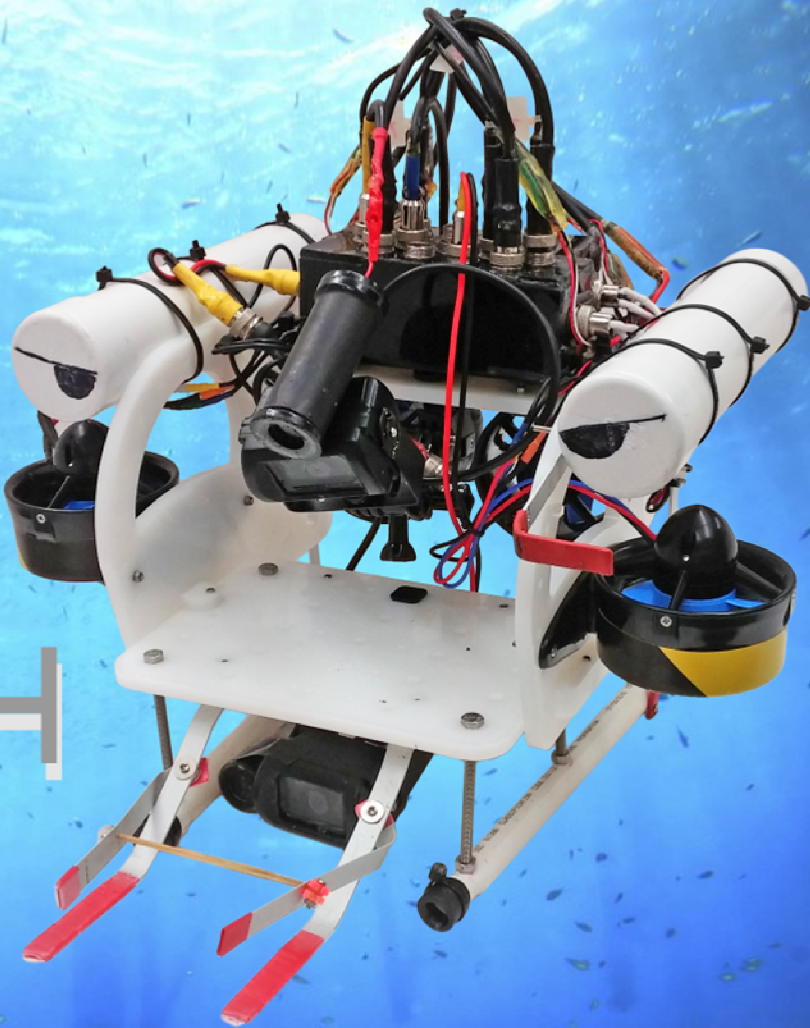
HONG KONG

Robotic Services Junior

水中ロボット



BATFISH

KI MING, TAM (Ming)	CEO, Logistic sectary, Imaging Specialist	11th Grade
Thanh Long, Thai (Longson)	CTO/ Chief Mechanical Engineer	11th Grade
Yat Tung, Yuen (1234)	System Specialist - control system	10th Grade
Ting Hin, Tsang (5678)	System Specialist - control system	10th Grade
Chi Kin, Wong (Jeffrey)	Logistic sectary / Sstem Specialist - Electronic	11th Grade
CHI NAO, NG (Panda)	Imaging & Electronic Specialist	8th Grade
Pong Yik, Ng	Payload Specialist	11th Grade
Lok Hin, Lee (Koala)	Payload Specialist	8th Grade
Chung Yeung ,Ding (DING DING)	Payload Specialist	8th Grade

Mentor : SAI HO, TSANG/LI WAI, HO/Hai Ming, Li

Robotic Services Junior Technical Document

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Abstract

Robotic Services Junior (RSJ) is a joint venture company participate every MATE ROV Competition since 2013 years. We are committed to build professional Remote Operated Vehicle (ROV) of the highest safety and efficiency standards at the most reasonable cost. After months of analysis, research and experiments, we now proudly present our ROV of this, ***Batfish****.*

Batfish is capable of tackling a variety of tasks under water including observation, measurement, installation, retrieving samples as well as maintenance work. The 40cm long, 45cm wide and 30cm tall, Bat1ish weights 6kg, and is equipped with universal mission tools, and three cameras.

What makes Batfish more powerful and extraordinary is that except for our T100 thrusters and the open source controller, all our components are in –house designed, and if possible, produced by our company. It has always been our company's mission to conserve and protect the marine environment. We want to take this opportunity to prove to the world that our company is not satisfied with simply producing an ROV that helps achieving missions, but we also go far as to make the ROV itself a realization of the concepts of ***"Simple is the Best"*** *without trading off any of our strictest safety and performance requirements.*

This technical document details the development process and the design details of Batfish, including the safety issues it entitles. Records on troubleshooting techniques, obstacles encountered, lessons learnt as well as the project budget are also carefully illustrated.

MISSION THEME

- ROVs have recently gained attention for their use in research expeditions to explore the deep sea and conservation of the ocean. Having explore larger part of the earth, scientists and engineers starts to explore Europa to conduct long-term investigations of the waters and seafloor below, to prove the probability of life elsewhere in our galaxy.
- More important mission is to recovery of Critical Equipment – CubeSat. It is also an important mission for NASA to recover and obtain observed data of the galaxy. The success in this recovery mission that indicating scientist can collect information to innovate new technologies, and furthering what we know about outer space.
- With the growth of Deepwater Horizon oil spill taking place in the Gulf of Mexico, the mariner living organisms are being affected. Scientists began studying the effects of human economic activities that affect the mariner living organisms and started to conduct conservative measure to protect the marine community.

Safety

- Our philosophy at RSJ is that safety is our number one priority. We upheld this philosophy by constantly referring back to the MATE safety specifications while building the ROV and creating a safety checklist (refer to Appendix A) to maximize safety and efficiency while working on the ROV. This ensured that no injuries or impairment occurred to any company members.
- Before conducting construction of ROV at each season, a safety training session must conduct to ensure that every team member understands RJS's safety protocol. For the past 2 year, the safety training session conducted by our mentor and other experienced ROV professionals. For this year, Longson – RSJ's CTO conduct the safety training session for every team member. Also, Job Safety Analysis (refer to Appendix B) document were sent to team members for reminding.
- During the construction phases, measures were taken to ensure the well-being of our company members. For example, when working with power tools (sanding, drilling, soldering, etc.), there were specific safety measures, such as wearing safety goggles, designating work areas. Special labeling attached on to Batfish, for example yellow tape for moving parts, red tape for potential dangerous mission tools.
- RSJ put more effort on to the control system and multiple safety precautions were also taken for the control boxes and control system. A 25 amp fuse was installed into the wiring, which would open the circuit in the event that too much current passes through the main power wire.

Fig.1 Yellow tape to identify moving parts (Photo credit : Panda)

- Batfish was constantly checked to ensure that no water could enter then electronics systems, prior to being placed into water. Every connection in the control system was constantly checked to ensure that every plug was secured and attached correctly. After everything was surveyed, the motors and mission tools were tested to confirm excellent connection between Batfish and the control system.

- From this year onward, a new system had conduct to the control box - Key man system. With a month of discussion, a new design for the control box is coming into concludes. The most important new design is the installation of a power switch which operated by Key. Before the pilot start to operate the ROV, pilot must obtain consent from CEO and get the key for operation. It is a security measure to protect Batfish that will not be operated by anyone. Also, in order to provide a clear operation of Batfish, RSJ also prepared SID to illustrate the system rundown of it. (refer to Appendix C)

Fig.2 New design of Control Box for Batfish (Photo Credit: Panda)

Fig.2a Key Switch for power up Batfish (Photo Credit: Panda)

Fig.2b Emergency stop button to terminate the operation of Batfish (Photo Credit: Panda)

Design Rationale: ROV Components

Frame

- **Design Description**

There were many special considerations that went into designing of a professional ROV capable of operating at INNER space and OUTER space. Generally, the main considerations to account for, such as the cost for the ROV launching payloads into orbit to the Outer Space. The frame was first designed with the aid of CAD drawing. This design employ a unique slot-and-tab construction so the pieces fit together perfectly in a clean, rigid structure. Only 8 pieces of M3 X 20mm screws were needed for in its assembly, which both minimizes the weight load on the thrusters and conserves space on the frame for mounting other systems. The vehicle's frame is constructed out of 8mm thick Starboard (High Density Polyethylene - HDPE).

Fig.3 Assembled HDPE Frame (Photo Credit: Panda)

Batfish is constructed at measuring 40 cm long, 45cm wide, and 30 cm tall (without wire plug-in and Mission tools). This configuration houses 4 thrusters, 3 cameras, and 3 mission tools, while remaining compact.

Design Rationale

The make used of HDPE for the reason that it is durable and dimensional stable. It will retain its physical characteristics underwater. Also, with its light in weight properties (just 1,068g for the frame after assembling), it is best material for production the ROV to meet the needs for delivery to outer space.

Last year, aluminum profile was used to construct the frame; it made attaching and detaching components efficient and less time consuming. Aluminum profile has grooves to allow the motors, mission tools, and cameras to be easily mounted to the frame. However, this year, aluminum profile were no longer chosen because the factor of the heavier weight of the ROV.

In order to attaching and detaching components efficiently, Batfish is designed to attach mission tools and camera by us of Go-Pro accessories. This design can make a balance of the weight and efficiency between HDPE frame and aluminum profile.

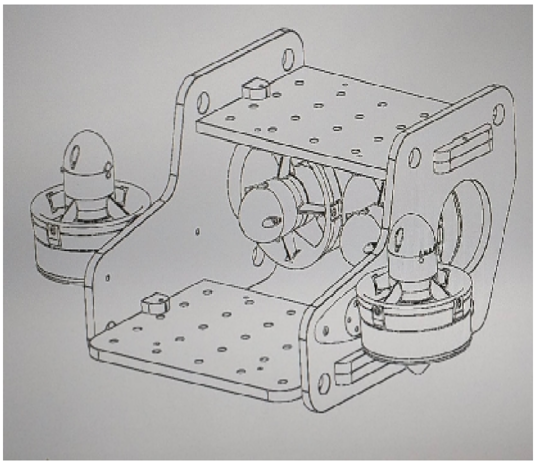


Fig.4 CAD drawing of first version of Batfish (Photo Credit: Panda)

Acrylic, an easier way for prototyping by laser engraving machine, was used to construct a prototype frame, which provided a way to accurately calculation of the size to meet the minimum volume required to contain all the components desired before the final product was built with HDPE.

Buoyancy/Ballast

Design Description

Batfish's goal was to achieve neutral buoyancy. With a rough estimation of weight, BATFISH required volume of floatation was calculated to be $0.5m^3$. The main source of buoyancy for BATFISH is the two 25 cm long ballast tanks that were constructed using 50mm PVC pipes and end caps. The tanks are mounted along the top of the frame.

Fig.5 Ballast material (Photo Credit: Panda)

Design Rationale

Our company chose to use PVC pipes and end caps for our main source of buoyancy because they will not compress at the depths we will be operating at.

For the buoyancy setting of BATFISH, our company makes a traditional method to make such small and powerful ROV at the most stable status. According to the ROV design theory, ballast must at the most upper part of the ROV. Under this setting, it is easier to tune the center of the gravity of the ROV.

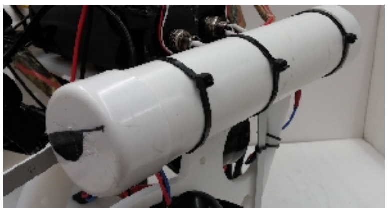


Fig.5a Ballast position of Batfish(Photo Credit: Panda)

Propulsion System

Design Description

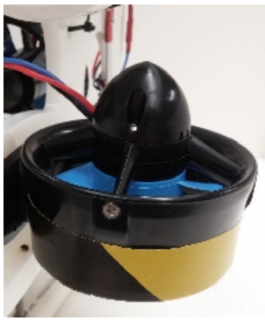


Fig.6 T100 thruster

(Photo Credit: Panda)

Four T100 Blue Robotics Thrusters supply linear thrust for the movement of Batfish. Two thruster produce thrust for lateral motion and the other two for vertical motion. Two T100 Blue Robotics Thruster motors are placed inside the ROV at 90° perpendicular to the back of the ROV. The other two attached outside of the frame at the front part of the ROV. T100 - Blue Robotics Thruster are able to produce maximum 2.36 kgf of thrust for forward (Blue Robotics Inc, 2016).

➢ **Design Rationale**

T100 thruster are used as we considerate the size and the weight of ROV. T100 thruster allows BATFISH to move at fast speed in water by producing enough thrust. At past our company design vectored thrusting for our first ROV because it enables the ROV to maneuver in every direction for larger size of ROV.

In this year, we were concerned about the size and weight of ROV. Also, we consider currents consume of T100 thruster, and felt that vectored thrust may not the best design in terms of economic point of view at outer space by higher energy consuming. Same as Seabotix thruster, T100 also have mounting bracket allow us easy to mount the thruster on to the frame. Also, it is physically safe as T100 has ABS nozzle to protecting the propeller.

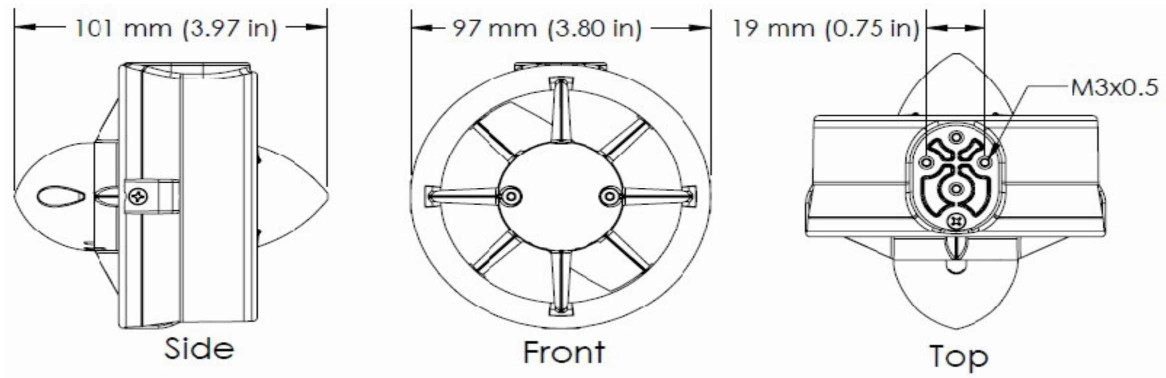


Fig.7 Dimension of T100 thruster (source: Blue Robotics Inc.)

Control System

➢ **Design Description**

The control system consists of 2 Arduino Nano board, RS485, joystick game pad, 4 brushless ESC. All the components are open source and easy to brought from the market.

There are total of 2 Arduino Nano boards have been used for this system, and illustrated as here below

- ✓ The electronics system, just the Arduino Nano Board is secured within an acrylic box which is placed on ROV. The first Arduino Nano board control The 4 brushless ESC provides PWM for T100 Blue Robotic thrusters to operate two set of thrust motion, vertically and laterally. While the ESC is attached near to the thruster. All ESC is water proofed by sealing with epoxy.
- ✓ The Second Arduino Nano board placed inside the shore side control box. This Arduino Nano board is the core for the system. When the pilot make use the joystick game pad to provide command to the Arduino Nano board, it transmit the signal the ROV.

Fig.8a Original Design of on bard Control Box (Photo Credit: Panda)

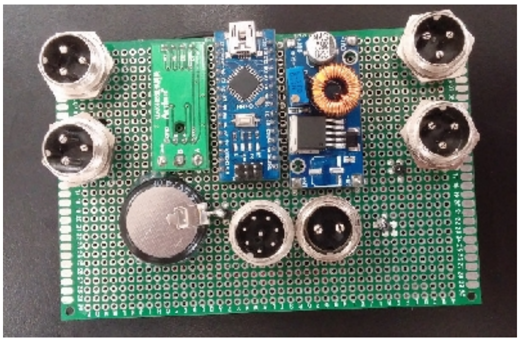


Fig.8b Photo taken of New Design of on bard Control Box before housing and sealed (Photo Credit: Panda)

➢ **Design Rationale**

Simple system concept

With such simple control system that allows our system specialist system find out the error within the system efficiently. Also, it is more cost effective for our company composition as our company just has two system specialists for control system, it is better for them to work together in programming the ROV. The more complex system, the more the man power involve is.

On the other hand, with the limit to the weight at outer space, the simpler the system and the lesser the weight of the ROV for totally sealed with epoxy , it is more cost effective than a complex system.

Open Source control system

During the previous MATE season, we use VEX control system as the core of our ROV's control system. During the production presentation of International competition, we got advises from the judge that it is better to develop company's own control system or use open source control system for future development. As a result, after several meeting between CTO and system specialist, we use Arduino board as the core of company's control system.

Programming (for software flowchart refer to Appendix G: Software Flowchart)

➢ **Design Description**

The joystick and the Arduino are programmed to specifically operate our ROV. The joystick generate signal to the on shore Arduino Board and transmit command to the onboard controller. The onboard controller provides PWM for the ESC and produce lateral and vertical motion of ROV. Arduino programming software is used to send Pulse Width Modulation (PWM) power signals to the motor controllers.

➢ **Design Rationale**

The Arduino software was chosen to program the electronics system because it is operable for amateur programmers and is free. This is the first year that programming was used for our new system specialist, so there were many problems that needed to be solved.

In one instance, the proper method to code a certain function could not be determined, so online tutorials and examples were utilized and applied to the system. Before the season started, our staff learned basic C language to ensure that we were capable of programming our desired functions.

For this ROV's programming, with our experience in Humanoid servo robot programming, our system specialist use servo libraries to control the ESC and the thruster. Therefore, we can transform our skilled programming to command transfer to control the ROV by joystick. It also can minimize the error of programming.

Also, our system specialist set up constrain to the intensity of thruster motion in order to control the amp consumption of the thruster that will not reach the maximum level. By using C language initial speed of the thruster is set at 70% in which pilot can easily drive the ROV.

Visibility

➢ **Design Description**

Batfish utilizes 3 strategically placed cameras: all these cameras are wide angle camera with 120 degree of vision and all of camera had been water proofed. All of them are attached with Go-Pro mounting accessory, which consolidated them on the ROV. Each camera has one LED light next to them to ensure that the vision of the view is bright enough for the pilot.

Fig. 9 Water proof for AV camera (credit: Panda)

The ***main camera*** is located at the front top of the frame which allows the pilot to observe the movement of the ROV and have a wide field of vision for the environment. The ***second camera*** is mounted toward the back of the frame and monitors the temperature sensor to successfully insert into the fluid. The ***finial camera*** monitors our mission tools which mounted on the bottom side of the ROV's frame.

- **Design Rationale**

Initially, the use of 650TVL AV cameras was attempted because they could produce higher quality images. In consideration the weight of ROV which includes tether, the number of camera reduced from 4 to 3. As the video signal is able to travel through twisted pairs of Cat-5e wires which can reduce the weight of tether.

At the past MATE season, our company use optical fiber to transmit the video signal. While, the use of optical fiber need to place optical fiber deliver box on the ROV, our system specialist and chief mechanical engineer had discussed the continuous use of optical fiber system and the use of AV camera through Cat-5e wires for the reason of the opportunity cost of weight of ROV between advanced of technology. In conclusion, we decided to directly transmit the video signal by Cat-5e from the camera to the monitors. It can also provide clear image under the deep sea.

Tether

- **Design Description**

The tether consists of a pairs of 12 AWG silicon wires, two Cat-5e cables and 1.5mm steel wire. The tether has a length of 20 meters. A pair of 12AWG silicon wires used to power thrusters and the ROV's on board system. One Cat-5e cables transfer video signals from the three cameras to the surface, one Cat-5e cables transfer Arduino signal to the surface. The 1.5mm wire is for safety to return of the ROV when the ROV cannot operate. In addition, the tether consists of two sensor cables (temperature sensor and pressure sensor) in order to accomplish the mission of measuring the temperature of fluid, the thickness of the ice crust and the depth under the sea.

Fig.10 Tether of Batfish is within PET tubing and attached buoys for every meter

(credit: Panda)

- **Design Rationale**

Our company chose the PET tubing because it can stretch and become longer with a smaller diameter or bunch up and become shorter but have a bigger diameter. We also used Cat-5e wires to carry signals to our ROV because Cat-5e wires contain four pairs of thin wires inside, thus allowing us to minimize the amount of space we used up in the tether. On the other hand, buoys on the tether reduced the weight the tether in order to ensure that the ROV would not be too heavy while diving.

Vehicle Systems

Batfish and each of its specially tailored mission tools were designed and constructed by the members of RSJ, with the exception of a few basic commercially purchased parts. Our company programmed and wired Arduino boards specifically for Batfish's missions. The decision to construct, rather than commercially purchase, advanced everyone's engineering and problem solving skills through hands-on experience and kept Batfish within the company's budget.

Our company underwent a long decision making process to decide whether or not to reuse components from our previous ROV. This process consisted of analyzing the requirements of each mission, brainstorming the design of the ROV, and holding a company meeting to discuss the reuse of certain components. In order to improve the performance of our ROV, the majority of Batfish's components are brand new, including the control system, electronics system, and frame.

Previously, RSJ had used aluminum profile as our main building material, but it was too heavy for this MATE season. Therefore, this year RSJ decided to use other material to in replacing of aluminum profile for its stable and effective characteristics.

The team discussed different frame materials and the decision was made to use HDPE. Although it made attaching and adjusting components on the frame less easy and quicker, it is lighter in weight and less costing to travel to the outer space. Throughout this year, our company held many meetings to discuss obstacles and brainstorm possible solutions. All members of RSJ were able to provide their insight and solutions to the multiple challenges that arose.

Batfish's design has evolved this year, in order to become fully functional in near-freezing water temperatures as past MATE season. The design of Batfish was also greatly influenced by issues and challenges that our company faced throughout previous MATE seasons.

Our company's mission is to produce a quality ROV that can effectively perform specific tasks. This year's theme incorporated missions that simulated the performance of tasks in inner space and outer space environments.

In addition, Arduino boards and brushless ESC, and Arduino programming software were utilized to create a completely new control and electronics system.

Every year, waterproofing difficulties required constant troubleshooting. This year, epoxy was implemented to protect the electronics system as the ROV needs to travel into deep sea to conduct Deepwater Coral Study. Previously, vacuum box was used; however, difficulties emerged when travel to deep sea. As the water pressure in deep sea would affect the performance of vacuum box. The result may be leakage of water into the electronic system and cause short circuit of the ROV's control system. For this year, in order to against the water pressure, our ROV implemented closed sealing with epoxy. All the electronic was full of epoxy to solve the problem of leakage caused by water pressure.

On the other hand, we source for low current consumed brushless motor to develop our manipulator. At the pervious season, manipulator implemented DC motor with gear box and needs to conduct a serious of waterproof testing in order to construct a reliable manipulator. In this season, we source for a F130 brushless motor and installed into same size metal gear box. From which, our payload specialist now develop a brushless manipulator without water proofing process. Such manipulator based on the concept of servo and controlled by ESC. The most critical point is to design the gripper that could not lock without props. With reference to the design of our pervious ROV, we design the gripper in make use of link and single opened mechanism to avoid the crush of the gripper.

After finishing the brushless manipulator, we found out that it will be too heavy in front of the ROV if we implement the manipulator on it. It would be hard to balance the ROV if we do so. After the discussion with our pilot, he will be more confident without using the manipulator. Therefore, we decided not to use the brushless manipulator.

Mission tools

Design Description

With reference to the company's goal, our goal is to build a simple and reliable ROV to work at extreme environment. Batfish attached simple but carefully designed mission tools combined with powerful thruster to complete tasks.

Based on our new philosophy - **Simple is the BEST**, we had detail discussion on the design of mission tools. Pervious MATE season, we had construct our pneumatic gripper for the first ROV and electricity manipulator for the second ROV. For this year, we decide to use pure mechanic mission tools for Batfish.

Design Rationale

First of all, the factor of reliable, pure mechanic mission tools will have risk of malfunction. Also, in consideration of company changes, the new comer can not take over all the tools design both pneumatic or electricity.

Temperature Sensor

Design Description

To measure the temperature of water emerging from a vent, we make use of simple digital thermometer and connect to the ROV and pass the signal to on shore display.

Design Rationale

Digital thermometer is only way to measure temperature in the deep sea. There is another way to measure the temperature of water emerging from a vent, use temperature sensor and connect to Arduino board to read the temperature and pass the signal to the on shore display. By use of stand alone digital thermometer is most simple way for the team member to set up control system. As the transmitting of temperature value will not reliable cased by resistance within the Cat 5e cable when it passes through 20 meter tether. Our payload specialist conducts several testing on the temperature change for 20 meters length, analysis the result and mapped into graphic for reference.

Fig.11 Payload specialist conducting experiment to test out data transfer of digital thermometer travels 20m long. (Photo credit : Panda)

Pressure sensor

Design Description

In order to measure the depth of the water, we decided to use the pressure sensor to take on this part of the mission. When the pressure sensor enters the water, the hydraulic pressure inside the pressure sensor will change according to the depth of the water. Therefore, we can easily measure the depth of the water with just only maintain the ROV in the right position.

Design Rationale

The measuring sensor is one of the external mission tools. Therefore, we decide to equip it with a horizontally level to our main camera. With this design, our pilot just need to drive the ROV to the right position, and that will let us have the depth of the water. We all trust that it is an easiest way to measure the depth of the water.

Long V-shaped hooks

Design Description

After careful analysis of the mission content, we designed universal hooks to fulfill the task. These hooks are made of aluminum and can be hand-shaped. Our payload specialist had design several sets of hook, and find that the V-shape hook can deal with different situation to tackle the task.

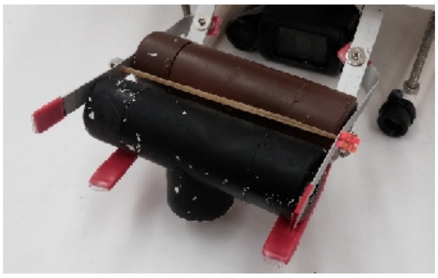


Fig.12a Hooks for collecting oil matt sample. (Photo Credit: Panda)

Design Rationale

The hook is designed to perform numerous tasks which involve deploying, retrieving, and lifting various objects, such as flange and wellhead cap. Specially, this hook is long enough to take on two sample of oil mats which can really save time for other mission. Moreover, we added to aluminum sheets beside the hook to ensure that the oil mats are consolidated inside the hook. Aluminum sheet metal was chosen for the hook because it could be easily formed to our desired shape. Also, we added a rubber band between the aluminum sheets to ensure the consolidation of the oil mats inside the long V-shape hooks. Also, our payload specialist considers to total weight of ROV and decided to use aluminum as it is strong and lightweight, and was already at the desired thickness.

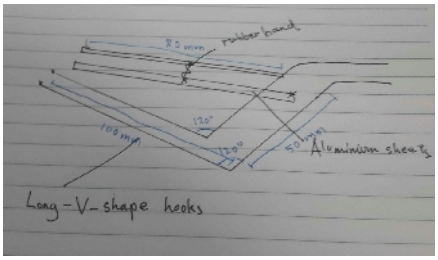


Fig.12b hand drawing of long V-shaped hooks(Photo Credit: Panda)

L-Hooks

Design Description

After the discussion about the methods of opening the door of the P&C hub, we decided to use this L-shape hook as the equipment for accomplish the mission part. The L-shape hook is made of aluminum and can be hand-shaped like others hooks.

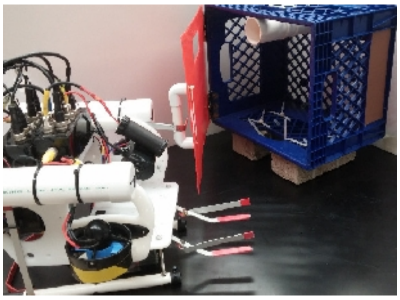


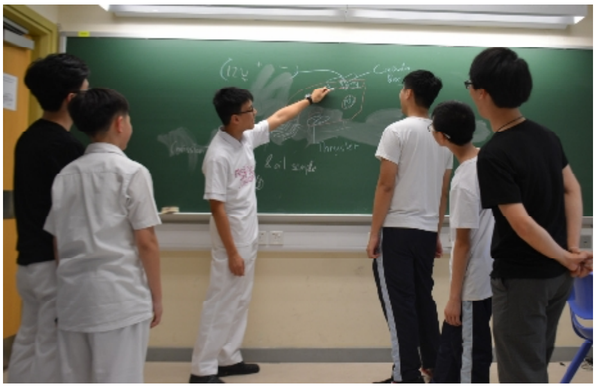
Fig. 13 L-shape hook (Photo Credit: Panda)

Design Rationale

As shown in fig.13, that is how L-shape hooks is perfectly fixed for dealing with different situation such as opening the door of the P&C hub, picking up the wellhead etc. Furthermore, the L-shape hook is implemented on the upper part on the left of the ROV. Therefore, it would not be disturbed other mission while the pilot is accomplishing the mission. We all think that this L-shape hook designed is effective tackling the mission.

Troubleshooting Techniques

With the implementation of new components this MATE season, the members of our company had to improve troubleshooting processes and procedures. The troubleshooting technique which we employed had three main steps: locating the source of the problem, finding the reason behind the problem, then creating and implementing a solution to the problem. If our initial solution did not completely solve the issue, a new solution was tested. We used this technique during the building and testing period. Numerous issues with waterproofing, electronics, and pneumatics taught us to quickly brainstorm possible solutions.



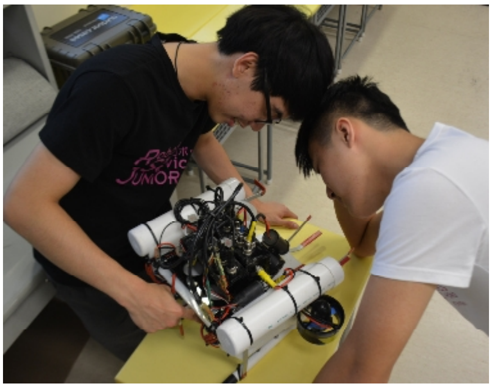


Fig.14 and 15 Discussing the position of control box in order to have the best balance of ROV

Reflection

While with our ROV building philosophy of this year – Simple is the Best, we try to construct a simple and reliable ROV to deal with this MATE season. In order to achieve our philosophy, we used more time to construct and design a simple construction for our ROV- Batfish. We all notice that it is not an easy way to accomplish the mission without a manipulator. With a simple and pure mechanic tools designs, we need a well-trained pilot to drive the ROV. Therefore, our company decided to provide more training for our new staff in the near future. For the next year, we decide to design an easy control manipulator as to build a more user friendly ROV to our customers. This year, without electronic manipulator, we learned a lot about mechanical and engineering but also the importance of teamwork. In fact, we are come from different schools and class. Not enough time is one of our problems, it is difficult for us to group up and discuss about our designs. Therefore, we decide to have an earlier ready for the next MATE season to ensure that we have enough time for tackle all the problems. We promise to have a more outstanding ROV in the near future.

Team Assignment

November	December	January	February	March	April	May	June
Plan / get to know ROV design (All Team Members)	Research the Europa and Gulf of Mexico region (Logistic secretary)	Brainstorm & write the Technical Document (Logistic secretary)	Calculate the budget & Write the Technical Document (Logistic secretary)		Solve the problems found out of the ROV (All Team Member)	Find and tackle the problem that found out after the ROV competition in Hong Kong (All team member)	Construct the control box (CTO, System specialist)
		Build ROV frame (CTO, Payload Specialist)	Design and construct Mission tools (Payload Specialist)	Design Marketing Display (Logistic secretary)		Re-construct the video system (Imaging Specialist)	Measuring the flight case for transporting the ROV (Logistic secretary, CTO)
	Design ROV structure and build camera positions (Imaging Specialist)			Attach the Ballast and thrusters on the ROV (CTO, Payload Specialist)	test and rehearse the missions with ROV in water (All Team Member)	Redesign the tether and the sensor allocation (Payload Specialist)	Amend the Technical Document (Logistic Secretary)
	Brainstorming to create initial design of ROV (CTO)				Finalize the Technical Document (Logistic secretary)	Redesign and fix the mission tools(CTO, Imaging Specialist, Payload Specialist)	Mission demonstration (All team members)
	Discuss the electrical software (system specialist)	Design and develop the presentation, design program Marketing Display, (system specialist) (All Team		Practice of control system Member)	Compete the regional competition (All Team Member)	Resign the control box (System specialist)	Final rehearse of product presentation (All member)
	Safety Training (All Team Member) Prepare safety checklists and Job Safety Analysis (All Team Member)		Find out the problems of the ROV (All Team Member)				

Project Management

In order to achieve our company's goal of producing a quality ROV that can efficiently perform the given tasks, we had to plan and organize the company well. One of the engineering problems that we faced while building the ROV was designing the mission tools. There were numerous factors that we had to keep in mind, which included our limited time frame, budget, and role in the company. The process that our company took to overcome this problem began with a group meeting where everyone could brainstorm and provide ideas. After a design was chosen, the team was split into smaller groups, each of which focused on a specific mission tool component, allowing every team member to remain highly involved in the company.

However, before the actual mission tool could be built, a list of materials and estimated costs had to be sent and approved by the CEO and CFO, in order for the design to pass. This procedure allowed our company to plan ahead and control our limited resources well. A schedule was made to ensure that the whole team was aware of which components would be worked on each day and helped us to effectively manage our time. However, we encountered many problems that we did not anticipate, causing us to occasionally fall behind the initial schedule. In order to get back on schedule, we had to spend many hours of overtime working on the ROV.

In the beginning, pencil and CADs drawings were used to accurately visualize every aspect of the ROV, because the design constantly changed before finalization. Acrylic frame prototypes were also constructed before building the final frame out of HDPE, allowing our company to manage our limited resources well and remain cost effective. After each mission tool was prototyped, the finalized components were then constructed and attached to Batfish's HDPE frame. Upholding and further improving the company's reputation were the key motivational factors in striving towards executing our company's goal. These methods of organization and planning allowed RSJ to operate as a successful company.

Challenges and Solutions

Our company experienced many technical difficulties during the course of this season. Efficiently programming and wiring the control system proved to be an ongoing technical challenge. Since this was the first year that Arduino programming was implemented, the members were required to learn how to program the control system. By watching numerous tutorials and reading online manuals that explained wiring and programming procedures, everyone was able to learn and implement these new skills. Lectures which explained the basics of programming were delivered to the staff by software engineer, who were introduced by our mentor.

We were also aware that our ROV had to perform tasks in current, therefore, we implemented a new method of orientating our drive thrusters, which limited the ROV to operate under strong currents.

Since RSJ is a joint school team and the mentor all have their job, many non-technical challenges arose, such as scheduling meeting times and practice days. Detailed schedules had to be made to accommodate the two different school schedules and various after-school activities. For example, many members are highly active in sports and other extracurricular programs, so meetings were mandatory all day on the weekends. Many methods were implemented to overcome this problem, such as creating a detailed schedule, which accommodated every member's hectic schedules, along with constant communication throughout the company via texting, emailing, and social media.

On the other hand some of team member started to focus on their study and change their role into mentor to assisting the other team member to construct the ROV and plan the mission task. And the disaster challenges is the lack member, as RSJ is not a school or college based team, it is hardly to recruit team member and the new comer are not skillful, a series of training need to conduct in order to make them replace the former member.

Lessons Learned: Technical

This season, RSJ gained many valuable skills while working on the electronics system. Due to the addition of new electronics (Arduino boards, regulator, brushless ESC) our company's system specialist had to quickly learn how to effectively utilize these new technologies. This system required programming, which gave everyone the opportunity to establish and enhance their programming and wiring skills. We also learned the importance of carefully waterproofing every component on the ROV to reduce the incidence of equipment failure that was experienced throughout the season. Every staff was able to gain and improve their technical skills, including the use of power tools and learning how to troubleshoot various challenging problems.

Lessons Learned: Interpersonal

Staffs learned to work together and gained many life skills, including communication and time management. For example, planning daily objectives for each work day helped all members stay aware of their vital roles in successfully meeting deadlines. The importance of respect, patience, and leadership continued to be emphasized throughout the season. As four new members joined the company, the experienced members needed to mentor, support, and assist them in learning and developing crucial engineering skills, which allowed the experienced members to enhance their leadership ability.

Future Improvements

RSJ continuously seeks ways to improve our company and the efficiency of our products. Next year, our company plans to start earlier, in order to provide additional time to design and test various components, increase practice time underwater, and improve our overall performance.

Our company also plans to expand the use of technology on next year's model. Instead of using electronic module, we plan on incorporating an on-board system to reduce the size of the tether. This would improve the functioning of the gripper and improve our overall efficiency of completing missions.

Financial Report

Robotic Services Junior is a training session of Robotic Services, team members come from different school in HK. Although Robotic Services will provide several support to member in joining MATE Competition, our company resource still limited. Therefore, we must be thoughtful and careful in order to control how much money we spend. We estimated that in order to build a new ROV we would need to spend more money, largely for prototyping more designs and for using higher quality parts. Team member conduct fund raising from school authority in order to gain sponsor as much as to build a new ROV for this MATE season.

Source of Sponsor

Source	From of Sponsor	Amount	
Robotic Services	Material	/	
SJAC STEM Funding	Fund	HKD 10,000.00	USD 1,282.05
Crazy Lab	Fund	HKD 3,000.00	USD 384.62
Members Donation	Fund	HKD 3,000.00	USD 384.62
Rev. Bro. Paul Sun Educational Funds	Fund	HKD 100,000.00	USD 12,820.51
	Total	HKD 114,415.00	USD 14,668.59

Budget

Expense	Amount in (HKD)	Amount in (USD)
Research and Design	HKD 3,000.00	USD 384.62
Frame	HKD 2,000.00	USD 256.41
Tether	HKD 1,200.00	USD 153.85
Control box	HKD 1,200.00	USD 153.85
Control System	HKD 1,000.00	USD 128.21
Motor	HKD 7,000.00	USD 897.44
Payload tools	HKD 1,000.00	USD 128.21
Marketing Display	HKD 500.00	USD 64.10
Logistic (HK)	HKD 500.00	USD 64.10
Imaging System	HKD 2,000.00	USD 256.41
Waterproof material	HKD 1,000.00	USD 128.21
Air ticket	HKD 81,000.00	USD 10,384.62
Hotel	HKD 21,000.00	USD 2,692.31
	HKD 122,400.00	USD 15,692.31

The following session details RSJ expense for this MATE season

Category	Description	Type	Value (USD)	Actual Cost (USD)
ROV	PVC Tubing/Joints	Purchased	USD 15.38	USD 15.38
	HDPE Board	Purchased	USD 51.28	USD 51.28
	CNC Milling	Paid Service	USD 102.56	USD 102.56
Mission Tools	Aluminum (FLAT)	Donated	USD 7.69	N/A
	Digital temperature Sensor (2)	Donated	USD 3.08	N/A
	Servo Mount	Donated	USD 15.38	N/A
Control System	Arduino Nano Microcontroller (4)	Donated	USD 70.77	N/A
	Arduino Uno Microcontroller (2)	Donated	USD 35.38	N/A
	Joystick button (4)	Donated	USD 10.26	N/A
	T100 Blue Thruster w/ smart ESC (4)	Purchased	USD 870.90	USD 870.90
	Brushless ESC (Waterproof)	Purchased	USD 116.92	USD 116.92
	12AWG Silicon wire (48m)	Purchased	USD 102.56	USD 102.56
	16AWG Silicon wire (40m)	Purchased	USD 76.92	USD 76.92
	Cat-5e Wire (a box)	Purchased	USD 30.77	USD 30.77
	Heat Shrink Tube	Purchased	USD 10.26	USD 10.26
	Acrylic Sheet (4' X 6' X 4.5mm)	Purchased	USD 82.05	USD 82.05
	Quick Connect Adapters (30)	Purchased	USD 28.21	USD 28.21
	epoxy - 6HR	Donated	USD 30.77	N/A
	epoxy - 30MINS (5)	Donated	USD 14.74	N/A
	epoxy - 5MINS (5)	Donated	USD 16.03	N/A
	Screws/Washers	Donated	USD 12.82	N/A
	Miscellaneous	Purchased	USD 173.85	USD 173.85
Imaging System	AV Camera (4)	Purchased	USD 76.92	USD 76.92
	7" Monitor (4)	Purchased	USD 153.85	USD 153.85
	LED Lighting (4)	Donated	USD 51.28	N/A
	Control Box	Donated	USD 65.38	N/A
Logistic	Logistic of ROV (HK)	Paid Service	USD 51.28	USD 51.28
	Marketing Display	Paid Service	USD 51.28	USD 51.28
Travel	Flight tickets(9)	Donated	USD 10,384.62	USD 10,384.62
	Hotel	Donated	USD 3,230.77	USD 3,230.77
		Total	USD 17,031.79	USD 16,698.21

The production cost of Batfish is USDD USD 2,328.59. With the sponsor from Robotic Services in form of material support, the actual cost for construct of Batfish is USD 1,995.00 . We can achieve the self-balance within the budget. Also, with the extra sponsor from Rev. Bro. Paul Sun Educational Funds, sponsor us the traveling and accommodation for International Competition held in Houston, USA.

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15. Acknowledgements

Robotic Services Junior **would also like to thank:**

All the judges of the MATE Regional Competition and International Competition

HKIET sponsor for

MATE Centre for organizing the competition

Principal and teachers of St. Joseph's Anglo Chinese Secondary School for supporting us in all means

Robotic Services for supporting us in all means

MATE International ROV Competition Organization

Hong Kong MATE ROV Competition Organizer

Venue Sponsor

International competition Sponsor

Safety Inspection Checklist

Company Members

☐ All members are wearing safety goggles when using power tools.

☐ Long hair is tied up and accessories are removed.

☐ Adult supervision while working with hazardous tools.

☐ No horseplay in the work place or at the pool.

Safety Specifications

☐ A 25 amp inline fuse is attached within 30 cm from the power supply attachment point.

☐ There are no exposed motors and all propellers are completely shrouded.

☐ All moving parts e.g. thruster, gripper are taped with yellow sticker or warning signal ☐ No exposed copper wire/all splices are soldered and sealed.

☐ There are no sharp edges on the ROV that can cause harm.

☐ Ensure that the buoyancy tanks are securely attached to the ROV's frame.

Cameras

☐ Double check the waterproofing.

☐ Ensure camera wires are not punctured or tangled.

☐ Cameras are securely attached after fixing the image.

☐ Check cameras for damage or flooding.

☐ Spray the cameras with fresh water, to get chlorine water off, which prevents corrosion.

Control System/Motors

☐ Ensure that the control box is securely place at a safety place.

☐ Ensure safety wire is connect to non moving position. e.g. wall or fence… ☐ Ensure that there are no visible shorts or broken connections in the system.

☐ Ensure that the plugs are inserted correctly.

☐ Ensure all components are responding to control system. e.g. camera, thruster…

☐ Clear notification to team member while start to turn the machine on. e.g. "Power on'

Appendix B

JOB SAFETY ANALYSIS

Safety for Robotic Services Junior

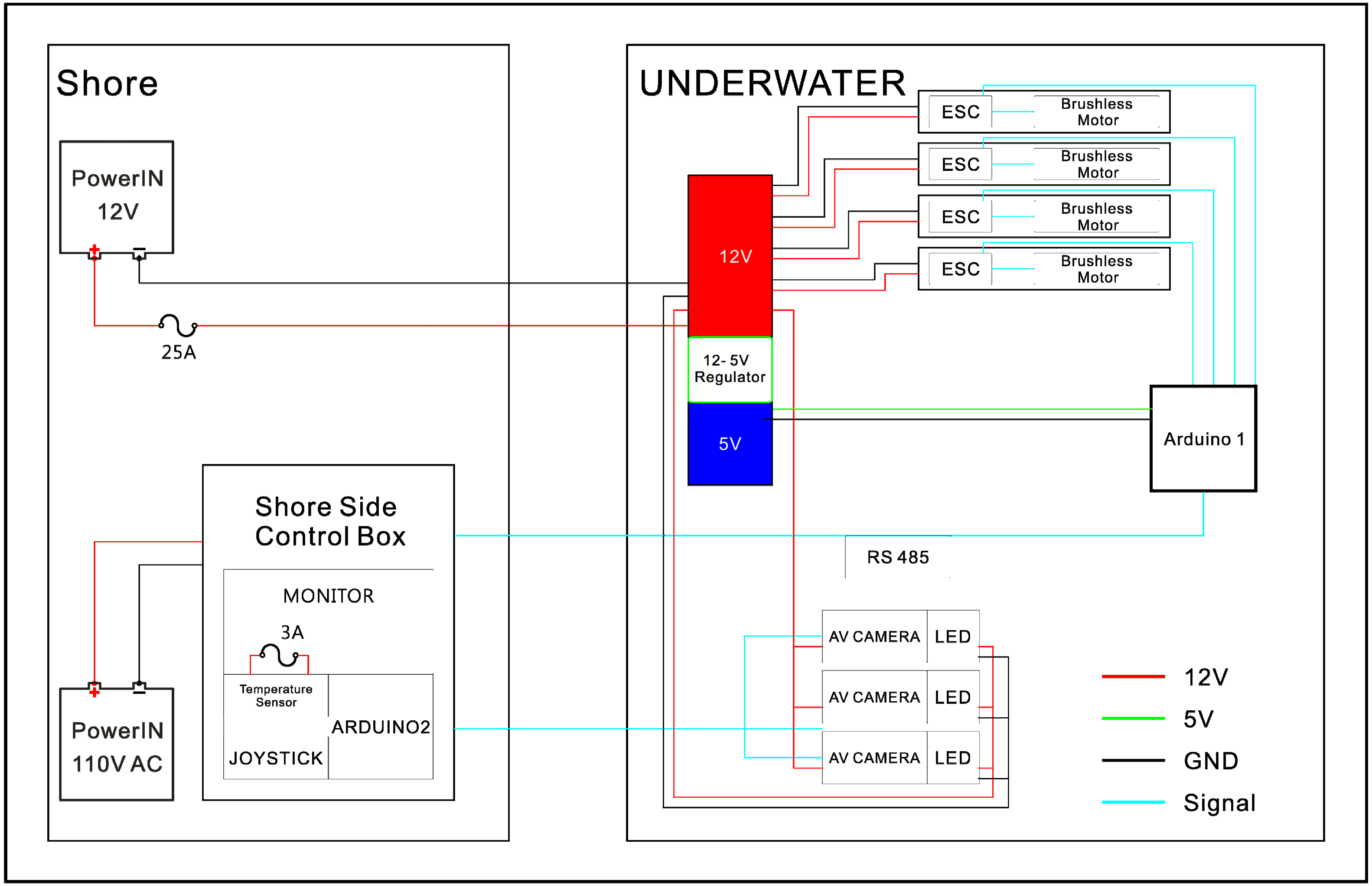
Building and Operating the Batfish

Activity	Hazard	Control
Building the ROV		
Electrical Currents	Electrocution	Keep items turned off until clean connections ensured
Hot Tools (Heat Gun, Soldering Iron, Glue Gun)	Burns	Use gloves and safety goggles when operating hot tools at all times; when not in use, turned off
	Equipment Damage	Ensure items have time to cool down before storing
Sharp Objects (Knives, Cutters)	Cuts	Use out of proximity of other team members, always use gloves and safety goggles (avoid fragments)
Operating the ROV		
Tether Management	Trip hazard	When not in use, keep tether in the tether reel; when in use, ensure tether is maintained
Loose Attachments/Tools	Trip hazard	Keep all items in their designated boxes
Slippery Surfaces	Trip hazard	Walk carefully, wear shoes with grip
starting of motors/ thrust	Hand injury or cut	Put warning sign/ stickers on the thruster. Ensure the thruster control is off when in contact with the Stingray. Call "Power on" before turn on the thruster
Control Box (when turned on)	Wet weather/ electrocution	Keep box turned off until in use, use sun shade to avoid rain

JSA Prepared By: CTO –Thanh Long, Thai and Logistic Secretary Chi Kin, Wong

JSA Prepared Date: 03/01/2016

System Integration Diagram



Software Flow Chat