ROV Engineering Report
Knight Diver ROV

Submitted by the

Robinson High School
Knight Diver ROV Team
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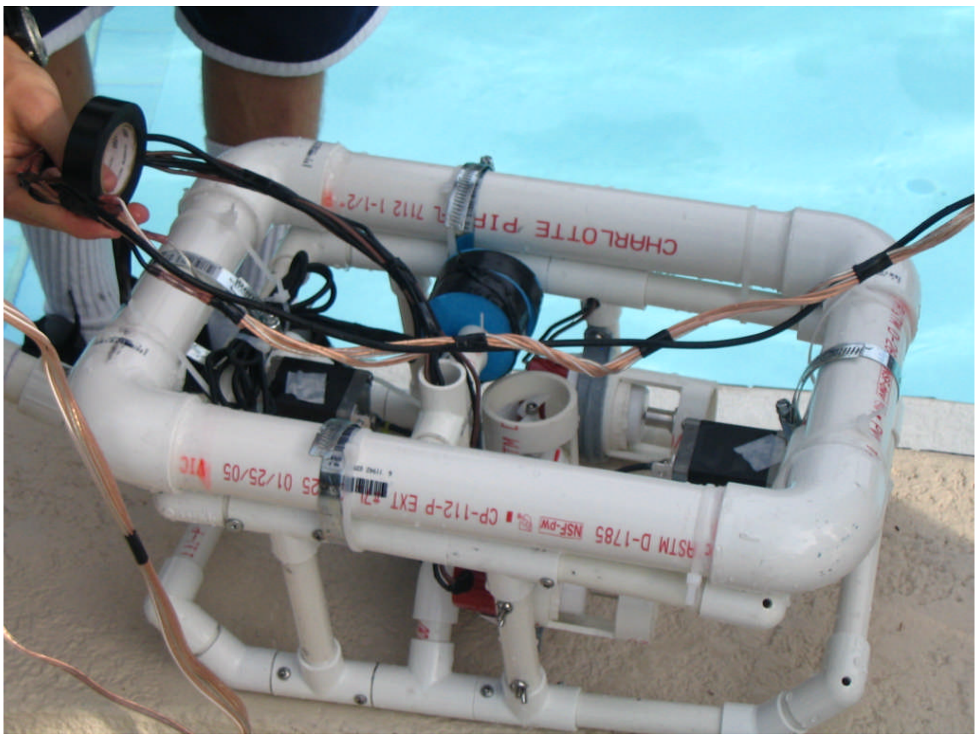
Submitted to the Marine Advanced Technology Education Center
(Note: Further modifications may occur as water trials continue.)



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Abstract (250 words)

This technical report describes the Remotely Operated Vehicle (ROV) *Knight Diver*, built by the Robinson High School Knight Diver ROV Team, 2005.

The ROV was designed to compete in the 2005 ROV Design Competition hosted by the Marine Advanced Technology Education Center (MATE). The mission of the *Knight Diver* is to compete in "underwater Olympic" events. These events range from installing a new instrument module on the Hubble space telescope to capping an old oil well, and repairing a telecommunications cable.

This paper also discusses the design rationale for the ROV, the design challenges encountered, troubleshooting ideas, lessons learned, ideas for future improvements, and a discussion of a career, organization, or technology that supports one of the mission themes.

ROV Final Design

Knight Diver ROV is 66 cm long (45 cm without grabber), 28.4 cm wide, 20 cm high and has a dry weigh of 3.22 kg or 31.67 N (7.12 lb). The entire unit, including tether and control box has a weight of 5.62 kg or 25.00 N (12.4 lbs). A payload tool adapter is located on the front of the ROV, directly below the dual camera system. The XY-axis thrusters are attached to the upper cross members. The Z-axis thrusters are attached to the side supports. The main termination can is located over the center axis on the rear upper crossbar.

1. **Frame**
   The frame is made of schedule 40 PVC pipe, Schedule 40 PVC fittings, as well as plastic 2-inch pipe clamp, and stainless steel hardware. The hardware includes #8 x ¾ inch screws, #10 x 1 ½ inch bolts, and wing nuts.

2. **Control System**
   The control system consists of one main control units. In order to maneuver the ROV with fine movements a control box was built with a switch to control each individual motor. The thruster control unit is built within a plastic housing, project box (Radio Shack #270-1806) 15.24 X 10.16 X 5.08 cm (6 X 4 X 2 in.). For safety and to protect the unit from a power surge a Universal in-line fuse, 1.5 x 6.8 cm was installed. A 25-amp fuse has been placed in the holder. Individual thrusters are controlled by DPDT Momentary Flip Switches (Radio Shack #275-709). The XY-axis thrusters have their switches mounted in an anterior position to the top surface of the control box. These switches are placed an equal distance from the midline of the project box. The Z-axis thruster has its switch mounted in a posterior position on the right top surface of the box.

3. **Video Camera & Monitor**
   To help navigate the Knight Diver we selected two black & white, wide-angle video cameras wired together within a junction box. These cameras were awarded to the Knight Diver ROV Team last year as a part of a scholarship program. We are using a Symphonic 9 inch (22.86 cm) AC/DC color TV/VCR as our monitor combination. This allows for videotaping of missions for debriefing, and flight evaluation.

4. **Payload Tools**
   The ROV has three interchangeable payload tools. The tools "quick connect" to the ROV frame via a ½ inch Schedule 40 PVC tee fitting (S x S x Fips) attached to the frame and a ½ inch

Schedule 40 PVC male adapter (S X Mips). Each tool is specifically designed to meet mission criteria.

The first tool is a ring adapter designed to fit over the handle of an oil well cap. This tool allows the ROV to cap or uncap an oil well in the Gulf of Mexico. It is constructed of a 17.785 cm (7 inch) piece of ½ inch Schedule 40 PVC pipe fitted with a ½ inch Schedule 40 PVC male fitting (S x Mips). Attached to the PVC pipe is a PVC 1 ½ pipe clamp. It is attached with 2 #10 stainless steel 1 ½ inch bolts and wing nuts. Overall tool length is18 cm (7.07 inches)

The second tool is a probe/clip. This tool allows the ROV to repair a damaged fiber optic cable connection and reestablish a communication link by delivering and inserting a communications probe into the open port on a junction box. It is constructed of a 17.785 cm (7 inch) piece of ½ inch Schedule 40 PVC pipe fitted with a ½ inch Schedule 40 PVC male fitting (S x Mips). The tee portion of the “quick connect” is fitted with a spring clamp that has been constructed from a wire coat hanger. Overall tool length is 18 cm (7.07 inches).

The third tool is an instrument module port. This tool allows the ROV to transport and install an instrument module on the Hubble space telescope. It is constructed of a series of Schedule 40 fittings, ½ Schedule 40 PVC pipe and 1 inch Schedule 200 PVC pipe. The fittings are sequenced in reducing order as you move toward the “quick connect” on the ROV. This allows the port to accept the back handle of the instrument module, while still connecting via the ½ Schedule 40 PVC tee fitting on the ROV frame. In order from the end of the port are the follow PVC items: 5 cm 1 inch Schedule 200 pipe/1 inch Schedule 40 coupling (S x S)/Schedule 40 Reducing Male Adapter 1 inch – ¾ (S x Mips)/Schedule 40 Reducing Male Adapter ¾ - ½ (Spig x Mips)/5 cm ½ inch Schedule 40 pipe/1/2 inch Male Adpater (S x Mips). Overall tool length is 18 cm (7.07 inches).

5. **Tether**
Three 18 AWG 2 conductors speaker wire conducts power through the tether to the ROV. The tether also contains one coaxial cable that terminates at the video camera junction box. The tether shielding is ¾ inch braided sleeving, which has pool noodle floatation spaced every 1.5 meters (5 feet) for floatation.

6. **Thrusters**
The Knight Diver ROV is equipped with three thrusters. These thrusters are made from 1100 GPH Rule Bilge Pump Replacement Cartridges (Model 27DR), Master Airscrew hubs, and 1.5-inch Dumas left-handed nylon propellers with a 1/8-inch bore. The propellers have been tapped with a 10-24 tap to attach them to the hub. Each thruster is protected with a 6-amp fuse that is a part of the cartridge assembly. Two thrusters are in a parallel configuration to move the ROV on the XY plane. One thruster provides up/down thrust.

7. **Power**
Our main power source is 12-volt battery. Power is fed through banana plugs and 16 AWG power wire into our control box. The main power is protected with a 25 amp fast acting fuse. Ancillary power includes 110/120-volt AC power adapters for the cameras and monitors.

Design Rationale

Design Rationale

As a first time team our design process was tenuous and chaotic. Our initial research on ROVs began with a video describing many different submersibles and their uses. Our instructor then reviewed with us the variety of ROVs currently in use. We explored many photos, videos, and the Internet. This background research laid the foundation for us to move towards designing and building our own ROV for the specific purpose of competing in the MATE National ROV Design & Build Competition. Our instructor laid out the following plan and attempted to keep us on track.

1. Define the need
2. Determine Specifications
3. Brainstorming
4. Analysis of Solutions
5. Modification of Design Based on Analysis
6. Selecting the Best Design
7. Assembly and Building
8. Make changes based on Building Process
9. Analysis and Testing
10. Modifications Based on Testing
11. Final Design and Evaluation

The 2005 MATE Competition Guidelines for the Ranger Class defined the requirements for our ROV. These requirements include:

- The ability to complete 3 Olympic mission tasks, 5 minutes per task.
- Depth rating of 5 meters (m), 16 feet (ft)
- Ability to be piloted by camera
- Turn a valve (horizontally) to stop the oil from flowing at an oil well in the Gulf of Mexico.
- Repair a damaged fiber optic cable connection to re-establish a communications link by inserting a probe into an open port on a junction box.
- Install a new instrument module on the Hubble space telescope by placing a module that is circular with a 10 centimeters (cm) diameter.
- Return to the surface after completion of tasks.

The design of our ROV was constrained primarily by the following:

- Budget of $2000.00 (U.S. currency)
- Capable of fitting through an entrance that will be no less than 60 cm (either circular or square)
- Capable of maneuvering in a space 80 cm x 60 cm x 60 cm.
- A minimum 12 m tether from control shack to ROV (Control shack is 2 m from side of pool)
- A maximum of 3 monitors
- Capable of being transported either by hand or cart
- Must not damage any part of the pool deck or bottom tiles
- Must be set up and deployed in 5 minutes
- May not release hazardous or non-biodegradable materials into the environment
- Only DC volts may run down the tether
- Must operate from a 12 to 13.5 volt, 25 amp power source
- Must connect to the power source via male banana plugs

- Must have short-circuit protection (fuse)
- Maximum DC voltage is 13.5 volts
- Maximum DC amperage is 25 amps
- Competition officials must be able to place a multi-meter inline to monitor voltage and amperage
- Power supplies must be at least 3 meters (m) from the pool edge

Each team member developed his or her own conceptual design for the ROV. These designs were drawn on paper and brought to the overall brainstorming meeting. These conceptual designs were presented. As a team we evaluated and weighted the criteria for designing our ROV. Each concept ROV was then compared to the weighted criteria, requirements, and constraints to determine our initial optimum design. The initial optimum design for our prototype ROV was a combination of elements from the various conceptual designs.

Partial Results from Analysis of Conceptual Designs

Criteria	Weight (Range 0-10)	Design (Score 0-5)	Multiple of score by Weight	Design (Score 0-5)	Multiple of score by Weight	Design (Score 0-5)	Multiple of score by Weight
Appearance	4	5	20	4	16	2	8
Propulsion System							
1. Speed	7	3	21	4	24	3	21
2. Maneuverability	9	3	27	4	36	2	18
Frame							
1. Stability	8	5	40	5	40	2	16
Manipulator/Payload	6	5	30	5	30	5	30
Control System	6	0	0	3	18	5	30
Camera System	10	3	30	4	40	3	30
Buoyancy Control	5	2	10	3	15	0	0
Totals:			148		219		123

Design rational for individual components is described below.

1. **Frame**
   We looked at many different photos of ROVs to get ideas for the frame materials and shape.

   The idea to build our frame out of Schedule 40 PVC came from the book *How to Build Your Own Underwater Robot and Other Wet Projects* (Bohm & Jensen). Our instructor and last year's team had already built an ROV from this book and the PVC had worked well for their designs. The other advantage of Schedule 40 PVC was cost. At approximately $2.00 per 3.05 m (10 ft.) length it allowed us to purchase large quantities. It was easily cut to our size requirements without any special equipment. Whenever we needed to make changes in our design or sizes, it was easily accomplished. Furthermore, it was readily available at many home improvement stores. Many of the students had experience with PVC as well since many of them had assisted their families with lawn irrigation systems. This background knowledge of the material allowed us to immediately begin working without much training or learning curve.

   Most ROV shapes we observed were either a box shape or a triangular shape in cross section. We opted for the box shape for ease of cutting and stability purposes. It also provided us the most space to affix our accessories such as cameras and payload tools. We decided to ream out the inside of the PVC fittings on the straight stretches of the frame so that a solid piece of PVC pipe could slide through all fittings, eliminating as many weak areas where the frame could pull apart. The compromise is that the fittings would rotate around the pipe. In order to eliminate this rotation, several options considered were epoxy, PVC cement and placing stainless steel screws through the frame at these points. We opted to use the stainless steel screws because it still allowed us the option to make changes to the frame if it was found that modifications would improve the performance of the ROV.

2. Control System

Our control system was the most difficult portion to design. Most of our experience with controllers comes from video game experience. Ultimately we would have liked to have joystick control or computer control of the ROV, however our personal experience with electronic wiring was minimal for a few members and completely absent for the rest or the team. We relied heavily on the wiring schematics in the book *How to Build Your Own Underwater Robot and Other Wet Projects* (Bohm & Jensen) and the recommendations made by Sound Marine Electronics. After reviewing schematics for joystick control and realizing it was beyond our experience, we chose to simplify our initial design from joystick control to DPDT switches. These allowed us to reverse the polarity of the motors in order to reverse the direction of thrust. For better control of the thrusters we switched from the DPDT flip switch to the DPDT momentary flip switch. This gave us better control in the water trials. The layout of the main control box was left to our ROV pilot since he would be the end user. He decided to mount the switches to the top of the box. The switches for the XY thrusters were mounted to the top forward portion of the control box. The switch for the Z thruster was mounted to the top back portion of the control box. It was offset to the right side for ergonomic comfort for the pilot.

3. Video Camera & Monitor

The competition guidelines state that the ROV must be controlled and piloted via a camera system. This is to simulate real world application of ROVs. For this reason we weighted our camera system as extremely important. Without a camera we will be unable to complete any of the mission tasks. We chose to use the Carrillo Underwater Systems camera because we had been awarded a scholarship for lights and cameras from this company for the 2004 ROV Competition. These cameras have been commercially designed for underwater applications. These cameras have a wide angle and worked very well for last year's team.

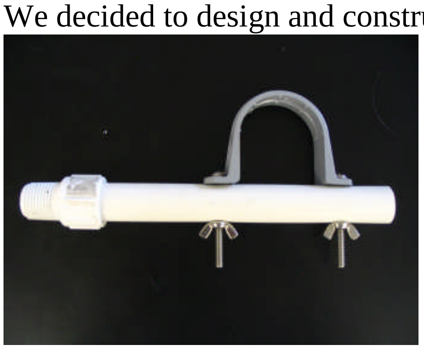
With the weighted importance of the camera guidance system we also decided that it was important to have a back-up camera system. We selected to use the X-10 Nightwatch 2 camera for several reasons. The camera met most of our requirements – light sensitivity, picture quality, small size, lightweight, and it had a 60 ft, hardwired cable. We constructed a watertight housing for this camera using a 8 cm length of 2 inch Schedule 40 PVC pipe, and 2 PVC end caps. The PVC pipe was fitted with a 1 ¼ PVC connector to serve a mount for the camera. The front-end cap was drilled out with a 1-inch hole saw to form a window. This window was then covered with a 1-½ inch circle of lexan. The lexan was affixed behind the window with marine goop. All seams were sealed with aquarium silicon. The back end-cap was fitted with a male and female ½-inch CPVC connector. These connectors were threaded through the hole that was drilled through the center of the end cap. The seams were again sealed with aquarium sealant. The cable was threaded through the length of PVC and the camera was mounted to the interior. The cable was then threaded through the CPVC connects in the back end cap. Both end caps were affixed to the PVC pipe with PVC cement and the seams were sealed with aquarium sealant. Finally, the connectors where the cable came through the housing were sealed with aquarium sealant.

4. Payload Tools

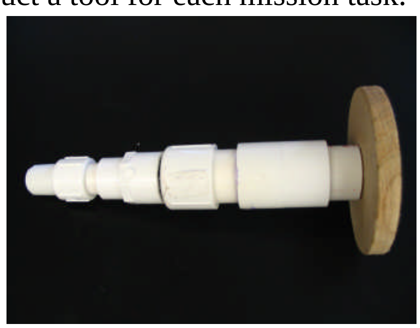
Our instructor gave us many toys and brochures that had a wide variety of manipulator arms and other payload tools for us to evaluate. Our mission tasks require that we have the capability to carry and deliver several different items of differing shape and size. We conducted several trials with the various toys to determine whether or not they would be best for picking up the items we needed to pick up. The results were as follows:

Manipulator	PVC Pipe	Plastic Ring	Balsa Wood	Rope
Robotic arm	Grabbed well, but pipe was difficult to get hold of due to small surface area on grabber.	Grabbed well, but ring would get caught on jaws upon release.	Was able to grip wood but required precision piloting to grab at the correct angle.	Rope slipped from grip. Required precision piloting.
Trash grabber	Grabbed well, but pipe was difficult to get hold of due to small surface area on grabber	Grabbed well, but ring would get caught on jaws when released.	Wood slipped from grip.	Unable to grip rope.
Bug jaws	Grabbed well, but opening was not big enough for pipe.	Grabbed well, but not enough surface to hold ring for length of time.	Too small of an opening to grab wood without precision piloting.	Unable to hold weight of rope.
Pololu Joinmax Gripper	Grabbed well, but opening was not big enough for pipe.	Grabbed well, but ring would fall out of grip. When released ring would get caught on jaws.	Had to have articulating motion or ROV had to be piloted into position to grab.	Precision piloting was needed in order to grab.
Glove Grabber	Grabbed & Released well.	Grabbed & Released well	Closed far enough to hold thin wood	Grabbed and held
Metal Clip	Easy to get around pope, but had no holding capability.	Held ring well; ring easily released.	Wood slipped from grip.	Rope slipped from grip.
PVC Spear	No ability to hold pipe. Could be used to push or poke at pipe.	Held ring well, but ring would fall off when in reverse	Wood held well with friction on the inside of spear.	Could move rope, but could not carry rope.
Hook	Easy to get around pipe, but had not holding capability.	Held ring well, but ring would fall off when in reverse	Did not hold wood. Could push or pull wood.	Could move rope, but could not carry rope unless draped over hook.

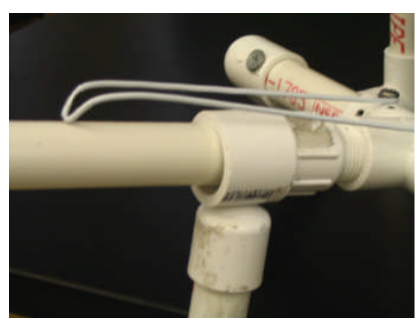
We decided to design and construct a tool for each mission task.



Hook or oil well.



Probe for Hubble space telescope.



Clip for Science Probe.

5. **Tether**
Our thrusters were already prefabricated with 16 AWG wire. We wanted to select wire that would carry enough voltage to the thruster units with the least amount of resistance and the least voltage drop. Originally we were going to use 14 AWG speaker wire. This wire had little

voltage drop over the distance of our tether, plus it was flexible. However, shortly after experimenting with this wire, we discovered that it lost a lot of flexibility when grouped together into a five-cable tether (four thrusters & one camera wire) due to the thickness of the tether. A review of the wiring experiments showed that 18 AWG wire should carry enough voltage to run the thrusters, and it provided more flexibility. (Note: We also reduced the tether by one wire when we removed the third XY thruster. The tether is shielded with ¾ inch braided sleeving.

Our camera cable is also run inside the tether. We originally wanted to attach these final cables to the outside of the tether. This design will allow for a quick change of cameras in the event of a camera failure. However, there was no protection for these cables. Due to the importance of both systems, it was decided that they should be run inside the protective covering with the other wires.

6. Thruster

We considered a number of different types of motor and propeller combinations as a thruster unit. Since our propulsion system had the second highest weight in our criteria we took a lot of time to determine what system would work best for our mission tasks.

Our first consideration was the actual motor we would use. We had several brands of bilge pump motors (Johnson, Rule, Shurflo Piranha) and two different Radio Shack motors that we originally considered. We extracted the bilge pump motors from their casings in order to evaluate them side by side with the Radio Shack motors. The bilge pump motors all appeared to rotate faster than the Radio Shack motors. We inferred that this faster rotation meant they would have more power and thrust. All of the motors appeared to be equally balanced. All motors turned in a counterclockwise motion.

Taking into consideration the fact that our ROV would be functioning in water and our motors would need to be waterproofed, we decided to use a bilge pump motor. Rule bilge pumps, manufactured by ITT Industries, make replacement cartridges for bilge pumps. These replacement cartridges allow for easier access to the motor shaft and impeller. For this reason we chose Rule Bilge Pump Replacement Cartridges.

In order to evaluate the power of each Rule bilge pump, we constructed a PVC mount for the motors. It was then submerged into an aquarium of freshwater. The motor was activated and the amount of thrust was evaluated by via a force meter. We chose the 1100 GPH Rule Replacement Bilge Pump Cartridges as our motors because they are more powerful than the 350 GPH, and the 700 GPH.

We designed a nozzle from 2 inch PVC in order to protect to propellers from debris and to protect the pool from damage from the spinning propeller. This nozzle was designed after a kort nozzle, which our research told us could also help to increase the thrust from the propeller.

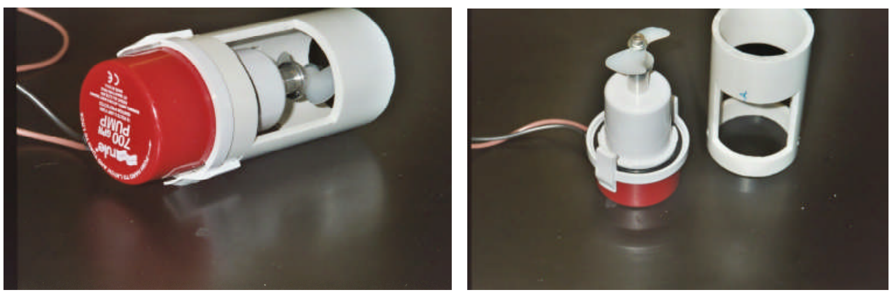
Once we selected our motor, we had to determine which propeller we would attach to the shaft. Bob Musselman of Admiral C & B Propeller gave us a lecture on how propellers work. After learning the different factors that affect a propeller and how much thrust it can provide, we decided we needed a non-metal propeller with a low pitch, larger surface area, and 3 blades. This type of propeller would provide adequate thrust but allow for more maneuverability. We went to all of the local hobby shops in search of a 3 bladed propeller but were unable to find one at these shops. Our search took us to the Internet, where we continued to have problems finding 3 bladed propellers. We purchased several 2 bladed propellers for evaluation. The propellers we compared included the followings:

- X Brand 55mm (Hobby Lobby)
- #3003 Nylon Propeller 1.75" Dia. Kit #3003 (Dumas Products)
  1.75" Dia. 1.50" Pitch Left Hand 1/8" Bore
- #3004 Nylon Propeller 1.75" Dia Kit #3004 (Dumas Products)
  1.75" Dia. 1.50" Pitch Left Hand 3/16" Bore
- #3105 Bronze Propeller 1.75" Kit #3105 (Dumas Products)
  Bronze Propeller 1.75" Dia. 1.50" Pitch Two Bladed Left Hand 3/16" Bore

We selected the #3003 Nylon Propeller 1.75" Dia. Kit #3003 (Dumas Products)
1.75" Dia. 1.50" Pitch Left Hand 1/8" Bore because it fit inside of our nozzle, was lightweight, inexpensive, and provided more maneuverability than the racing propellers.

Several methods were used to attach the propeller to the shaft of the motor. We used bushings, set-pins, J.B. Weld, cauter pins, and a Master Airscrew Hub. We decided to use the Master Airscrew Hubs for several reasons. First, they were easy to attach to the shaft. Second, they moved the propeller further away from the motor allowing more water to flow across the blades without interference. Third, the hub allowed for easy change of propellers in the event of damage. The only modification that was necessary was to change the hardware to stainless steel.

The entire thruster unit is connected into the PVC frame with a 2-inch plastic c-clamp. This connection was sturdy, allowed us to place the thruster anywhere on the frame. It also allowed us to adjust the angle of the thrusters for maximum maneuverability simply by rotating the PVC pipe.



Photos of Thruster Unit

7. **Power**
   As mandated by competition guidelines, our main power source is 12-volt battery. Power is fed through banana plugs and 10 AWG power wire into our control box. The main power is protected with a 25 amp fast acting fuse. This fuse was selected because it would blow as soon as we surpassed the 25 amp maximum requirement. It would also protect our electronics better than a slow acting fuse. Ancillary power includes 110/120-volt AC power adapters for the cameras and monitors. The adapters were supplied with the monitor.

Challenges

<u>Organizational</u>

1. Inexperience in the field of engineering was a challenge, yet it was also the reason we entered into this project. Not only were the student members of the team inexperienced, the instructor/advisor had minimal experience in the field of engineering. To overcome this gap in our knowledge base, our instructor/advisor purchased numerous books on robotics for team members to reference. She also assigned research and background readings. She often created worksheets and fact sheets to focus our research and practice exercises. This helped to provide some of the fundamental basics. However, there were other times when we needed to call upon

the expertise of others. Often it was difficult to find someone with either the knowledge or the willingness to help the team.

2. Scheduling posed a significant challenge. Team members had school, work, families, and personal obligations to fulfill. Our meetings were after school on our own time, it was rare that there was an opportunity during the school day for us to meet as a team. Often there was a lack of communication because some team members were at some meetings and some were at others. Making sure everyone got the information they needed was difficult and caused problems as team members attempted to fulfill their assignments and responsibilities. Originally the team met once every two weeks. These meetings occurred for one hour during the school day. It quickly became apparent that this was not sufficient time, so we held an additional meeting once a week after school. These meetings often conflicted with sports practice. By March, we it was apparent that we needed to dedicate far more time to building so we could begin water trials. The team voted to meet twice a week after school. Increasing the number of official meeting times was difficult. Each meeting required School Board approval. Often we held informal “unscheduled” meetings after school.

3. We also faced organizational challenges. Our instructor/advisor did a good job of pointing out what needed to be done, and what areas we needed to focus our efforts. We also had a team leader that had lots of ideas, and motivated the team. Brainstorming went well, but when it came time to make decisions about what materials and component to use, then acquire those materials we often had the expectation that our advisor would tell us what to do, or provide us the materials. Team members were not doing anything outside of team meetings. To help us become more productive, our advisor suggested we begin our meetings with an agenda. Our first task at each meeting would be to review the progress of team members on their assigned tasks. These tasks were assigned at the end of each meeting. This would hold each of us accountable for getting things done outside of meetings. It also helped the student team members to take ownership of the ROV project, making us more independent in our problem solving abilities.

4. Funding was one of the largest challenges. Although our advisor worked hard to get local companies to sponsor our team by donating materials and funds, we often found companies to be unresponsive. Many local stores referred us to the corporate headquarters. Despite sending multiple letters, leaving phone messages, and following up many of these corporate headquarters did not respond. Other companies replied with statements such as, “we receive many of these requests, but are unable to help at this time”, or “due to the current economic status of our company, we have suspended such activities at this time”. We found that locally owned and operated companies were more willing to help us out. During the building phase we had two companies, T.A. Mahoney, that was willing to sell parts to us at a discounted price. We also received a $500 donation from Doug Levin, Ph.D. This money was in exchange for our instructor writing curriculum materials for a robotics grant. More often than not, it was our advisor that funded our project. We are very grateful to her and her family for their generosity with their time and money, we know that teachers do not make much money and she willingly gave whatever was needed to make our project a success.

5. Team member retention was a unique challenge. We experienced drop out of team members for a variety of reasons including: administrative withdrawals of students from the school, dismissal from the team for lack of attendance, commitment to project, or behavioral issues. There were times when the loss of team members seemed devastating to the project. We usually felt this way when the team member was in a leadership position or had very specific skills that others of us did not have. On the other hand, there were times when we seemed to be more productive when there were fewer people around. During team meetings that had high attendance we often felt

like we were wasting time answering questions and catching people up that had not been involved due to absenteeism. Sometimes these team members would argue that their ideas were not incorporated into the ROV and would want to change things that had been decided in earlier meetings. This would often lead to arguments that resulted in tension between team members. In many cases, team members that were removed from the team either by the school or by our advisor were often team members that were not reliable enough to complete tasks on time, which often slowed the team down as well. Working out these team dynamics was often the most stressful part of handing the ROV project.

Engineering

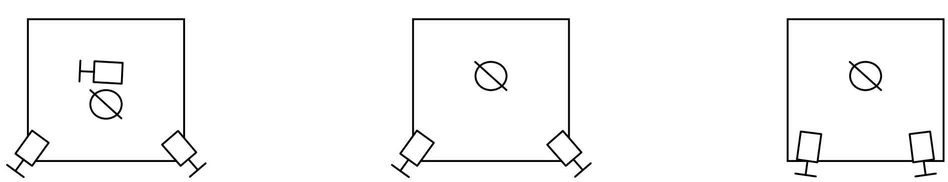
1. Developing a small, stable, maneuverable platform was an engineering challenge. Many of the team members argued to design a bigger and bigger frame. Our instructor would always refer us back to the competition guidelines, reminding us to make sure we were keeping the specifications in mind as we designed. Two team member decided that they would go ahead an build a frame that was big, even though they were reminded of the guidelines. To emphasize her point, our instructor build a PVC cube that matched the dimensions specified. We were to test each of our frames inside of the cube to see if the ROV would be able to turn inside the dimensions. It quickly became evident that we needed to build smaller. Once the payload tools were designed, we again had to test the ROV to see if the tools were going to keep the vehicle from being able to turn.

Troubleshooting Techniques

This being the first competition for our current team, the trouble-shooting techniques that we utilized were often trial and error. We would also take our ROV to our team of experts for assistance in trouble shooting. With time, we adopted the method of designing, prototyping, testing, modifying based on results, testing after modifications, etc. We learned that this was the most efficient method of developing a workable ROV, and it mimics the engineering design process that we had been taught about.

Once we began water testing our ROV we discovered that our thruster arrangement did not provide us the maneuverability we desired. Below are diagrams of our thruster arrangements.

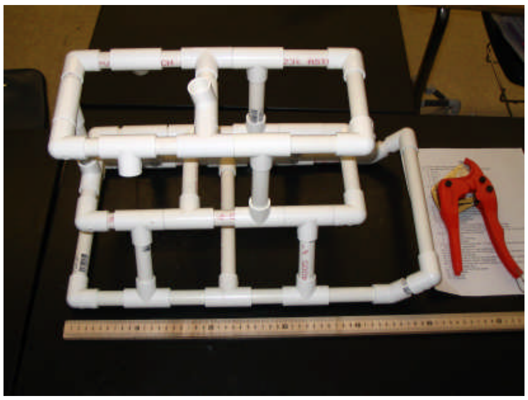
Thruster arrangements



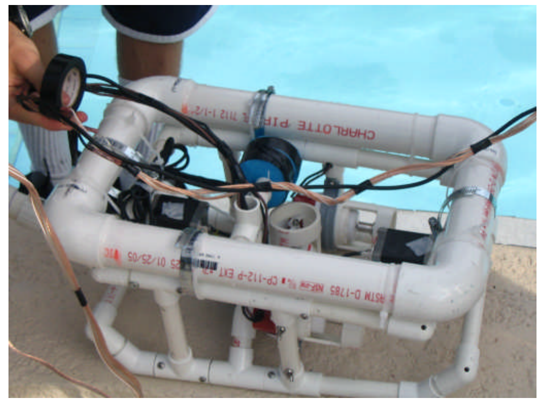
Initial thruster arrangement | Modified thruster arrangement | Final thruster arrangement

Although the initial thruster arrangement was modeled after the Outland ROV and , it did not provide the lateral movement we were looking for. The placement within the frame on both the XY axis and the Z axis had been chosen based on what we had seen in photos of commercial ROVs and personal experience with a Video Ray ROV. The slightly forward position of the lateral thruster did not move the ROV side to side; rather it turned it in an arc. We returned to these photos to determine the exact angle and vectors that were used for the thrusters. Our final arrangement is based on these photos. It allows for much quicker turning.

Developing a stable maneuverable platform was an engineering challenge. Our ROV was stable in the water when it was not under power. This stability was obtained by designing a small, low profile, ROV, with its floatation on the top and its weight primarily on the bottom of the frame. We also built a floatation ring that would distribute the buoyancy evenly around the frame. However, when we applied power to the thrusters our ROV had a tendency to "buck". The front end would angle upwards, changing the overall thrust pattern, similar to a boat with its engines in the rear. We attempted to rectify this issue by moving the thrusters forward to change the center of effort. This change somewhat corrected the issue.



Original Frame Design (High Profile)



Final Frame Design (Low Profile)

Lessons Learned

1. We learned that to be a successful team, team members must be willing to compromise their ideas and take suggestions. If the team doesn't work together, time will be wasted arguing rather than designing and building. Team members must be willing to listen to their teammates. Also, team members must be mindful of their communications techniques. Sometimes constructive criticisms came across as cut downs and would often lead to anger between team members. With cooperation, more is accomplished.

2. Remaining dedicated and following through with assignments is vital to the team being successful. Setting a timeline with deadlines will help to keep us on track. Since this was our first attempt to build an ROV, we did not know that amount of time it would take to complete any task. We also had to wait for materials to be shipped to us. The FL Regional Competition was held on May 21st, 2005 and we had only minimal water/pilot practice.

3. Problem solving can be a frustrating process. We learned that we needed to methodically work through issues. We needed to record what we tried and whether or not the result was positive. This would avoid duplication of efforts and minimize our frustration level when things did not go as planned. Sometimes we simply had to leave a problem to another practice, this gave team members time to think about different options. Also, tensions seemed to arise due to malfunctions and plans gone awry it allowed us to make more efficient use of our time.

4. Documentation throughout the design process is vital. Although we had a product by the end of this process we had a difficult time writing our engineering report because we did not document each step. It took a lot of time, discussion, reflection, and redoing work that had already been done in order to be accurate in our report. Being able to communicate our ideas to the world is just as important to engineering as having the idea itself. Not matter with scientific discipline you are involved in you must be able to communicate in both written and verbal formats for your

ideas to be received, reviewed, and accepted by the scientific community. In the future we will be diligent about documenting our progress. Although we began keeping a design log, we became more interested in the building process and neglected the documentation of our efforts. Without us knowing, or instructor/advisor did document our progress and kept a photo journal of our work. Only when we were completely stuck on a topic and our deadline for the report was quickly approaching did she offer her documentation for our reference.

5. When conducting our analysis, we have also learned that it is important to use measurable variables and data instead of subjective opinions. When we evaluated our motors for our thrusters our results were purely subjective. These opinions, although we feel they served our purpose are not very valid when another person questions our decisions. It has been difficult to sound credible when asked, "How do you know that is the most powerful motor? or How do you know that motor provides the most thrust?, or exactly how much more thrust is the 1100 GPH motor providing over the 700 GPH or 500 GPH?" Our instructor/advisor had always told us to record our observations and make certain that our results are measurable. She often asked us if our descriptions were as specific as we thought they could be and if the results were measurable. Often she would ask us how we measured our results and if our measurement was subject to bias. We were more interested in moving ahead with the building process rather than taking the time to be specific on our comparisons of the motors. Now we understand the importance of being specific and finding methods such as force meters to measure our results.

Future Improvements

1. The wire we used was thicker than we had originally anticipated. This presented a challenge as we tried to thread it through the ½ inch P VC frame. If we decided that PVC was still the best choice for our frame we would change to ¾ inch PVC. This would provide us more room to thread the wire.
2. We would use pronged connectors to allow us to remove the tether from both the ROV and the control box. Currently all of the electronics are hardwired. We had connected all of the wires before we considered options for covering and protecting the tether.
3. We would use a potentiometer to control the overall power to each thruster. Our only option with the current design is to pulse the electricity to the thrusters.
4. Future improvements would include propeller/thruster control via a joystick or overall r/c controller. This would allow us to fine tune our movements through the water and provide more maneuverability. It would also be easier on our fingers than the current DPDT momentary switches.
5. We would incorporate a circuit breaker to reduce the cost of fuses.
6. Our next project we will be certain to maintain a journal and diagrams throughout the entire design process. This would make the reporting of our project much easier rather than having to rely completely on our memory.

Acknowledgements

The Robinson High School Knight Diver ROV Team, 2005 would like to thank many people and companies that have contributed to this project. We wish to acknowledge our mentors: Kristy Loman Chiodo, Robinson High School Science Instructor; Doug Levin, NOAA; Bob Musselman, Owner of Admiral C&B Propeller, John Broderick of Sound Marine Electronics. Without the guidance and leadership of these individuals our team would not have achieved as much as we did.

Additionally, we especially thank our main sponsors for their generous support allowing us to participate in the 2005 ROV Design Competition:

Supplier	**Part Donated/Discounted**	**Contact Name**	**Address**	**Phone**
Admiral C&B Propeller www.abcprop.com	Propeller workshop	Bob Musselman	6235 South Manhattan Tampa, FL 33616	813-837-9746
Carrillo Underwater Systems www.carrillounderwater.com	Camera, lights	Jessica Carrillo	P.O. Box 6217, Brookings, OR 97415	888-728-2226
Florida Industrial Products	Sch. 80 pvc nipples connectors & bushings	Tony	1602 N. 39th St. Tampa, FL 33605	813-247-5356
Forward Air	Shipping of ROV	Mr. Cranford		
Heinsman Dukes Robinson High School Auto Shop Instructor	Soldering workshop	Heinsman Dukes	6311 S. Lois Ave. Tampa, FL 33616	813-272-3006
ITT Industries Rule www.rule-industries.com	Bilge Pumps	Jeff Schopperle	Cape Ann Industrial Park, Gloucester, MA 01930	978-281-0440
Sound Marine Electronics	Wire, camera, electronics review	John Broderick	1302 S. 22nd St. Tampa, FL 33605	813-247-
T.A. Mahoney Co. www.fishing-boating.com/mahoney/	Battery Box, Bilge Pump Replacement Motor, connectors	Mike Mahoney	4990 East Adamo Dr. Tampa, FL 33605	813-241-6500
Team World Wide Express	Delivery of ROV to Neutral Buoyancy Lab	Mr. Cranford		

Appendix A:
Knight Diver ROV Team Timeline, 2004-2005

Activity	August	September	October	November	December	January	February	March	April	May	June	July
Team Transition: Team Draft, Team Roster, and Team Leaders. Determine practice time, confirm pool usage.	■	■										
Public Relations: Mentors, Guest Speakers, Press Releases, Fundraisers, Sponsorship	■	■	■	■	■	■	■	■	■	■	■	■
Background Knowledge: Research ROVs (structure & usage). Electronics, Propulsion, Frame, Payload	■	■	■	■								
Mission Specs & Tasks: Read mission scenario. Determine ROV specs and mission tasks.				■								
Concept Design: Brainstorm and develop an initial concept design.				■	■							
Obtain Parts and Materials: Obtain materials specific to ROV design. Propellers, motors, frame materials, wire, switches, control boxes.				■	■							
Build Mock-up: Build mock-up of objects, mazes, and other competition models.				■	■							
Build Prototype: Build prototype of the optimal concept design.				■	■	■						
Testing: Test various individual systems as they are designed. Test overall ROV prototype with mission tasks.				■	■	■						
Modification: Research, redesign and modify the ROV based on results of testing.				■	■	■	■	■	■			
Poster: Construct poster according to guidelines.									■	■		
Engineering Report: Write engineering evaluation according to guidelines and based on daily documentation.									■	■	■	
Mission Practice: Determine team skills and appoint positions (pilot, co-pilot, tether).					■	■	■	■	■	■	■	
Regional Competition: Location TBD										■		
National Competition: Location TBD											■	
Follow-up: Media, Thank You Gifts												■

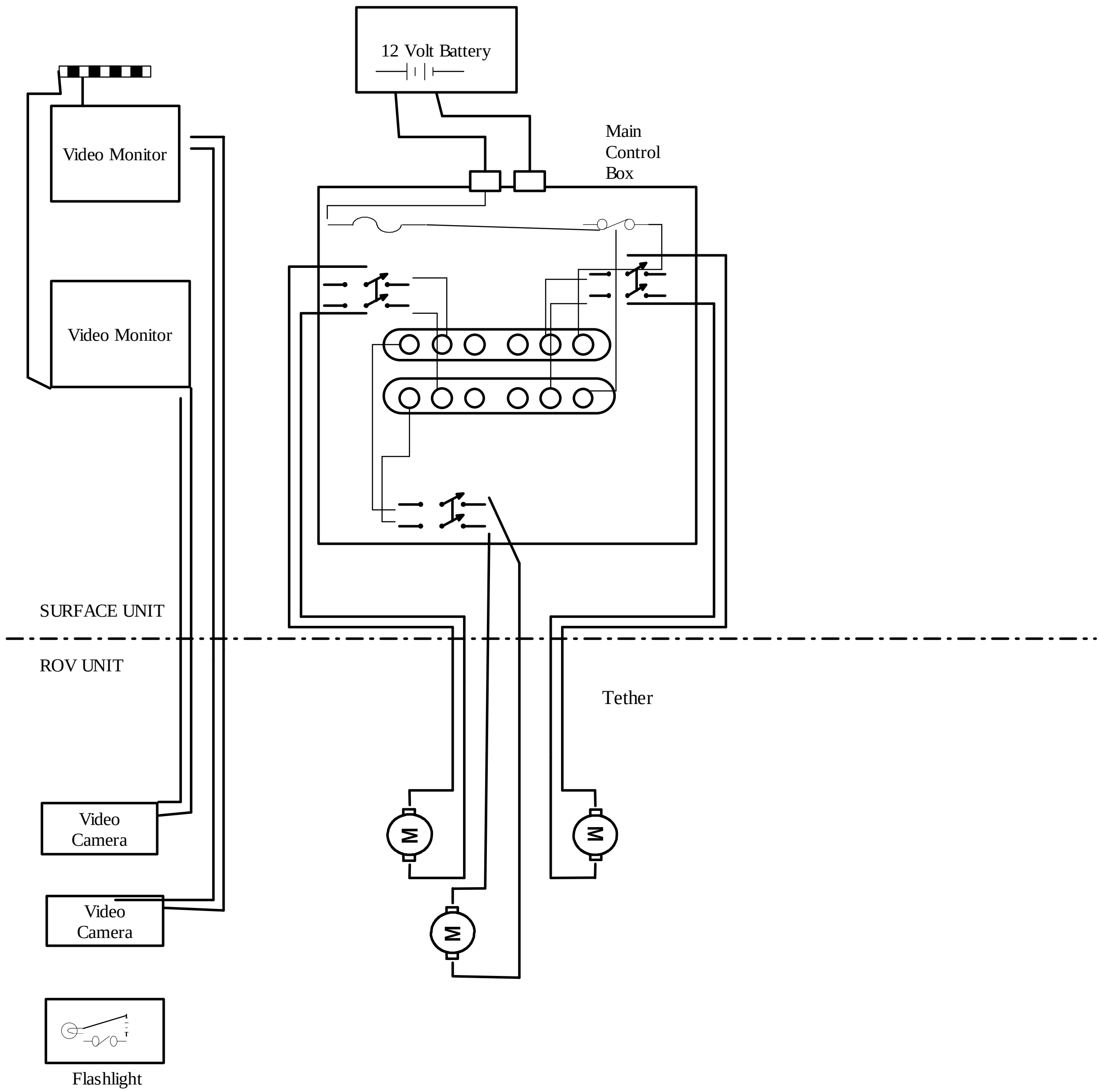
Appendix B:
Budget/Expense Sheet

The following sheet lists the expenditures for The Knight Diver ROV. Only monetary donations are represented in the figures, however, the names of companies or individuals that have donated product are also denoted.

2004 Robinson High School - Knight Diver ROV Team

ROV Parts	Unit Cost	Number of Units	Gifts/Donations	Total
PVC Frame & Fittings	varies	numerous		$123.90
Lexan	1	$1.79		$1.92
Motors:				
Bilge Pump	$47.50	4		$190.00
Propellers & Hubs	varies	numerous		$91.70
Electrical Components:				
Electrical Wire	varies	5 types		$175.00
switches	$5.99	numerous		$23.96
connectors & terminator bars	varies	numerous		$64.14
fuses & holder	varies	10 & 2		$8.65
Electrical Misc. (box, tape, solder)	varies	numerous		$82.93
Cameras	$69.99	2		$139.98
Camers		2	CSU	
Monitors	varies	2		$171.00
Hardware	varies	numerous		$52.54
Misc. (sealants, goggles,etc.)	varies	numerous		$297.70
Other				
Tools	varies	numerous		$421.37
Experimental Toys	varies	7		$51.00
Reference Books	varies	11		$241.37
			Subtotal:	$2137.18
	$100.00		MATE Donation	**$100.00**
			Total:	**$2037.18**
TOTAL Team Expenditures:	**$3,260.34**			

Appendix C:
Electrical Schematic



MATE ROV Competition 2005

Electrical Schematic for **Knight Diver ROV**

May 27, 2005

T. R. Robinson High School, Tampa, Florida

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