



2013 MATE ROV Competition Technical Report

The Mechanics

German Swiss International School
Hong Kong, Hong Kong SAR

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Fergus Wong (16): Design Engineer

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Caitlin Fischer (16): Design Engineer

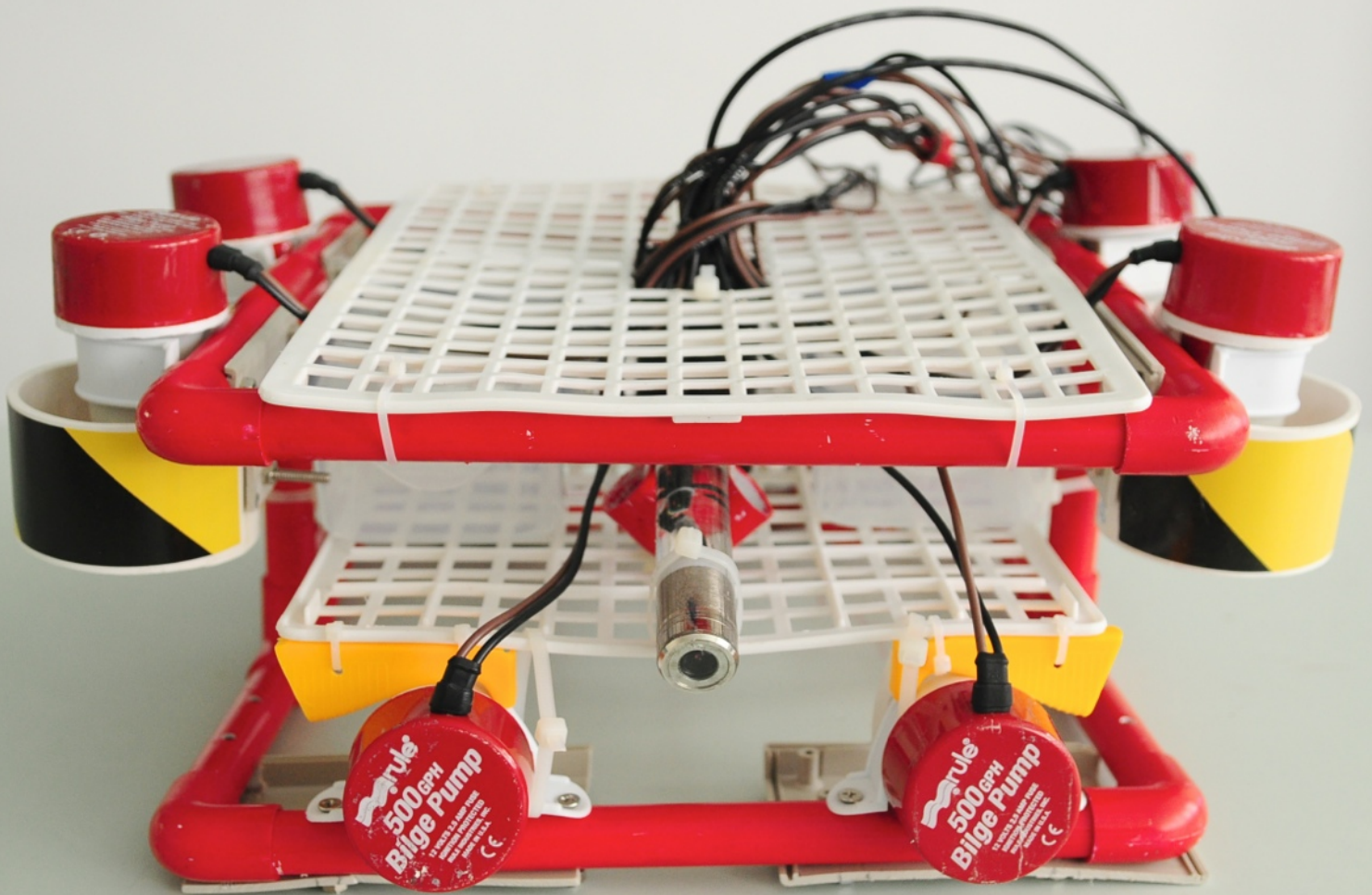
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Abstract

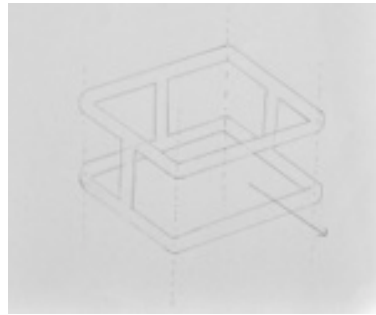
Founded in 2011, *The Mechanics* is a Hong Kong-based entrepreneurial organization committed to cost-effective oceanographic research assisted by Remotely Operated Vehicles (ROVs). Understanding that oceans are absolutely crucial to almost every aspect of the Earth, from eco-system biology to global climate change, we have made it our priority to help in efforts to monitor this vast environmental body through Ocean Observing Systems, which track changes in the ocean real-time. ROVs are an absolutely integral part of constructing and maintaining these monitoring systems; our company aims to provide such ROVs using affordable materials and easily-replicable designs, so that research can continue with fewer expenses. We do not always succeed, but we at least attempt to overcome these setbacks with self-deprecating humor, technical expertise, and an optimistic company spirit.

Specifically, this report is a direct response to the Request For Proposal from the Ocean Observations Initiative of the University of Washington. This report intends to introduce an ROV design to tackle the issues faced in the expansion of the observation system at the Axial Seamount of the Regional Scale Node (RSN) in Newport, Oregon, which involves the installation and maintenance of a network of cables, nodes, and sensory instruments, to monitor the ocean as well as a hydrothermal vent located in the area.

Design Rationale

ROV Chassis

Every ROV begins with a framework, onto which all other components are attached to. Thus our design began with a chassis too. For materials we chose polyvinyl-chloride (PVC) pipes. Durable, neutrally buoyant, un-reactive, and light, the pipes were the ideal choice for the basic framework of the ROV and provided space for housing all the necessary components. We chose thin, low diameter pipes (0.025m), because we appreciated that thinner pipes would reduce drag on the ROV and provide more space for components held internally.



The design concept (left) and product: the bare chassis of the ROV. Note the one unsupported edge and simple shape.

An added benefit of PVC pipes was the incredibly low cost (Approximately five US\$ for the entire chassis with spare left over) which is in line with our company ethos of cost-effective design.

For the shape of the chassis we chose a very basic two-tiered square structure, with three connecting supports. We allowed a gap on the fourth edge go to allow for space for an arm/payload system. The advantages of such extra space outweighed any potential disadvantages of reduced structural support, since the PVC pipes were rigid enough to maintain stability with only three supports.

Our simple structure enabled inherent stability through relative flatness while still allowing space for internal structural components, such as the vertical motors, and easy motor placement. Exact dimensions are included in the specification sheet attached.

Propulsion System

To save valuable time waterproofing a non-waterproof motor system and installing it into our circuitry, we instead chose to use, as recommended at a MATE workshop, converted commercial bilge-pump motors as a propulsion method. We felt that this was one area where we were plenty justified in using modified commercial components because of the incredible tediousness of creating such a system from scratch.

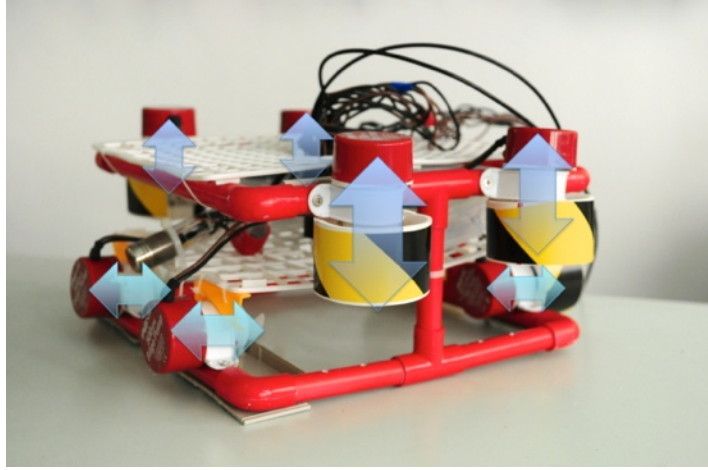
Sawing removed the pumping component of the bilge pump and left the exposed motor (a safety concern addressed in the Safety section), enabling us to connect (with epoxy) a propellor onto the motor. In our situation this was ideal for providing the necessary propulsion.

We kept important design principles in mind when placing these motors



A secured bilge pump with pump component removed and (exposed) propellor fixed to a pipe

throughout the ROV. We aimed to maintain precise and specific control for direction, speed, turning consistency and buoyancy, since responsive and accurate controls are essential for almost all of the tasks, especially those involving picking up and transporting payloads. Careful motor placement, was therefore of the utmost importance in completing the tasks. With respect to the number of motors, we had to maintain the fine balance between speed, weight on the ROV, actual space, and expense. Placing too many motors would ensure speed but at great costs – financial expenses, a lack of space, safety hazards, extra circuitry, and so on – whereas too few would mean poor control and slow speed and reaction time.

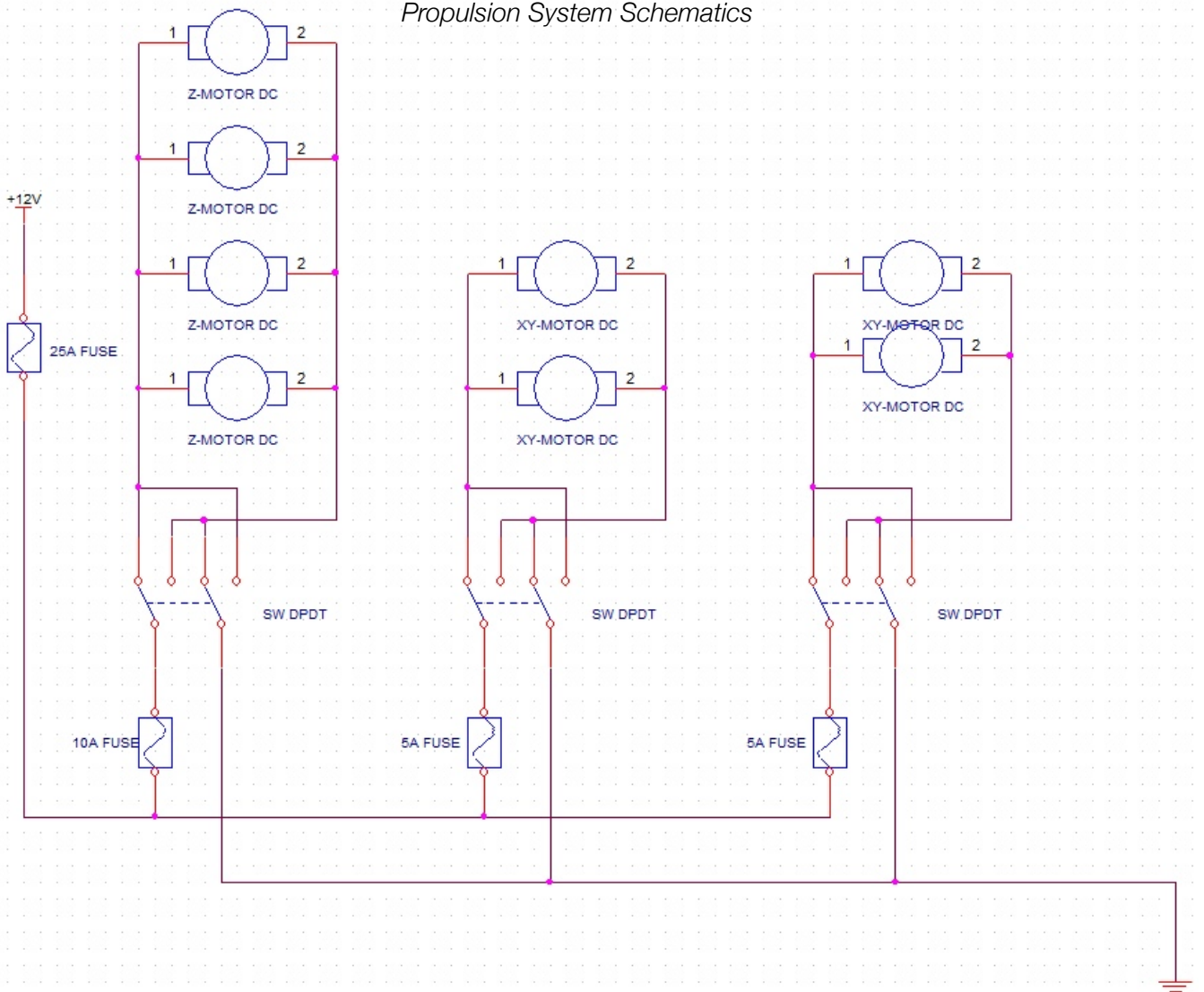


Eight motors: four for up-down movement (blue), two for left-right-forward (light green).

After some experimentation, we agreed on the motor placements (pictured right) to achieve the best possible balance of all of these factors. Eight motors, specifically placed.

For controlling the motors, we decided against using microprocessor control because the added complexity and increased chance of unexpected malfunctions had hindered us in the last competition. Instead we used DPDT switches, a simpler, more reliable and more robust system. The four motors responsible for z-axis translation were wired in parallel to a DPDT switch, with a 10A fuse attached to the live wire. The four motors responsible for x-y-axis translation were wired in pairs, with each pair consisting of two motors in parallel wired to a DPDT

Propulsion System Schematics



switch (each with a 5A fuse attached to the live wire). This left us with three simple DPDT switches: one for up/down thrust, one for right thrust and one for left thrust.

Buoyancy Adjustment System

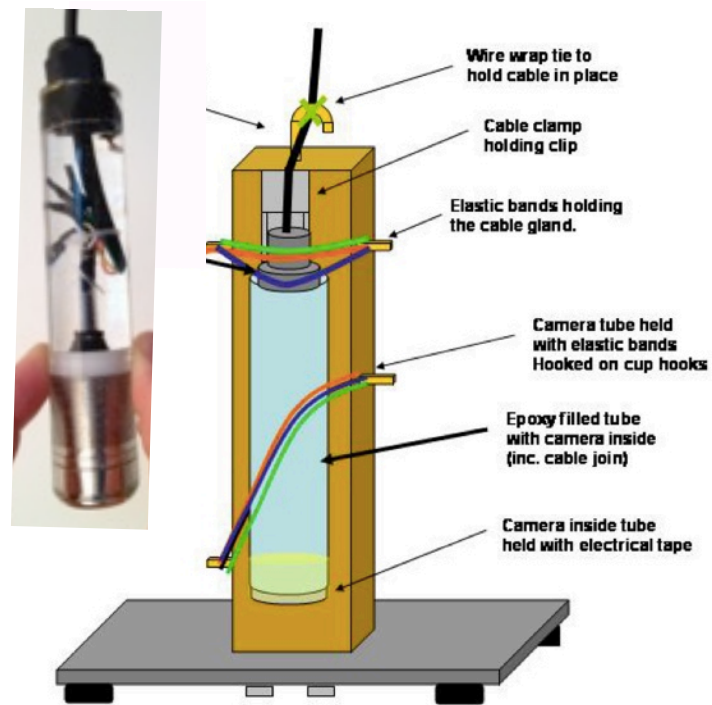
Buoyancy was achieved through drilling holes into the chassis PVC to ensure neutrality, and regulating any discrepancies with floating devices: epoxy-sealed plastic lunchbox containers which could be added or removed in increments as necessary (and thus would be able to provide quick and effective adjustments to buoyancy on the day). Although aesthetically obtrusive, the low cost of the lunchboxes and their robustness justified their use.

Camera Systems

Cameras are essential to the ROV. Analyzing the tasks required of the ROV, we decided that a downward facing camera and forward facing camera would achieve the best results without extra complexity. We experimented with the best angle for the forward facing camera and determined that a slight downward angle gave the best view over the seafloor and surroundings.

Using a drying stand (pictured) we took a clear plastic tube, implanted a camera with all the necessary electronics, and filled the entire tube with clear epoxy. This ensured an absolutely watertight camera housing, but still allowed us to see through the epoxy to check for bubbles or leakages. Of course, if the wires leading from the camera were infiltrated with water, water would simply channel through into the camera anyway, rendering the epoxy pointless. To prevent this we used strong waterproof cabling and made all the connections within the epoxied tube.

From an electrical or control perspective: The cameras ran on 5 volts, so we used a voltage regulator which steps 12V down to 5V using an OCL camera interface chip provided by MATE. It took 12V from a power supply. The cameras had a power, ground, and video cable, which we attached to the interface chips' screw terminals. The chips had an s-video (3.5mm) banana plug output, which we plugged directly into our



Drying the camera (above, right). The finished product (above, left). The forward facing camera in position (below, middle), and the downward facing camera (below, right).



monitors. The full schematics are in the appendices at the end of the report.

Task Specific Design

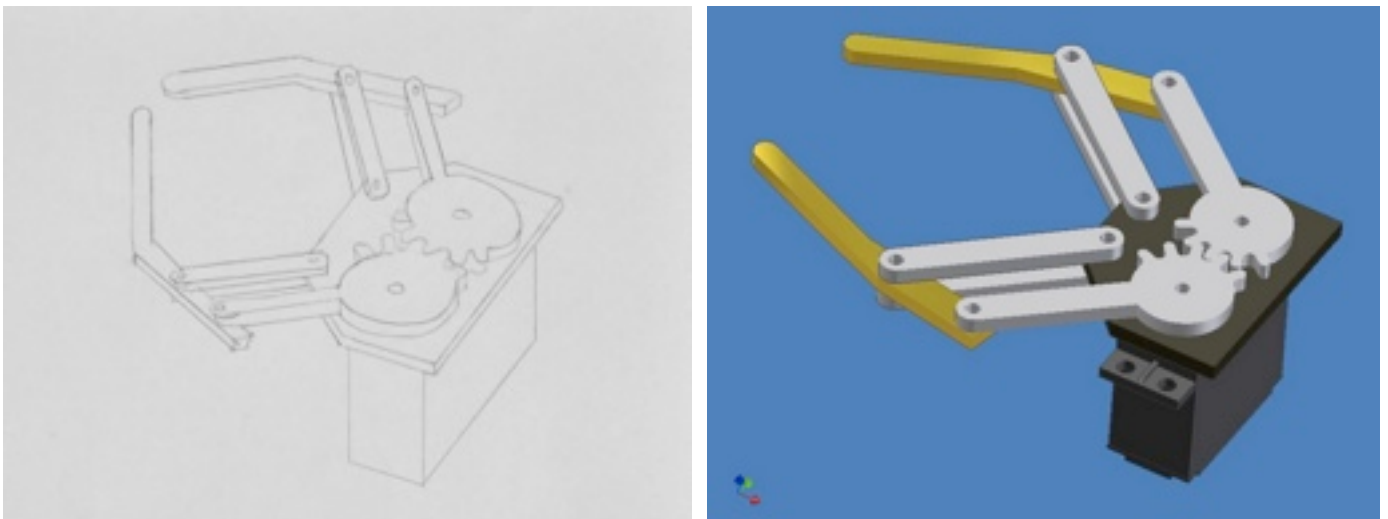
Task 1, 3 and 4: Payload System/Gripper

(Completing A Primary Node/Installing A Scientific Instrument On The Seafloor/Replacing an ADCP On a Mooring Platform/Removing Biofouling)

Both of these tasks assess the ability of the ROV to interact with its environment, and to lift and transport objects from point A to point B with precision. For lifting and moving objects off the seafloor we used a simple coat-hanger hook attached to the bottom of the ROV. The downward facing camera allowed us to maneuver the ROV as needed.

But the other aspects of the task required more complex movements and interaction: to tackle these we designed and implemented a generic, multi-purpose gripper, which factored in important information specific to the tasks but was flexible enough to tackle different tasks. For instance, it worked at a maximum payload of 3 Newtons, and the maximum payload required of it is about 2 Newtons.

The gripper was intended to be easily replicable, and easy to prototype. Our design was first sketched and then modelled in 3D-modelling software – and then created on an acrylic cutting machine. It operates on one water-

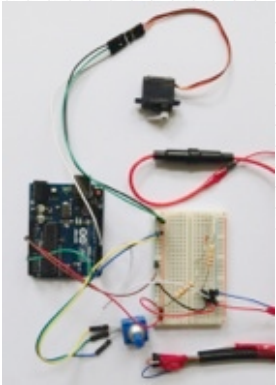
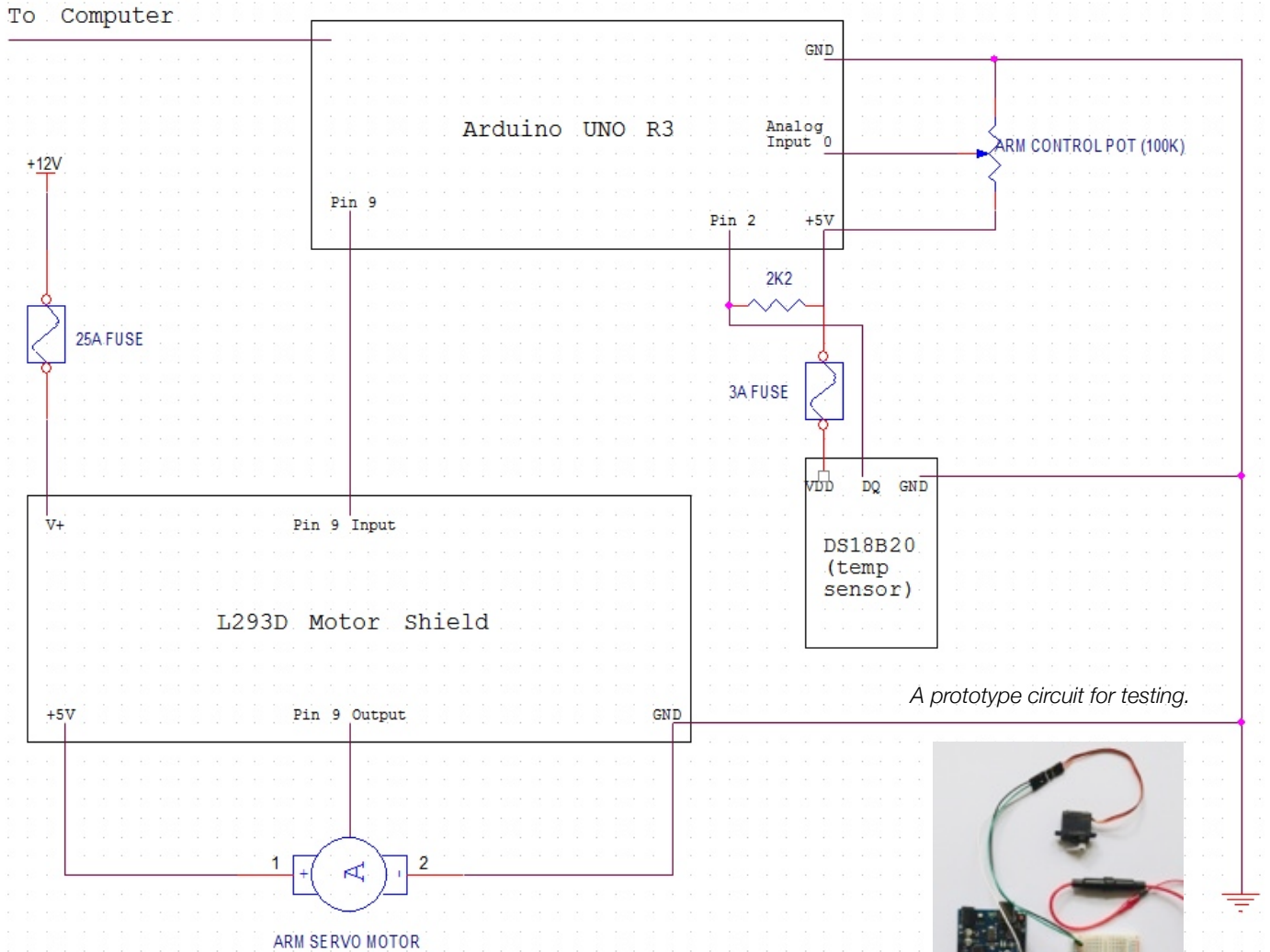


The design process for the gripper. At the time of writing, the physical claw was still in development because rotation was being perfected.

proof servo motor, which rotates one of the gears in the gripper. This allows us to tackle the specific aspect of task 3 which requires a handle rotation of 90 degrees.

For the servo motor attached to our claw, we decided to also use an Arduino Uno R3 to control its motion. Using a 100k sweep potentiometer as an input (middle terminal to A0 pin with the other two terminals attached to +5v and GND), the code in the stock Arduino software (see appendix) converts the sweep into an angle from 0 to 180 degrees.

The servo motor is attached to an L293D motor driver shield (schematics in appendix), as the Arduino Uno R3 board does not provide enough power for the servo. The L293D motor driver takes 12V through the VDD terminal, and with an onboard 5V regulator, outputs 5V to the servo motor. We also connected the digital output from pin 9 on the Arduino Uno R3 board to the input on the motor shield, so the signal controlling the servo motor is also sent through the motor driver. Pin 9 outputs a PWM signal, and according to the analog input,



changes the width of the pulses, thus changing the angle at which the servo is rotated.

Task 2: Temperature Sensors (Hydrothermal Temperature Monitoring)

The second task involved designing, creating, and deploying a real-time temperature sensor and recording results.

There are many methods of temperature sensing that were all considered: a simple liquid-in-glass thermometer, a thermocouple, an analogue thermistor-based sensor, a digital thermometer.

Liquid-in-glass thermometer did not seem like a viable option, as it was difficult to relay information back to the control unit. We initially experimented with laboratory thermocouples, extending the connections with long speaker cables. It worked nicely above ground, but once we put it into water, the readings were both inconsistent and incorrect. We eventually discovered that a thermocouple would not work as we had to submerge the cold junction underwater during the task.

We then had to make a decision between using an analogue or digital thermometer. On the one hand, analogue thermometer circuitry was more simple and we did not have to use an Arduino microprocessor. However, the long 10m cable needed between the reading end and the thermometer meant that an analogue thermometer was simply not viable as the voltage drop across the cable would severely impair the thermometers ability to take readings.

Given that we already had a functioning Arduino, we decided to use a 1-wire thermometer, a DS18B20. It could

obtain power from the data line of the Arduino UNO R3, and ground, removing the need for an external power supply. Thus it could work independently. We built the sensor into a PVC pipe (with hooks on the side to grasp onto the sides of the PVC hydrothermal vent ready for deployment via the PUAMSS constructed for Task 1.

The sensor connecting to the Arduino wired into a computer where the data could be read real-time, and then transcribed into a graph via either software like Microsoft's Excel, or pen-and-paper.



A bare DS18B20 thermometer without its PVC mounting.

Safety

Company Safety Philosophy

Simplicity and cost-effectiveness aside, safety has always resided at the forefront of our company philosophy. There was always a tradeoff between adhering to safety precautions and working quickly, but we constantly reminded ourselves of the importance of the former. We never believed in pursuing add-on features that could pose a danger to involved parties later, or in compromising the well-being of our team or other individuals for the sake of the ROV.

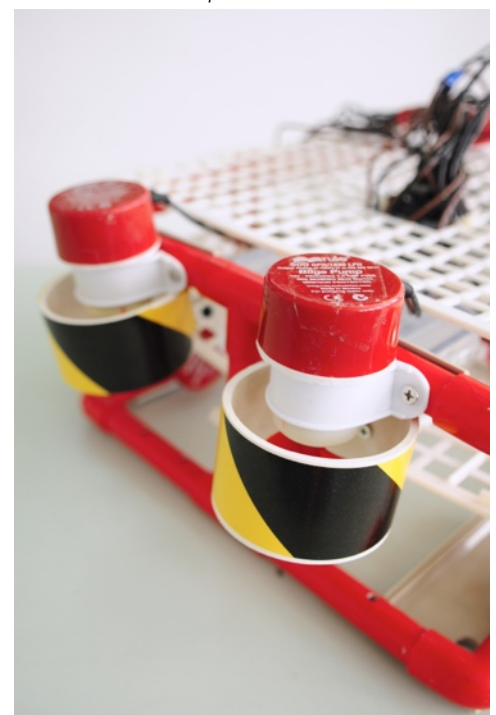
Our approach to safety was a collaborative one. If we wanted to make a change to our ROV's design, or our engineering techniques, we would come together and discuss how we could implement it in a manner that would not endanger anything coming into contact with our ROV. This guiding principle ensured that as our ROV became more functional, it did not grow in its ability to be a hazard.

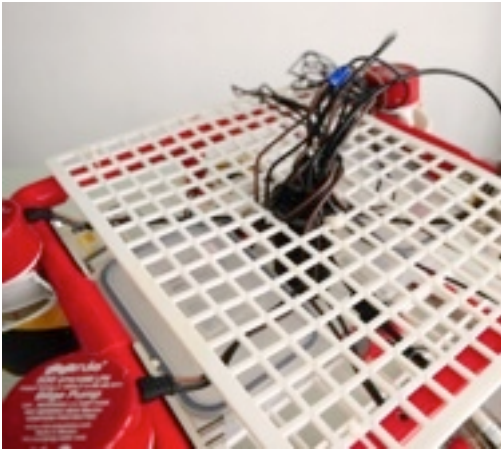
Specific Safety Features

A consistent philosophy is all well and good; specific safety features are even better. Our ROV had a number of specific features designed to prevent harm.

80mm-diameter PVC pipe was cut into short sections, which were then attached to the chassis by T-shaped mounting brackets made out of PVC. These were placed around the propellers and used to prevent potential injury from the spinning propellers. Plastic mesh, cheap and effective, was used to protect wildlife from the motors as well as prying hands. For electrical safety, fuses were used within the circuitry to prevent overheating and melting wires. A 25A quick-blow fuse was used in the connection between the motor circuits and the power, and for the motors themselves, 1 10A fuse was used for the Z motors and 2 5A fuses were used for the X and Y motors respectively. Connections between wires were insulated firstly using heatshrink and then epoxy to seal off any gaps, which ensured that no water was to seep into the connections and risk short circuiting the electronics. Testing afterwards ensured that there were no short circuits. Of course, particularly careful soldering assists in this process. Any sharp edges presented by ends of bolts or any other screws were wrapped in electrical

Warning labels and PVC pipe protect exposed motors.





Plastic mesh: Contained our tether and kept prying hands out of the inner heart of the ROV.

tape to protect those working on the ROV, as well as divers and most importantly, the sea floor and marine life . All loose wires were secured inside the A final safety feature was simple: we coated the ROV in bright red paint, to indicate to divers and ROV handlers alike the dangerous areas of the ROV: anywhere close to the chassis is, after all, a potentially hazardous area. We stuck warning signs to the edges of dangerous components like motors, too.

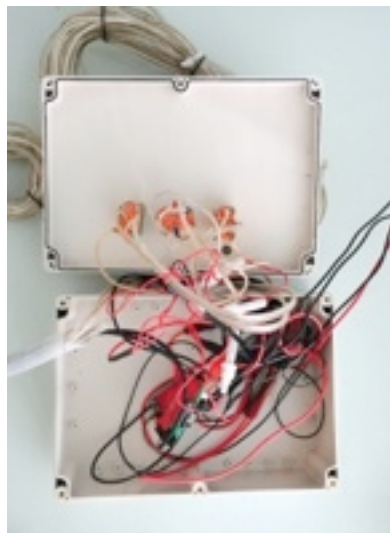
consistent philosophy is all well and good; specific safety features are even better. Our ROV has a number of specific features designed to prevent harm and lower risk of contact with harm.

The conventional metal safety guards were used to prevent potential injury from the spinning propellers. Plastic mesh, cheap and effective, was used to protect wildlife from the motors as well as

prying hands. For electrical safety, fuses were used within the circuitry to prevent overheating and melting wires. Strong insulation and testing ensured no short circuits and particularly careful soldering assists in this process. A final safety feature was simple: we coated the ROV in bright red paint, to indicate to divers and ROV handlers alike the dangerous areas of the ROV: anywhere close to the chassis is, after all, a potentially hazardous area. We stuck warning signs to the edges of dangerous components like motors, too.



Fuses. Essential for electrical safety.



Containing the wires of the control box effectively, cleanly and safely.



Safety Precautions and Checklists

We made sure to implement a number of precautions while working with the ROV. A company Safety Checklist is provided in in appendix 2 at the end of this report, which outlines the steps we took when working with each aspect of the ROV.

Overcoming Challenges and Obstacles

Non-Technical Challenges: Time-Management, Funding, and Organization

One of our first non-technical challenges was one of organization. Our CEO was unpracticed in working with small teams, and had difficulty coordinating our efforts effectively. For the initial months before the competition, we encountered great inertia in actually meeting together to begin work on the ROV. Team members were unsure of what they were responsible for, and delegation was inconsistent.

In addition, serious funding deficiencies and a lack of starting materials hindered progress when we did try to begin. Our school's funding was split between our two teams, and our supervisors provided little knowledge of where to cheaply obtain many of the components needed, since we had no regular suppliers or previous buying locations.

With the competition fast approaching, and our work still set out for us, we needed a change in thinking.

Our approach to tackling this challenge was three-pronged. Each of us re-evaluated our roles in the team and volunteered to take on responsibility for a specific aspect of the ROV. Then, our Communications Officer set up a schedule for what needed to be done, by whom, and when (the schedule is attached in the appendix 3 at the end of this report). In terms of funding, we committed our design principles to 'as simple as possible, but no simpler' and attempted to use creative, cheap solutions to address task problems, as outlined in the Design Rationale.

These guidelines assisted us greatly in moving forward to progress on working with the ROV.

Technical Challenges

A main technical challenge we faced was using our temperature-sensor-to-computer-interface. When we prototyped our circuit with a spring-loaded breadboard, the temperature sensor was inputting temperature values into our laptop software without any issues, but when we connected our temperature sensor to 10m of underwater cabling and to our circuit, the readings stopped, and a stream of error messages displayed on our serial monitor.

At first we thought it was a bad connection, so we checked every solder joint, but we still could not isolate the problem. We then thought it was our temperature sensor that had burned out, but replacing it with a new one still lead to the same error messages.

We originally used a 4700 Ohm pull-up resistor between the power and data line, as recommended by the DS18B20 specification sheet. We decided to consult one of our teachers, who mentioned that it could be voltage drop across the 10 m of wire which was causing the issue. He recommended we use a lower resistance

pull-up resistor, and through a bit of trial and error we found that 2002 Ohm resistor worked perfectly. Only after tedious re-soldering, multiple part replacements, and a few hours of painful trial and error did we find out that all that was needed was a simple resistor swap.

Troubleshooting Techniques

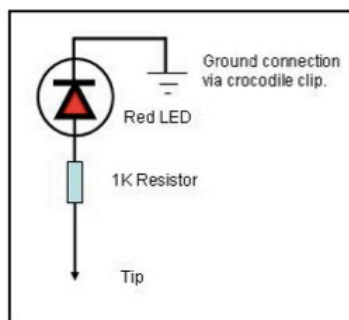
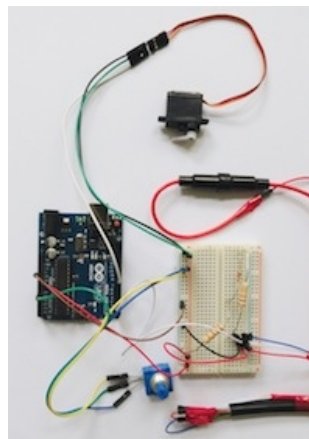
Throughout the design and construction of our ROV, several significant problems cropped up, all of which took a great deal of troubleshooting to solve. This process, albeit a taxing one, allowed us to not just repair faults in our ROV, but also afforded us crucial signals as to which areas we needed to improve our skills in.

Our electronic systems demanded a great deal of our time in troubleshooting. Hence, to troubleshoot our electronics, such as our Arduino UNO R3 chip and our L293D motor driver, we used a light pen to test major joints, comparing them to working chips to find out which solder joints were cold. In the end, this simple trouble-shooting technique saved us a lot of time, as we did not have to check each component separately with a voltmeter and ammeter, and were able to accurately identify the issue at hand for us to specifically address.

If the light pen solution did not indicate the problem immediately, we resorted to testing each individual component of the circuits. Afterwards, our team converged, discussed and decided the best option through which to resolve the

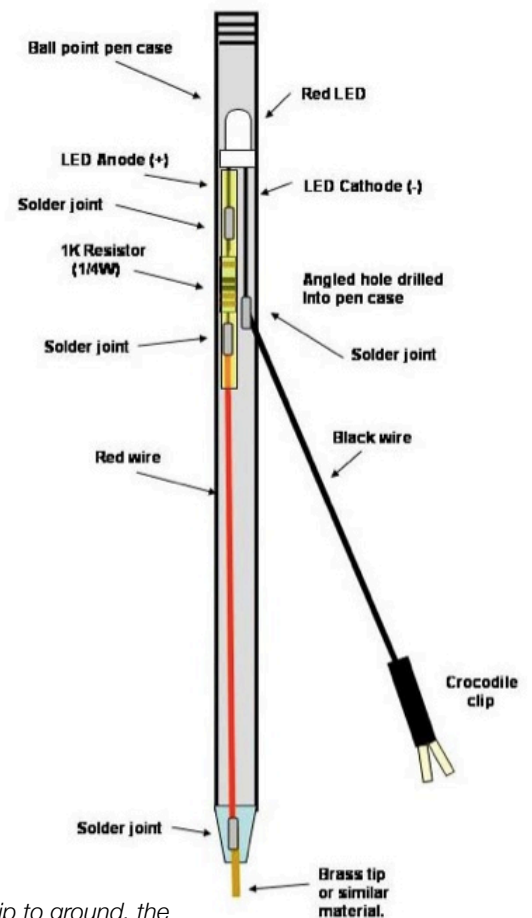
problem, allowing us to get input from a greater number of people and hence expand the knowledge base from which we could draw problem-solving approaches. This collaborative approach made sure that all suggestions were heard, and that we could criticize and improve weaker solutions into a cohesive, working system.

Water-testing also yielded important information on problems that needed to be addressed. When a component failed during water testing, we'd first carefully remove the component, in case the failure led to a dangerous situation, and completely dry it. We would then test it on land to make sure that shoddy waterproofing was not the root cause of the problem, and if it was, we would epoxy every potentially exposed area to solve the issue. When waterproofing was not at fault, we'd instead test every aspect of the device to attempt to resolve the errors.



Circuit Diagram

After connecting the crocodile clip to ground, the light pen lights up if it is touching a positive contact.



Looking Back & Looking Ahead

Lessons Learned

The most important lesson learnt from this experience was primarily about teamwork, interpersonal skills, and time management. We learnt that time management and effective task delegation are key to a productive company, and we hope that next year we will be able implement these guidelines earlier.

A second important lesson we learned was the absolute importance of technical testing and troubleshooting before implementation. Water-testing is absolutely essential. Murphy's law is king. Everything tends to go wrong, especially when the team is our team and the robot our robot. Extensive troubleshooting beforehand not only enables you to work with a more reliable ROV, but brings with it a positive mindset with which to approach problems. We learned the real value of being patient and persevering, and are consequently more open to trying unconventional solutions. This open-mindedness allowed our ROV and our skills to begin to take form, with our work culminating into a functional ROV.

Future Improvement

Next year, we hope to greatly improve our propulsion system by introducing microprocessor motor control. We decided to only use DPDT switches this year to control our motors, and although it is a more robust system, precise maneuvering is somewhat restricted with this system. Next year, we hope to control the speeds of our motors accurately using PWM signals generated by the Arduino UNO R3 chip, and use multiple L293D motor driver shields to act as an interface between the Arduino and the motors. If possible, we hope to be able to control the speed of the motors in real-time through a software interface on a laptop, instead of using a potentiometer.

Team Reflections

Caitlin Fischer (16): Design Engineer:

"Our teamwork and efforts were tried and tested countless times as we endeavored to build our underwater robot. Layers of complexity shrouded every seemingly simple task, and solving each initially-impossible problem that arose took hours of frustration, perseverance and sheer, simple, hard work. That said, though, seeing our team's vague, broad ideas begin to take shape into a functional robot was more rewarding than we could've ever predicted, and the experience that we now have is invaluable. Next year, we hope to better apply our experience, and cooperate together as a team to create a more purposeful and effective ROV."

Edwin "MCE" Fong (17): Electrical Engineer:

"This year, I took a bunch of wires and made magic happen. It really was just great. Oh, and, Arduino. Programming experience. That stuff was great too. But seriously, it was actually pretty difficult to get working electronics. I'm quite proud of what I've achieved personally and what we've achieved as a team."

Alexander Nehmzow (17): Communications Officer:

"This year was tough. I'm really glad that we managed to persevere to the end. I'd like to thank my family and friends for support, because without them – oh god, I just can't do this anymore. We'd be better off building three-piece lego and doodling in crayons."

亞瑟“墨菲”黃 (17)：行政總裁:

“不能等待最後！只是開個玩笑，我只是用一種冥想的技術稱為設置低期望，使我避免失望。”

[Translated via Google]: Arthur "Murphy" Wong (17): Chief Executive Officer:

"Can not wait for the last place in race! Just a joke, I just use a meditation technique called set low expectations, so I avoid disappointment."



"Memories"

References and Acknowledgements

References

MATE ROV website, MATE ROV HK website, for scoring information and task information:

<http://www.rovcontest.hk/>

<http://www.marinetech.org/>

The website that provided our circuit diagrams:

<http://www.ladyada.net/images/mshield/mshieldv1-schem.png>

The Arduino Reference Library, which provided software programming details (<http://arduino.cc/en/Reference/Libraries>).

Google translate, www.google.com

Acknowledgements

We would like to extend a serious thank you to the Hong Kong MATE ROV Workshops for their invaluable assistance, and for the basic materials they donated (see the budget sheet).

Thank you to Dr Robin Bradbeer, Dr Tsaja, and Paul Hodgson, for hosting the aforementioned workshops. Their effort, time spent, and contributions were of paramount importance to our ROV and we only hope we can live up to their examples (an unlikely prospect).

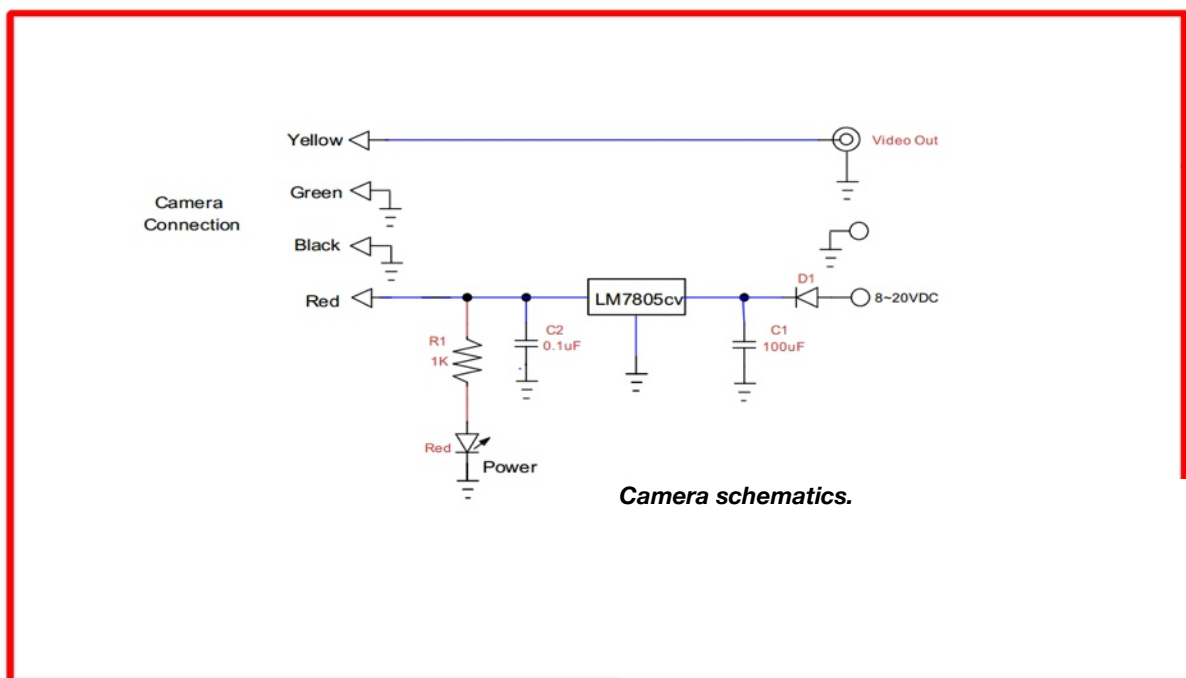
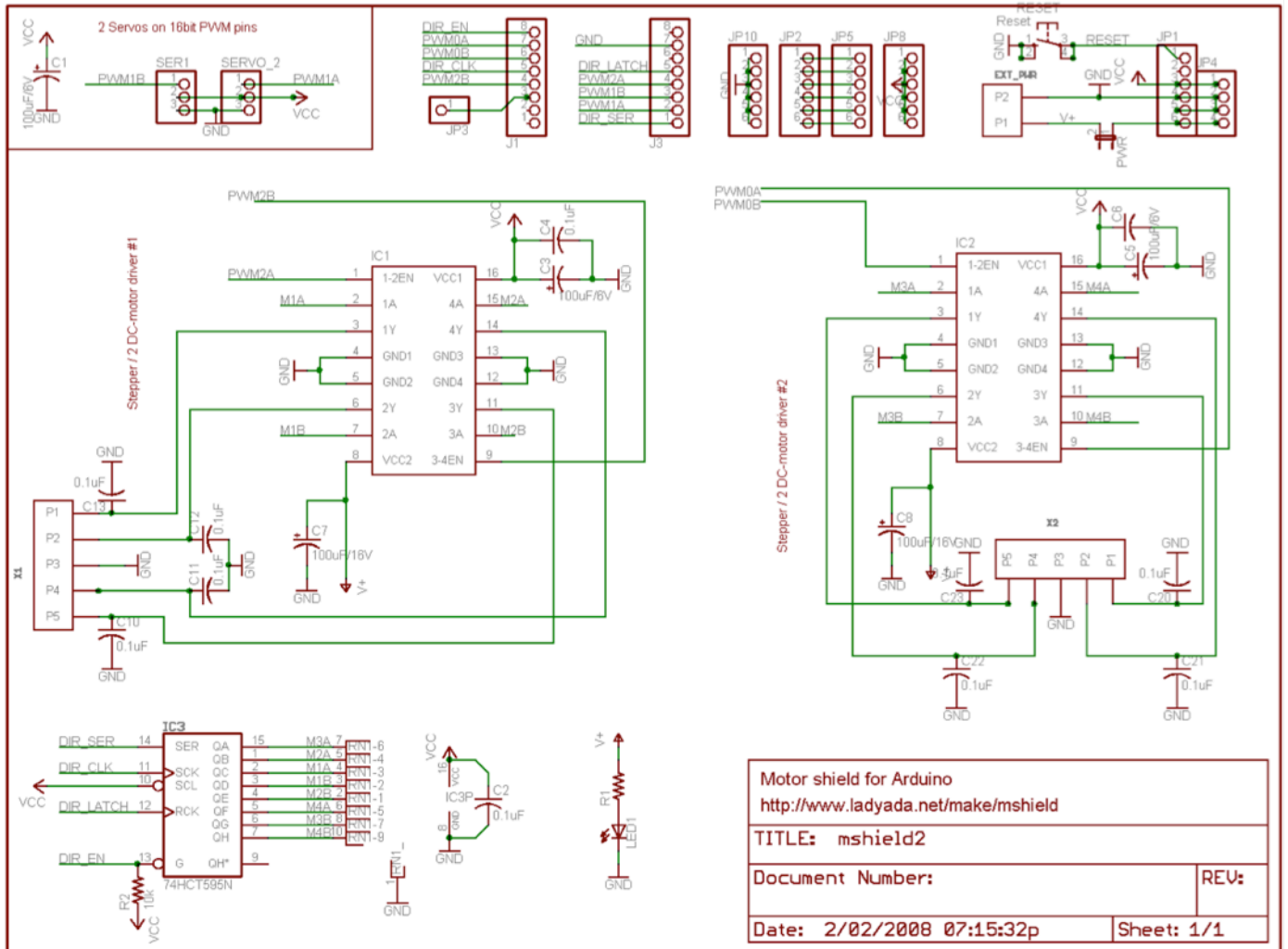
Thank you to John Shearman, for his invaluable advice and guidance, and monetary support.

Special thanks to Paul Hodgson for additional assistance with the servo-motor gripper.

Special thanks to Dr Bradbeer, Paul Hodgson and HKUST for providing a set of props to water-test the ROV on.

Appendices

L293D Motor Shield Schematics



Appendix 2: Safety Checklist Before ROV Deployment

Electrical

	No exposed propellers; must be covered by a mesh casing
	Sharp edges on the ROV have been filed down
	All components are securely attached to the chassis
	Hazardous areas of the ROV are painted a bright colour
	ROV chassis is securely put together

Mechanical

	Each motor is in series with a 2.5A fuse
	No exposed wire
	All control circuits are mounted inside a grounded container
	Any soldering joints in the tether are covered in heatshrink
	Only one attachment to main power source
	No frayed wires which may cause shorts in the control box
	Motor casing is intact and does not expose the motor
	Wires must be secured together; no loose wires

Appendix 3: Company Schedule

Target	Deadline	Members Involved /In Charge
Chassis System Constructed and Complete	January	Edwin, Alex, Caitlin, Arthur, Fergus
Cameras Functional	March 1st	All Members
Control System Complete	March 5th	Edwin
Task 1 System Complete	March 10th	Arthur, Fergus, Edwin
Other Task Systems Complete	March 20th	All Members
Poster Started	March 31st	Christina
Technical Report Started	March 20th	Alex
Technical Report Finished	24th May	All Members
Final Checkups and Safety Inspections	6th June	All Members
Day of Competition 1	21st June	All Members
Day of Competition 2	22nd June	All Members

Appendix 4: Budget Sheet

ROV Expense Sheet						
Category	Description	Use	Quantity	Amount (HKD)	Donated/ Bought	Donor/ Source
Parts	PVC Pipe (20mm diameter)	Chassis	3m	\$50	Bought	n/a
Parts	PVC T Joints and L Joints	Chassis	8 x L Joints, 6 x T Joints	\$28	Bought	n/a
Parts	PVC Pipe (35mm diameter)	Chassis	1m	\$10	Donated	GSIS
Electronics	Rule Submersible Bilge Pump (500 GPH)	Movement	2	\$270	Bought	n/a
Electronics	Rule Submersible Bilge Pump (500 GPH)	Movement	6	\$810	Reused from last year	n/a
Electronics	Arduino Uno	Motor Control	2	\$300	Bought	n/a
Electronics	Arduino Kit 293D	Motor Control	1	\$70	Bought	n/a
Electronics	Arduino Kit 298N	Motor Control	2	\$120	Bought	n/a
Electronics	Arduino Cables	Motor Control	50	\$35	Bought	n/a
Electronics	Temperature Sensor	Temperature Sensor	1	\$25	Bought	n/a
Parts	Speaker Cable	Motor Control	96m	\$200	Reused from last year	n/a
Parts	Pump U-mounts	Chassis	8	\$80	Reused	n/a
Parts	Clamp	Claw	1	\$100	Donated	GSIS
Parts	Epoxy + Hardener	Waterproofing	1 x each	\$220	Bought	n/a
Parts	Waterproofed Camera	Camera	2	\$500	Donated	MATE ROV Workshop
Electronics	Camera Power Supply	Camera	2	\$40	Donated	MATE ROV Workshop

Total expenses for 2013 competition: \$1118 (USD \$144)

Total estimated value of the ROV: \$2858 (USD \$368)

(NB: as of 24 May 2013, USD \$1: HKD \$7.76)

Appendix 4: Code for Arduino Servo Motor Control

```
int DS18S20_Pin = 2; //DS18S20 Signal pin on digital 2

//Temperature chip i/o

OneWireds(DS18S20_Pin); // on digital pin 2

#include <Servo.h>

Servo myservo; // create servo object to control a servo

intpotpin = 0; // analog pin used to connect the potentiometer

intval; // variable to read the value from the analog pin

void setup(void) {

Serial.begin(9600);

myservo.attach(9); // attaches the servo on pin 9 to the servo object

}

void loop(void) {

val = analogRead(potpin); // reads the value of the potentiometer (value between 0 and 1023)

val = map(val, 0, 1023, 0, 179); // scale it to use it with the servo (value between 0 and 180)

myservo.write(val); // sets the servo position according to the scaled value

delay(15); // waits for the servo to get there

float temperature = getTemp();

Serial.println(temperature);

delay(10); //just here to slow down the output so it is easier to read

}

floatgetTemp(){

//returns the temperature from one DS18S20 in DEG Celsius

byte data[12];

byteaddr[8];

if ( !ds.search(addr)) {

//no more sensors on chain, reset search

ds.reset_search();

return -1000;

}

if ( OneWire::crc8( addr, 7) != addr[7]) {

Serial.println("CRC is not valid!");

return -1000;

}

if ( addr[0] != 0x10 &&addr[0] != 0x28) {

Serial.print("Device is not recognized");

return -1000;

}

ds.reset();

ds.select(addr);

ds.write(0x44,1); // start conversion, with parasite power on at the end

byte present = ds.reset();

ds.select(addr);

ds.write(0xBE); // Read Scratchpad

for (inti = 0; i< 9; i++) { // we need 9 bytes

data[i] = ds.read();

}

ds.reset_search();

byte MSB = data[1];

byte LSB = data[0];

floattempRead = ((MSB << 8) | LSB); //using two's compliment

floatTemperatureSum = tempRead / 16;

returnTemperatureSum;

}

}
```