'Io O Lalo Kai Kokua
Undersea Rescue Hawk

Kealakehe Intermediate School ROV Team
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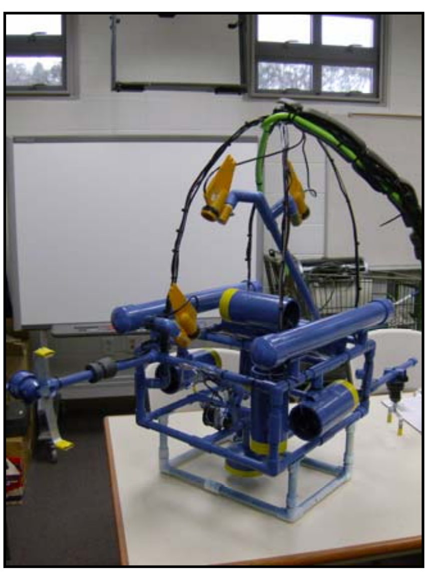
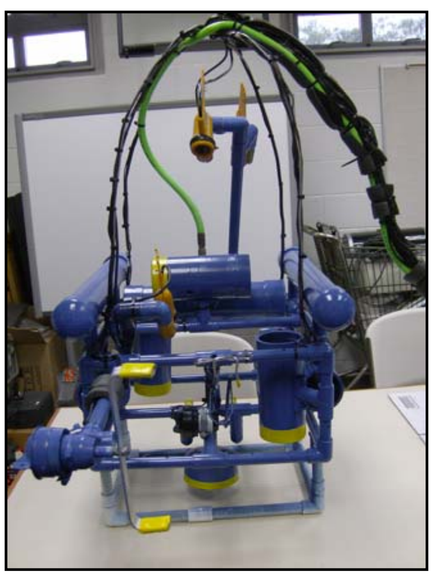
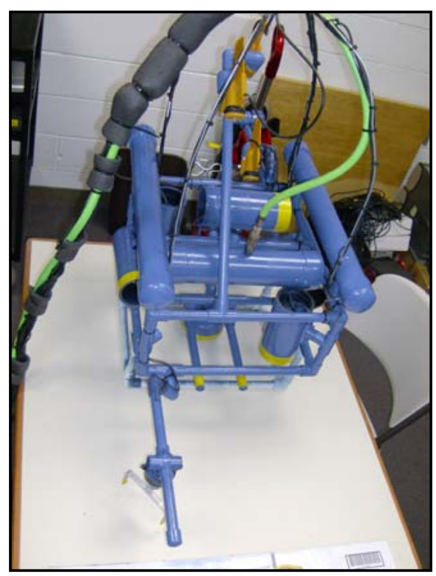
ABSTRACT:

'IO O LALO KAI KOKUA

UNDERSEA RESCUE HAWK ROV

'Io O Lalo Kai Kokua was designed by a team of six intermediate school students. In the preparation for the 2009 MATE missions, we interviewed 2008 competitors, reviewed previous ROV designs and examined competitor's ROV designs from our competitions. We designed six tools around the 2009 MATE missions: 1) air valve tool, 2) air insertion tool, 3) docking collar, 4) pod lifter, 5) hatch opener, 6) hatch lifter. The frame is made of PVC pipes with the dimensions of 131cm long, 48cm high and 50cm wide, weighing 5.4kg. The ROV is able to safely dive to 8 meters. The ROV tether is 15 meters and has 16 conductors. The propulsion is operated by 4 heavy duty DPDT switches through 10 conductors to 5 bilge cartridge thrusters in custom safety housings. The tools are operated by 3 heavy duty DPDT switches through 6 conductors to 3 bilge cartridge motors used as custom waterproof tool actuators. The ROV uses three underwater rated cameras to monitor the tools and position. There are two sealed pontoons that provide the ROV with fixed neutral buoyancy. The ROV has an adjustable ballast system using compressed air up to 40 PSI to maintain neutral buoyancy after collecting the pods. The compressed air system is rated for a maximum of over 200 PSI. The ROV's maximum draw is 21.75 amps. All thrusters and tools are protected by a 25 amp main fuse with the cameras protected with their own three amp fuses for additional safety.

2009 ROV BUDGET & EXPENSES:

Items:	Category:	Amount:
NEW: PVC pipe, T's, elbows, end-caps, couplers, zip-ties, hose clamps	**Frame**	**43.98**
PVC, T's, elbows, Couplers, wire, screws, shaft, zip-ties. Coupler, aluminum bars	**Mission Tools**	**35.63**
Toggle switches, wire, cable, solder, shrink wraps, Electrical tape, control boxes, banana plugs, propellers	**Electrical & Propulsion**	**160.03**
Compressor, 100 PSI fittings, pool noodles, tie-wraps, weights	**Ballast System**	**105.79**
NEW '09 OUT OF POCKET EXPENSES	**SUBTOTAL**	**$365.43**
PROPS: PVC, ABS, elbows, couplers, caps, epoxy, U-bolts, screws, zip ties, plastic netting, milk crates	**Mission Prop Supplies**	**52.95**
TOOLS 2 Utility saws, pliers, Dremel Drill, vice	**Tool Box**	**97.72**
TOTAL '09 NEW ROV PROJECT EXPENSES:		**$516.10**

DONATED ITEMS:	DONORS /GRANTORS:	
Monitor & 100 PSI rated compressor hose (to be returned)	**Diaz & Meier**	**200.00**
Propulsion Motors: Four 1250 GPH cartridge motors	**ISIS BIRR Grant**	**240.00**
Sensors: 3u/w cameras	**ISIS BIRR Grant**	**183.00**
Soldering Iron & station (TOOLS)	**ISIS BIRR Grant**	**40.00**
'09 DONATIONS & GRANTS TOTAL:		**663.00**

RE-USED ITEMS FROM '06- '08 ROV PROJECTS:	Category:	Estimate:
Marine bilge cartridge motors (1) 1000 GPH, (2) 500 GPH	Motors	75.00
1 Harbor Freight Monitor kit w/shipping	Sensors	99.99
PVC 1/2" pipe for frame left over from '08 Lava trough prop	Frame	50.00
12 volt Marine Battery	Power/Electrical	39.00
Hot stab/ air line	Mission Props	~10.00
Tool box & basic tools	Larry Rice '06 Grant	~100.00
TOTAL RE-USED ITEMS		**~$373.00**

TOTAL COST TO BUILD '09 ROV (new parts ($365.43), granted parts($463), re-used parts ($125)) **$953.43**

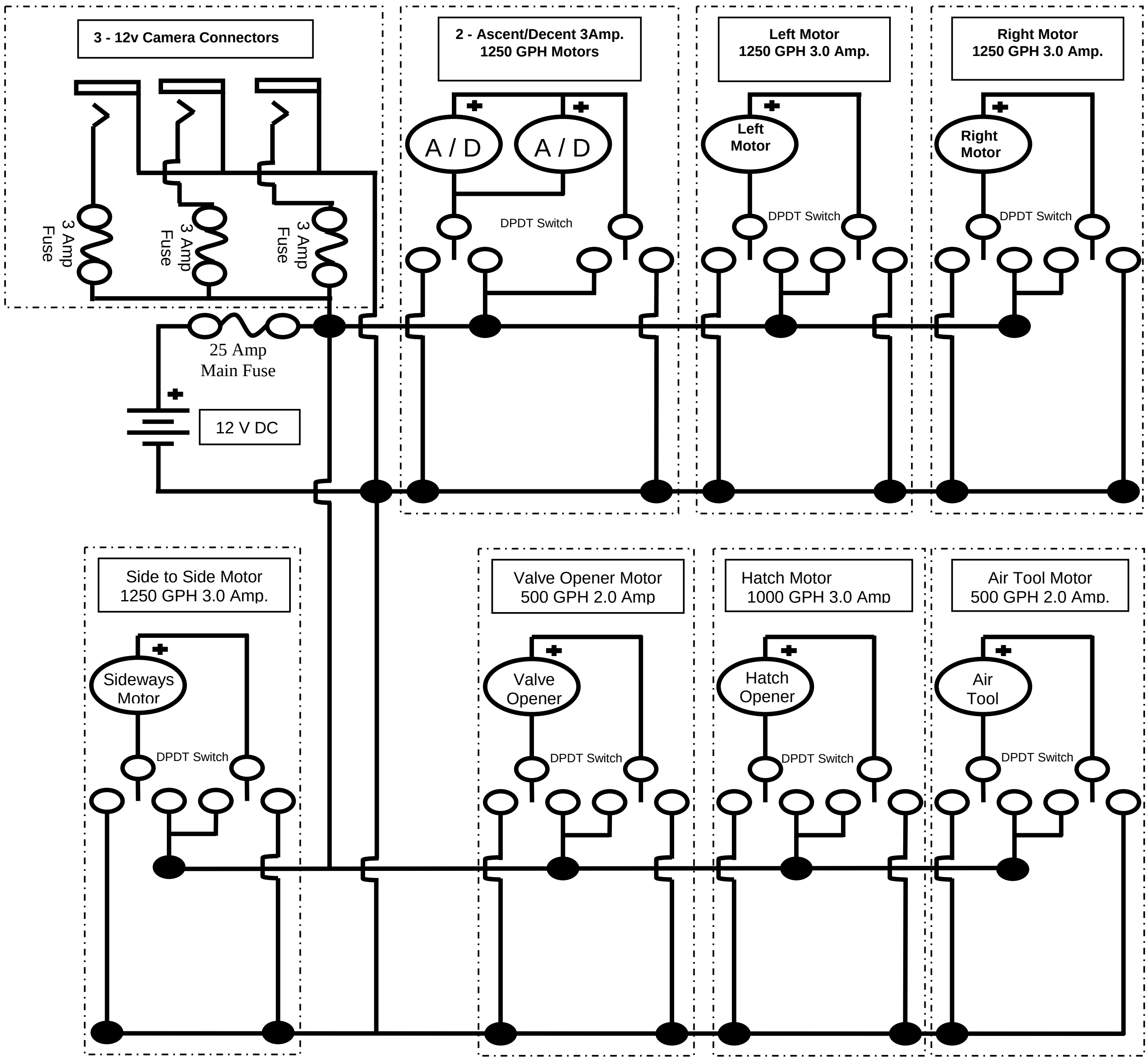
STUDENT HOURS:

TOTAL ESTIMATED STUDENT (9 STUDENTS) DESIGN/CONSTRUCTION	**HRS:**	**300**
TOTAL ESTIMATED STUDENT (9 STUDENTS) RESEARCH/TECH REPORT/DISPLAY	**HRS:**	**50**
TOTAL ESTIMATED STUDENT (9 STUDENTS) POOL PRACTICE HOURS:		**100**
TOTAL ESTIMATED STUDENT (9 STUDENTS) COMMUNITY SERVICE HRS:		**70**
	TOTAL STUDENT HOURS:	**520**

ADULT HOURS:

TOTAL ESTIMATED MENTOR (2) /PARENT (2) (Safety supervision) HOURS :	**130**
TOTAL ESTIMATED TEACHER (1) (Shopping, supervising) HOURS:	**100**
TOTAL ESTIMATED ADULT HOURS:	**230**

Electrical Schematic



<u>DESIGN RATIONALE</u>: ***'IO O LALO KAI KOKUA***

We designed our ROV around our payload tools fashioned to accomplish the mission tasks. Our goal was to create an efficient, low maintenance ROV to quickly complete the submarine rescue. We designed our ROV shape and frame by researching past ROV models, videos, websites, and currently deployed ocean going ROV's for design ideas. We interviewed our ‘07 & ‘08 ROV teams to brainstorm possible modifications or improvements. Through a step by step planning process we measured and tested our tools on the simulated submarine mission props designed by MATE.

The ROV was designed with hardware only controls to simplify driver use, system troubleshooting and repair. Six innovative mission tools accomplish the underwater rescue mission tasks. Our two unique air deployment tools allow simultaneous air stab insertion and air valve operation for optimum speed and efficiency. The air valve tool is also used to open the air hatch for simplicity. The docking collar is centered positioned and the lowest part of the ROV to allow unobstructed docking from any heading. The pod lifting arms are designed to gather as many pods as possible at one time. This helps to reduce transit time to deploy the pods to the submarine. The pod hatch opener and lift tool are installed on an outrigger to allow the operation of the hatch while the ROV is fully loaded with pods.

We experimented with two motor housings, three propeller types, plus four ballast systems. We chose the best performing designs after testing thrust and conducting time trials. We designed a custom tether harness frame to improve stability, reduce entanglement and avoid obscuring camera views. This helps to insure safe deployment. In addition, a compressed air ballast system was installed to assist maintaining neutral buoyancy during payload deployment.

Our three camera positions were designed for optimum efficiency in mind. Each camera is arranged to view two tools at once. Camera #1 views the docking collar and the pod lifting arms. Camera #2 monitors the hatch opening tool and the hatch lift tool. Camera #3 observes the air stab tool and air valve actuator tool. In addition Cameras #2 & #3 double as the pilots “birds-eye” navigational system.

MISSION TOOLS:

We were creative in designing 6 simple, effective, low maintenance tools for the mission tasks.

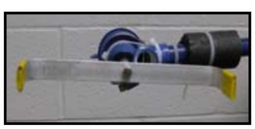
Tool # 1: Docking Collar: allows us to dock with the submarine and hold a stable position for 20 seconds. Tool # 1 is fabricated from a 4" PVC cap.

Tool # 2: Motorized Hatch Opener: is rear positioned to enable us to unlock and re-lock the hatch. Tool #2 is constructed of a bilge motor, aluminum bar and custom adapter.

Tool # 3: Hatch Lifting Tool: is attached to tool #2 and enables us to lift and lower hatch after unlocking. Tool # 3 is made out of 1/2" PVC and an end cap.

Tool # 4: Pod Lift Tool: delivers life-support pods. It is positioned directly below the adjustable ballast system. The Pod Lift Tool consists of two 1/2" PVC pipes.

Tool # 5: Motorized Air Insertion Tool: holds & releases an air line while maintaining position to activate tool #6, decreasing time to deliver air. Tool #5 is powered by a bilge motor and is made out of custom formed tongs and lift arm.



Tool #6: Motorized Air Valve Opener: opens & closes the airway valve at the air insert receptacle. Tool #6 is constructed of an aluminum bar and powered by a bilge motor with a custom adapter.

STRUCTURE:

Our frame measures 131 cm long, 50 cm wide and 48 cm high. We designed a streamlined PVC frame around the mission tasks and the tools needed to carry out the rescue mission.

SENSORS:

We have 3 Lammensco # C420 u/w security cameras on our ROV. Camera #1 is positioned at the front and aimed to view the docking collar and the pod lift tool at the center of the ROV. Camera #2 is positioned above the ROV to view the hatch tools at the rear. Camera

#3 is also positioned above the ROV and overlooks the air tools at the front. In addition, both Camera #2 & #3 are bird's eye view cameras for pilot navigation. Each camera is depth rated to 18.29 meters. Our cameras have standard RCA output, 20-meter tethers and white LED lights. The cameras use 12 volts DC at a maximum of a 3 amp draw and have a net weight of 1.3 kg each.

<u>SPECIFICATIONS</u>*:*

I'o o Lalo Kai Kokua can dive up to 8 meters and weighs 5.4 kilograms, operating at a maximum of 25 amps with power furnished by a 12 volt marine battery. The tether is 15 meters, with 16 conductors. Total amperage is 21.75 amps.

<u>PROPULSION:</u>

I'o o Lalo Kai Kokua has five thrusters configured as follows: two opposing corner-mounted thrusters, for ascent and descent power, two side mounted motors for forward, reverse, left and right propulsion, and one center-mounted lateral thrust motor to move sideways. All motors are surrounded by custom safety housings that direct propulsion in a steady stream. Each motor draws 3.25 amps under a full load and spins at a rate of 4,732 LPH [liters per hour] or 1,250 GPH [gallons per hour]. The Johnson Pump heavy duty bilge cartridge motors are depth rated to 8 meters and outfitted with stainless steel drive dogs and RC 2-screw boat propellers.

<u>THRUST:</u>

The thrust of each motor is .50 kg forward and .30 kg reverse. We constructed a thrust tester out of 1.27 cm diameter PVC pipe in 30 cm lengths joined in a "+" formation. We zip-tied a 4,732 LPH bilge pump motor with a propeller on a cut PVC "T" and made a custom 16 gauge wire harness to ensure a safe electrical connection for the test. A digital luggage scale was used and secured to an opposing PVC "T" for the readings. We secured the tester and submerged the motor in 20 Liters of water, applied power and measured the forward and reverse force in kilograms. We also tested for amperage use of the motor under load with various propellers designs with a multi-meter. The propeller that performed best in both force and amperage use was chosen for the ROV.

BALLAST SYSTEM:

I'o o Lalo Kai Kokua's ballast system consists of 2-capped 5.08 cm PVC pipe pontoon floats positioned on the topsides of our frame for neutral buoyancy at launch. We added one capped, open bottom 7.62 cm ballast tube to hold up to 6515 cm^3 of air delivered via a 110 volt mini compressor to adjust our buoyancy when the pods are loaded. Our compressor, hose and fittings are rated for a minimum of 100 PSI per MATE requirements. We zip-tied pipe insulation onto our tether, and adjusted the floats to achieve neutral buoyancy. We drilled holes in our frame to help keep the ROV from trapping air and listing.

ELECTRICAL CONTROL SYSTEM:

Our control system is housed in two electrical boxes. Box #1 controls propulsion and Box #2 controls the ROV tools. Box # 1 has four heavy-duty toggle switches to simplify our controls for the pilot. Our switches are double pull double throw center off switches. Switch #1 controls the left motor and switch # 2 controls the right motor. Activating switches #1 & #2 forward together, the ROV propels forward. Switching #1 & #2 both backwards propels the ROV in reverse. Alternating the switches causes the ROV to rotate. Switch # 3 controls the ascent/descent motors and is switched up to ascend and down to descend. Switch #4 controls the lateral thrust motor enabling sideways adjustments. Box #2 has 3 switches. Switch #1 controls the hatch opener. The hatch opener uses a 3785 LPH [liters per hour] or 1,000 GPH [gallons per hour] motor to operate the hatch. Switch #2 operates the Air Insertion Tool, via an 1893 LPH or 500 GPH motor. Switch #3 operates the Air Valve Opener, powered by another 1893 LPH or 500 GPH motor to open the airway valve.

SAFETY:

Our team carefully soldered the two control boxes and waterproofed our electrical system with shrink-wraps and electrical tape, to ensure safe, reliable, electrical controls. Our 15 meter tether contains 16 conductors. Total motor amperage is 21.75 amps. We installed a 25 amp fuse and two heavy-duty banana plugs in a power box. The power box connects to two heavy duty battery clamps which connect to the 12 volt marine battery. Each one of our three cameras draws 0.16 amp for a total of 0.48 amps. The cameras are wired into the banana plug harness with a 3 amp fuse per camera for additional protection, to enable powering the cameras via a 12 V marine battery. All motors are surrounded by custom safety housings that prevent propeller injury and line entanglement.

TROUBLESHOOTING:

We had to re-design our frame to optimize camera views. We had initially planned on using computer fans as propellers, as when tested they moved more water; however testing with our multi-meter showed that the computer fan propellers caused the motors to draw too much amperage. We tried cutting off three out of the seven computer fan blades plus two entirely different model propeller types. Ultimately, we had to forgo using the more powerful computer fan propellers to avoid blowing fuses and keep within Ranger class requirements. We tried three screw model boat propellers and found through time trials that we did not have enough thrust. So, we opted for smaller two screw model boat propellers, which had a greater pitch which tested to give more thrust and rated better in our time trials. We could not find outdoor 16 gauge speaker wire in Kona this year so we opted for 16 gauge outdoor landscape lighting wire to minimize corrosion. After the regional competition, we re-designed a smaller, more compact frame and shorter motor housings to reduce weight and drag which improve speed. The re-design and waiting for equipment caused time setbacks.

REFLECTIONS: CHALLENGES & LESSONS LEARNED:

This year our team was challenged by equipment delivery delay, design agreement and time management issues. We found time management very difficult, as we had many scheduling conflicts with school and community events such as the Hawaii State Science & Engineering Fair, our BIRR community service project, and HSA Testing. We continue to improve our team communication and efficiency, although we sometimes lose focus and have to keep each other on track. We learned the importance of perseverance, discipline, time management, teamwork and safety.

TEAMWORK STRATEGIES & PROJECT MANAGEMENT:

Four returning '08 members taught five new teammates about ROV construction and electronics. Building an ROV is unpredictable, and when we faced problems, we had to re-group and stay late until we gained a working solution. We encouraged each other not to give up, and not to argue. We split into partner teams to be able to accomplish more work. One team focused on frame construction, one on tools and another on the engines. This strategy helped us to be able to finish our ROV on time.

FUTURE IMPROVEMENTS:

We hope to try servo motors to improve the control of our tools. However, waterproofing servos is a challenge. We also would like to try joysticks to make the pilot's job easier by simplifying the driving controls. Pneumatic motors are another option. Pneumatics use compressed air and are powerful, efficient, and durable. Disadvantages of servo and pneumatic motors are that they are expensive and difficult to waterproof.

ACCOMPLISHMENTS: PERSONAL, ACADEMIC and PROFESSIONAL

We improved our knowledge of electrical systems, and learned a lot from studying working ROVs and submarine rescue. We learned a new, more accurate method to estimate thrust. We also learned from our experience with our 2009 competition ROV. For example, we re-designed our motor safety housings to let in more water to improve speed. We kept our academic grades up during the ROV project, and 2 team members won best of category at the Hawaii State Science Fair. Building an ROV gave us new confidence and valuable lessons in teamwork, discipline and problem solving.

ACKNOWLEDGEMENTS:

We thank our mentors: Mr. Hauck, Mr. Meier and teacher, Lisa Diaz, for guidance.

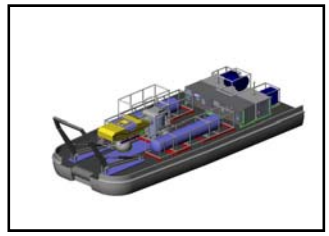
We thank our sponsors for their financial support: BIRR, ISIS Hawaii, NOAA B-Wet, HELCO, Jack's Diving Locker, Ferguson Plumbing Supply, Kealakehe School PTO, Buccaneer Plumbing, K-Mart, Hawaii Dredging Company, Hawaii community federal Credit Union, Coldwell Banker Realty, Windmere Properties, Doug Perrine, Marjorie & Dewayne Erway and Rep. Josh Green.

We would also like to give special thanks to: Cynthia Fong, BIRR Director, MATE, the BIRR Judges and volunteers, KECK Observatory, Cindi Punihaole of Kohala Center, Sarah Peck of UH Sea Grant, Carolyn Stuart & Elizabeth Pickett of Malama Kai Foundation, our parents, teachers and classmates.

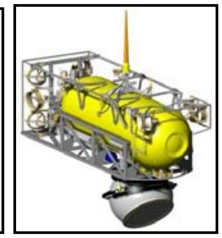
SUBMARINE RESCUE:

SDRS AUWS ROV

RORV with Passengers



SDRS RORV on Mother ship



TUP Hatch Skirt

The U.S. Navy has endured 6 submarine disasters, including the S-4 in 1927, the Squalus in 1939, the Cochino in 1949 and the Thresher, Scorpion, and Chopper in the 1960's. Russian subs have met disaster at least 5 times, with the Kursk tragedy of 119 submariners lost in 2000.

The USS THRESHER, a U.S. nuclear submarine sank on April 10th, 1963, while conducting sea trials. During a deep dive, experts believe a pipe broke, causing an automatic nuclear reactor shut down. The crew was unable to restart the reactor and the sub sank beyond crush depth. Moments later, the U.S. Navy's underwater listening system picked up a powerful implosion. All 129 lives on board were lost, as the only equipment the U.S. Navy had in 1963 was a McCann Rescue Bell, whose maximum depth was 330 meters. In 1968, the USS SCORPION sunk during an exercise below crush depth and all crew were killed.

History of DSRVs

In 1964, the Navy Ocean Engineering Program contracted Lockheed Corporation to construct a deep-diving DSRV rescue sub. **Deep Submergence Rescue Vehicles (DSRVs)** are manned, free swimming, battery powered, submarines used for rescuing disabled submarines below 330 meters. DSRVs are ~15 meters long, and 2.4 meters wide, diving to a maximum depth of 5,000 feet (1,524 meters). DSRVs run on 4 electric 7.5 horsepower motors, silver zinc batteries and 28 VDC emergency batteries. The DSRV dives, locates the disabled submarine by conducting a sonar search. The DSRV then attaches itself to the submarine's escape hatch, rescuing crew and providing life support. Deep Submergence Rescue Vehicles can hold up to 24 passengers. DSRV navigation is based around an Inertial Reference Unit that operates a transponder (a sonar transceiver that automatically transmits a signal upon receiving a designated incoming signal), an effecter (a device used to produce a desired change in an object in response to input), a Doppler, and an integrated navigation system. The Navy required that all DSRV's be able to reach any point in the world within 24 hours, transported by aircraft, ship, or specially configured attack submarines. DSRVs are useful if the damaged submarine does not sink beyond crush depth. DSRV MYSTIC and DSRV AVALON were tested and deployed in 1971. Mystic was deactivated on October 1, 2008 and replaced with remotely operated tethered ROV's as part of the new **SRDRS system.**

SRDRS Class: Submarine Rescue Diving Recompression System

The Navy started SRDRS to replace DSRVs in 1998 to function as a 21st century submarine rescue system. SRDRS includes an air transportable, quick assessment work system, a recompression chamber system and a pressurized rescue transporter. SRDRS consists of three new systems: Assessment/underwater Work System (AUWS), Submarine Decompression System (SDS), and the Pressurized Rescue Module System (PRMS).

Submarine Rescue Diving Recompression System (SRDRS) improvements are a more rapid response time, a continual power source, rapid transfer hatch skirt and no need for a surface mother ship containing a recompression chamber. SRDRS is tethered, unlike autonomous DSRVs, and does not require the DSRV 2 hour battery charging. SRDRS is remotely piloted from a surface ship, which reduces complexity and improves response time. No new lives are put at risk. It has the ability to mate and transfer personnel from three participating submarines. SDRS can be deployed and mated to a distressed submarine within 72 hours. SRDRS is based in San Diego, CA.

The SRDRS Assessment/underwater Work System (AUWS) consists of specialized, tethered ROV's that are the first to be deployed to assess damage and deliver life support air and pods to a disabled submarine. AUWS also deploys ADS 2000 manned 1-atmosphere dive suits to inspect and clear debris from escape hatches. The system also features Falcon, a remotely operated, tethered, PRM, or Pressurized Rescue Module. Falcon can rescue at depths of up to 607 meters and can transfer 16 people from a disabled sub. SRDRS can work around the clock non-stop since it is connected via tether to a continual power source. In 2008, the SRDRS system was tested in international submarine rescue trials involving the U.S., NATO allies, Israel, China, Russia, India, and Singapore. SDRS will be finalized in 2012 and if requested, can be used to rescue submarines from all world navies to save lives via international cooperation.

Sources:

http://www.nationalgeographic.com/k19/disasters_main.html

www.phnxinternational.us/Submarine%20Rescue.html

www.navy.mil/navydata/cno/n87/usw/issue_9/sub_rescue.html

www.globalsecurity.org/military/systems/ship/systems/srdrs.html

Images: http://www.phnx-international.us

COMMUNITY SERVICE LEARNING PROJECTS:

2009 Kealakehe Intermediate ROV Team at the Earth & Ocean Earth Day Festival, at Outrigger Keauhou Beach Hotel and Kahalu'u Bay Beach Park.

The Earth and Ocean Earth Day Festival, at the Outrigger Keauhou Beach Resort, on April 25th was attended by ~1000 residents and visitors. The theme was to celebrate Earth Day while learning about ocean conservation, recycling, renewable energy, and sustainable living. Kealakehe Intermediate ROV team had a display booth to inform the public about the MATE/BIRR robotics program and about the importance of ROV's in ocean rescue and conservation. Team members presented our ROV project to young students, teachers and the general public. Our team was also interviewed by Big Island T.V. & Radio, Sustainable Hawaii, and Green Hawaii websites. In the interviews, we promoted the BIRR competition and the MATE/BIRR robotics program. We entertained children of all ages with facts, about how scientist uses ROV's, as well as how kids can help save our planet. 30 total ROV team student hours were volunteered at the festival including preparation.

Kealakehe Intermediate School Fall Parent Open House Night and Spring Book Fair:

Our team presented the ' 08 ROV project & MATE/BIRR robotics program to students & parents at our fall open house, and for the entire week to other science classes to interest new members. We displayed our ROV at the Spring Book Fair. 25 total student hours were volunteered at school events.

Jack's Diving Locker Pool Demonstrations:

Our team practices the MATE ROV Missions at Jack's Diving Locker Pool, which is in the center of downtown Kona. Residents and tourists often watch our practice sessions through an underground pool viewing window and we take turns educating the public about the MATE/BIRR robotics program, as well as answer questions about ROV's. Approximately 20 student hours was spent on community demonstrations at Jack's Diving Locker pool. Kealakehe Intermediate ROV team has spent a total of 70 hours of student volunteer time this 2008/09 school year, at public and school events to educate our community about ocean conservation and the importance of ROV's in ocean research and rescue.