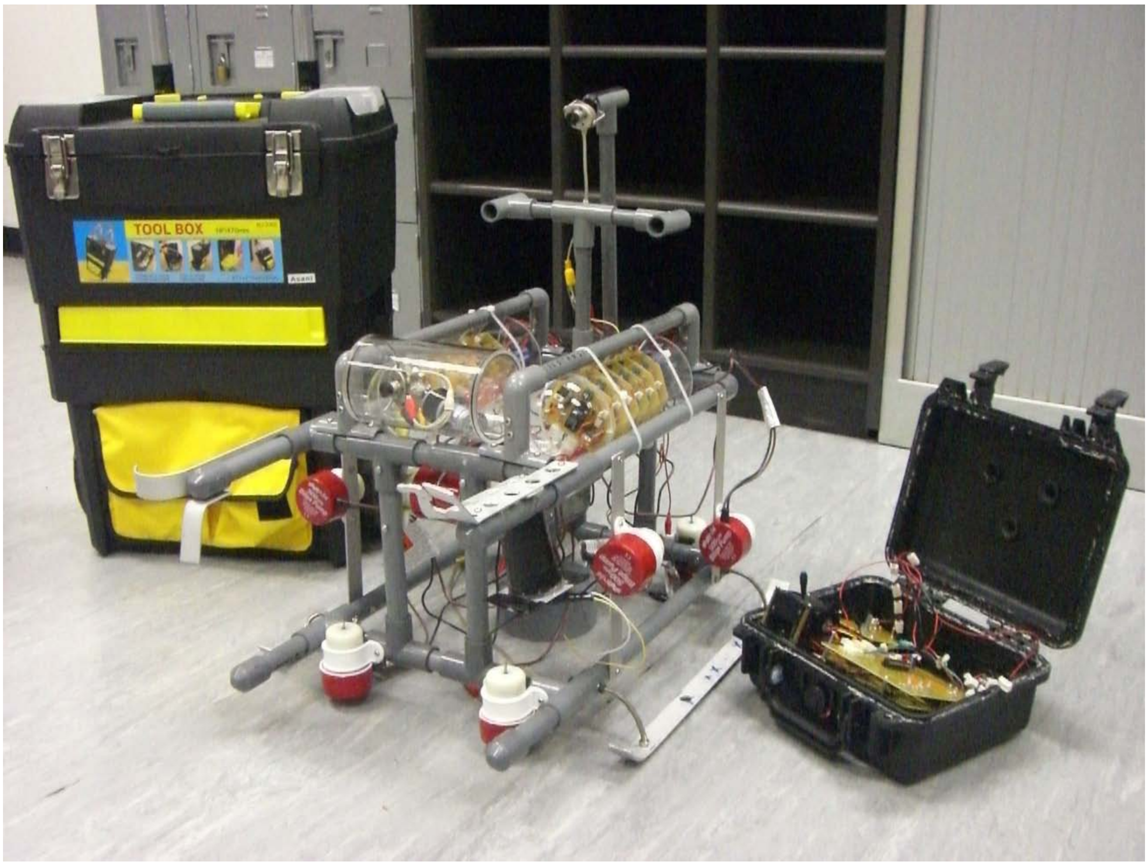
Technical Report

2009 MATE Center International ROV Competition

ROVs: The Next Generation of Submarine Rescue Vehicle

Team: TEAM DRAGON

ROV Name: SHADOW of DRAGON



2009 MATE International ROV Competition

By:

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Content

1.Abstract

This is the second time for ROV team from City University of Hong Kong to compete in the MATE International ROV Competition. This time the TEAM DRAGON of CityU, boasting a ROV with whole new design and special features namely '**SHADOW of DRAGON**', come to the US and bring the ROV engineering idea from orient.

The purpose of this ROV is to accomplish a series of mission highly simulating a real submarine rescue. Our design was fully discussed on a practical basis. It is because of our down-to-earth design that makes up our incapability in accessing advanced equipments and resources. Having a relatively small dimension of 40*30*20 cm, the powerful 12 thrusters of our ROV trade off its shortage in mathematically modeled aerodynamics. Bearing in mind the competition mission setting, we endeavored to fabricate each independent manipulator with the simplest but the most efficient design. The deployment of 3 cameras with 2 movable and 1 fixed also managed to view all tasks. The prototype ROV '**Poly-thrusters**' used for local competition gave us confidence in using simple but concrete configurations. The experiences gained from the local competition made us realize that 'multi-functional gripper' is tedious and redundant in this competition. In addition, our craftsmanship followed the designing concept of achieving an excellent performance in flexibility, stability and maneuverability, which are essential to underwater rescue.
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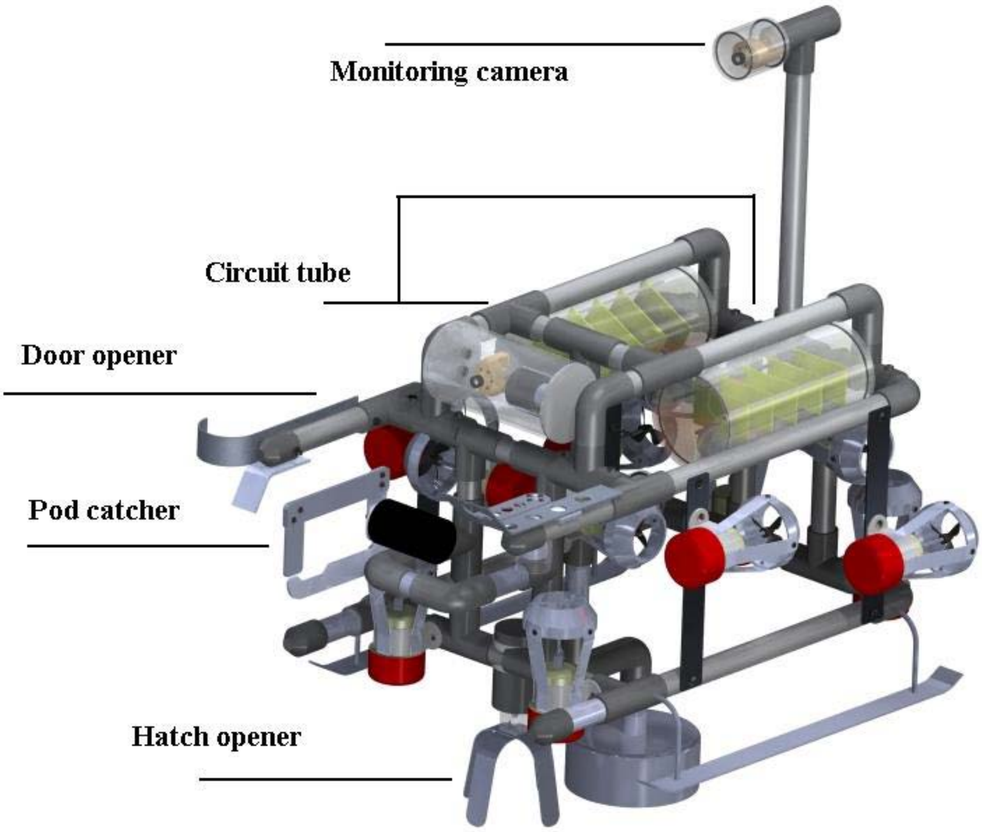
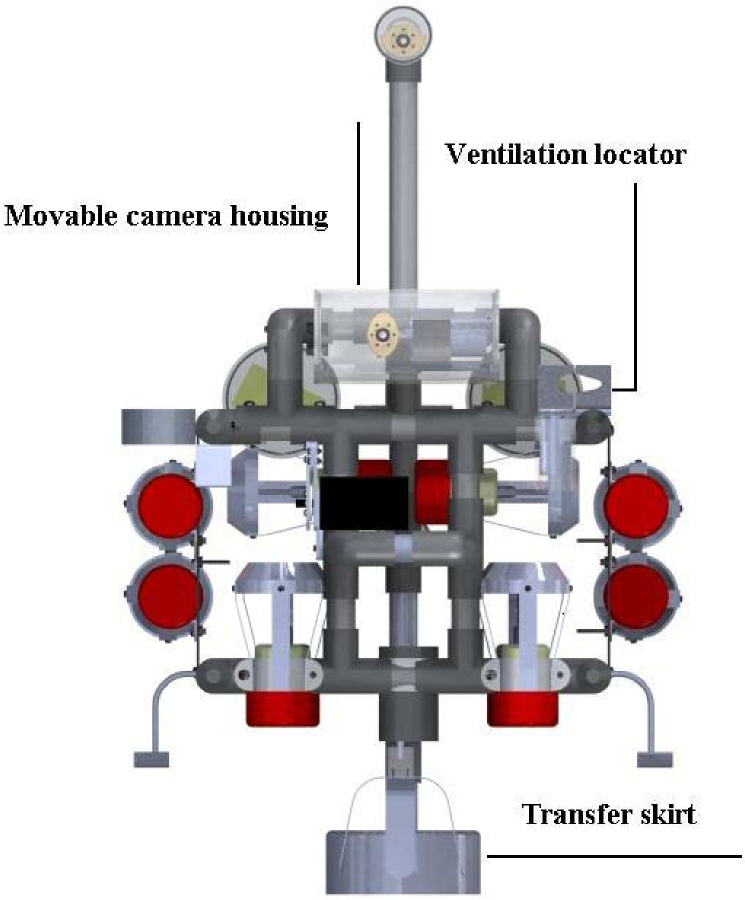
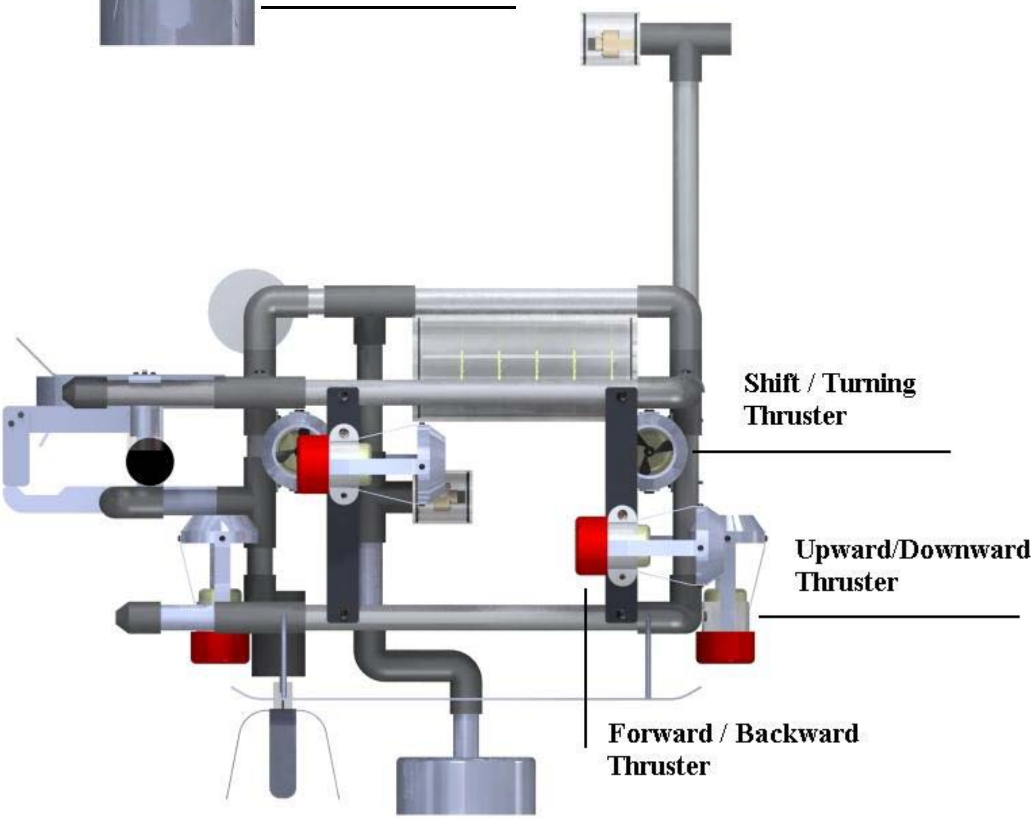



Ventilation locator
Movable camera housing
Transfer skirt


Shift / Turning Thruster
Upward/Downward Thruster
Forward / Backward Thruster

2. Electronic Schematics

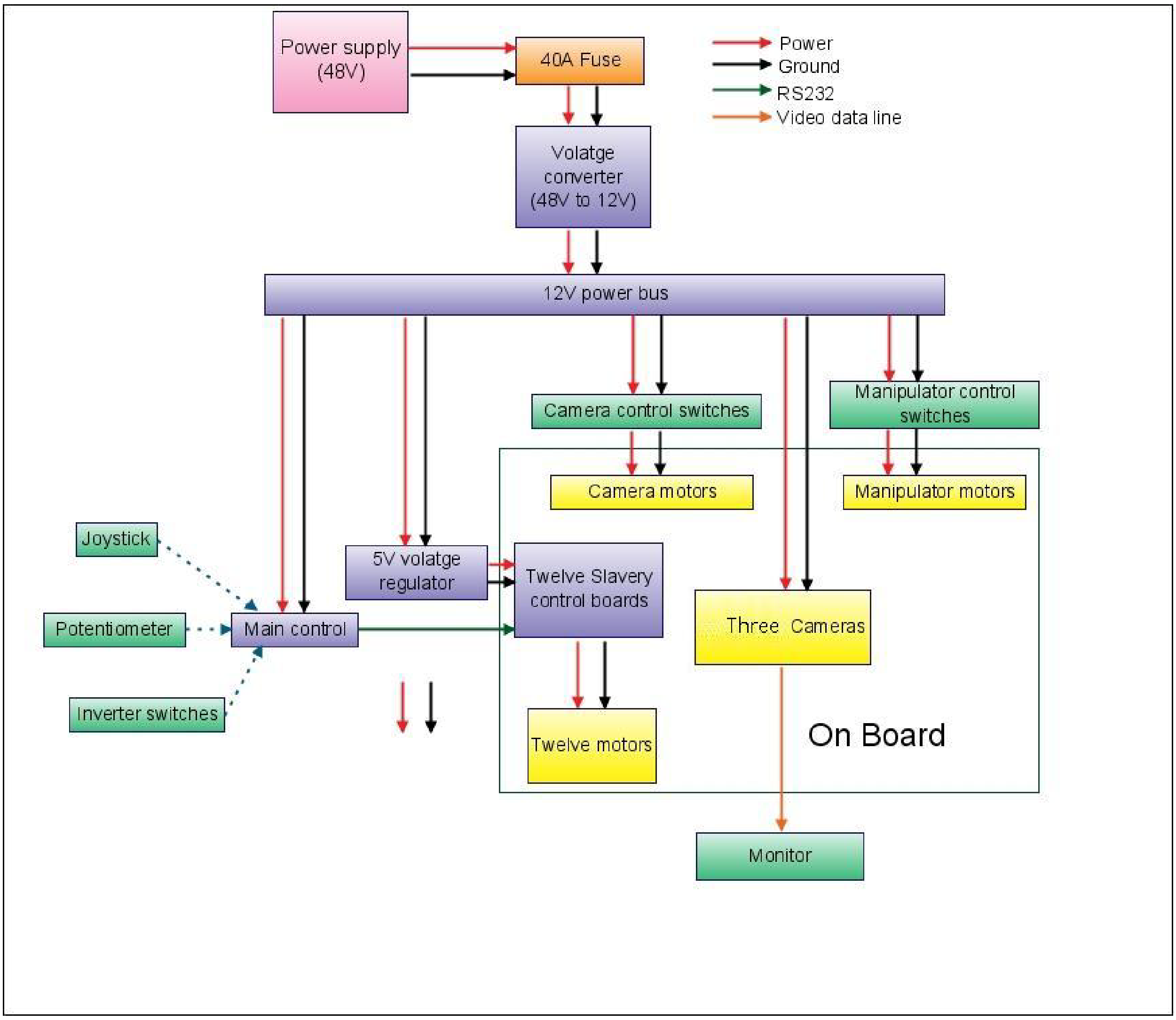


Figure1. Overall Electronic Schematics

3. Budget / Expenses Sheet

School name:		City University of Hong Kong		TEAM DRAGON	
Period:		From February 2009 to May 2009			
Budget					
Item	Unit Price	Quantity	Source	Donated	Expenses
Framework					
PVC pipe	$5/meter	4 meter	Ming Kee plastic water pipe shop, Mon Kok	-	$34
	$7/meter	2 meter			
PVC joint	$2(all) shape)	50		-	$100
Item	Unit Price	Quantity	Source	Donated	Expenses

Aluminum stripe	2mm thick, $-	Take when need	University	Departmental Student workshop	$-
	1mm thick, $-				
Screws	All kinds, $-	Take when need	University	Departmental Student workshop	$-
Acrylic boards	$15/dm^2	15dm^2	Ming Kee plastic water pipe shop, Mon Kok	-	$225
Thrusters					
Water pumps	$125	14	Bak Kee Fisherman's home	-	$1,750
3–leaf Propellers	$30	14	Professional Model shop, Ngau Tau Kok	-	$420
Shaft/extension system	$250	14	-	-	$3,500
Current nozzle	$-	12	University	Student Canteen	$-
Metal sticks	$-	36	University	Departmental Student workshop	$-
Cameras					
Cameras of two kinds	$400	2	Wah Fei Camera and monitor shop, Sham Shui Po	-	$1,136
	$168	2			
Waterproof equipments					
Acrylic tubes	$25/dm	20	Man Tak Plastic shop, Mon Kok	-	$500
Plastic pipe covers	$-	4	Mr. Lau, the technician	Departmental student workshop	$-
Covers with O-ring	$-	8	Oceanway corporation	Mr. Paul Hodgson	$-
Baby diapers	$50/bag	1	Taste supermarket	-	$50
Dryers bags	$-	4	-	Gabriel	$-
Silicone gel	$25	2	Wing Kee hardware shop	-	$50
Electronic control devices					
PIC-12F683	¥5	24(12 for spare)	Shenzhen Saige Electronic Market	-	¥120
PIC-4N26	¥6	24(12 for spare)		-	¥144
NPN-transistor (TIP 107T)	¥4	24(12 for spare)		-	¥96
Relay	¥5	24(12 for spare)		-	¥120
Voltage regulator (L7805CV)	¥4	24(12 for spare)		-	¥96
Diode 1N4001	¥2	24(12 for spare)		-	¥48
LEDs (Red and Green)	$-	24(12 for spare)	University	Departmental student workshop	$-
Capacitor 1 µF and 0.1 µF	$-	24(12 for spare)			$-
Resistor 470 Ω and 1KΩ	$-	150			$-
Diode jumper (1N 4148)	¥2	24(12 for spare)	Shenzhen Saige Electronic Market	-	¥48
PIC-16F876	¥15	3		-	¥45
R13-28E Toggle Switch	¥8	6		-	¥48

Joy stick	$-	5	University	Departmental student workshop	$-
Potentiometer	$-	10			$-
RS-232 serial port	$-	5			$-
Sensitive board	¥11	15	Shenzhen Saige Electronic Market	-	¥165
Developing power	¥50 / bag	1		-	¥50
Manipulators					
Aluminum stripes	2mm thick $- 1mm thick $-	Take when need	University	Departmental Student workshop	$-
High-torque slow speed DC motor	$-	4	MEEM student workshop (Approved by Dr. Liu)	Dr. LIU's research team	$-
PVC plastic cubes	$-	Take when need	University	Departmental Student workshop	$-
Acrylic cube connectors	$-	Take when need	University	Same As above	$-
Wires and electrical connections					
Power line (40A)	$10/m	10 meters long	Sham Shui Po		$100
Normal wires	$-	Take when we need	University	Underwater laboratory and Signal Analysis laboratory	$-
Glues and paints					
Stain proof paint	$14	1	Sham Shui Po	-	$14
Silicone glue	$28	2	Bak Kee Fisherman's home	-	$56
Glass glue	$10	2	Sham Shui Po	-	$20
Epoxy glue	$24	2		-	$48
Normal oil paint	$14	2		-	$28
Others					
Lightning devices	$48	2	Wong Kok market	-	$96
Team T-shirts	$75	25		-	$1,875

With all the '$' representing Hong Kong dollars, excluding the travel and other transportation fee.

Total: HKD 10,002 and ¥765 (totally about 1403 USD)

Income: HKD 10,000 Sponsorship from Department of Electronic Engineering, City University of Hong Kong

Travel and transportation	Price
Flight	$ 10000 * 7
Transportation in US	USD 500

Note: In order to reduce cost, some electronic components were purchased from Shenzhen, Mainland China by RMB.

4. Design Rationale

4.1 General Descriptions and Features

We realized that our team must take advantage of the fact that **most of the participating team are from US knowing little about us**. Therefore, we made profound research on previous and current design of their ROVs on the web to facilitate our design as follows.

The whole ROV consists of a frame, a propulsion system, an electronic control system, manipulators, three cameras, buoyancy materials and other affiliated parts. It is a unique design with several features.

- **The frame is simple and neat.** Fabricated with PVCs, it is easy to handle, which made every connection easy. Without advanced cutting machines, it is a wise choice to use PVC as the major material.

- **Powerful thrusters are used.** As mentioned earlier, although the dimension of our ROV is relatively small, an amazing number of 12 thrusters were installed. This powerful propulsion system, 'SHADOW of DRAGON' can cruise with high flexibility and maneuverability. This arrangement of 12 thrusters is efficient because they are aligned with on the corners of the ROV without water torrent being blocked with each other.

- **Unique and originate circuit design is applied.** Instead of the commonly used H-bridge motor driving circuit, we adopt a circuit originally designed by ourselves. The creative design can outperform others' circuit in terms of its safety.

- **Several different 'manipulator tools' were targeted.** They succeeded in performing independent functions and the whole ROV body performs as an arm by agile. Again, with its powerful movement underwater, SHADOW of DRAGON successfully avoids our shortage in advanced mechanical fabrication.

- **Budget in this whole project is reasonably used.** We associated with company outside the campus and professors of other department for assistance. We seek help from our part-time supervisor in this field and also seek for inspirations from previous models. This decision made it possible for us to purchase professional model for our propulsion system.

4.2 Frame Structures and Materials

The **dimension** of SHADOW of DRAGON is 40 * 30 * 20cm. And the entire vehicle **weigh**s 11.4 kg. The ROV has a simple cube main frame and a small volume in order to maintain **symmetry**, balance and maneuverability. All the components are arranged compactly on it. According to basic knowledge in Fluid Dynamics, the water flow resistance force is proportional to S root square (S is the cross-sectional area) for low speed situations. Therefore its small volume and surface area can reduce the resistance when the ROV is moving. In the robot construction process, we did our best to place all the components on the frame symmetrically to ensure the center of the gravity for maximum balance.

Our robot frame is constructed by **Polyvinyl Chloride (PVC)** pipes and junctions which are tightened simply by screws and glue. This decision is made after many prudent considerations. Originally, a streamlined rigid aluminum shell was considered. However this idea was soon discarded because of the lack in sufficient experiences on the bench work and sheet-metal work, the discussion on the reliability of not using skeletons, the economical and convenience usage of PVC. Besides, considering that SHADOW of DRAGON must go across continent to participate in the MATE competition, our using PVC as main frame material is also beneficial for transportation from Hong Kong to US.

4.3 Propulsion System

There are totally twelve 500 Gallons/hour (=1.892m^3/hour) 12V bilge pump motors installed on SHADOW of DRAGON. They are originally used for fish aquarium air exchanging systems, but we made use of its compact size, waterproof ability and strong power after dismantle the pump installations.

Figure2. Thruster without nozzle attached

Four motors are used for up-down motion, four motors are used for left-right direction and the other four are for back-forward movement. With this classical but not redundant arrangement, SHADOW of DRAGON can move in all the six directions. The swap of moving direction is controlled by our electronic system, which will be discussed in Chapter 3.4 Electronic Control System. The maximum working current of each motor is 2.5A and the power is 30W. Three-bladed plastic propellers with a radius of 3.5 cm are attached to the motors by shafts with 4.5cm length. To avoid oscillation, the shaft, the propeller and the motor box are connected by bolts tightly.

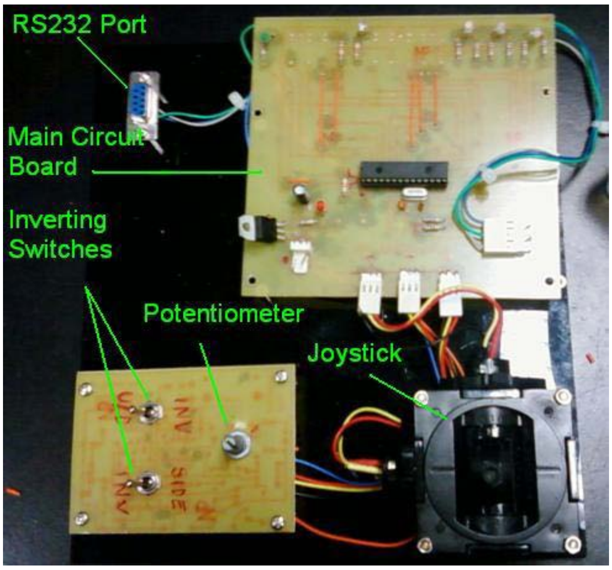
To guarantee reliability and quality, we invest a good sum of budget to buy the whole set of the gear from professional model shop. The use shaft came from the failure of our prototype ROV, the '**Poly-thruster**'. When the propeller is reversely running, the motor itself will block the water flow, thus reducing the running speed. Therefore an extension shaft is necessary for equal propulsion in opposite directions since it allows space for both sides of the propellers. After adding nozzles, which are not specified in the report, the water torrent will be even stronger.

4.4 Electronic Control System

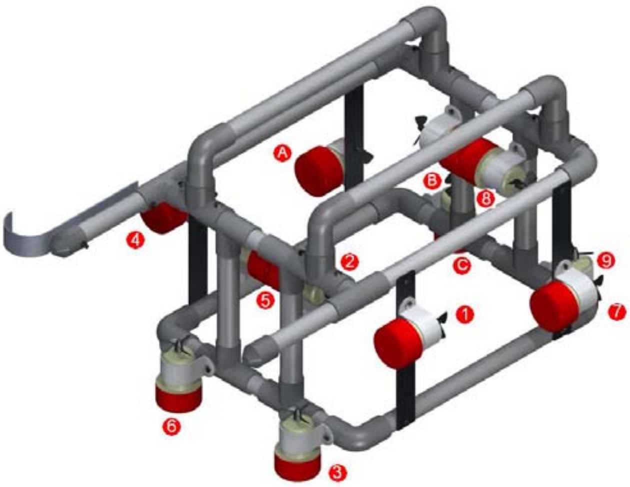
The electronic control system is the most complicated system on our robot, which contains two parts: the **topside control** and the **onboard control**. The topside control runs on a circuit board containing the main microprocessor PIC-16F876A with four user input devices, a joystick, a potentiometer and two inverting switches. The onboard control, which goes underwater, is developed with 12 slavery PWM control boards which communicate with the topside control via RS-232 serial communication.

In contrast with the control system adopting computer software as operation interface, our **hardware interface** is more practical and portable. SHADOW of DRAGON can accomplish any movement as those otherwise laptop-controlled ROVs. The pilot operation of SHADOW of DRAGON is not as smart as a computer graphical user interface but after some practice, the pilot can use the friendly interface to control the robot. The software for SHADOW of DRAGON served for the laptop-control is being investigated by software experts in our team. The introduction of it will be introduced in latter chapters.

Topside Control



There are 12 thrusters in **3 groups** attached on the frame. The **joystick** controls the speed in the horizontal plane, both forward/backward and left/right, by sending analogue signals through two ports. The **potentiometer** controls the speed of the four up-down direction motors and therefore the depth. The **side inverting** switch reverses the two side motors, enabling it to shift or turn. Similarly, the **up/down inverting** switch reverses the two vertical direction motors, enabling it to roll over.

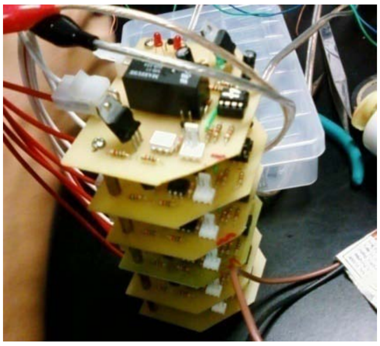


The main processor PIC-16F876A acts as the kernel part of the controlling system. The PIC analyzes the signal and sends the command produced by the controlling devices mentioned just above to the **onboard control** where the motors execute the command via **RS-232 serial connector**. The RS-232 carries encoded information of the corresponding **Serial No. of motors** (Assigned by us) and the rotating speed of the propeller to digital signals. The speed is digitalized into the integer from 0 to 500. The integer of **0~300** represents rotating **clockwise**; while **301~500** represents rotating counter-clockwise.

Figure3. Main Circuit Board Diagram

Figure4. Arrangement of thrusters with octal numbers

Onboard Control



The onboard control is governed by a PIC-12F683 on each **slavery control board**, each of which is corresponding to a numbered motor as stated before. Each board is connected to a motor and the No. of motor is stored in the PIC. The signal from the topside control is transmitted to each PIC-12F683 through RS-232, which starts with the assigned number of the PICs, followed by the speed of the corresponding motor. ('2-255' meaning Motor No.2 rotate full speed clockwise) After analyzing the RS-232 signal, the slavery PIC generates a **pulse width modulation signal** to the **opt-coupler** and a direction signal to the **relay**, which will apply a voltage with expected magnitude and direction to the motor.

Different from the traditional H-bridge circuit widely used in ROV controls, the circuit used in SHADOW of DRAGON is safer because the change of rotation direction is controlled by a single relay instead of four switches.

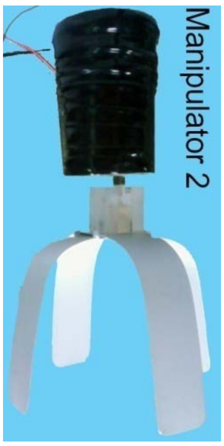
Figure5. Slavery Circuit Board Diagram

4.5 Buoyancy

The ascending and descending of SHADOW of DRAGON is controlled by the 4 motors in vertical direction. When none of the motors is running, **neutral buoyancy** is required to make the ROV stationary at any depth in the water. On our ROV, the three acrylic waterproof tubes housing the slavery circuit boards and the movable camera can provide positive buoyancy. The tubes can tolerate the water pressure as deep as **5 meters**, more than the depth on the competition. We use professional **O-rings**, **O-ring grease** as well **silicone gel** for total seal. We also use the tissue in **baby diapers** (Boy use) and home **drying agent** to lower the humility inside the tube.

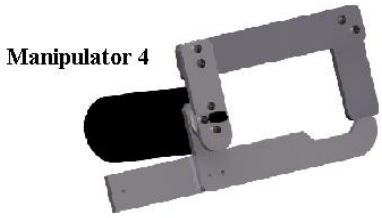
Figure6. Acrylic camera tubes

4.6 Manipulators



We use multiple simple manipulators to instead of the seemingly fancy 'multi-functional' gripper to fulfil all the missions. As shown in Figure, **Manipulator 1** is composed of two iron strips and one of which is driven by a motor. The two strips driven by a high torque DC motor perform well enough in holding and releasing the ventilation airline in Task 3. **Manipulator 2** is also a rotating device driven by an identical high torque DC motor, which is used for turning the hand wheel. **Manipulator 3** is two iron strips fixed in the front of the ROV. The function of this simple design is convenient to handle. It is easy to use with the monitoring of the camera system and can perform to open and close the valve and hatch. **Manipulator 4** shown in the 3-D sketch-up is used for pod lifting and transportation as well as hatch opening. During the test on the prototype ROV, we confirmed the idea that our manipulators are cheap to made and easy to use.

The two manipulators with motors are controlled by our classical controlling switch circuit which comprises a **toggle switch and a potentiometer**. The schematics of the system are shown below. In order to make the motor rotate in two directions, a R13-28E toggle switch and a potentiometer are connected in series to form a simple circuit to adjust the polarity and magnitude of the voltage across the motor. In the competition, our team will have two pilots, one for the propulsion system and the other for the camera and manipulator switch control.



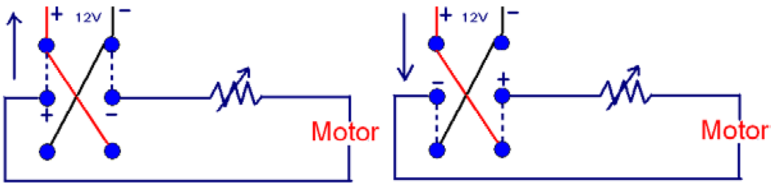


Figure 7 8 9 10 Manipulators

Figure11. Circuit of the toggle switch used for movable camera

4.7 Cameras

One color CMOS-SS200CA camera is used on SHADOW of DRAGON for navigation. Since there is no pan and tilt devices associated with each camera. We installed a 5V high torque motor again under each camera to obtain a 180-degree view (360 degree is theoretically possible). The two cameras are working under 12V DC voltage and has a resolution of 420-line. The decreasing of the voltage is achieved with the simple serial connection of a potentiometer.

Figure12. CMOS-SS200CA Camera

Figure13. Camera housing

4.8 Power Supply

We use **only electrical power** which requires no additional devices and has adequate capability to support all the systems on SHADOW of DRAGON. The total current of SHADOW of DRAGON is calculated as below:

Twelve motors in the propulsion system: 2.5A * 12 = 30A

Three motors for Manipulator 1 and Manipulator 2: 2.5A * 2 = 5A

One motors for cameras: 0.5A

Total current = 35.5A, total power ~ 432Watt

The actual current value will be slightly smaller than the theoretical value due to the voltage drop on the power line.

The tether between SHADOW of DRAGON and the control panel is composed of power lines, a pair of RS-232 data line and two video data lines. All the lines have waterproof insulated cover. We use a self made **DC voltage converter** (power modulator) to obtain the 12V we want. Because 12V is the most convenient voltage for our fabrication, so the DC voltage converter is cheap and simple run all of our system.

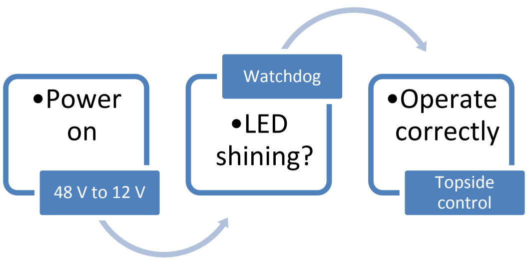
5. Trouble Shooting Techniques

4.1 Electronics

For any electronic circuit fabrication in practical use, problems are inevitable. We meet catastrophic problems almost every day. Therefore, troubleshooting is always critical. Actually from the very beginning, troubleshooting techniques were adopted all the time.

-Watchdog LED

On the main control panel the blinking blue LED indicates that the power is on. If the LED fails to shine, which means something goes wrong at nowhere but the main PIC (PIC-16F876). This **'watchdog LED'** should also indicate whether the PIC is receiving and handling the input signal. If the watchdog emits light normally, the onboard circuit could be connected to the main control and the serial communication signal can be checked.



-Slavery Circuit

If there is no problem found in the **topside control** (the main board), the 12 slavery circuit boards should be checked one by one. To check the slavery circuit, we connect the RS-232 wires of slavery board to the serial port of PC and run the Windows integrated program **Hyper Terminal**.

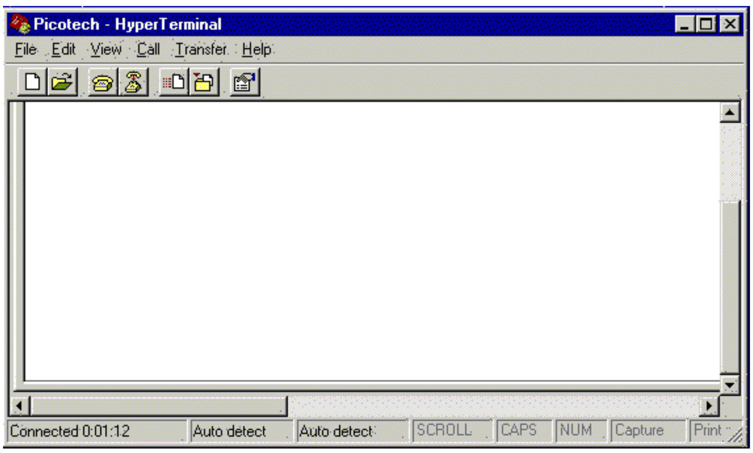
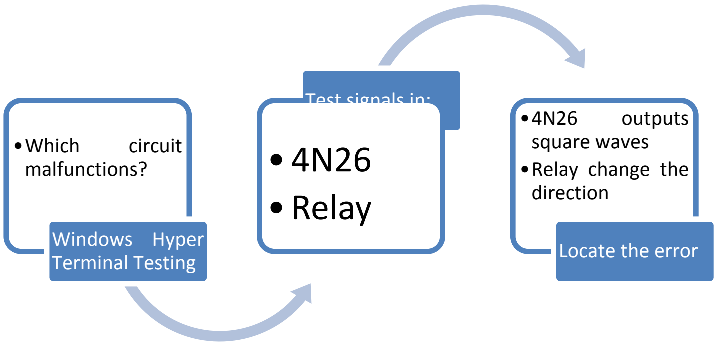


Figure14. Interface of Hyper Terminal

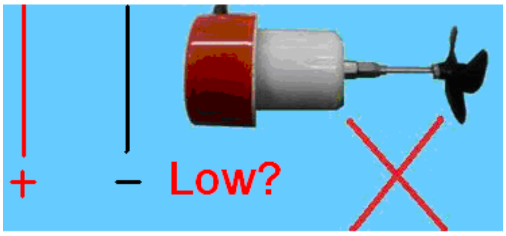
Then the No. of motors and an arbitrary speed within the range could be typed as the program indicates from **1 to C (Octal)**. The wrongly operated motors means malfunctions. To locate where the problem is, we check the power to the PIC-12F683 and then two main output pins from the PIC: the **PWM signal to 4N26** and the **inverting signal to the relay**.



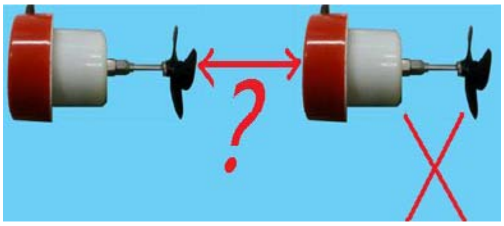
4.2 ROV Construction

In the ROV construction process, we were faced with a number of technical challenges as well. When all the 12 thrusters were installed, the reverse motion of our ROV was observed to be much slower than expected. We thought about several reasons but were puzzled by the weird small value of experimental current rating.

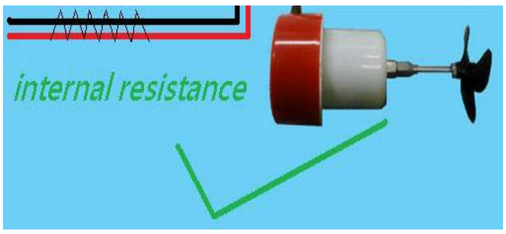
- Initially the cause of this weird reading was considered to be the insufficiency of the supply power voltage. However when voltage is adjusted to 15V, much higher than normal value 12V, the low performance of the thrusters were not changed.



- Then it was suggested that the arrangement of the thrusters might be the problem. If two thrusters in an array were close to each other, the propellers of the two will cancel out each other. But the fact was when the motors were rearranged not intervening each other, no difference was made.



- We went on to move our attention to lack of the shaft between the propeller blades and the motor. But it proved still not true after the shaft was attached.



- In the end, after further investigation, the cause was discovered and proved to be very simple. The internal resistance of the power tether was high due to its small thickness therefore the voltage drop on the tether was considerably high. The problem solving approach was simply to replace the power line by a thicker one.

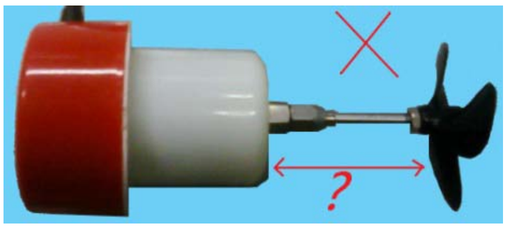


Figure 15 16 17 18 Troubleshooting flow for propulsion problem

6. Challenges We Met

We encountered many challenges in the arduous journey of this project.

- **Lack of experience and necessary knowledge**
  At the beginning, every member of our team was new to robot design and construction. All the team members and helpers were Year 1 electronic engineering students and we only had some fundamental knowledge in electronics. A complete electronic design was a difficult task for everyone. It was lucky that we have diligent teammates like Grady and Edward that learned the knowledge from senior students and the supervisor. **Self-learning ability is extremely valued in this part.**

- **Lack of mechanical engineering manpower and resources.**
  Most EE students did not have much background in mechanics, but we have Gabriel and Jason who are interested in this field. We also seek for help from MEEM department in terms of their labs, parts, manpower and guidance from the professors. **Communication skills are particularly needed** in terms of merging forces from all directions to help us fabricate the manipulators.

- **Time and attention constraint**
  Our schedule was falling behind and we commence our project in February this year. Besides, since we helped the settings of local HK underwater robot challenge, we further delayed our schedule. But as we divide the students involved in the project into several groups according their course schedule, and different groups work at different time with regular meetings. We **saved time and maximize our efficiency.**

- **Lack of professional and managed equipments and resources**
  Compared to most competing teams in US, we have a disadvantage that CityU does not provide robotics courses nor offer student oriented workshops. Hong Kong is a business city and we had terrible experience in finding the material we need. To make matters worse, the laboratory regulation system is stubborn and inefficient, declining many of our application in using them. Our university even gives up the CAD programmable machine for the excuse of limit in budget, making us helpless in doing the design we want. So we have to **find smart ways and even compromise to achieve the most**.

However through the whole process, we strictly follow the competition slogan of **"An Event for STUDENTS"** and our spirit of **"It is our robot"** and only ask the mentors for advice but not direct help. In this way, we truly gain a lot in all terms.

7. Lessons We Learnt

As engineering students, one important thing we learnt from the project was the **difference between the course work and the practical engineering work.** When we are taking a course, **getting good grade is the ultimate goal**. If we understand the textbook and lecture, apply suitable methods to solve the exam problems and get the correct answer, we can. But a practical project is not as simple as a course and there is no standard answer for every problem we encountered. Engineers are concerned with developing economical and safe solutions to practical problems while considering technical constraints. We need to deal with more simple, real but **concrete engineering problems**. In our robot project, it happens frequently that an idea originally thought to be theoretically perfect but failed in reality due to high cost, lack of materials, time constraints, incompetence with the missions in the competition and so forth.

- In a course or exam, a problem approach with advanced knowledge is often appreciated but in our robot design a simple but effective design is more feasible.
- In a course we are only required to solve one single problem however when we were designing one part or solving one problem of the robot, we had to consider its effect to other design groups and chose the best approach after balancing.
- In an engineering course we do not consider anything about business, but in the robot construction, we need to purchase components, search for sponsors and implement a financial budget. How to be economical and minimize the cost under limited sponsor becomes a key issue.

Through our work, we have a deeper understanding of general engineering, which offers good insight for our deliberate majors.

8. Further Improvement

Due to our knowledge levels and limited time and funds, there are many potential to improve SHADOW of DRAGON in the future.

At the moment, SHADOW of DRAGON is only equipped with hardware control panel. It is a feasible choice. However, a **user-friendly computer controlling software** is necessary for a profound rescue underwater robot. With controlling software, the pilot can control the motion of the robot on a convenient computer graphical user interface. Moreover, some actions like camera video analysis can be automatically performed with appropriate software programming. The efficiency of the ROV will be increased significantly.

Another point to be improved is the **manipulator**. We use three separate manipulators to accomplish all the tasks, which is not suitable in real world situations. A single ‘multi-functional’ manipulator should be the focus of our future improvement in this field although we analytically deny that in previous chapters. But it is more natural and compatible for a ROV.

9. Reflections

	**Gabriel Jiabei GAO** *"I can learn a lot from the robot project. At the beginning, I am new to robot design and construction but now I have gained many technical skills and experiences. I am in charge of almost all the works and perform as a team leader. This project was really an eye-opener for me since it is so integrated. It was the first time that I manage a team in such project, from which the precious experience I gain is really beneficial to my future career."*
	**Eddy GONG Yibo** *"As year 1 students, I think we have done a great job with our efforts. Facing the challenging task, we use our creativity, knowledge and teamwork to overcome a lot of difficulties. "No pain, no gain". Our hard work deserves."*
	**Jason GUO Hao** *"We have devoted a lot of time and energy to the project. Now it is completed. We are very happy. In the past a few months, we worked as a team. We started from zero and finally reached the goals. As a electronic student, I have also learnt a lot of mechanical knowledge."*
	**Edward HAN Duo** *"This project taught me to think creatively. In order to solve engineering problems, we have to brainstorm as many ideas as possible. Teamwork and cooperation are also very important. Overall, the whole project is very interesting."*
	**Vincent HU Qifan** *"This is the first time for me to participate in an international robot competition. I am very glad. In the robot making process, I have a chance to put what I have learnt in secondary school and university into practice. There is a lot of fun."*
	**Albert JIAO Shuming** *"I learnt many things from participating in the MATE competition. I developed my ability of solving problems in real world situations. The importance of time management and project planning is very impressive to me."*
	**Grady ZHANG Ce** *"I was very interested in robotics when I was young but I do not have an opportunity. This competition provided a platform for me to peruse my dream and work together with friends."*

	**Peter CHU Hungwing** *"The ROV competition is a very interesting and demanding competition for engineering students. I am glad that I can help to polish the design and contribute myself to finish the graphical drawings in the technical report."*
	**Hoffman TSUI Hokwan** *"As a mechanical engineering student, I used my knowledge and advantage in gripper design to make the ROV functional. I realized that the most important thing is to collect enough materials and get hold of appropriate resources."*

10. The Scorpio-45 and SHADOW of DRAGON

Remotely Operated underwater Vehicle (ROV) has been extensively developed and applied in scientific exploration, oil industry and military fields since 1960s. The Scorpio ROV series is one of the most advanced and commonly used ROV in current world. At the Submarine Rescue Service Headquarters, UK's Ministry of Defense, the **Scorpio-45** ROV is operated by a civil team for submarine emergency and rescue purpose. This robot craft gain international popularity in 2006 due to its excellent performance in saving 7 Russian sailors' life. On August 7th, 2005, a **Russian submarine PRIZ AS-28** had been entangled with aerial cables and fishing lines in 190 meters underwater for more than three days. Several rescue attempts of Russian Navy ended in failure and the seven sailors on board were facing the threat of death because the oxygen was nearly exhausted. At this time, the UK's Scorpio-45 ROV rescue team arrived under Russia's rescue assistance request. The Scorpio-45 descended to the position of the trapped submarine accurately. After cutting away the antenna and fishing nets around quickly, the Russian submarine ascended to the water surface with all the people survived. The officers from Russian Navy were free from the blame of frequent submarine tragedy while humiliated by the fact that Russia's lacking of submarine rescue equipment for many years.

- **Basic Configurations**

In order to implement these goals, the Scorpio-45 is designed and constructed to be a complex system. It has dimensions of 2.75 * 1.8 * 1.8m and a weight of 1.4 tones. The small volume and low cost property makes Scorpio-45 an extremely practical and economical machine. The maximum descending depth of Scorpio-45 is 914m, which is capable of implementing all rescue tasks in coastal waters. As a submarine rescue ROV, the basic function of Scorpio-45 consists of assisting locating a distressed submarine, surveying the damage, clearing obstructions from the escape hatches and then transferring life support stores in special containers via the submarine's escape hatch.

- **Usage Method**

Like most ROVs, it is connected to the ship by a tether and a bundle of cables. Although the tether is a restriction factor of a robot's flexibility and mobility, but it is significant and essential for continuous and stable power supply and stable signal communication.

- **Features**

For accurate target detection and locating, **six 250W lights** and three **high resolution color cameras** including one on the forward frame and two on the tilt unit are installed. In addition, a **sonar system** consisting of an acoustic pinger, a receiver and a set of obstacle avoidance sonar are used for navigation in deep and dark water. Scorpio-45 has **two arm manipulators** in the front and each one has a payload of 110kg. The manipulators can rotate by 360 degrees and implement different missions such pulling, cutting and rotating. The **propulsion systems** are designed to support full motion in different directions and the **buoyancy** is implemented by hydraulic power. With the help of advanced craftsmanship, all the parts of the ROV have brilliant water proof and water pressure resistance capability.

Compared with SHADOW of DRAGON, the professional Scorpio-45 is much more sophisticated in all terms. But the basic structure is very similar:

- Division into different systems
- Firm skeleton structure
- Powerful propulsion system

There are also obvious difference between SHADOW of DRAGON and Scorpio-45 in terms of:

- Operation depth
- Operation environment (Temperature, Pressure, Lightning)
- Advanced monitoring and location system (Sonar)
- Material used (PVC vs. Steel and intensified plastics)

However we found that there are also some disadvantages in Scorpio-45:

- Skeleton without outer shell (Easy to be hurt with internal devices)
- Power line length and old design. (Easy to cause the ROV to be trapped by itself)
- Limitation in setting up (Clumsy capstan and big vessels must be used)

From many news reports about the submarine rescue event, the Scorpio-45 was said to be frequently put forwarded as the second-to-none choice. Also, we suggest that Scorpio-45 could be further and widely used in **underwater archeology sampling collection and research** due to its size and function features. For **SHADOW of DRAGON**, its best usage is for aquarium cleaning and repair.

Reference list of Chapter 9
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http://www.janes.com/articles/Janes-Underwater-Security-Systems-and-Technology/Scorpio-45-United-Kingdom.html, ***Figure 19.***
http://www.globalsecurity.org/intell/systems/tuwvs-pics.htm ***Figure 20.***

Chapter 9 was synthesized by us based on the references listed above and our consideration.

11. Acknowledgement

The guidance from **Mr. Paul Hodgson** and **Dr. Robin Sarah Bradbeer** is particularly acknowledged and appraised by TEAM DRAGON in terms of technical guidance, design consulting, electronics assistance and venue booking.

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CityU EE Department Student Workshop (Technician Mr. Lau)
CityU MEEM Department Student Workshop
Dr. Louis Liu
CityU swimming pool
CityU underwater technology laboratory
Oceanway Coporation HK

We would like to extend our sincere thanks to the MATE center for providing a platform for students from all over the world to learn from each other. It really opens our horizon preparing for such an intense and practical project. Bringing in fresh engineering ideas from other continent can make MATE ROV competitions more vivid and interesting.

For information of our team please check: *http://averyrobotics.21.forumer.com/*

Appendix

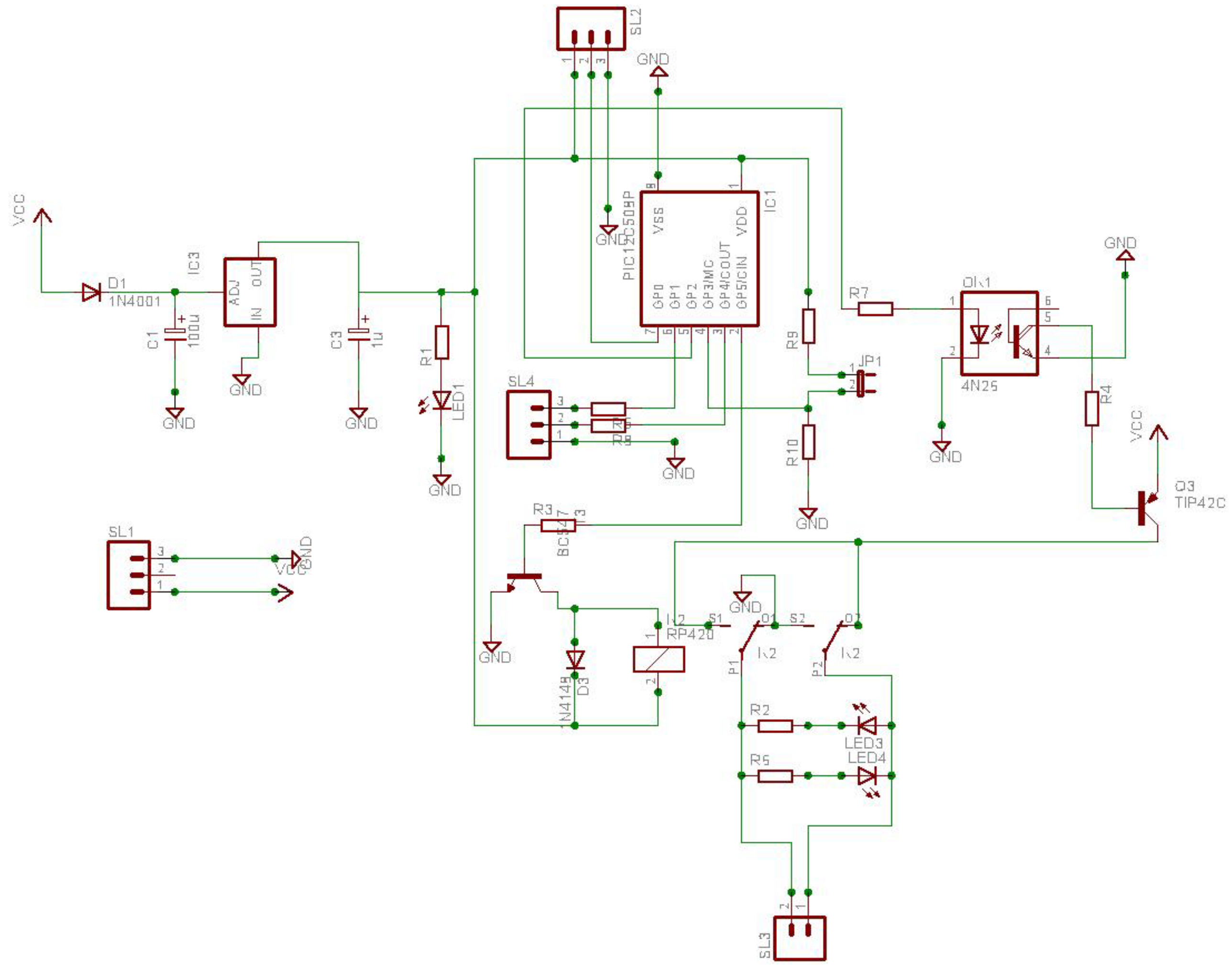

Figure21. The Main Circuit Board Diagram

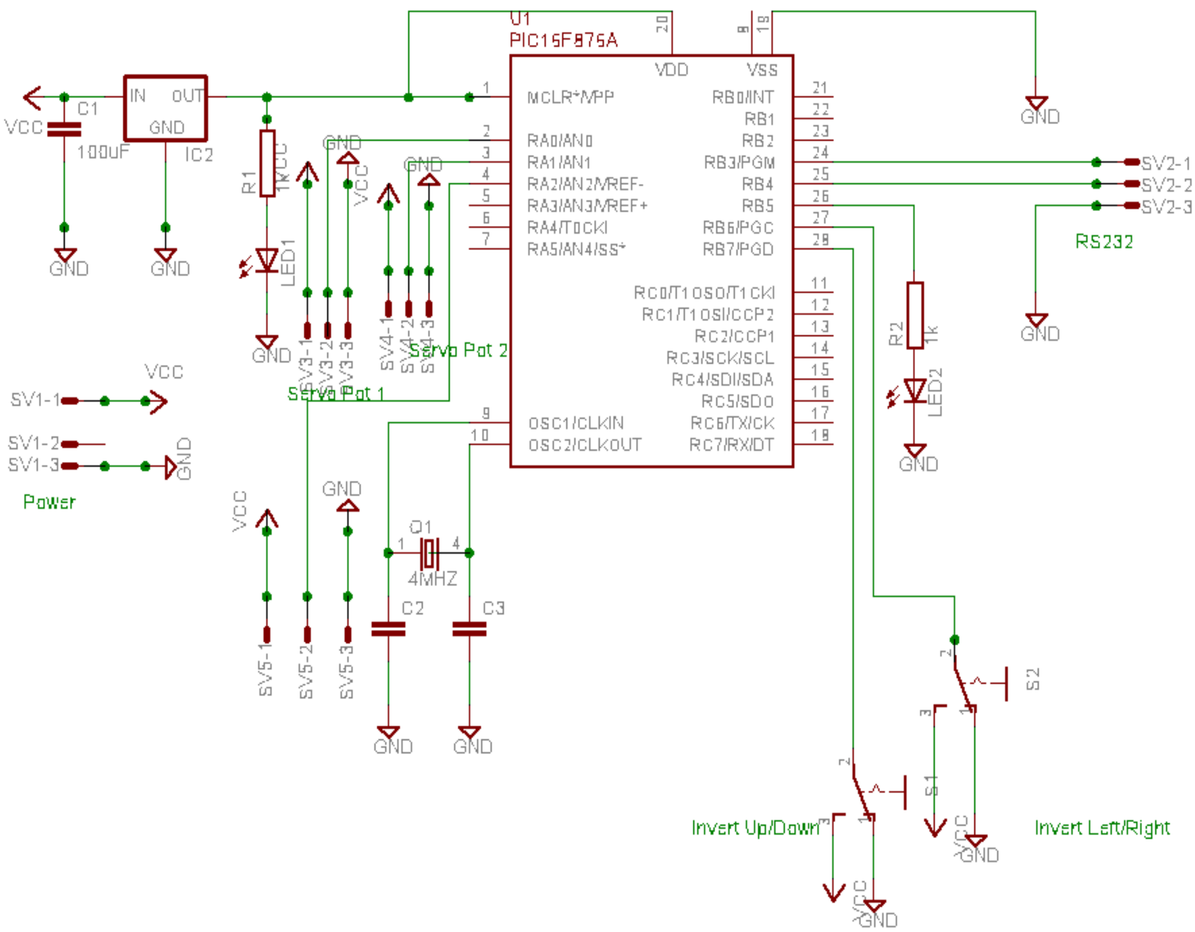

Figure22. *The Main Circuit Board Diagram*

There are 9 team members of TEAM DRAGON. This year 7 of them represent the team to compete in the MATE competition. But many students helped the whole project. Everything is really a team product. Below is a list of our helpers and student advisors

Year 1 ECE students	Senior student advisors and helpers	Program and grade
Victor CHEN Jixiang Sarah CHUAI Jie Sophie HE Jie Sally LIU Sili Andy LI Xudong Kimmy SONG Jiaqi William SUN Zhenhan Terry XU Wenbo Charlie YANG Yifang Lucas ZHANG Lu	Brian Yip Larry CHEN Cihan GAO Wei Ronald, LIU Hao Arthur, LIU Zhao Andy, WANG Xian	ECE Year 3 ECE Year 2 Computer Science Year2 Material Engineering Year 2 ECE Year 2 ECE Year 2

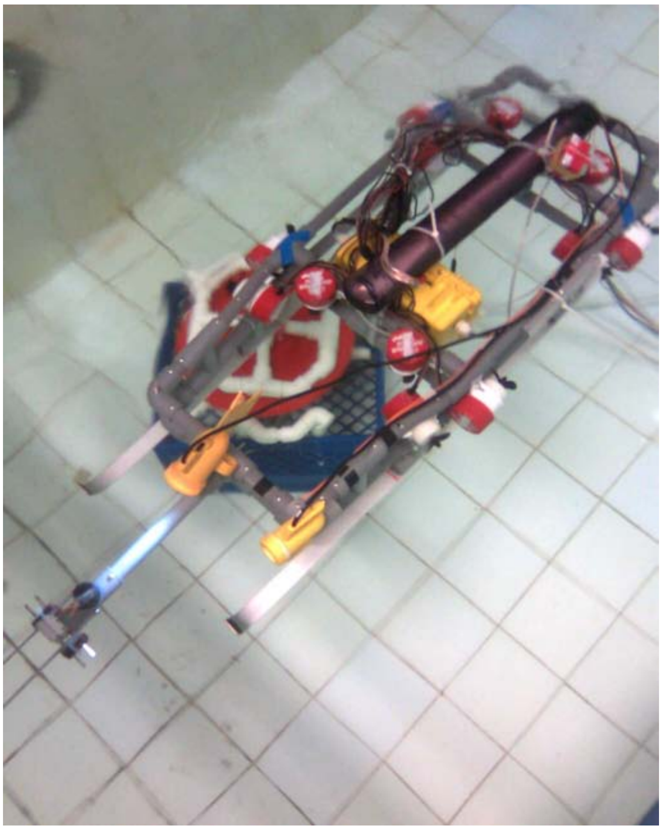

Figure23. Prototype ROV- 'Poly-thruster'

Figure24. TEAM DRAGON with our machine-'SHADOW of DRAGON'