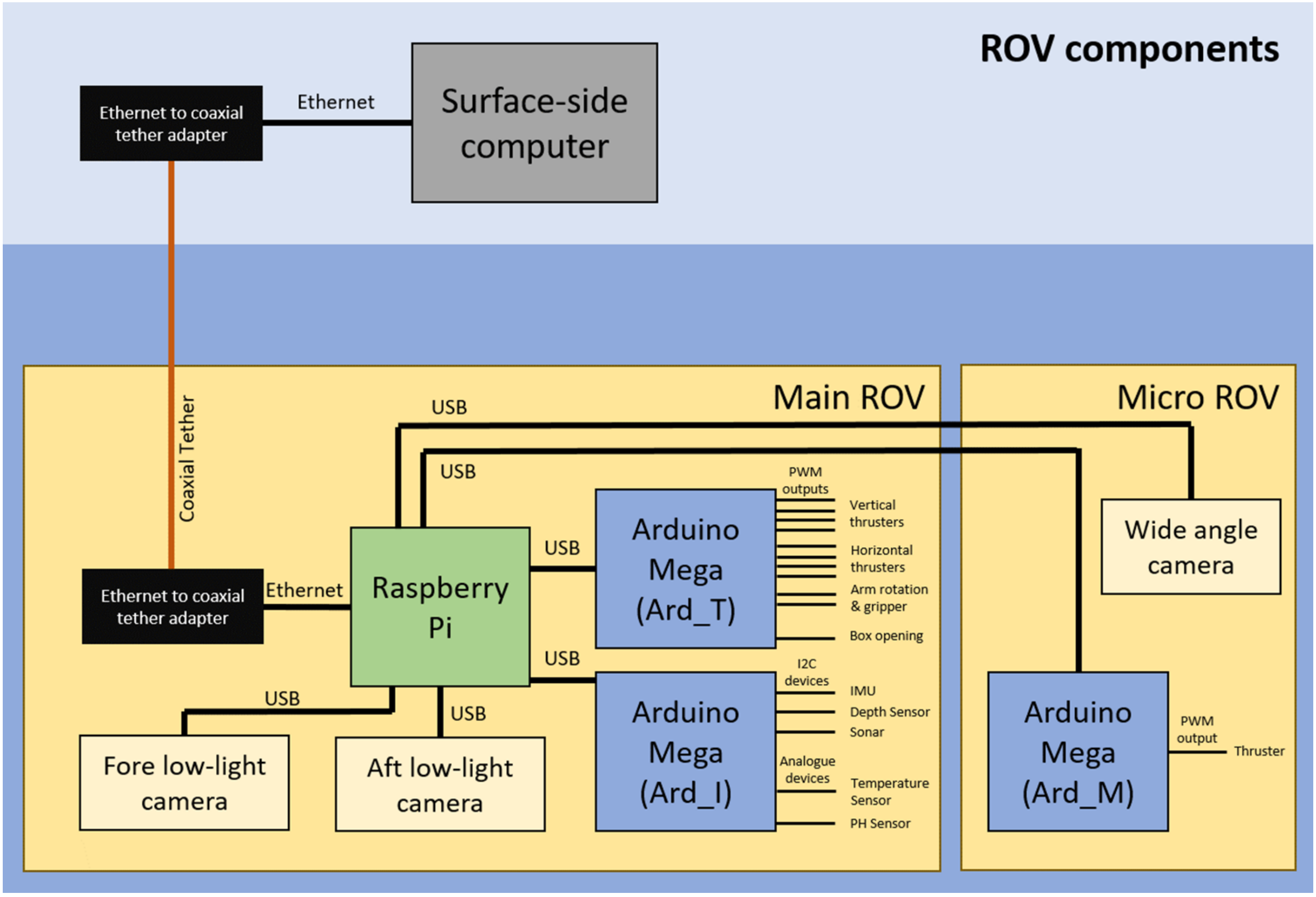
The boxes were fitted on a steel sheet metal mount which was mounted on the ROV. The boxes were made of Polypropylene Plastic (PP) as PP is light-weight, stiff enough to act as a container and can be drilled into. The rack was installed on the same sheet metal mount to operate the boxes, the actuator was fitted with the pinion gear shaft, and the pinion gear shaft connects to the same sheet metal mount to maintain the alignment between the gear set. The rack and pinion were custom made for the purpose of this project using wire cutting to ensure high accuracy.

7. SYSTEMS DESIGN

7.1 THREE-LAYER SYSTEM

The ROV consists of three control layers - the surface control station, middle-level layer and low-level components - which are connected together to create a complex software system. The code is written in Python and C++ programming languages, and is shared online using GitHub for version control.

The surface station performs the majority of computing tasks and transmits the necessary information to the middle-level software layer. It is responsible for operation of the vehicle, execution of computer vision algorithms and management of the data flowing through all components, as well as provision of a graphical user interface to track the whole process.



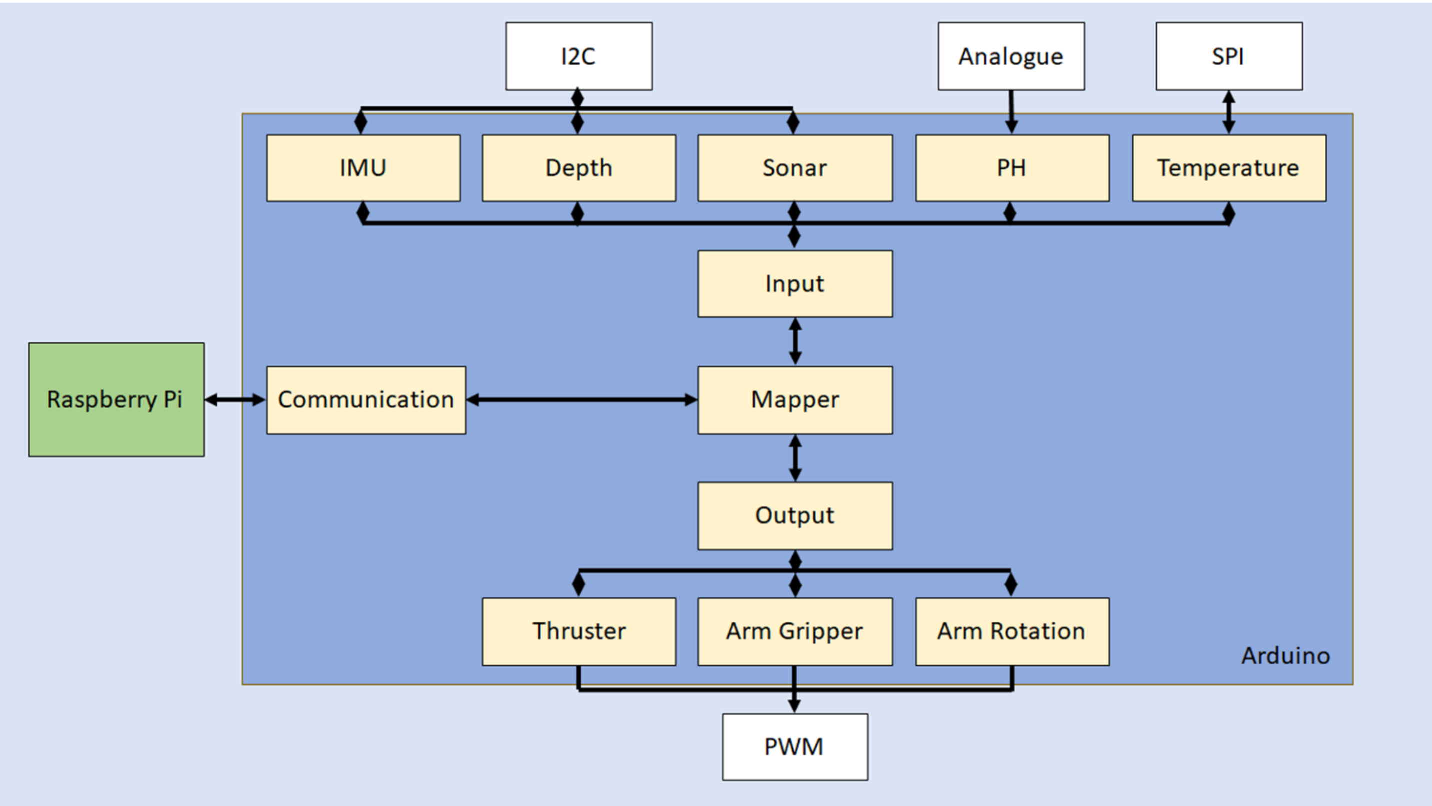
The middle-level layer, a Raspberry Pi, is the heart of the ROV. It runs on a modified Raspbian operating system and manages the data exchange between the surface and the lower-level electronics, as well as streams the videos from the cameras.

Lastly, the low-level layer for controlling electronics consist of three Arduinos which directly interact with the hardware, such as thrusters, motors or sensors.

7.2 LOW-LEVEL & ELECTRONICS

OVERVIEW

Due to the limited processing power of the Raspberry Pi, and the lack of PWM pins, Arduinos were utilised for all interaction with the hardware. Precisely, Arduino Megas were used because of the number of pins required to control the thrusters and other actuators, as well as due to their large internal memory capacity, which could handle more complex code than other Arduino models (such as Uno). Each Arduino was additionally assigned an ID to distinguish the devices. "Ard_T" stands for the "Thruster" control as well as the arm control. "Ard_I" stands for any "Input"s (i.e. sensors). "Ard_M" stands for the "Micro" ROV.



OUTPUTS

All output devices (thrusters, arm rotator, gripper and the box-opening motor) are waterproof PWM-controlled motors. The corresponding Arduino writes values between 1100us and 1900us to control the speed of the motors, with 1500us being the idle position.

INPUTS

Several sensors are utilised to measure the data and relay the information to the surface control station. The IMU, depth sensor and sonar communicate using the I2C protocol, whereas the temperature sensor communicates over SPI. The PH sensor returns a voltage which is relative to the PH level detected in the reading.

MAPPER

With the absence of a map-like data structure in C++ (which is present in the higher-level languages), the code written for the Arduinos has a basic mapping system to allow the user to find a certain object based on its ID string, e.g. "Thr_FP" for the fore port horizontal thruster. This allows the program to receive key-value pairs from the middle-level and directly control the corresponding hardware.

COMMUNICATION

The Arduino communicates with the Raspberry Pi using UART over USB. It sends and receives messages in a JSON format with key-value pairs directly mapping to those in the Pi's data manager dictionary.

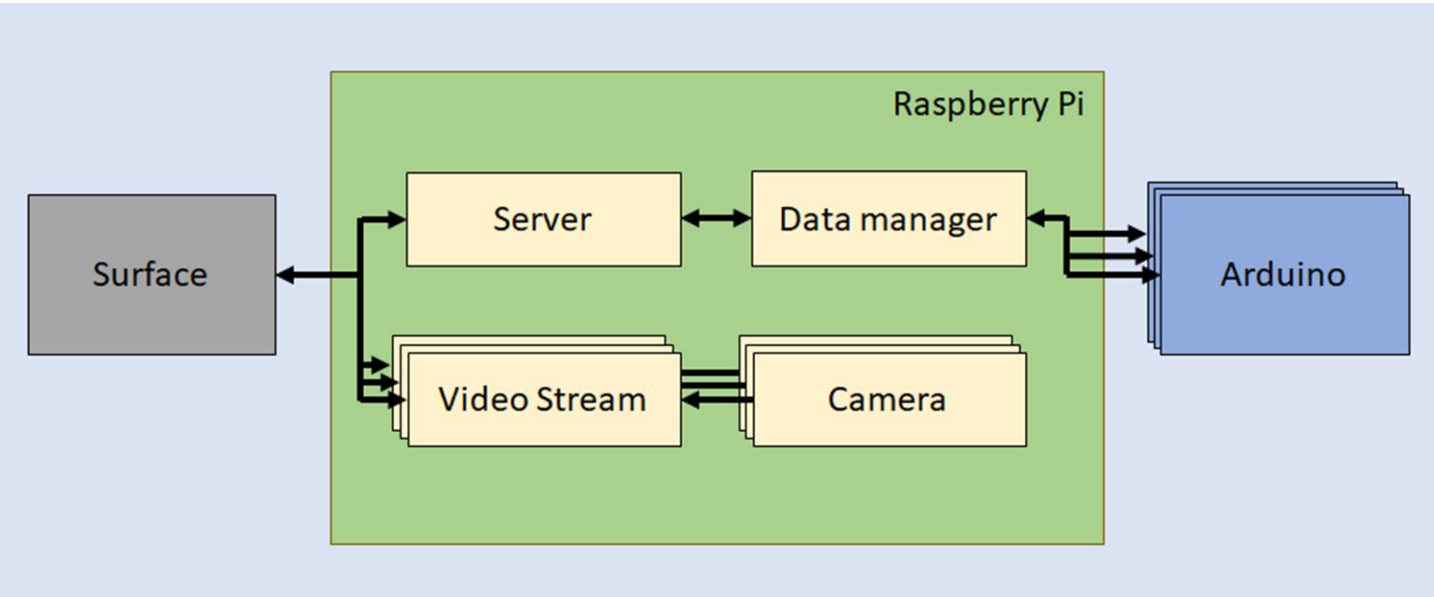
7.3 RASPBERRY PI

OVERVIEW

The middle-level software is comprised of a modified Raspbian operating system and the Python code written to perform all tasks.

The custom Raspbian is built by enabling standard Raspbian features such as the VNC and SSH connections, installing additional software (Python 3.6, OpenCV), as well as adding new system files to run the software on boot. Specifically, program execution lines are added to the "rc.local" file, which is then included as a startup service. This way, the surface control station is able to automatically connect (or reconnect e.g. on power loss) to the ROV.

The Python code consists of several components, as shown in the figure below.



SERVER

"server.py" handles the networking with surface control station and the low-level layer of the system. It consists of 2 classes - "Server" and "Arduino". The former is used to initialise the networking and communicate with the surface over TCP-based sockets using JSON-encoded data, whereas the latter manages the serial connection with an Arduino, also using JSON encoding.

Both classes were coded with guards against errors in mind and catch various exceptions to attempt re-connection on connection loss. The "Arduino" class also automatically detects which device it is connected to via the ID reference, and adjusts accordingly. Additionally, to ensure reliable data flow, the module uses threading to run each class instance separately, but with values shared together via the data manager (threading allows the objects to have shared memory space).

DATA MANAGER

"data_manager.py" maintains different states of the data across the system. It provides data dispatching functionality to relay information from the surface control station to the Arduinos and vice-versa. Specifically, it stores key-value mappings for each Arduino and the surface control station which are then accessible and modifiable via the "get" and "set" functions, and dispatches them as specified by the transmission keys mapping.

Additionally, rather than updating the values directly, it provides a ramp up/down functionality to slowly change the thrusters and motors speed, so that no extreme current changes are introduced. Furthermore, it populates the data with default values on connection loss, to customize the behaviour of the vehicle in such case.

VIDEO STREAM

"video_stream.py" provides a video stream of a single camera using the "VideoStream" class. As the system features three cameras, a total of three streams are utilised to send the frames to the surface control station. The data is in the "OpenCV" format, pickled (encoded) using the "dill" library and sent using the TCP-based sockets.

Additionally, in order to offload some computing power to the other cores of Raspberry Pi, the module is spawned in a separate process. Furthermore, just like in the "Server", the video stream provides guards against common connection errors.

MAIN

"main.py" is used to run each code component and is executed on boot. Firstly, it builds the communication server to exchange the data with the surface control station. Next, it detects which video captures are the on-board cameras associated with, in order to build the corresponding video streams. Finally, it starts both the server and the streams in separate processes to fully utilise its computing capabilities. Additionally, all errors redirected by the execution of the command are logged into a text file for later analysis.

7.4 SURFACE CONTROL STATION

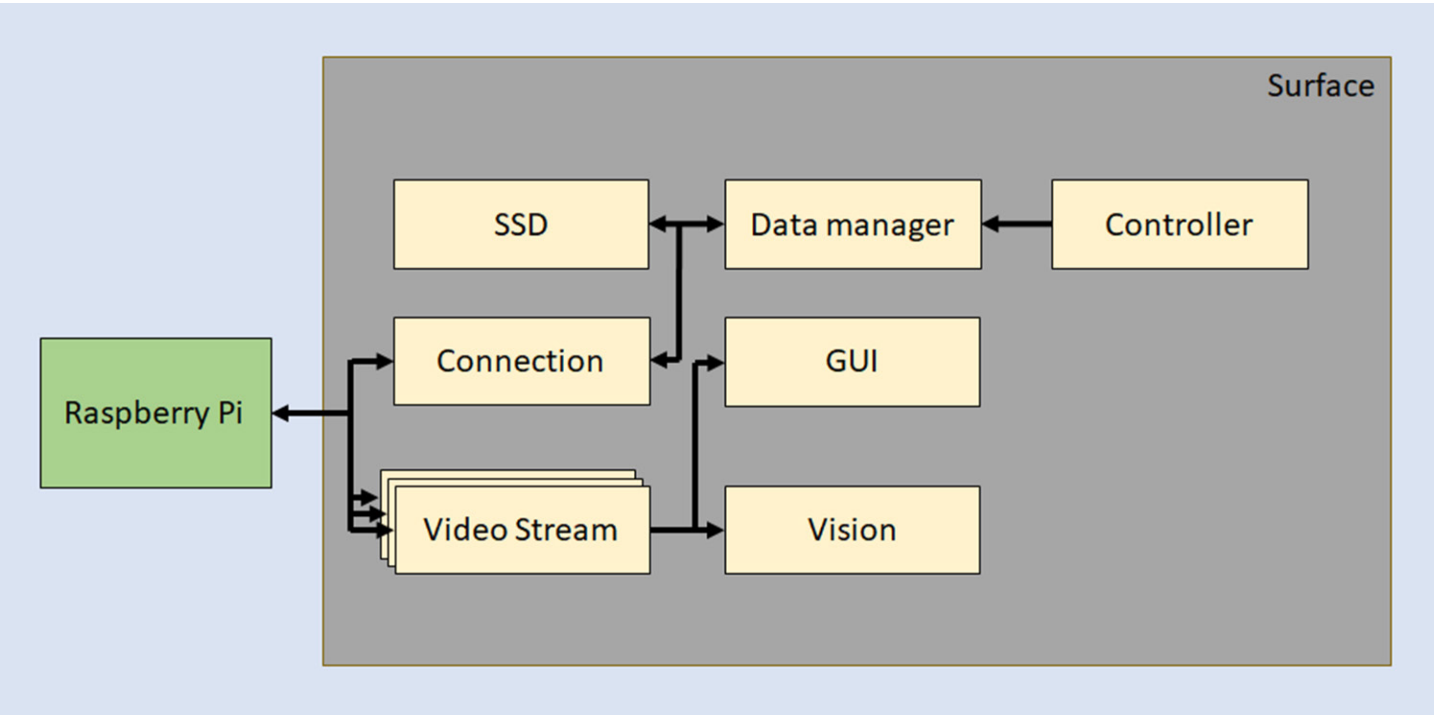
OVERVIEW

The surface control station (laptop) consists of several packages to easily navigate through the software - communication, control, graphical user interface and vision - all written in Python.

The role of each package is as follows:

1. Communication is responsible for management of the data flow between all components and networking with the lower system layers
2. Control decides how the vehicle should be behaving on different controller readings, as well as dispatches these readings to the data manager.
3. Graphical user interface displays neatly organised information to allow navigation of the vehicle, error troubleshooting and data analysis.
4. Vision provides the computer vision algorithms and other mathematical calculations to complete the competition tasks falling under this category.

The components are connected together as show in the figure below:



7.5 COMMUNICATION

CONNECTION

"connection.py" handles the networking with the middle layer of the system through the "Connection" class. Similarly to the coding of Raspberry Pi, it provides a TCP-based socket communication using JSON-encoded data and guards against common connection errors. Additionally, the module runs on a separate process using "pathos" multiprocessing tool.

DATA MANAGER

"data_manager.py" maintains different states of the data across the system. It features disc caching (using "diskcache") functionality to provide accessibility and modifiability across several modules and processes. Furthermore, rather than allowing to create an instance of itself, the "DataManager" class is encapsulated (enclosed) in the global scope, and can only be interacted with via the "get_data", "set_data" and "clear" functions. This removes the necessity of storing the reference to the "DataManager" in disjunctive parts of the system and restricts access to the shared data.

Additionally, the module provides safeguards against overcurrent by adjusting the data values under keys present in "SAFEGUARD_KEYS". Through a combination of ratio calculations and quadratic equations the values are evenly decreased before being transmitted to the Raspberry Pi. The safeguarding only happens when the resulting current would be too high, and is only applied to the networked values.

VIDEO STREAM

"video_stream.py" provides a video stream of a single camera using the "VideoStream" class. As the system features three cameras, a total of three streams are utilised to receive the frames from the middle-level layer. The data is in the "OpenCV" format, unpickled (decoded) using the "dill" library and received using the TCP-based sockets.

Additionally, in order to share the frames throughout the system, each stream is spawned in a separate thread and allows accessing the frame via its "frame" property. Furthermore, just like in the "Connection", the video stream provides guards against common connection errors.

7.6 CONTROL

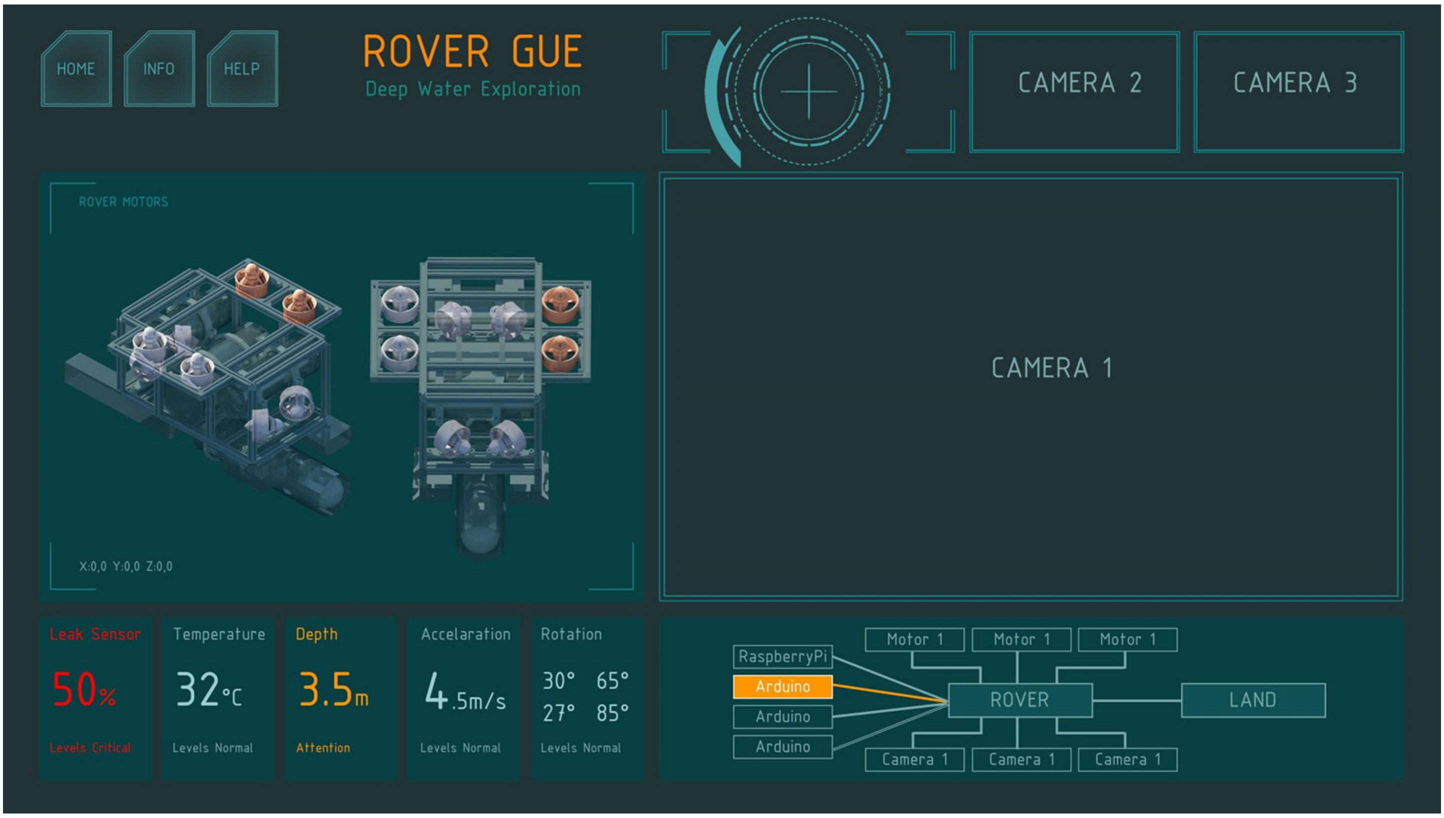
"controller.py" reads and processes the gamepad input, as well as providing the control instructions for the vehicle. It uses threading, data dispatching and the code encapsulation techniques, as well as works with the data manager to globally share all the information.

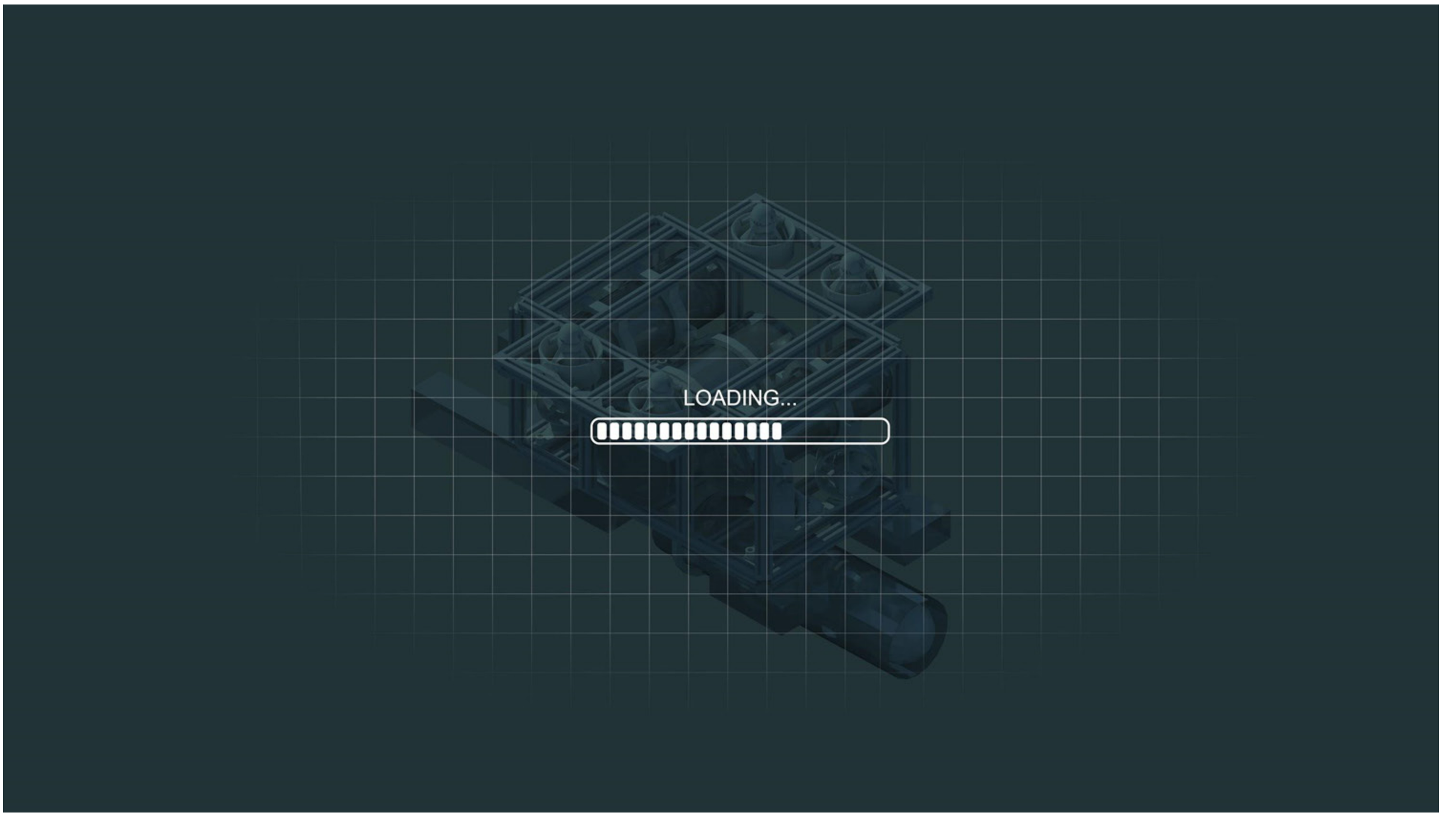
The "Controller" class reads the data using the "inputs" library and populates the data manager in parallel. It features a variety of map-based interfaces to properly dispatch all values as well as uses min/max normalisation calculations to scale the readings into the expected format.

Additionally, it specifies the vehicle controls by registering thruster and motor hierarchical control functions, which encapsulate control-specific information and can be adjusted or expanded when needed.

7.7 GRAPHICAL USER INTERFACE

The graphical user interface package is currently being developed, and will provide modules and classes based on the Python's QT implementation using the "PySide2" module. The overall functionality will consist of video streams, networks and sensors status and interactive components to successfully finish the computer vision tasks. The implementation will follow the design style presented below:





7.8 VISION

The computer vision package is currently being developed, and will provide modules and classes based on the OpenCV vision tools. The overall functionality will consist of an abstract Dam model, shape and colour recognition algorithms, dimension measurement calculations and the self-driving functionality for autonomous navigation.

Specifically, several techniques will be applied, such as HSV-based colour recognition, contour-based shape recognition, image processing vision kernels. and distance based dimension implication.

7.9 MAIN

"main.py" is used to run each code component. Firstly, it boots the graphical user interface to display a loading screen. Next, it builds the communication server and the video streams to exchange the data with the surface control station, as well as prepares the controller instance. Finally, it starts the server and the streams, initialises the controller, and redirects to the main screen of the graphical user interface.

8. SAFETY

8.1 ELECTRONICS SAFETY

The primary working environments for the group were the larger undergraduate teaching labs, the society's smaller lab and the School's towing tank laboratory. All of these have risk assessment specific to electrical safety in their environment.

All members of the Electrical team were made aware of the measures in place for using electrical equipment in the room including: ventilation, lead free solder, buddy system, risk of burn and eye protection. All members were made aware of how to arrange and access the necessary personal protective equipment and who they should ask in case of confusion.

8.2 WORKSHOP SAFETY

The NUROVers takes safety of all its members seriously and a complete risk assessment with guiding policies must be adhered to at all times

HAZARDS	PERSONS AT RISK	CURRENT CONTROL MEASURES	CONTROL MEASURES ADEQUATE	FURTHER CONTROLS IF NEEDED
Heavy objects dropped on toes in Workshop Slips due to slippery floor in Workshop	All Team Members	All members required to wear steel capped safety shoes while working in Workshop	Yes	Members who do not have safety shoes and need to work in the labs will be loaned a pair.
Injury arising from improper use of power tools (e.g. power saw/drill)	All Team Members	Power tools can only be used in the labs. Any usage of power tools supervised by lab technicians. First Aid Kit available in the Hydrolabs. Lab Technicians are trained in first aid.	Yes	Members who are unsure of the proper way to use any power tools must seek advice from lab technicians.
Injury arising from unfamiliarity to Workshop and tools in the lab	All Non-Marine-Technology Team Members	Marine Technology Students will have received a safety induction from lab technicians at the start of their degree programme. Non-Marine-Technology students must be briefed prior to working in the labs First Aid Kit available in the Hydrolabs. Lab Technicians are trained in first aid.	Yes	New members who join the team later in the academic year will be briefed by the lab technicians about standard safety protocol in the labs. Permission to be sought from the lab technicians for any new team members needing to work in the labs.
Electrocution from usage of high power source	Team Members setting up ROV/other engineering projects	Proper insulation for power supply wires Ensure that power supply is switched off and fully shut down prior to connecting and disconnecting cables Rubber gloves to be used when handling power supply	Yes	
Burns arising from welding or soldering	Team Members involved with assembly of ROV and wiring of electronic components	Proper protocol to be following while handling soldering iron and welding equipment Ensure that equipment has sufficient time to cool down before touching any hot parts All team members to be briefed on proper usage of welding and soldering equipment by lab technicians Gloves to be used when using spot welder which require metal pieces to be hand-held	Yes	

8.3 POOLSIDE SAFETY

At the poolside and during testing/operations of the ROV, a dedicated Operations In-Charge (IC) will be responsible for the safety of all team members. This entails a number of things that he/she must lookout for, including but not limited to:

> Waiting for team members to announce "CLEAR" after lowering ROV into pool prior to operating controls

> Sounding out "SURFACED" upon return of ROV to poolside and terminating all operation of controls prior to allowing team members to retrieve ROV from poolside.

> Ensuring that no non-team observers are in hazardous locations near ROV Dive

9. CHALLENGES AND LESSONS LEARNED

Time Management

One of the key lessons members learned is the balancing of normal academic load while still working on the ROV. This requires good time management and self-discipline to juggle extra-curricular pursuits while maintaining grades.

Better Coordination

A point for improvement is to work on better inter-team coordination. This can manifest in the form of more Captains meetings, as well as having attachés from each team sitting into other team meetings/worksessions.

10. REFLECTIONS

Junwei Fan, President/CEO

During the course of this project, I've learned and improved upon quite a few things - from technical skills to soft skills such as better people management. But picking one thing to elaborate upon, I think I've realised the importance of not micro-managing. As Captain, it is important to have the bigger picture in mind rather than getting bogged down by the nitty-gritty details. This allows me to concentrate on tasks such as integration while trusting the sub-team captains to iron out the finer technical details.

Edward Land, Project Manager/CTO

Working as project manager of NURovers required me to improve my time management skills, having to keep on top of my studies whilst coordinating the separate teams and ensuring they kept on task. It also improved my understanding of the ROV since I was involved at a basic level with all of the teams and so learnt things which were otherwise outside of my current discipline.

11. ACKNOWLEDGEMENTS

NUROVers would like to express our sincere gratitude to the following group of people who've helped make this project a success:

NEWCASTLE UNIVERSITY
for consistently backing our team and giving us support in terms of funding, moral, working space, logistics, etc.

NEWCASTLE UNIVERSITY STUDENTS' UNION
for their strong support of our society and granting us much needed funding to procure parts for the ROV

RHYTHMSOFT ROBOTICS AND AUTOMATION PVT. LTD.
for their generosity in manufacturing the mechanical arm at no cost to the team

HYDROLAB TECHNICIANS
for sharing wisdom from their experience, offering advice, loaning us equipment, and permitting us to use the towing tank for ROV testing

DR MARYAM HAROUTUNIAN
for her dedicated supervision and for going out of her way to support and help us in any and all circumstances

DR ROSE NORMAN
for her advice on electrical matters and invaluable support as Marine Technology Degree Programme Director

PROF PHIL TAYLOR
for lending his weight behind our team as Head of School (Engineering) and for believing in our project

ROBERT GORDON UNIVERSITY
for organising the Scotland Regionals where we gained a lot of experience, and for supporting our team's endeavour

MATE
for organising this international ROV competition and giving us the opportunity to learn beyond regular academic curriculumn

A. BUDGET & EXPENSE

ROV PROPOSED BUDGET

CATEGORY	DESCRIPTION	TOTAL (GBP)
Research & Development	Eletronics/Systems	1,700.00
	Marine	2,700,00
	Mechanical	1,600.00
Props		100.00
	TOTAL	**6,100.00**

INCOME

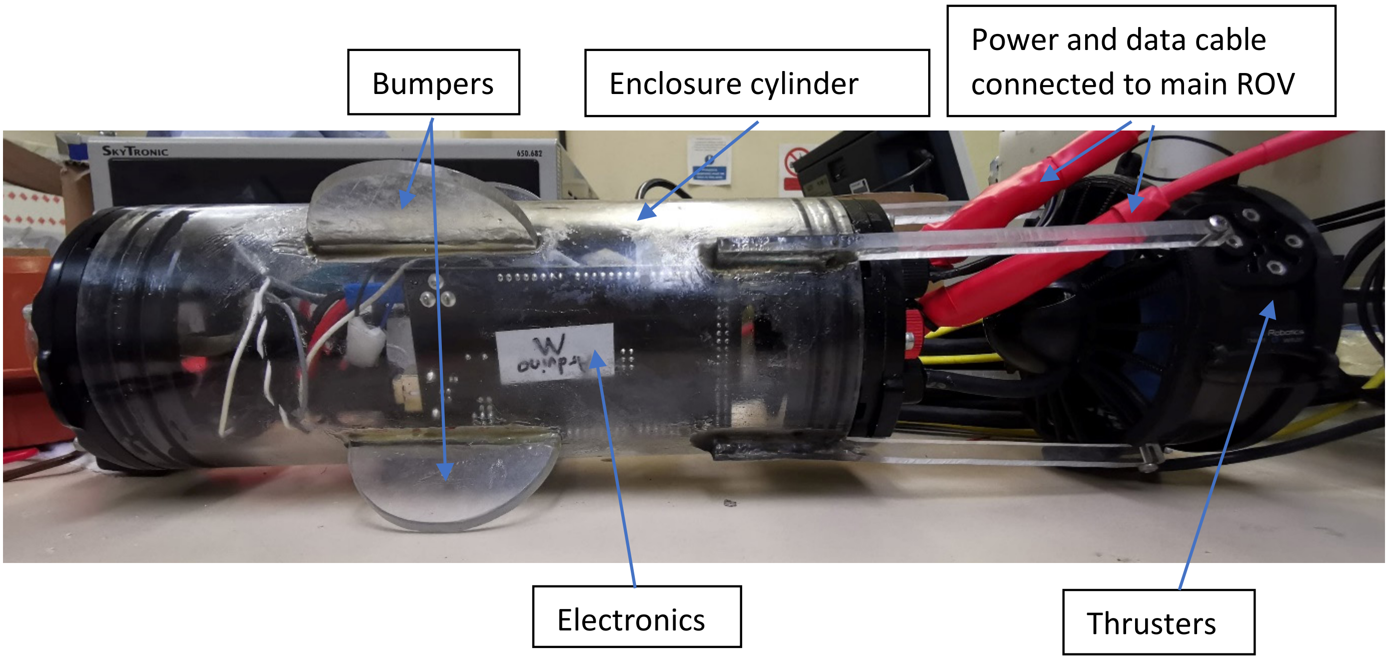
Newcastle University School of Engineering Grants	2,400.00
Newcastle University Students' Union (NUSU) Special Grants	3,700.00
TOTAL	**6,100.00**

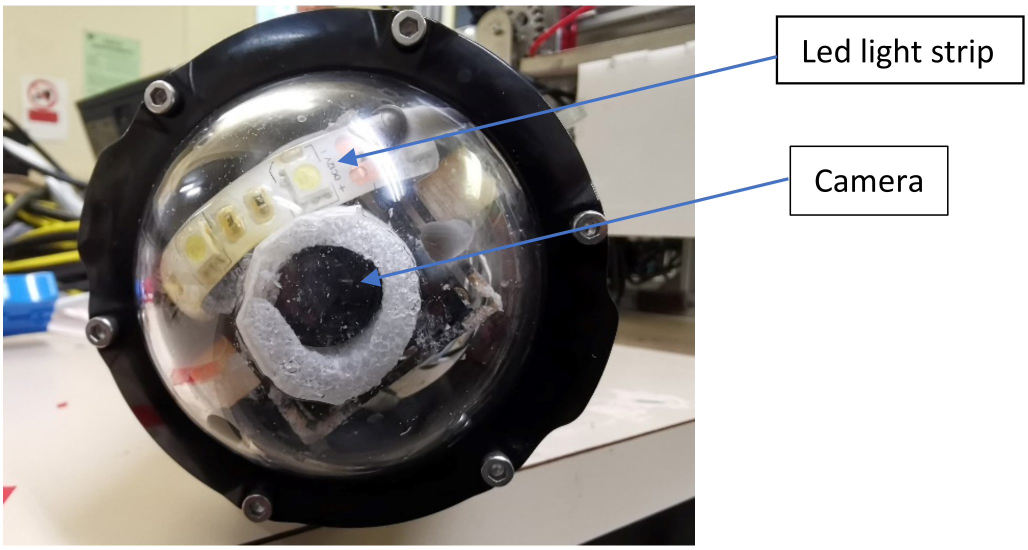
ROV COST BREAKDOWN

DISCIPLINE	DESCRIPTION	TYPE	TOTAL (GBP)
Electronics/ Systems	Cameras	Purchased	109.98
	Raspberry Pi	Purchased	74.92
	SD Card	Purchased	8.68
	Cables	Purchased	7.21
	LED Light Strip	Purchased	8.81
	Fuse Block & Cover	Purchased	71.53
	DC/DC Buck Converter	Purchased	327.23
	Screw Shield	Purchased	43.62
	Power Converter	Purchased	450.00
	Thermal & pH Sensors	Purchased	126.41
	Additional Components	Purchased	473.07
	Sonar	Purchased	219.69
		Subtotal	**£ 1,701.46**
Marine	3D Printed Thruster Guards	Purchased	105.43
	Enclosure	Purchased	106.07
	Lift Bag Equipment	Purchased	111.14
	Acrylic Sheet	Purchased	25.41
	Additional Enclosures	Purchased	345.55
	Thrusters (T200)	Purchased	322.87
	Equipment	Purchased	700.00
	Aluminium Frame	Purchased	961.63
	Micro ROV Equipment	Purchased	49.04
	Consumables	Purchased	67.50
		Subtotal	**£ 2,794.64**
Mechanical	ROV Equipment	Purchased	700.00
	Gearboxes	Purchased	804.00
	Servo Motors	Purchased	40.59
		Subtotal	**£ 1,544.59**
		Total Expenditure (GBP)	**£ 6,040.69**
		Total Expenditure (USD)	**$ 7,671.68**

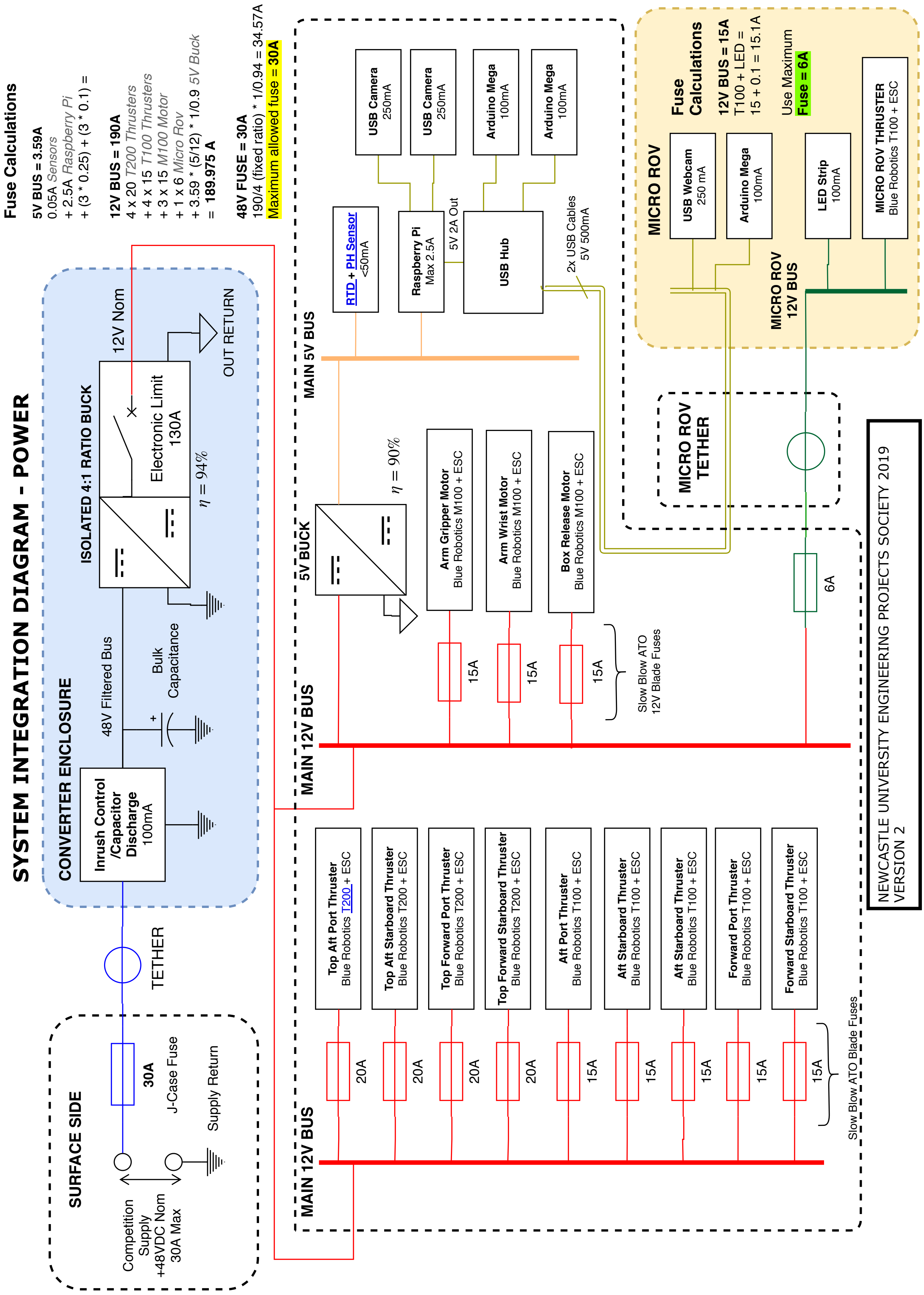
B. MICRO-ROV DESIGN DOCUMENT

The mini-ROV is mounted underneath the main ROV frame facing backwards so as to not impede on the actions of the mechanical arm. The mini-ROV comprises an enclosure cylinder, fitted with a camera, an LED strip for light, and a single T100 thruster. As the only objective required of the mini-ROV would be to explore a 6-inch diameter pipe for any defects, there is no a need for any vertical propulsion and controls, since it just needs to be capable of moving forwards and backwards. It is fitted with 4 semi-circle bumpers placed in the 4 cardinal directions with respect to the cylinder. These allows for a smooth transition along the pipe, since the enclosure cylinder's diameter is 3-inch, making it prone to getting stuck or misaligned without the bumpers. It is powered from the main ROV rather than being self-powered. For this, copper wires are used for the data and power cables that are attached to the mini-ROV.

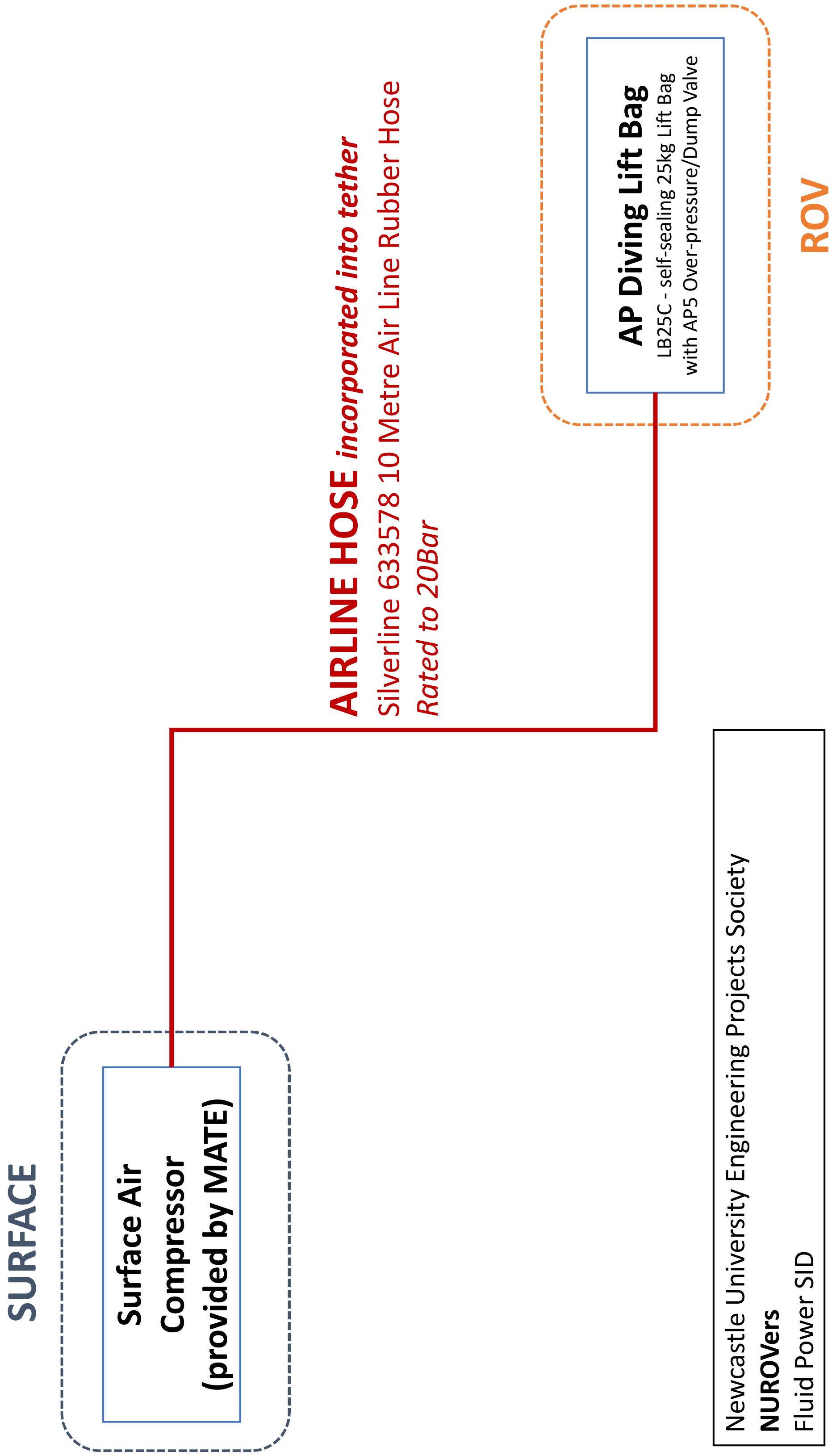




C. ELECTRICAL SID



D. FLUID POWER SID

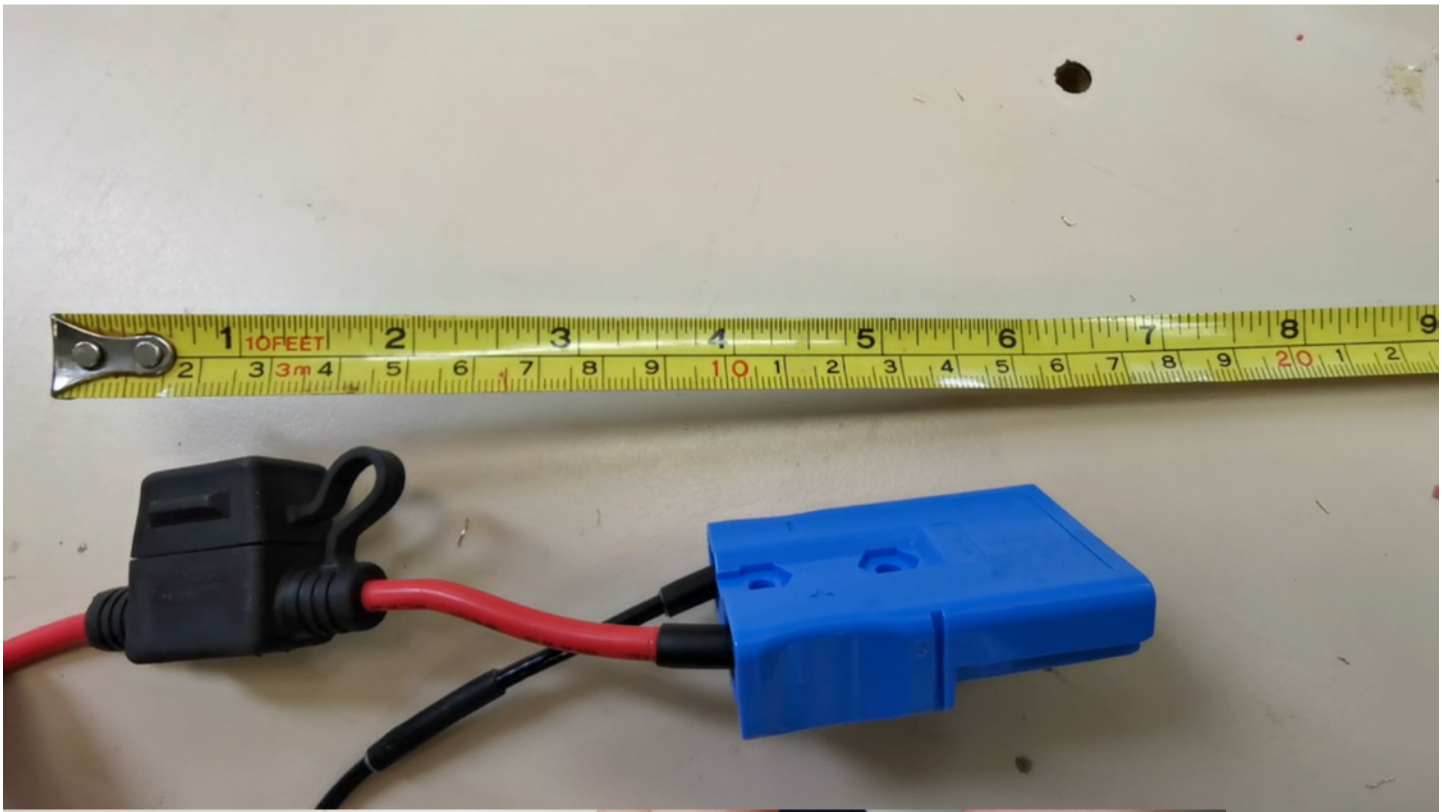


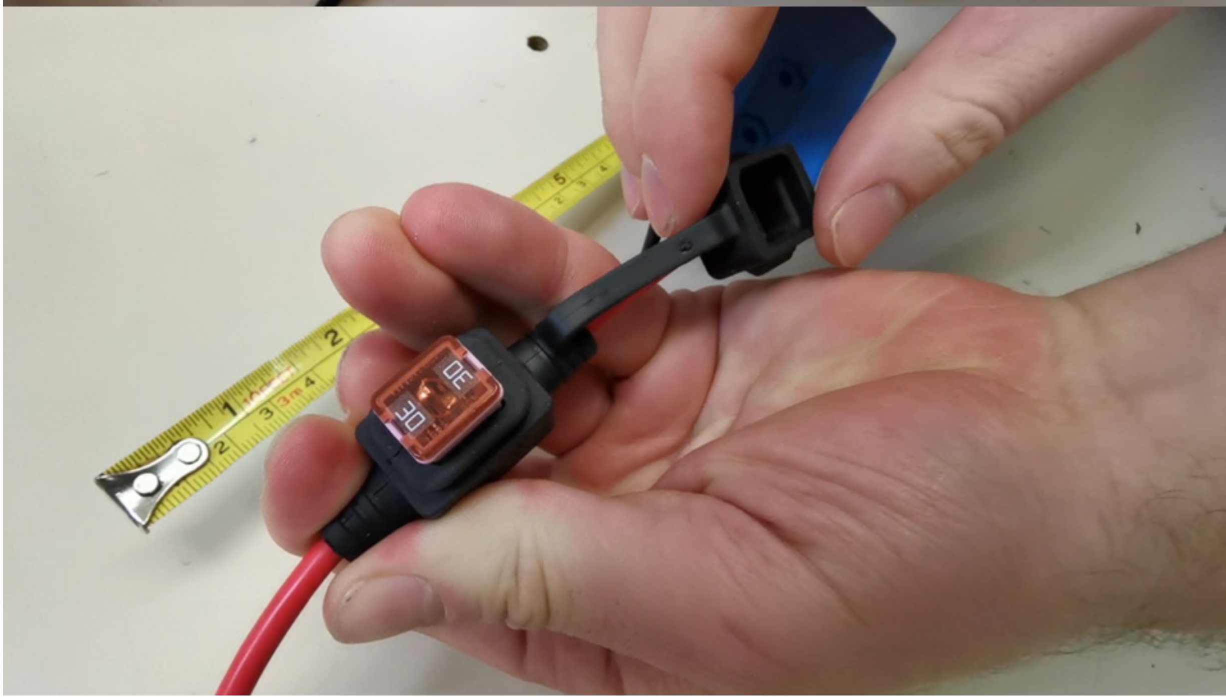
E. COMPANY SAFETY REVIEW

This review demonstrates NUROVers' compliance with MATE safety specifications.

(ELEC-010R)
SBS50 Anderson Powerpole connectors are the main point of connection to the MATE supply.

(ELEC-008E)
A 30A fuse is within 30 cm of the main point of connection.





(ELEC-008E)
Fuse calculations

The maximum power draw from the distribution board is calculated at: 2460W (calculations detailed in table below), the current at 48 V DC is 51A DC. SInce the competition limit is 30A, a 30 A tether fuse is hence selected.

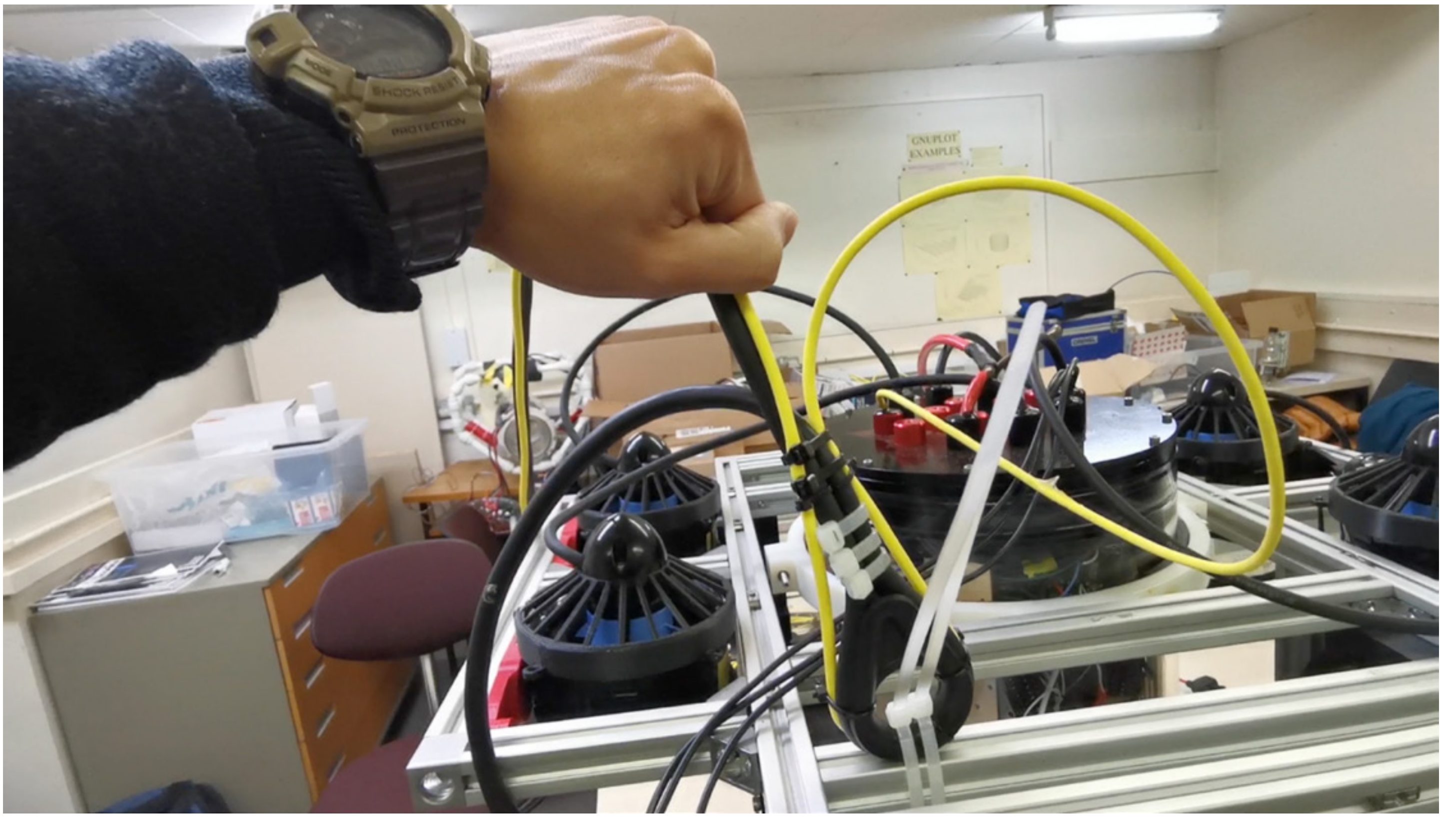
Load	Voltage (V DC)	Current (A DC	Quantity ()	Load consumption (W)
Thruster + ARM motors	12	25	8	2400
Embedded	12	5	1	60
	Total			**2460**

(ELEC-017E), (ELEC-022E), (ELEC-023E)

The inside of the control box is does not have exposed wiring, and the control box is neatly laid out with attention to workmanship. No DC Voltage is used near the control box as the data line of the tether splits from the power line upon emergence from water.

(ELEC-024E)

The tether leading to the ROV has proper strain relief.



(FLUID-014), (FLUID-007), (FLUID-011), (FLUID-012), (FLUID-013)

NUROVers has passed the Fluid Power Quiz. Compressed air will be used for filling the lift bag through the compressor on surface provided by MATE at the international competition. There is no fluid power on board the actual ROV. The LB25C lift bag is manufactured by AP Diving and is designed for object retrieval by divers, rated to carry 25kg, and comes pre-installed with a AP5 Over-pressure/Dump Valve to automatically discharge over-pressure.

(MECH-001)

All watertight housing on the ROV are BlueRobotics cylinders, made of cast acrylic. The 8" tube is designed for depth-rating of 40m, while the 4" tubes are rated for 100m.

(MECH-006)

All thrusters on the ROV are shrouded with custom designed thruster guards.

(MECH-006, ELEC-017R)

All sharp edges on the ROV where frame elements meet are rounded off with corner caps.