ENVIRONMENTAL SAMPLING TOOLS DESIGNED FOR USE ON A LOW COST REMOTELY OPERATED VEHICLE (LCROV)

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One of the tools most frequently utilized by the National Undersea Research Center at the University of North Carolina at Wilmington (NURC/UNCW) is a low cost remotely operated vehicle (LCROV or ROV). In the past, the primary functions of this ROV have been visual reconnaissance and data sampling via electronic sensors. Due to the development of the devices discussed in this paper, the ROV now has the additional capability of obtaining and storing multiple samples of seawater and some types of seafloor. Two water samplers and two seafloor samplers have been designed and fabricated to operate as an extension of an existing ROV mounted manipulator arm. The devices are controlled by one or more of the existing manipulator motors. Each of these tools are intended to be part of a growing resource pool of interchangeable ROV-based instruments for use by the Center in its support of undersea research.

Introduction

Exploration in an alien environment, whether under the sea or on some distant planet, can be greatly enhanced by the use of remotely operated or autonomous robotic devices. Such devices allow scientists to obtain information, collect environmental samples, and perform tasks at sites where extended human presence is difficult, dangerous, or impossible. An example of this type of device is the remotely operated vehicle (ROV) used by the National Undersea Research Center at the University of North Carolina at Wilmington (NURC/UNCW) in its support of undersea research. As the result of a joint venture between the Mars Mission Research Center at North Carolina State University (MMRC/NCSU) and NURC/UNCW, four research tools were recently developed for use with this ROV system. These devices will allow the ROV to accomplish tasks that previously required some other system. These new research tools are the focus of this paper.

The ROV, a Deep Ocean Engineering Super Phantom II, was purchased by the Center in 1987. This highly portable vehicle has since been used over 300 hours in support of more than 25 different science missions. During this time, the principal function of the ROV has been to collect scientific information using video cameras and electronic environmental sensors. Through the use of a simple claw with two-
degree-of-freedom positioning, limited environmental sampling has been possible. Due to the technical needs of the Center-funded science community, NURC/UNCW personnel decided to develop a selection of interchangeable tools that would allow the ROV to collect a variety of physical samples. With the ROV and these new tools, a scientist could simultaneously view a research site, measure a variety of in situ physical properties, and collect multiple samples of the environment in question.

The technical expertise that made this tool development possible was found primarily in a group of students and faculty at the North Carolina State University (NCSU) component of the Mars Mission Research Center (MMRC). After initial discussions between representatives of the two research centers, a decision was made by NURC/UNCW to fund the design and fabrication of four prototype sampling tools by a group of sixteen NCSU undergraduate students and their faculty advisors.

**Design Requirements**

The students were given a list of constraints including:

- Each sampler must attach to the existing manipulator arm in place of the existing simple claw.
- Each sampler must be actuated only by existing manipulator motors.
- The samplers must operate at depths of up to 1000 ft.
- The tools must be durable. Reliability of the devices during multiple operations at sea must be insured.
- Maintenance and repair must be easily accomplished in the field with standard components.
- Drag on the ROV system should be kept to a minimum by limiting the size of the device(s).
- Each water sampler must collect six separate 100 ml water samples, each on the command of the operator.
- Each seafloor sampler must gather three separate 100 cc sand or mud samples, each on the command of the operator.
- Each seafloor sample must be obtained from the top 5 cm of sand or mud.
- Once collection is complete, sample containers should be sealed to prevent contamination.
- The fabrication costs of each sampler, including materials and machining, should be under $1000.
- Each device is to have a target in-water weight of 3 lb. The water sampler has an allowed tolerance of 0.25 lb. The bottom sampler has an allowed tolerance of 0.5 lb. Similar weights for each device allow for the quick exchange of tools without a required alteration of ROV trim.

Additional desired characteristics included the visual confirmation of sample capture, limited requirements on the operator, and the ease of sample removal at the surface.

Based upon these requirements and desired characteristics, two student design teams for the water sampler and two student design teams for the seafloor sampler were assembled. These teams underwent a series of design reviews attended by their faculty advisors and NURC/UNCW personnel. During these reviews, the design basis of each team was critiqued and potential problem areas were discussed.
Following this review process, each design team performed structural analysis testing, completed fabrication of the sampler prototypes, documented their designs, presented a seminar on operational procedures, and assisted in the integration and testing of each device at NURC/UNCW. All four teams were successful in their efforts. The following section of this paper demonstrates two solutions to each design problem. Experience gained during field tests of these devices during the upcoming NURC/UNCW operational season will prove valuable in the future development of additional environmental sampling tools.

Results

LCPD Water Sampler:
The LCPD water sampler (Fig. 1a,1b) incorporates six separate syringe mechanisms into one turntable structure. Each of these sample containers is fitted with a check valve and a drain plug. The actuator originally intended to rotate the manipulator about its longitudinal axis is now used to select the syringe to be operated. The actuator designed to control the operation of the claw pulls the selected piston. The movement of this piston creates a pressure differential that opens the check valve and draws water into the sample chamber. Multiple seals are used throughout each syringe to ensure that each sample remains uncontaminated.

The turntable body consists of six wound fiberglass tubes sandwiched between two circular plates of lexan. The apparatus is held together by stainless bolts spaced around each cylinder. The rest of the structure is aluminum with the exceptions of Teflon bushings, one stainless steel spring, and ethylene
propylene o-rings. One stainless steel 5 psi check valve and screwtop drainplug are located at the end of each cylinder. High density syntactic foam is used to fulfill the in-water weight requirements.

Figure 1b. LCPD Water Sampler (camera view)

Once the ROV is on site, water collection is a simple process. The operator, relying on video or a measured rotation time period, selects a cylinder by rotating the tool. On the command of the operator the piston is fully retracted. As a result, the check valve opens and water fills the chamber. The operator must then allow the sliding actuator to return to the ready position. This process is continued until up to six samples have been taken. After recovery of the ROV, the samples are retrieved by removing each drain plug and manually depressing each piston head. A distilled water rinse of the syringes is all that is required to prepare the device for reuse.

NVLA Water Sampler:

The NVLA water sampling tool (Fig. 2a,2b) consists of a long cylinder containing a multistage plunger. This combination of plunger and cylinder form six sample chambers. When one or more of these chambers is located in the open portion of the cylinder, circulation holes allow free flow between that chamber and the surrounding water. As the plunger assembly is moved, these chambers shift into the closed area of the cylinder. Since this area has no circulation holes, the samples are confined until removal on the surface. The plunger is moved by a drive mechanism similar to that of a caulking gun. The plunger shaft fits through a hole in one end of a stainless steel lever. When the claw pull motor is activated, a cable pulls on the free end of this lever. The lever first rotates and then locks on the shaft. Continued operation of the motor slides the plunger until one chamber is moved from the open section to the closed section of the cylinder. Release of the cable allows a spring to return the lever to its original position. This mechanism ensures the capture of a single sample per activation without the need for visual confirmation. To allow removal of the samples, six drain plugs are located in a bar attached to the outside of the closed end of the cylinder.
Both the cylinder and the plunger are machined from low friction 1900 UHMW polymer. Silicon O-rings are used to separate the sample chambers. The incrementing device, illustrated in Fig. 4, consists of a stainless steel push rod, spring, and lever arm encased in a UHMW cylinder.

This tool is prepared for operation by sliding the plunger so that all chambers are in the open section of the cylinder. Once on site, the operator actuates the plunger using the claw pull motor. This process is repeated until up to six samples have been collected. Once the ROV is on the surface, the samples can be recovered with a syringe through the use of drain plugs fitted into the side of the cylinder.
**Tri-Scoop 1000 Seafloor Sampler:**

The Tri-Scoop 1000 seafloor sampler (Fig. 3) is a disk structure with three cups equally spaced around its perimeter. These cups have spring loaded lids that close automatically after a sample is taken. The manipulator elevation control motor lowers and raises the sampler relative to the ocean floor. After the disk is placed on the ocean floor, a rotation of the device, coupled with a short sideways thrust of the ROV motors, collects a sample, seals the storage container, and brings the next cup into position.

![Tri-Scoop 1000 Ocean Bottom Sampler](http://archive.rubicon-foundation.org)

**Figure 3. Tri-scoop 1000 Ocean Bottom Sampler**

The device is composed of two lexan discs that are supported through their centers by an aluminum shaft. The exposed end of this shaft fits into the manipulator rotation motor. Between the discs, equally spaced around the perimeter, are three UHMW mounting blocks. Each mounting block holds a 180 cc aluminum cylindrical cup. Each container has an aluminum lid that pivots about a stainless steel shaft. An aluminum O-ring seat, fitted with a nitrile O-ring, is bolted to each lid. The mouth of each of the aluminum containers is chamfered for a water tight seal between the lid, O-ring, and container. Each lid is held in position with two stainless steel extension springs. A UHMW static trigger arm, used for closing the container lids, is clamped to the manipulator rotation motor.

When preparing this tool for use, the operator opens all three of the spring loaded container lids. The tool is then positioned so that the first container is ready to enter the bottom. After the ROV is positioned on the ocean floor, the sampler is lowered with the elevation motor until the bottom edge of the tool touches the seafloor. To take a sample, the operator activates the manipulator motor necessary to rotate the sampler disk. This rotation causes the first container to rotate downward and scoop a sample of the bottom. During the final portion of the rotation, the extended end of the lid/trigger rod comes in contact with the fixed lever. The rod end slides along the surface of the lever,
forcing the lid to rotate. At a critical point, the springs take over and snap the lid shut. The operator then stops the rotation of the tool and the device is ready to take another sample. This process can be completed three times. Once on the surface, the samples can be removed by manually opening the spring loaded lids.

**NCSU-2 Sand Sampling Tool:**

The NCSU-2 Seafloor Sampler (Fig. 4) is similar to the Tri-Scoop 1000 in that they both have three cups that scoop the sand or mud and then seal until manual retrieval on the surface. The fundamental difference is that instead of rotating the entire tool, this NCSU-2 tool relies on a sprocket driven conveyor belt to drive the sample cups into the bottom. This belt is driven by a system of two sprockets sandwiched between lexan plates and one pulley. The pulley, fixed to the axle of the upper sprocket, is rotated by the manipulator claw motor pull cable. This action causes the belt and cup assembly to rotate. The lower cup enters the seafloor, collects a sample, and exits the soft bottom. Additional rotation allows the torsional spring to close and seal the lid.

![Diagram of NCSU-2 Ocean Bottom Sampler](http://archive.rubicon-foundation.org)

**Figure 4. NCSU-2 Ocean Bottom Sampler**

The sampling cups are 125 cc lexan containers screwed into an aluminum adapter. This adapter is rigidly attached to the acetal plastic and stainless steel belt. This belt rides on nylon sprockets housed between two lexan panels. The aluminum container lids are controlled by tracks in the two side panels. These tracks are designed to keep the lids in an open position until the sample is taken and to allow a
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torsional spring to close the lid when sampling is complete. A two-inch diameter nylon pulley is
employed to transmit the torque generated by the pull cable to the sprocket. The sprockets rotate on
two stainless steel shafts.

To prepare the sampler for operation, the drive pulley is reversed manually until the doors on all
three containers are open. The belt is rotated forward until just before the first sample cup reaches the
bottom of the conveyer belt loop. In order to take a sample, the ROV is first placed on the bottom. The
operator then rotates the conveyer using the claw pull motor. This action causes the first sample cup to
collect a sample of the soft bottom and seal itself against contamination. Once the lid on the sample jar
is closed and the second jar is moved into position, the rotation is halted. This process may be
completed up to three times. Removal of the ocean floor samples is achieved on the surface by either
manually opening the lid or disconnecting the jar from the adapter.

Conclusions

A group of undergraduate students successfully designed, fabricated and tested four tools that allow
the NURC/UNCW ROV to take multiple samples of seawater and seafloor in a design effort funded by
NURC/UNCW. All samplers function as anticipated, are simple to operate, and are easy to maintain.
As a result of this project, the students received a valuable educational experience in engineering design
and project management. The sponsoring institution received custom designed research tools that will
expand the capabilities of a proven undersea research system. Results of this project indicate that an
inter-university collaborative effort can provide benefits to all parties involved.

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with relevant high tech diving systems. The Center currently has access to virtually all of the region's
marine ecosystems through a unique combination of in-house expertise and equipment and leased
systems. The Center currently has expertise in leased submersibles, the underwater laboratory
AQUARIUS, air and enriched air (NITROX) diving support, manned submersibles, and unmanned
remotely operated vehicles.

The Mars Mission Research Center, co-located at North Carolina State University and North
Carolina A&T University, is one of nine engineering research centers sponsored by the National
Aeronautics and Astronautics Administration (NASA). Its mission includes the development of basic
technologies that may be used both for space exploration and the education of students in aerospace
engineering. Emphasis is placed on mission planning, hypersonic aerodynamics, composite materials,
and structural dynamics and control.