2009 MATE International ROV Competition

Technical Report

by

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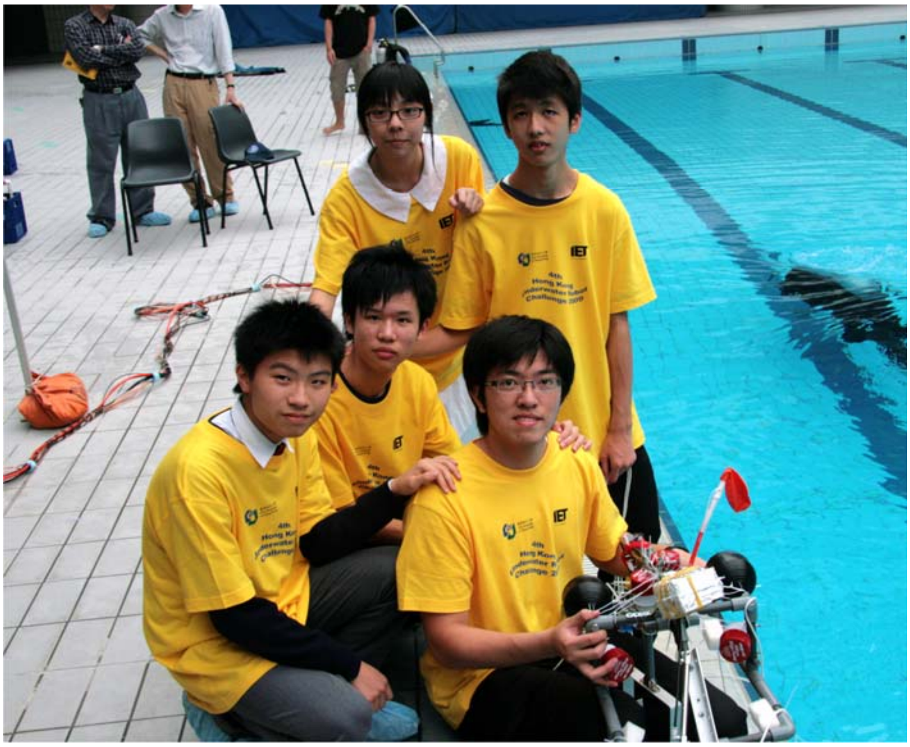
(KTSCSS)
IT School Team



Team Members: **Game Field Members**

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Abstract

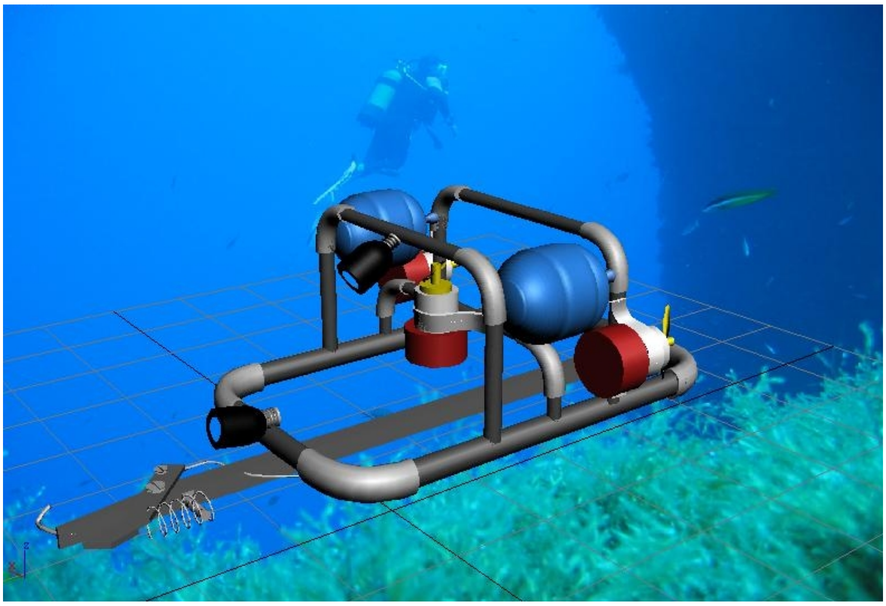
Our ROV team is composed of six members, all of whom are new to this project. The scenario of this year's ROV competition is to complete a submarine rescue training exercise. Different components of our ROV is built to tackle the following four tasks assigned by MATE

Task 1: Survey and inspect the submarine for damage
Task 2: Pod posting
Task 3: Ventilation
Task 4: RORV (remotely operated rescue vehicle) mating

Accordingly, the ROV should be capable to move under water, viewing underwater, grabbing and turning objects. A total of three factors are taken into consideration including the cost, reliability, and efficiency.

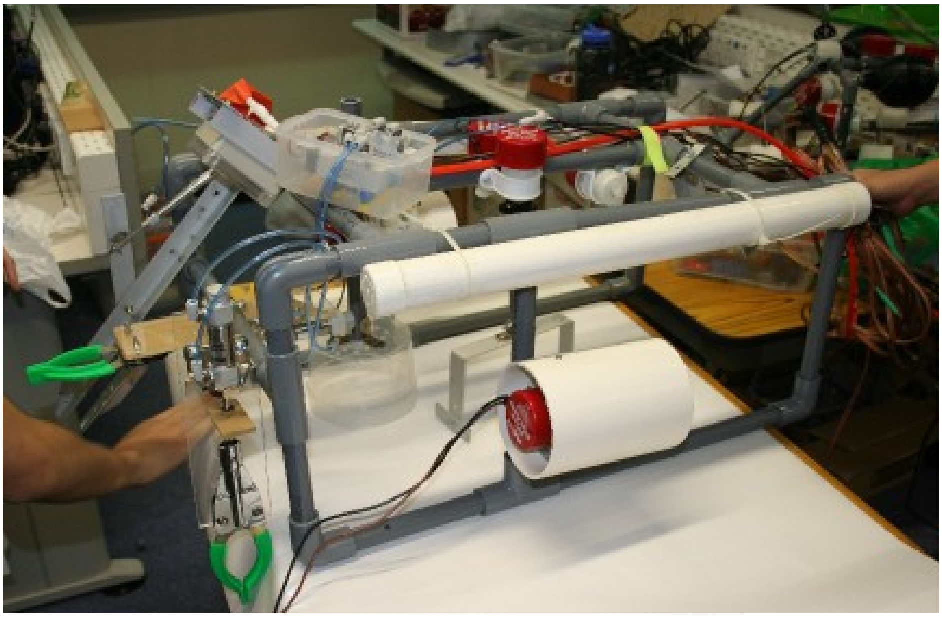
First of all, there will be buoyancy pontoons that can balance the vehicle to an equilibrium state under water. Focusing on the four tasks, we designed three devices to achieve these tasks. To deal with the first task, three **water-proof cameras** are built and located in different position (top-front, side-back) of the ROV in order to inspect the submarine damage in different views. All of them are adjustable for the position and the focus. For task 2 and 3, two **pliers** which are motivated by pneumatics system are built to grab and hold object (ELSS pods, Ventilation system valve, insertion point) under water and open the hatch or door handle. Also, a **rotational robotic arm** is made to turn (lock / unlock) the hatch. To achieve this, an electrical circuit board is made to control the speed of rotation together with direction of rotation such that it can turn clockwise and anticlockwise. For the last task, a **transfer skirt** is build to complete surround the escape hatch.

Our ROV, KTSCSS, is the result of well-planning, creativity, problem solving techniques, and the most important one, teamwork.



Primitive design of our ROV

Table of contents



Design Rationale

In order to complete all tasks, we made out the ROV step by step following the requirements of different missions. Firstly, we made out the frame of the ROV using plastic tubes which is controlled by six thrusters. Each thrusters can be individually switched to perform different directional movement of the ROV. Secondly, we made the pneumatic driven pliers which are motivated by pneumatic system for clipping the ELSS pods, Ventilation system valve, insertion point as mission required. Thirdly, we made three water-proofed cameras, each connected with a bundle of metal wire which can be bent for a better and flexible sight. Three cameras are needed to minimize the vision illusion by only one camera. Following the tasks' requirements, to open and close the escape door hatch, a rotational robotic arm is also made out. To achieve this, an electrical circuit board is made to control the speed of rotation together with direction of rotation such that it can turn clockwise and anticlockwise in different speed. Besides, a plastics transfer skirt is built to complete the mission of surrounding the escape hatch of the last task. At last, some floating material are added to the robot, in order to meet the equilibrium of the floating force and the sinking force.

The final result of our hard work is a functional ROV which performed well in different missions. All features of the ROV are showed in detail in the following technical report

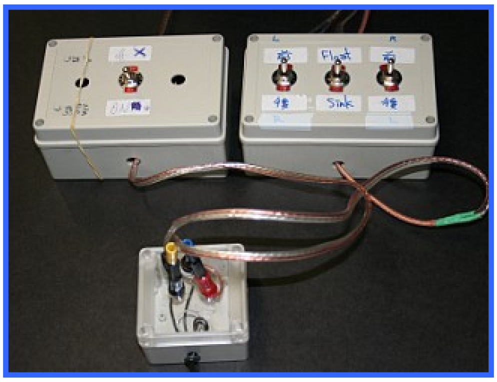
Detail design

Control System

Our team decided to use a relatively simple control system, so that it can be repaired and improved whenever needed. Hence, we avoid to use any software for the control of different tools of the ROV, but using manual control system in order to make it more flexible and can be repaired at any time.

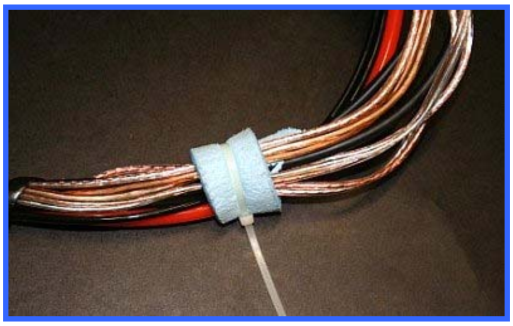
We have built six simple thrusters, each with a small propeller to control the direction of movement of the ROV. Each of the 12V thrusters is connected to the same electronic circuit, with a 1A fuse in the positive pole, while the electronic circuit is driven with a 12V DC power supply for all parts and accessories. All the thrusters are controlled with individual switches by hands, so to perform different directional movement of the ROV. One thruster responses for the vertical movement, two for horizontal movement, and two for left and right turning and the last one is linked with the rotational arm as task required. The circuit is shown in the electrical schematic

For simpler control system as decided, three pneumatic driven pliers are all controlled by pneumatic system for easier access to the control and repair. One pliers are controlled by a separate switch while the other two are controlled together by another switch. The air compressor of the system is droved with 12V D.C and it provides a maximum of 250 PSI as per the MATE safety rules required. Further explanation of the pneumatic system is showed in the part of the pliers.



Pneumatic Control Switch

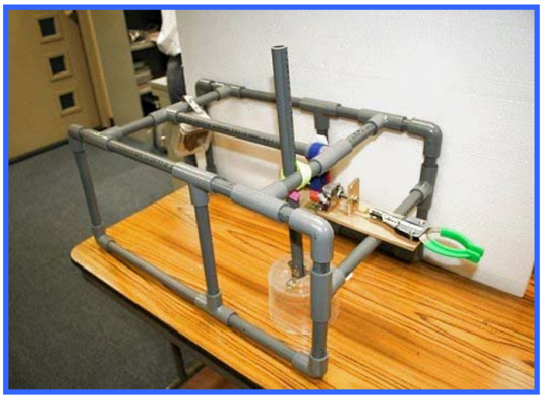
After placing all the components in their proper locations, we bundled all their cables together as the tether. The tether has a length of 10m which is affirmatively enough for accomplishing all the tasks required. Included in the tether are cables that carry the power for the thrusters, video signal for the cameras and air pressure of the pneumatic system. We decided to use two lines of 4mm polyurethane tubing for the pneumatics because the tubing functions well that can stand for 116 PSI inner pressure. We chose coaxial cable for the cameras because of its durability and compatibility with the input and display portions of the camera.



Frame

The frame was all made of PVC, including the main tubing and all the joints. We chose to use PVC because it costs much lower than other kinds of materials such as aluminum and it is relatively light and strong. It can be easily cut and drilled without affecting its stability. It can also support mounted items easily.

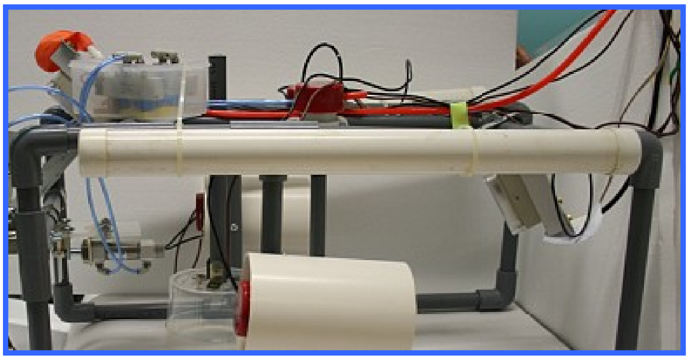
To complete those four missions, different devices have been made. In order to equip all these devices into the ROV, the original frame is modified and now shaped as rectangularity, so to provide enough places for the attachment of all the devices. The length of the frame is 68cm, with a width of 39cm and height of 32cm. All systems and components are attached directly to the frame of the ROV by screws. They are mainly placed inside the frame, so that the frame can also act as a protection for these devices.

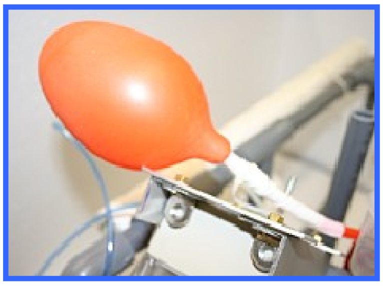


We tried to make the frame as light as we could, and we also controlled its size not to be too large. Thus, the ROV can move much flexibly than the large one with a smaller force provided. It is also more convenient for transportation.

Buoyancy

Originally, buoyancy of the ROV was maintained by some buoyant balls which location can be changed easily. However, it can hardly work well underwater. Therefore, we decided to replace the buoyant balls with two pontoons, one on each side, so to balance the weight of the other devices. These pontoons were built by using 4mm PVC pipes because of its lightweight and strong upward-floating force induced. The ends of the pontoons are repeatedly sealed up, so to prevent the leakage of air inside. As the size of the pontoons is fixed and the location of them cannot be changed, we decided to tie some foam onto the frame for fine adjustment of the buoyancy according to different situation we would face. Hence, buoyancy of the ROV is much flexible than before.

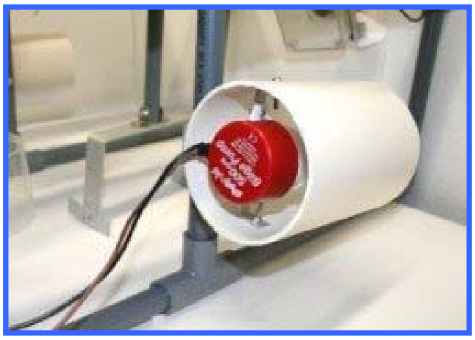




In case any object that we need to transfer is too heavy for the ROV to uplift and move it, we also decided to add a balloon at the top of the frame. If the object is hard to transfer, we would blow up the balloon to provide the floating force for the ROV to transport it. It is also design for emergency. If the thruster which controlling the up and downward movement of ROV fails, we can use it to float the ROV to the water surface for fast repair.

Propulsion

Our propulsion system consists of six simple thrusters. Initially, all motors of the thrusters are those can pump 500 gallons per hour only. Since we found that were not powerful enough for the whole movement of the ROV, we replaced the motors with other stronger ones. The motors of these thrusters now were used be the marine bilge pumps that can pump 1000 gallons per hour. After this replacement, the ROV can move much quicker and easier now.

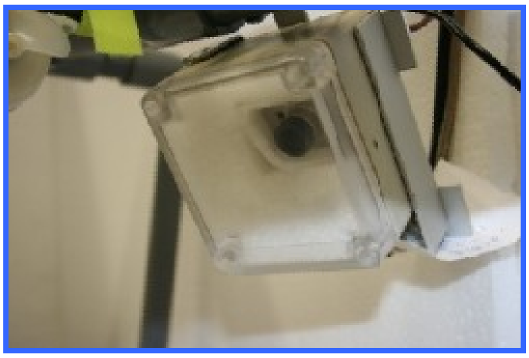


After adjustment of turning the pumps into pure motors, each thruster is now connected with a two blade propeller to control the direction of movement of the ROV. All the thrusters are controlled with individual switches by hands, so to perform different directional movement of the ROV. One thruster responses for the vertical movement, two for horizontal movement, and the last two for left and right turning control.

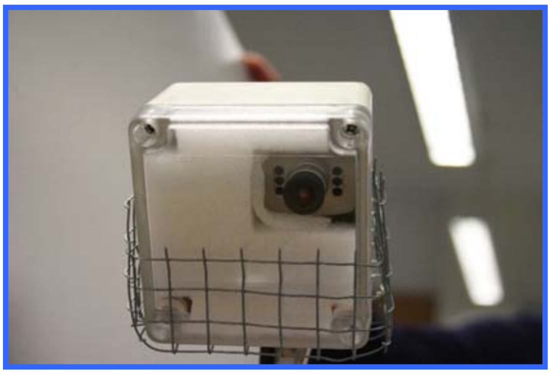
Since most of our propellers are built on the inside of the frame, but not attached on the outside, they are safer and much better protected by the frame. For extra protection, a cover made of PVC pipe is also added to surround each of the propellers. The cover can protect the propellers from hurting the marine life like fishes or sea weeds. It also helps in concentrating the force induced by the propellers, so to increase the efficiency of it and the ROV moves even quicker.

Cameras

Our team decided to incorporate a total of three cameras into the ROV as we thought that three cameras could bring us the best view with good perspective and enhance the depth perception. All three cameras are combined with wide-angle lens, so that we could capture a greater viewing area which would be easier for completing the tasks. As the cameras do not weight much, so we did not need to worry about the unbalance of the ROV that may cause by the cameras.



As we have limited budget, we decided to make the water-proofed cameras by ourselves instead of buying an entirely new camera from outside. We had put the camera into a plastic box and then sealed the box up after connecting the cameras with the cables. To ensure water could not get into the box, we put a rubber band between the cover and the box which is the same as those water-proofed watches, so that water can hardly pushed into the box under the hydrostatic pressure. All three water-proofed cameras are powered by a 12V DC power supply and the video signal of cameras are sent to the TV set through the coaxial cables. Each camera is attached to the frame by an aluminum bar. Thus, it can be taken out for repair easily and the direction of the camera could still be able to change after attachment.



The cameras act as our eyes underwater to locate objects. Two is for focusing on the tools which can help us to pick up the objects and drop them underwater. It helps us to finish the task more easily. And the other one is for the ROV directional control. It can also help us to perform a better control with the ROV. Besides, it is used to capture some view which is far away from the ROV in order to search the targets easily.

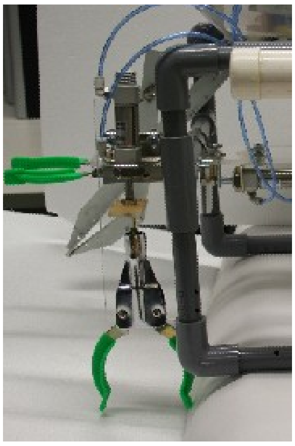
Each camera requires 12V to activate and coaxial cables are connected to receive the video signals under water. A adapter is needed to convert 220V A.C into 12V D.C.

In order to improve our views under water from the ROV, we use a 4-in-1 video signal adapter to view all the scenes from the three cameras.

Tools - Pneumatic driven pliers

Attempting to accomplish different tasks requirement, a total of three pneumatic driven pliers are made. Two pliers (A, B) are made using the front part of rubbish clipper while the other one (C) is completely hand-made. All three pliers are mainly made of aluminum which is non-ferrous and light weighted.

A



B

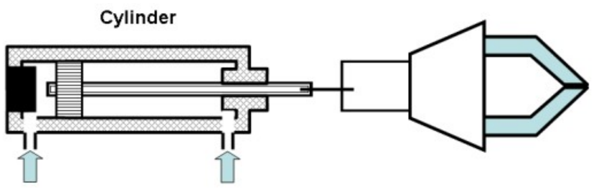
C

A : Placed horizontally to open the hatch of the ventilation system

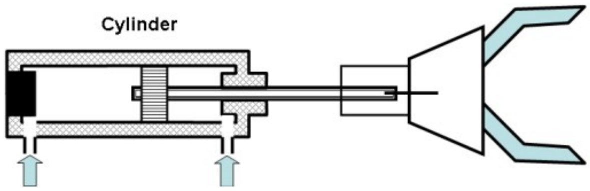
B: Placed 90° to the frame for carrying the ELSS pod

C: Placed 45° to the frame for inserting the pod into the escape tower

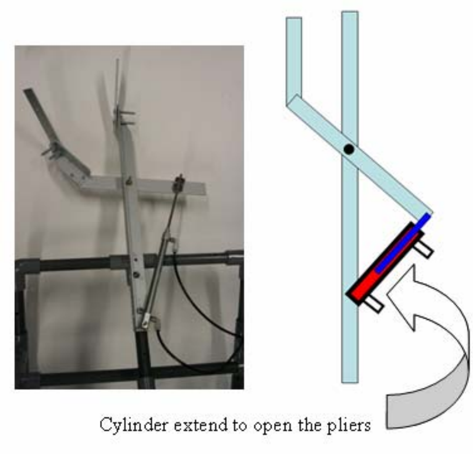
As the mechanical pliers are built to grab objects under water. The pliers are controlled by the pneumatic system which provides more stable force to the pliers. The pneumatic system uses air pressure to push a cylinder moving forward and backward such that it can adjust the pliers to grab and release object. The pliers are controlled through a long wire which is connected to the compressor by adding or decreasing the air pressure inside the wire, while the compressor is controlled on land using a separate switch. So that the pliers can open up or close tightly and the object can be picked up and drop down underwater by the pliers.

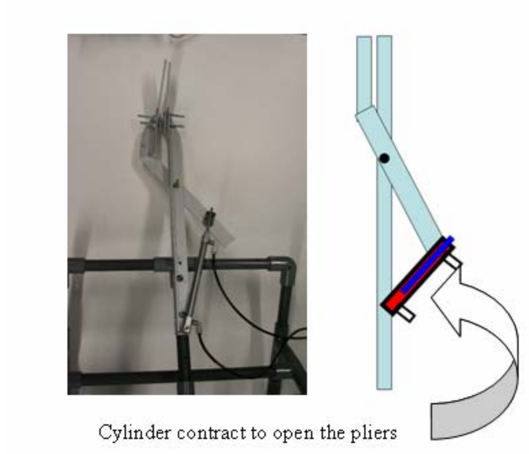


Cylinder shrink to close the pliers



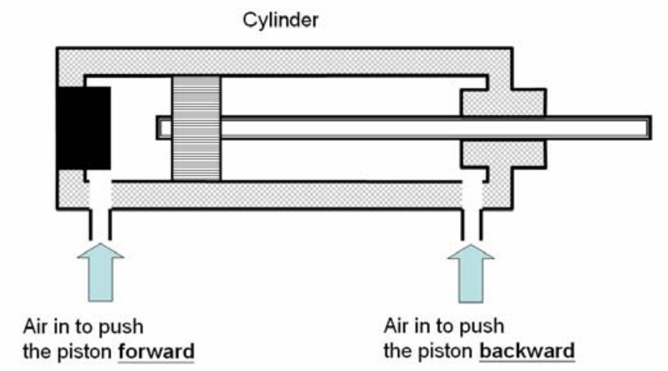
Cylinder contract to open the pliers





Pneumatic System

Device used on land to control the air pressure make used of the pneumatic system. When air is pumped by the compressor into the device, air is transported through the connecting tubing to the cylinder of the system. Hence, air pressure can be controlled by us.



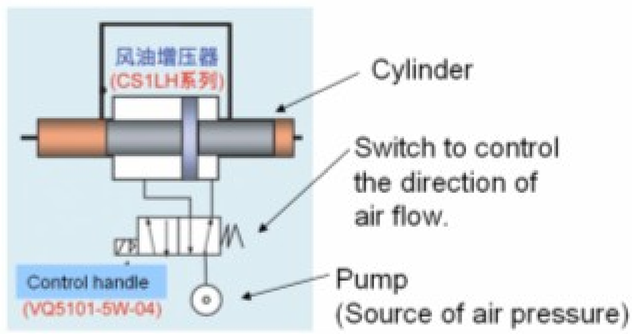
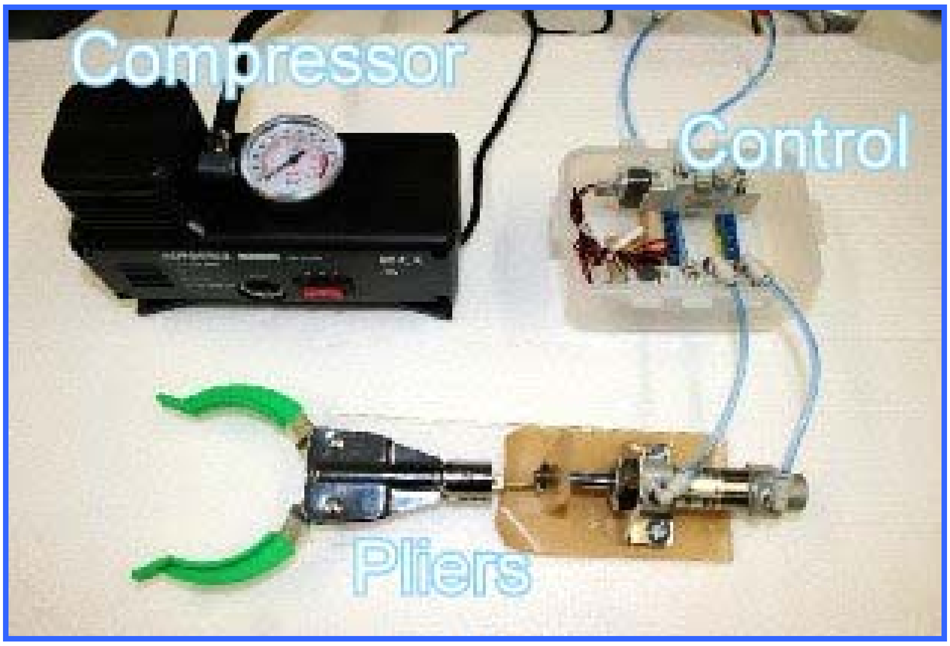
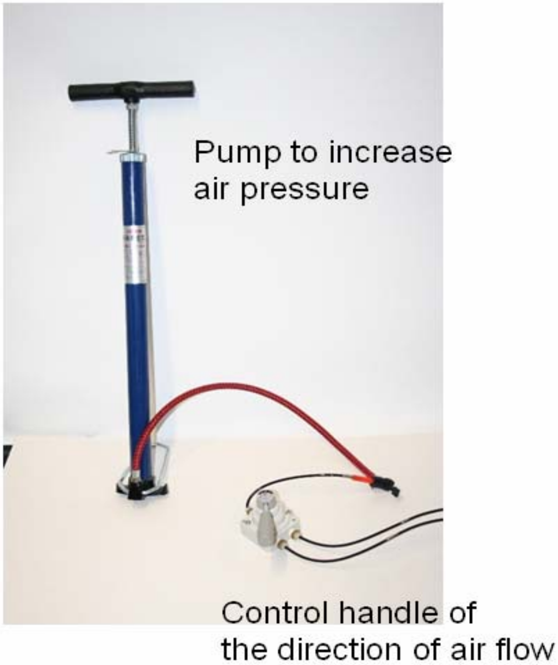


Diagram showing the mechanism of the pneumatic System



The whole Pneumatic System for one pliers.

The pneumatic system works based on the change in air pressure inside different parts of the cylinder. When the pump is controlled to release air into the rear part of the cylinder, the air pressure at the rear part increases. As the air pressure increases and it is larger than that of the front side, the tubing inside the cylinder separating the front and the rear part is forced to move forward. The tubing is then extended out of the cylinder and the arm is opened. It is the same way to make the arm closed while the pump has to release air into the front of the cylinder to push the tubing move backwards.

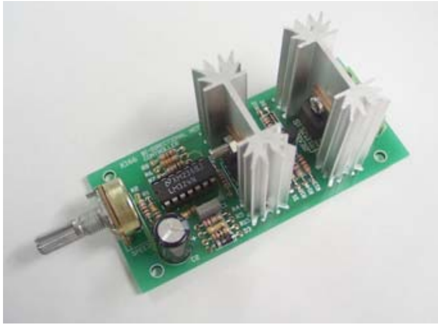


Initially, we used to use this manual pump to change the air pressure of the system. However, this method was lack of efficiency and accuracy. Hence, we make use of the compressor this time.

Compressor

Tools - Rotational robotic arm

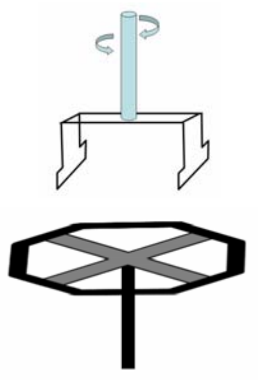
A robotic arm is made of aluminum which is non-ferrous and light weighted. It is used to open and close hand wheel of the escape door hatch. The robotic arm placed near the middle of the ROV, inside the frame. It is powered by a 12V DC power supply. To control the robotic arm, an electrical circuit board is added. It is used for controlling the speed of rotation together with direction of rotation such that the arm can turn clockwise and anticlockwise in different speed. Hence, the hatch can be opened by the robotic arm as the direction we controlled.



Circuit Board for controlling the speed and direction of rotation of motor

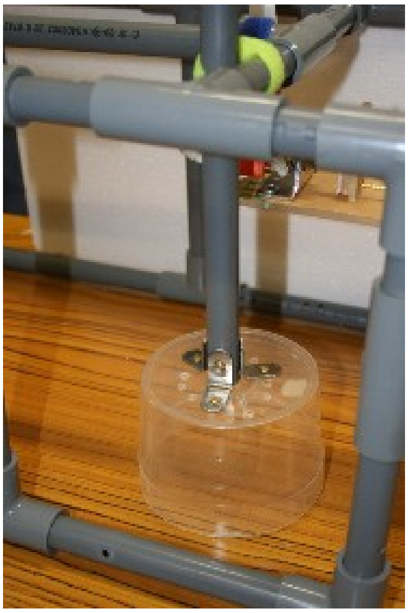
Robotic arm made of aluminium for turning the escape hatch

After the lower part of the robotic arm gets stuck into the gap of the hatch, the arm would be controlled to rotate. As enough force is produced for the rotation of the arm. The hatch is therefore forced to follow the arm to turn. In other word, the hatch is pushed by the robotic arm to turn and get opened.



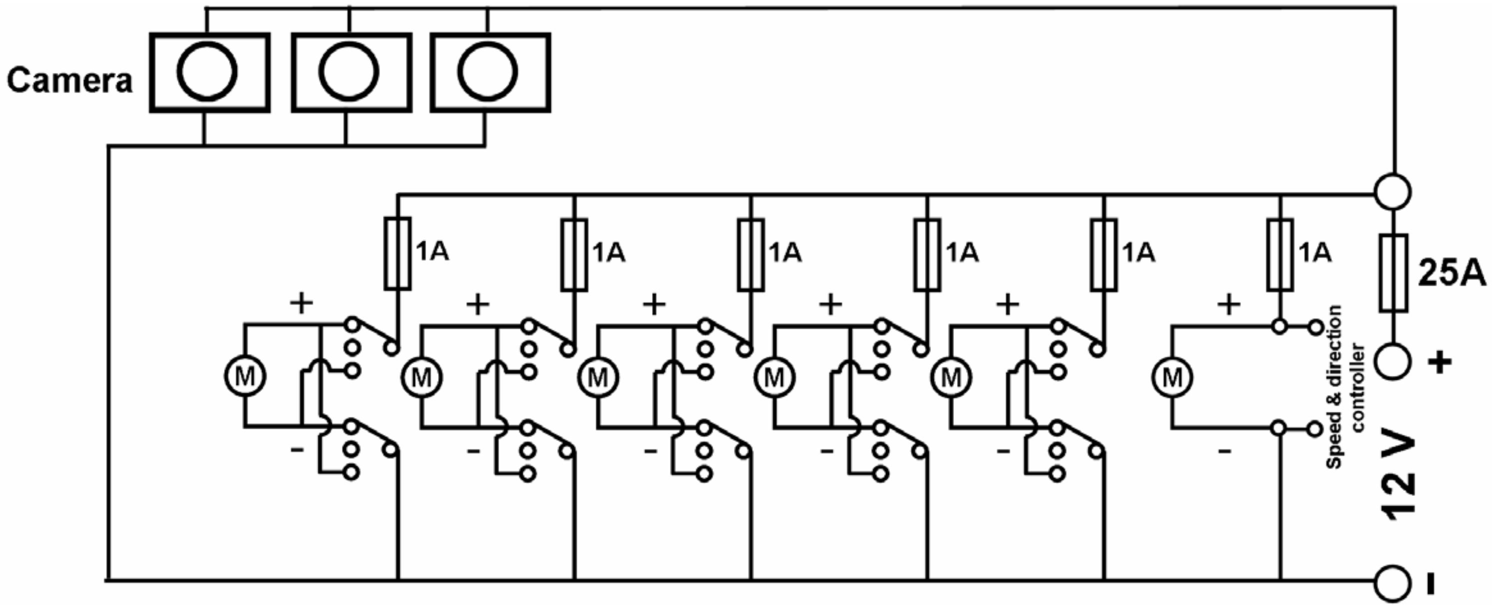
Tools - Plastics transfer skirt

A plastics transfer skirt is built for mating to the escape hatch. It is placed right next to the robotic arm, near the middle of the ROV, inside the frame. It is the simplest design of the whole ROV, but also the most reliable one. On the skirt, there are some holes drilled on the top of it. They are made for allowing the water inside to flow out, so to mate the escape hatch successfully.

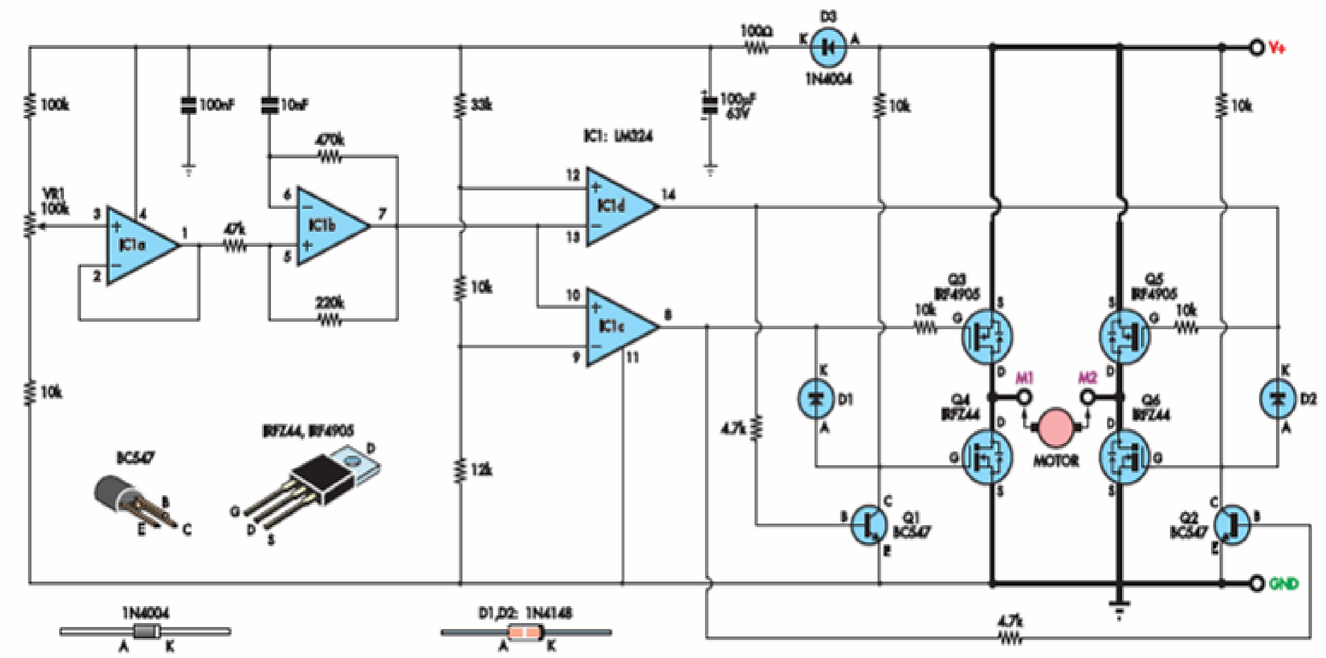


Electrical schematic

Overall ROV electrical schematic



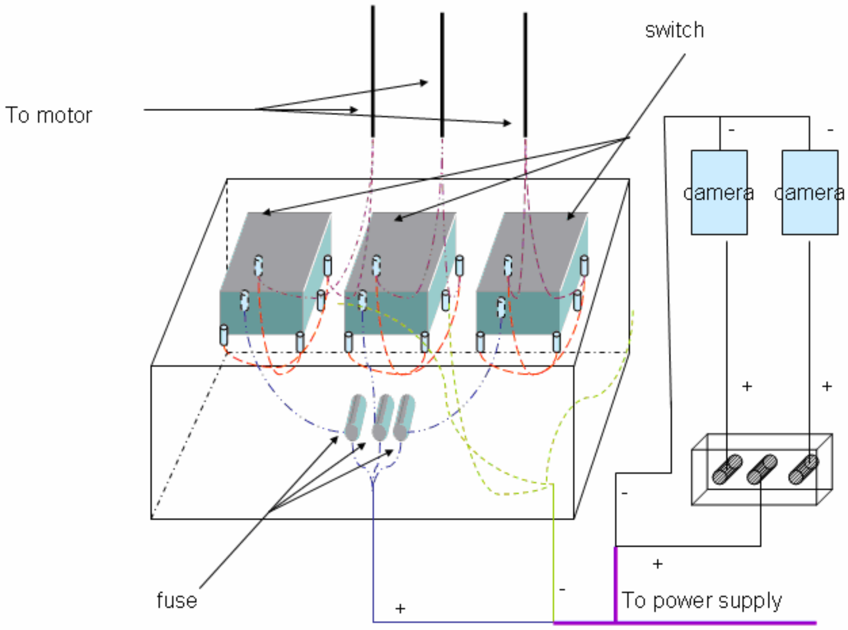
Motor speed and direction controller for Rotational robotic arm



SC BIDIRECTIONAL MOTOR SPEED CONTROLLER

Fig.1: four power Mosfets can drive the motor in either direction, the speed and direction set by potentiometer RV1.

3D view of the circuit connection



Challenge Faced

We have faced quite a lot of challenges while making the robot. The most common one is to set a working schedule. The members of our team are from different forms, so we have totally different timetable. Also, all of us are really busy in our own study. Thus, it is pretty hard for us to find the suitable time to have meetings or discussion together for this project. To cope with this problem, we decided to have meetings every day after school. Whoever are free on that day, they should attend the meeting and write down their ideas on the board as a reference and record to other members. Only after all members agreement, the idea on the board would be use on the ROV.

During discussion, we often have different ideas or conceptions for how to improve the design of the robot. And we sometimes argue for that. Luckily, under the calmly and logically coordination of each other, we can always find out the best decision together. If we are still unable able to find out the solution, we would do tests to proof what the best solution would be. That’s how we deal with the problem of communication.

For technical challenges, we found that friction of the cables and the plastic tubing will greatly reduce the efficiency of power. To solve the problem, we use a new method in which we got the idea from the gear set of toy car, which needs lubricating oil to reduce power loss. We used lubricating oil to lubricate both wire and the inner wall of the tube. After finishing this work, the friction between the wire and the plastic tube decreased and we could transfer most of the energy to the ROV. From this experience, we found that observation of normal life is surprisingly helpful in doing this project.

Troubleshooting techniques

Since all of the members in our team are completely new to make ROV, we had to over come plenty of problems throughout the process of making the ROV, especially for those technical problems that really need experience to help solving. After many times of failure, we finally found out a better way to deal with this problem. We first need to concentrate on the basic system to check whether the problem is caused by the whole system or not. Then, we have to check separate components. After finding out the reason, we have to calm down to look for solutions. If and only if we can stay calm, we can find out the solution in the shortest time. That’s how we solve the following problems.

Firstly, as the rotational arm would not be powerful enough to turn the wheal if the motor rotate too fast and the force cannot be concentrated on the arm. Thus, we attempted to control the rotation speed of the motors, we decided to make out a new circuit board by welding it ourselves. After using this system, speed of rotation together with direction of rotation can be controlled by ourselves such that the arm can turn clockwise and anticlockwise in different speed.

Secondly, one of the most challenging tasks is the construction of the camera. We were facing batches of problems and they must be solved because we could not finish all the tasks in ‘blind’ status. In order to make our sight clear after the robot is put into the water. We took lots of time to make the camera a water-proofed one. We put the camera into a box which is sealed up and we kept all the connective parts of the wires inside the box. Hence, water can hardly enter the box and interference to the camera due to the water is therefore prevented.

Thirdly, as if the pliers are controlled through the motor activated by electricity, the force produced would not be enough to finish the mission. That is because the total power provided is fixed, all the electrical devices have to be activated by that fixed power. Therefore, the more the electrical devices are used, the less the power each electrical device can have. As the consequence, not enough electrical power could be provide to the motor controlling the pliers and not enough power would be generated for the movement of the pliers. Therefore, we use a different design using air pressure to push the pliers to move. The pliers are controlled by the pneumatic system which uses air pressure to push a cylinder moving forward and backward such that it can adjust the pliers to grab and release object. The pliers can be controlled through a long wire which can be controlled on land by adding or decreasing the air pressure inside the wire. Thus, less electricity is consumed and the pliers can function well. In addition, as the pliers don not need electricity to activate, more electricity can be used for the other parts of the robot.

Lesson learned or skill gained

We have found that front engine is more convenient to change the direction of the ROV facing since it can reduce the error distance made during the rotation. This moving system can help us to accurate the movement of the vehicle.

Besides, glass bond cannot prevent entry of water even the part is totally coated. On the other hand, mixed micelles can finish the task of preventing the entry of water. Also, rubber band provides a better performance in water than using another wire to bring it back to initial position.

Apart from that, we also found that power would lose when the distance between the vehicle and the control centre increases. That is probably because of the electrical resistance of the connecting wires. Part of the electrical power is consumed to against the resistance before the power reach the robot.

At last, we knew that it takes lots of caution while making the water-proofed camera. All the rims and gaps must be sealed up carefully. Not any gaps are allowed to be available, in order to make sure no water would be able to get into the box. Otherwise, the sight would be blurred.

Discuss of Future Improvement

Our future improvement to make would be the practicability in reality. In real cases of rescue operation under water, the screw propeller may be jammed by the seaweed or other objects in the water. This would cause great troubles to the rescue as the robot could be stopped from moving on and the motors may even ran out because of that. The whole rescue would have to stop if the motors ran out.

Therefore, it is better to add a cover to each screw propeller as a protection for it. The cover should be built surrounding the screw propeller. After adding the cover, objects in the water cannot reach the screw propeller directly, so chance of getting jam of the screw propeller would be reduced. It would be safer for the whole rescue.

It is also better to reduce the size of the robot. If the size of the robot is smaller, less power is needed to move the robot. The robot can move faster as more energy is available. Also, the movement of the robot would be far flexible if the size of it is smaller.

Reflection

WONG KWOK KIN - Being the first time player to make these kinds of underwater vehicles, we did come across a great deal of difficulties. It sometimes made us frustrated. However, with the concerted efforts and time we devoted to, we finally managed to solve the problem we met. The goal of taking part in the competition is not only to grab awards, but also to learn valuables things which we cannot find in the books we learn in the school.

LI WAI KAI - Persuaded by my classmates, I joined the team unwillingly. After a week, I found my attitude was totally wrong. I realized that the competition is meaningful. Despite the electronic and mechanic knowledge I have acquired, I have built a close relationship with my team mates. We discuss and have fun in the process of making the ROV. I know that everyone cannot reach the peak of learning but I would try my best to be more attentive and cooperate with my teammates in order to display our best work.

CHEUNG LONG CHING - Building a ROV is really a harsh and difficult work. We often argue with different solutions to tackle the problem faced although all of these solutions work! Luckily, we comprehend each other in the group and understand that all of us are going to think out the best solution. We easily and undoubtedly forgive the others. In conclude, this project not just improve our ability or interest in science but also learn to hold together and the sense of belongings.

YU SZE WAI – Making a ROV is definitely an eye opening experience to me. I had never realized that making a vehicle needs so much time, skills and knowledge, don't even mention the energy brainstorming needed. Although it is a pretty tiring experience, I am so glad that I have joined this event. What it brings to me is not only treasurable memories, but also a far closer relationship with my friends.

TANG TSZ HO - ROV was an entire new idea for me in a few months ago. But now, I'm fully responsible for the camera part of this machine. In fact, it is an extraordinary difficult job for turning a normal video camera to a waterproofed one. We spent a long period of time on this. Finally, we built a completely waterproof camera. What I learnt from this event is cooperation. Since building an ROV is not as simple as I think. If we can't cooperate well, we won't success.

CHUNG KA SHING - As a participant of the competition, I am responsible for the ROV body construction. During the preparation, I have learnt how to build a multi-functional ROV with much consideration. Besides the knowledge I acquired from the textbook, I have learnt that every teammate have to contributed their creative solution to solve the problems. To conclude, I think the competition is meaningful and magnificent. My mind is inspired by the diverse ideas from my teammates. The competition gives me an engraved impression that I can never forget.

Budget Sheet

Date	Company	Item	Amount HK$
24/1/2009	CityU ROV workshop	fuse X 3	0
24/1/2009	CityU ROV workshop	switch X3	0
24/1/2009	CityU ROV workshop	motor X 3	0
8/12/2008	利豐五金	L －joint and screws	24
9/12/2008	永強（龍記）文具公司	Paper	11
	金豐五金家庭用品	Plastics adhesive tape	3
11/12/2008	永強（龍記）文具公司	paper	18
23/12/2008	香港萬豐電子行	Cameras(2)	200
22/2/2009	聯記電業	electrical cable	30
	聯記電業	40R RCA cable	64
27/2/2009	華輝電子科技	RITEC RP1056C Water-proofed box	100
	華輝電子科技	Samson 2core B/C wire,	10
	華輝電子科技	JR-6507C RCA 曲插（免焊型）	10
	華輝電子科技	JR=105B RCA 插 （金+紅）	8
9/3/2009	五金堂	針筒混合膠 (adhesive)	25
	五金堂	鯉魚鉗 **(pliers)** 鋼喉拮打	57
	五金堂	9.6V electrical screw driver	280
	有信電業器材行有限公司	熱縮喉	3
	SMC Pneumatics (Homg Kong)Ltd.	CDJ2D10 - 100 – B	84
10/3/2009	SMC Pneumatics (Homg Kong)Ltd.	KJL04 - M5	24.8
	SMC Pneumatics (Homg Kong)Ltd.	CJ - L010B	3.2
	SMC Pneumatics (Homg Kong)Ltd.	TUO425B – 20	44
	SMC Pneumatics (Homg Kong)Ltd.	VH200 -02-	260
	SMC Pneumatics (Homg Kong)Ltd.	KQ2H04 - 02s	32
	SMC Pneumatics (Homg Kong)Ltd.	AW3002 - 01DG	258
12/3/2009	金豐五金家庭用品	Air Pump , Plastic tube	58
14/3/2009	B & Q	17” tool box set	68
	聯記電業	4–in-1 video signal adaptor	280
5/5/2009	SMC Pneumatics (Homg Kong)Ltd.	Electrical switches	1268
7/5/2009	五金堂	PVC Conduit	60
9/5/2009	RONSIL DEVELOPMENT LTD	1000GPH motor	800
10/5/2009	五金堂	Compressor	178
		Total :	**4261**

10. NATO SUBMARINE RESCUE SYSTEM (NSRS)

The NATO Submarine Rescue System (NSRS) is a jointly funded project by France, Norway and the United Kingdom, to procure and operate a submarine rescue system with worldwide capability. It consists of two sub-systems that can be mobilised independently of each other.

The system is Government Owned and Contractor Operated, and entered into full Service during August 2008.

NSRS is available to be deployed anywhere in the world. As such, all equipment is fully road and air transportable to the necessary port, whereupon it shall be embarked upon the selected Mother ship (MOSHIP) before being deployed. Different aircraft and ships may be available at any particular time and location, thus the equipment is designed to maximise the use of any potential aircraft.

Resource
http://en.wikipedia.org/wiki/NATO_Submarine_Rescue_System
http://www.ismerlo.org/assets/NSRS/NSRS%20Factsheet%20Issue%204%201%20lo-res1%20_2_.pdf
http://www.sonistics.com/smer_update_ind.php?id=35

Reference

Websites

1. http://www.smc.com/
2. http://en.wikipedia.org/wiki/Submarine
3. http://web.islandnet.com/~yesmag/how_work/submarine.html

Books

1. *Jane's underwater security systems and technology.*
by Coulsdon, Surrey ; Alexandria, VA : Jane's Information Group, 2007

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Appendix A - Diagram showing the speed and direction controlling circuit board