UNIVERSITY OF CENTRAL FLORIDA

Team Knightmare

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Abstract

This report contains the research, experience, and findings our team encountered in the creation of our explorer class ROV. The information within is less focused on theory craft and debate as much as it is on the practical aspects of research and development encountered through the build process. Our team worked hard to differentiate itself from the standard in areas where the standard may not have been the best way and to embrace the techniques and methods that worked best. We chose to construct our ROV with the objectives we set forth mostly because our experiences to that point showed that while the state of the art has come far and ROVs are capable machines able to perform the tasks required, the modern generation of designs has become stale and the development process stagnant. Almost all newcomers to the field look to their predecessors and produce a near replica of the bot that came before it. We learned that the accepted design aspects work and serve their desired purpose, but a willingness to start from a clean slate can produce a machine whose capability exceeds those of the more general design and can be done in a more cost effective manner. It is our hope that as so many look to the classic box design to start from now, that some in the future will look at our creation and realize that there are still other avenues of design not yet fully explored.

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I The Completed ROV

The complete UCF Team Knightmare ROV.

The 2010 MATE ROV competition was the first experience anyone on our team had ever had with underwater ROVs or challenge based competitions so we decided to focus on simplicity. Our design rationale was to create an ROV as simply as possible that would still meet the challenges of the competition. Research of previous forays into submersible ROVs showed us that the majority of failed creations were not due to a lack of functionality, but the opposite. Most ROVs that did not perform as intended and anticipated most often failed to do so because they were designed with an excess of unduly complicated mechanisms and components when so often a simpler, and usually more reliable, option was available. While we realized that part of the challenge lay in engineering a craft of as much sophistication as possible, our lack of prior experience and meager personal budget prompted us to create our craft in a manner as direct and effective as possible.

To illustrate our design process a breakdown of work stages and details follows.

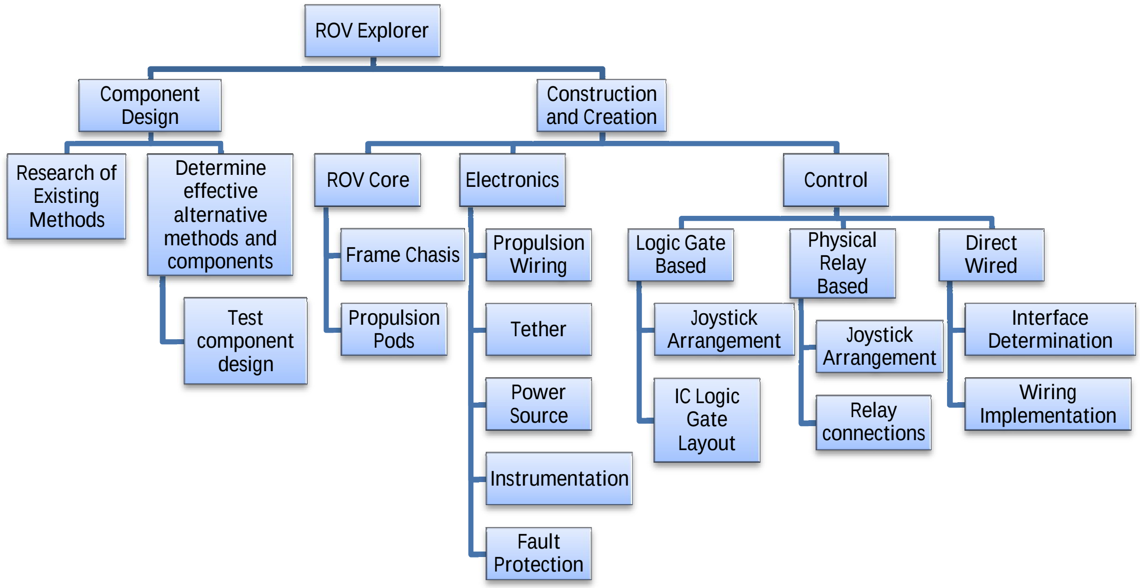


Chart depicting procession and organization of work.

1) ROV Explorer – The final product of the project is an explorer class ROV. Being and explorer class machine means that its primary purpose and role is the agile and maneuverable exploration of the desired environment to determine the state and nature of its intended destination.
   a) Component Design – Creation of the ROV itself cannot take place until it is determined what components and methods will be used in its formation. This stage also includes a limited sense of overall ROV design in how it relates to the required needs of each component.
      i) Research of Existing Methods – While the intention of the project is to create a new ROV design scheme that would not be possible without a firm understanding of the current offerings in the realm of component design and creation. While our complete ROV design is innovative and improved that does not necessarily mean that the input components must be entirely new in and of themselves.
      ii) Determine Effective Alternative Methods and Components – Through the process of component design it is an eventuality that certain aspects of the current market offerings will found to be lacking or prohibitive to use given our personal production constraints and objectives. More often than not this stage will be focused on the production of a component replacement at a significantly lower cost.
         (1) Test Component Design – All the designs in existence are not worth very much of anything unless they are tested and proven to be effective in the manner they were intended to be.
   b) Construction and Creation – This stage is the physical assembly and construction of the final use ROV

i) ROV Core – The primary step in ROV construction is the creation of the main body itself. Its design and layout impact the effectiveness of each other part in turn and the ROV as a whole

   (1) Frame Chassis – The skeleton of the ROV. It is essential that the frame remain lightweight and streamlined enough to maintain the requirements of agility and maneuverability while supporting and unifying all other aspects of the ROV. Frame was constructed primarily of nominal 1'' PVC piping with some 3'' pipe for propulsion support.

   (2) Propulsion Pods – Contains the motor and propeller assembly. One of the defining needs of an ROV is the ability to explore its environment so proper choice and assembly of the propulsion system is critical. Just as vital is the housing and configuration of the propulsion drive. If the housing fails to support the propulsion components than the ROV will fail and often do so disastrously. The propulsion pods of made from MAXACC Long Can 348 motors with 5 bladed ducted fans.

ii) Electronics – Any component of the ROV that will require a power source or current of any kind is handled here. It is important that all electrical components be considered together in order to assure that their combined usage is possible and effective.

   (1) Propulsion Wiring – Creation of the propulsion pods is a key stage of production but serves as little more than decoration of they are not wired to operate correctly. This stage involves the physical attachment of wiring as well as its arrangement and channeling through the ROV body. 16 AWG wire was used for wiring all the motors and electronics to the power supply

   (2) Tether – The ROVs ability to communicate with the surface and receive power to operate are determined by the tether. It must be neutrally buoyant and thin enough to remain flexible. It is made of 6 strands of 16 AWG wire and a multithreaded A/V cable, made to 20m long and has craft foam buoyancy assists of 11cm long every 28cm.

   (3) Power Source – The power source to be used for the ROV was defined by the need of portability and availability, but additional power sources and connections were needed for the proper testing and final use of the ROV. For competition and testing automotive 12V batteries were used, but for in house testing and demonstration a modified 350 Watt PC power supply was used a bench power source.

   (4) Instrumentation – Explorer class ROVs can play host to a number of instruments to convey the state of their environment to their user. Our ROV is intended to be a low cost and super agile design meaning that the only instrument necessary would be the camera and display. It is important that all electronics used are confirmed and prepared to operate in the underwater environment as well as under the less than lab ideal power conditions sources. We used a black and white underwater camera that outputs in NTSC format with 420 horizontal

lines and 60 Hz refresh. It is capable of vision at 0 LUX due to the inclusion of a series of IR LEDs and runs off of the same power supply as does the ROV.

(5) Fault Protection - Anything involving more than trivial electrical power necessitates that some form of fault protection be in place. Failure of an unprotected power source can be dangerous and deadly. The mobile and moist conditions of the project environment mean that complex fault protection would in and of itself be in jeopardy of failure and that special considerations must be made. A pair of inline water tight fuse holders were installed on both the ROV power leads and the camera connection with 20amp fuses installed.

iii) Control – The creation of the ROV is not complete without a method of control. By definition an ROV needs to be controlled by an active user and the interface through which that is done requires special attention.

(1) Logic Gate Based – Our design initially included the use of a logic gate based design to translate control commands to physical motor impulses. Use of CMOS CD40XX series chips were the primary building point of this stage.

(a) Joystick Arrangement – The commands of the user are given through use of a joystick to the control circuit, but in order for the arrangement to work the proper joystick selection is necessary. An 8-way digital joystick with interior microswitches was selected.

(b) IC Logic Gate Layout – The joystick commands given by the user indicate must be translated from directional commands to motor commands. This was done through the use of simple IC logic gates and a line driver module to power the motors.

(2) Physical Relay Based – After extended manufacturer delays we were unable to make use of our IC based design and so designed a control method centered on the creative wiring of relays to serve as their signal interpreters and logic handling mechanism.

(a) Joystick Arrangement – Just as with the Logic Gate Based control scheme a joystick was to be used to receive user inputs and begin the interface from user desire to electrical signal.

(b) Relay Connections – In order to accommodate the loss of the logic gate based translations of direction to motor signal DPDT relays were used and wired in such a way as to provide their own control processing and ensure the motors continued operate as desired. The relays needed were a set of 4 DPDT 9VDC coil at 100mA with contacts rated for 12VDC at 20amps

(3) Direct Wiring – In order to accommodate the need of our ROV to work effectively with use of varying quality and strength power sources the relay design was given up for a simpler and more reliable method of control using On-Off- On switches. This control scheme proved to be the best illustration of the effectiveness of simple design and a testament to reliability.

(a) Interface Determination – With the changeover of control schemes a new ROV interface was needed. It was decided that a set of 3 simple switches would replace the joystick and double button configuration. The 3 switch design proved easy to use and more directly accurate than joystick control.

(b) Wiring Implementation – In order to control all the ROV motors and provide maximum control a set of DPDT switches were used to all for instantaneous reversal of motor polarity in any sequence desired. Momentary On-Off-On DPDT switches were used.

II Expenses

Item	Cost	Quantity	Total
BP- Ducted Fan Unit , 7.6 cm diameter	$10.95	4	$43.80
MAXACC 348 Long CAN 400 Brush Motor	$9.95	4	$39.80
100 Pack Zip Ties	$2.49	1	$2.49
Underwater Camera with Black and White Monitor	$99.99	1	$99.99
Solder Kit	$4.50	1	$4.50
DPDT On-Off- On Switch	$3.50	3	$10.50
Spool of Wire, 75 meter, 16 AWG, Black & Red	$12.00	2	$24.00
Heat Shrink tubing	$0.80	1	$0.80
Hose Clamps	$1.45	4	$5.80
3x2 PVC Pipe	$4.05	1	$4.05
PVC40 Pipe	$1.56	1	$1.56
¾ Tee Shape PVC	$0.33	4	$1.32
PVC Cement	$3.76	1	$3.76
Purple Primer	$4.58	1	$4.58
TOTAL:			**$246.23**

Table of expenses incurred for the construction of the ROV.

As team formed at the very end of the registration deadline and totally bereft of prior experience we found ourselves unable to obtain outside funding for the project and so were reduced to using only what spare personal funds we had on hand. With our modest means in mind we set out to create as much as we could using as little as possible. The above component cost list shows our results.

III The Project Work Cycle

As we began work on our ROV we quickly discovered how very little we knew about the field and how very much we would need to learn. From background history, best practices, and the practicalities of construction every member of our team has come out of this experience far richer in knowledge than they were when we started.

Perhaps nothing taught us more during our work than those times where things did not go as according to plan and expectation. One of our simplest obstacles, but one that best highlights our approach to overcoming those obstacles, was when our tabletop testing battery died. It was toward the end of the build process and we were doing final work on the motor wirings and controls when we found ourselves no longer able to test our work because of something as mundane as a dead battery. Until that point we had been using an available lithium polymer rechargeable battery for testing because of its lightweight and portability, the fact that we already had it on hand, and because none of us were willing to pull the battery from our cars to work from. Trouble arose when we overdrained the battery while testing the motors, this would not normally be a problem except that LiPo batteries are only rechargeable as long as they do not fall below a specific nominal voltage, which we had done. We sat to discuss our alternatives, realizing that any replacement batteries would likely suffer the same fate we discarded that idea, none of us were willing to sacrifice the battery from our own cars for testing, it was late into the night on what we felt may be our last day to work on our ROV before the regional competition meaning that both waiting till later and purchasing a replacement system were out. It was then realized that the power specifications we were using matched those used by many computer components. With that thought we pulled the power supply from an old computer we had going unused and set to work.

While the PC power supply had the capacity to power our craft it was not designed for that purpose and so lacked the capability to directly interface with it. On top of that, the design specifications of a PC power supply call for certain check and monitoring operations to ensure that the PC receiving the power is working as intended and to cut power if it is determined that it is not. We knew we would be unable to modify the ROV to include the complex electronics required to emulate an active PC interface so we instead modified the power supply. After a few hours work on the power supply we had bypassed all the built in PC checks, re-organized and soldered the necessary conduits to produce the voltage and amperage we needed, modified the unit to interface with a pair of banana plugs such as we were using on the ROV, and had safely terminated and shielded all then exposed contacts and interfaces. After resealing the power supply unit we went to put it to use, unfortunately we discovered that our efforts had failed and the power supply was non operable.

Realizing that without the power supply we would be unable to perform and further testing on the ROV until it actually came time to place it in the water for competition; we pulled out our trusty multimeters and began troubleshooting. We made a diagram of the power supply complete with every stage between the wall outlet and the banana plug interface. Systematically and in series we began testing each component and interface in turn searching for where the problem lie. It was only when we reached the connection point that led to the outputs did we find that our power levels were other than expected, the power was being provided, but without a sufficiently high amperage. We knew that the manufacturer specifications for the outputs we were using should have been producing greater amperage than it was, and since we knew the power supply worked fine until we made our modifications, we determined that it was one of our modifications that was causing the change. After careful thought about what the impacts of each modification would be we suspected that it was our bypassing of the PC monitoring functions. Since normally the monitor power circuit is run parallel to the circuit we were intending to use it is expected that the resistance that would normally be present on the first would force the current to divert to the second path. Our bypass removed the check involved as well as the expected resistance on that line. After the inclusion of a 100 ohm resistor to the other paths we found that the current provided on our target interfaces reached the levels we had expected and required.

In the end we were successful and completed all work on the ROV on time, but we came close to failing. That experience reinforced a valuable lesson. No matter how confident and straightforward a body of work may seem, unexpected obstacles and delays can and do occur, and without allowing ample overflow time in the work schedule one can easily find themselves in dire straits unable to meet deadlines and incurring the consequences. It is a lesson that is obvious enough, but until one faces so impactful an event they do not often learn it as thoroughly as they should.

IV Looking Back and Moving Forward

Now that our ROV is complete and the regional competition is done with we can stop and appreciate how far we have come. A few short months ago none of use was even familiar with modern ROV usage underwater let alone how to design and build one, but now we can appreciate how far the field has developed and realize the significant role they play in present underwater environments. Beyond that, each of us has had the opportunity to put what is normally idle though into practice with the creation of our ROV and have picked up valuable skills and experience. After the design and research stage of the project we had learned how logic gate chips work, how to use logic circuit simulation software to map out and design our own integrated circuits, and polished our skills with CAD software SolidWorks (a program we had already utilized in the classroom before, but never with a real world product as the goal). Once we progressed into the physical build stage we learned how to solder neatly, assemble circuit boards, and gained practical experience with the tools and hardware necessary to translate design into reality.

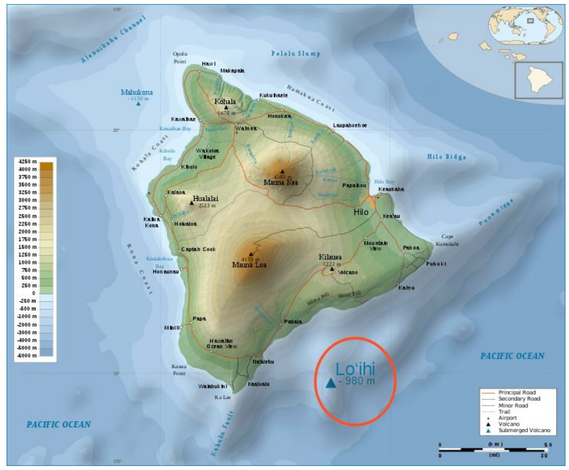
The entire process has entailed more work than we had initially realized, but it has all been worthwhile. Qualifying at the regional event was certainly a joyful moment, but even more satisfying is knowing that the effort put into this project carries beyond it. The skills we gained will serve as a launch point for developing even further and hopefully give us a foot in the door for our future ventures, while working together to complete what was at times a stressful endeavor has made us better aware of how best to with and within a team. It is something they teach you since you are a child, but true teamwork doesn't fully show itself until you are in a situation where the final result of all your efforts truly depends on the effective and productive cooperation of your group.

Moving on we have all benefited from the project, but in addition to that we have also gained a new interest. While the 2010 MATE ROV competition is over, we have discovered that we not only enjoyed the challenge, but want to do it again. It is too soon to begin work on next year's competition, but that isn't stopping us from branching out and looking for other mechanical craft competitions to enter. We will go into any other challenge knowing that because of this experience we are leaps further ahead than we were before and can now expand our ambitions to take on the design and construction of more sophisticated vehicles.

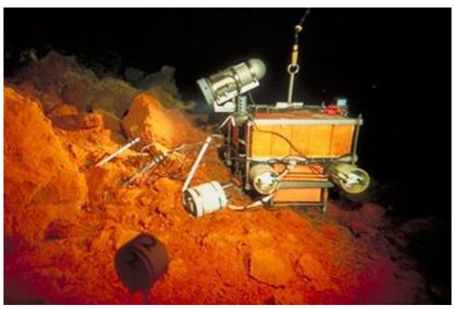
For at least the next few months we will focus ourselves on other projects, but we still want to make returning to next year's competition a priority. With that in mind we have given though to what we plan to do differently. Since this year was our first time constructing anything more involved than a Lego set we sought to make simplicity a key point of all our designs and have learned that such an approach is effective and leads to more efficient and streamlined results. However, in our adherence to simplicity in design we forwent much in the way of instrumentation and tools. This led to the production of an efficient craft, but unfortunately was not as capable and versatile as it could be otherwise. With experience to back us we feel that we can try again next year, still keeping simplicity a goal, but while still also including added functionality. A proper balance of the two results would set the path for a greater success than we achieved so far. We have also learned a great deal about the organizations and corporations that make up the industry and plan to use that to our advantage next year. While working on the project we learned of many resources and opportunities that were made available to us, but unfortunately we learned about them too late. Knowing about them now means that next year we can plan around them take advantage of them, allowing us to potentially gain outside sponsorship, subsidized materials, and utilize more productive tools than we have access to otherwise.

V The Lo'ihi Seamount

This year's competition was inspired by the real life challenges faced by scientists and researchers in their attempts to study the Lo'ihi seamount. Lo'ihi, meaning 'long' in Hawaiian, is a young active volcano just 30km southeast offshore of the island of Hawai'i characterized by its iron laden organic mats and rock. Until the 1970's it was thought that Lo'ihi was an ancient seamount akin to those that formed the big island of Hawai'i that are around 80-100 million years old. It wasn't until expeditions to Lo'ihi in 1970 intending to study a recent earthquake swarm that we learned that it was not an ancient dead volcano, but a young and active volcano instead.



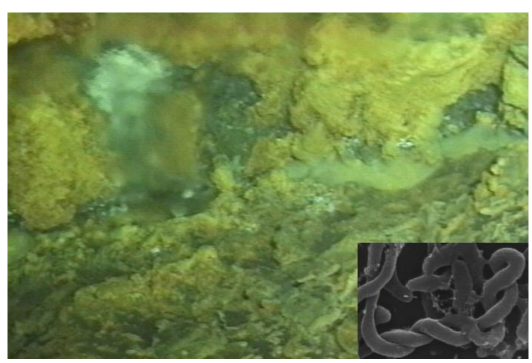
Location of Lo'ihi – Courtesy of Semhur of Atelier Graphique.



Ocean Bottom Observatory – Courtesy of the NOAA.

Since then it has earned the attention and been the focus of study by many researchers from the islands and beyond, especially since late 1996. In the summer of 1996 an intense earthquake swarm of 4,070 quakes emanated from Lo'ihi renewing and amplifying interest in the seamount. Those quakes were so strong as to entirely collapse nearby Pele's Vents, earning it a rename to Pele's Pit, and have been recorded as the largest earthquake swarm in Hawaiian history.

In the years after the massive swarm of 1996 Lo'ihi remained mostly quiet until a significant resurgence of activity in 2005. The ANSS reported a pair of major quakes in May and July measuring magnitude 5.1 and 5.4. It's status as both a young and active volcano that has made so much record breaking news has ensured that it will be the focus of study of educational institutions such as the University of Hawai'i and local and national organizations such as the Hawai'i Undersea Geological Observatory (HUGO) and the National Oceanic and Atmospheric Administration (NOAA). The geological marvel of the seamount coupled with its unique species of iron-oxidizing bacteria and rare specimens of invertebrates and crustaceans make for an exciting and rich source of educational research that will keep us coming back to Lo'ihi for a long time to come.



Bacterial mat around a Lo'ihi vent – Courtesy of the NOAA.

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VI Acknowledgements

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