# Small RV-Based Deep-Towed Seafloor Sampling Systems


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***Abstract*—This paper presents several small research vessel-based deep-towed seafloor sampling systems developed by the Institute of Undersea Technology (IUT) at National Sun Yat-sen University. First of all, the paper presents the Video-guided Multi-Corer (V-Corer) and the TV-Grabber (TVG). The V-Corer and the TVG can be used for video-guided seafloor sampling through a small research vessel, such as RV Ocean Researcher III in Taiwan. Some seafloor sampling results obtained through the V-Corer and the TVG in waters of northeastern and southwestern Taiwan are presented in the paper as well. The paper also illustrates the concept of using the IUT's Fiber-optical Instrumentation Towed System (FITS) as a depressor to enable the ROV close-up seafloor observation and sampling through a small research vessel. Moreover, the paper introduces a prototype automatic push corer (APC) developed by the IUT. The IUT prototype APC was designed to be integrated with an ROV as a payload device for seafloor sediment sampling without the need of using manipulators. The sampling and tube-changing functions of the IUT prototype APC were successfully verified through a standalone version of the APC in Kaohsiung harbor, Taiwan.**



***Keywords—Small RV-based seafloor sampling; Video-guided seafloor sampling; ROV push coring; Deep-towed vehicle.***


## I. Introduction

A remotely operated vehicle (ROV) and a large research vessel (RV) with a dynamic positioning system (DPS) are typically required in order to carry out deep seafloor survey and sampling missions. However, the overall cost for such an arrangement is beyond the budget plan of most mid-size research projects. Currently in Taiwan, three of the four national research vessels are small ships without a DPS, two of which have a gross tonnage of 295 tons (RV Ocean Researcher II and RV Ocean Researcher III) and one of which has a gross tonnage of 800 tons (RV Ocean Researcher I). On each of the three small RVs, a CTD winch system serves as the main device for deploying underwater instruments to reach the seafloor. In the meantime, such a CTD winch system also brings constraints for the design of underwater systems. The key constraints include: the weight of an underwater system in the air and in the water has to be less than 1,000 kg; no power or limited power is available through the winch cable; the operating depth is limited by the cable length; the effectiveness of the digital communication is influenced by the cable length in a nonlinear manner. Under the above constraints, real-time video streaming was determined as the most important specification of the underwater systems developed by the Institute of Undersea Technology (IUT) at National Sun Yat-sen University, Taiwan.

Among the underwater systems developed by the IUT, the Video-guided Multi-Corer (V-Corer) and the TV-Grabber (TVG) [1, 2], are two deep-towed video-guided systems for seafloor sampling. With real-time video streams, features on the seafloor can be continuously monitored, such that it becomes more likely to execute seafloor sampling at locations with environmental parameters that have important scientific values. Over the past few years, the V-Corer and the TVG have been utilized for seafloor imaging and sampling offshore Taiwan through two small research vessels not equipped with a DPS. Samples of sediments, basal water, rocks, and deep-sea creatures have been collected and a large number of seafloor videos have also been recorded. Seafloor survey results including samples and videos obtained by the V-Corer and the TVG have been provided to scientists for further studies on marine geophysics, marine geology, marine geochemistry, and marine biological ecology.

Currently, in order to retrieve sediment cores from the seafloor using push corers, an ROV is required to equip with manipulators [3]. A well-trained pilot is also required to assure sampling efficiency. However, even to a well-trained pilot, it is still challenging to perform sediment sampling by manipulating robotic arms under bad weather. Moreover, it is essentially infeasible to install robotic arms with high degrees of freedom on small and medium-sized ROVs. To this end, the IUT has developed a prototype automatic push corer (APC) to validate the idea of performing seafloor push coring without the need of using manipulator systems.


This research is supported by the Ministry of Science and Technology, Taiwan.



978-1-7281-1450-7/19/$31.00 ©2019 IEEE

## II. Deep-Towed Sampling Systems of IUT

This section presents two deep-towed vehicles developed by the IUT, including the V-Corer and the TVG, for video-guided seafloor sampling operations.

### A. *Video-Guided Multi-Corer*

The V-Corer, as shown in Fig. 1, was developed as a deep-towed vehicle for video-guided seafloor coring. The V-Corer is a multi-corer equipped with a video camera, LED lights, an altimeter with depth sensor, a USBL transponder, and batteries. The V-Corer needs to be towed behind a supporting surface vessel through a CTD twisted-pair cable. The viewing system and sensors can be turned on or off via a graphical user interface (GUI), and the required commands are transmitted from the surface vessel to the V-Corer through the CTD twisted-pair cable. Meanwhile, the sensor data and image data are transmitted from the V-Corer to the surface vessel through the CTD twisted-pair cable as well. The acoustic pulses for USBL underwater positioning are transmitted between the shipboard transceiver and the subsea transponder directly through the water column. The altitude, depth, and position of the V-Corer and the seafloor live video are displayed on the corresponding GUIs.

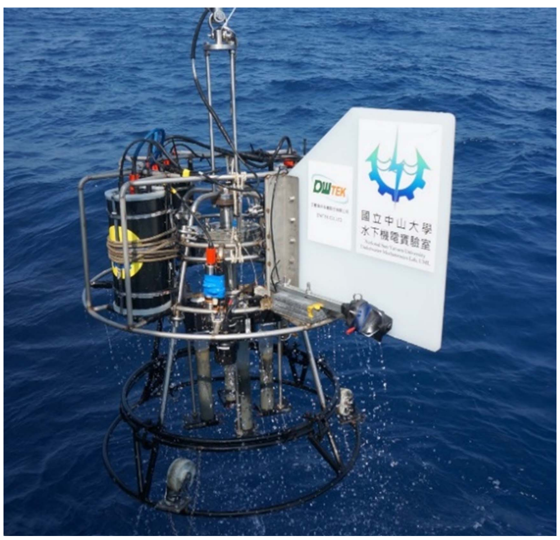


Fig. 1 V-Corer developed by IUT, NSYSU.

### B. *TV-Grabber*

The TVG, as shown in Fig. 2 was developed as a deep-towed vehicle for video-guided seafloor sampling. The TVG is a grab bucket equipped with three video cameras, LED lights, an altimeter with depth sensor, a USBL transponder, and batteries. Such as the V-Corer, the TVG needs to be towed behind a supporting surface vessel through a CTD twisted-pair cable. The viewing system and sensors can be turned on or off and the grab bucket can be opened or closed through a GUI. The required commands are transmitted from the surface vessel to the TVG through the CTD twisted-pair cable. On the other hand, the sensor data and image data are transmitted from the TVG to the surface vessel through the CTD twisted-pair cable as well. The acoustic signals for USBL underwater positioning are transmitted between the shipboard transceiver and the subsea transponder directly through the water column. The altitude, depth, and position of the TVG and the seafloor live video are displayed on the corresponding GUIs.

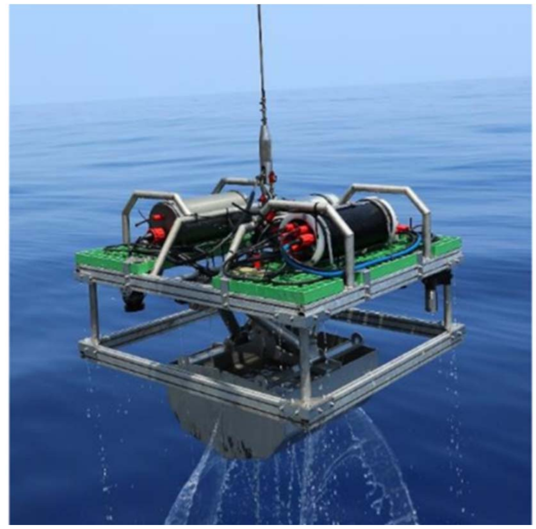

Fig. 2 TVG developed by IUT, NSYSU.

## III. Deep-Towed Depressor of IUT

In addition to the V-Corer and the TVG operated by the CTD winch system, the IUT has also developed the Fiber-optical Instrumentation Towed System (FITS) that is operated by a multipurpose winch equipped with an armored hybrid cable, as shown in Fig. 3. Electric power, sensor data, video streams, and commands are transmitted between the research vessel and the FITS through the armored hybrid cable. The FITS was developed as a testbed on which mandatory sensors and payload devices can be integrated for in-situ imaging and multi-sensing purposes.

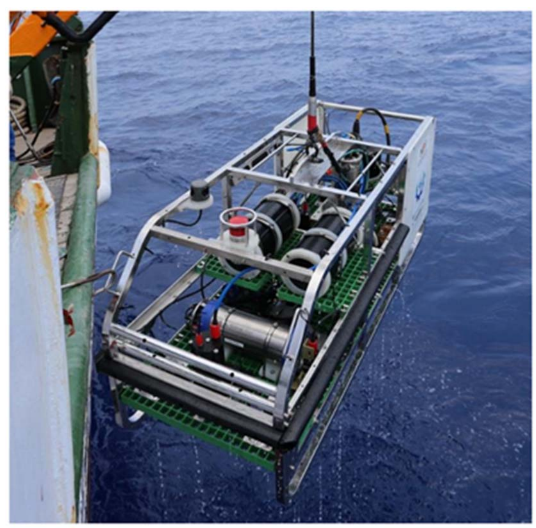

Fig. 3 FITS developed by IUT, NSYSU.

In addition, the FITS can also act as a stabilizing depressor for an ROV. In other words, the ROV perform tasks in tandem with the FITS that dangles at the end of the armored hybrid cable from the research vessel, as shown in Fig. 4. Therefore, the ROV can be operated from a small research vessel without dynamic positioning capability to perform close-up deep seafloor inspection and sampling.

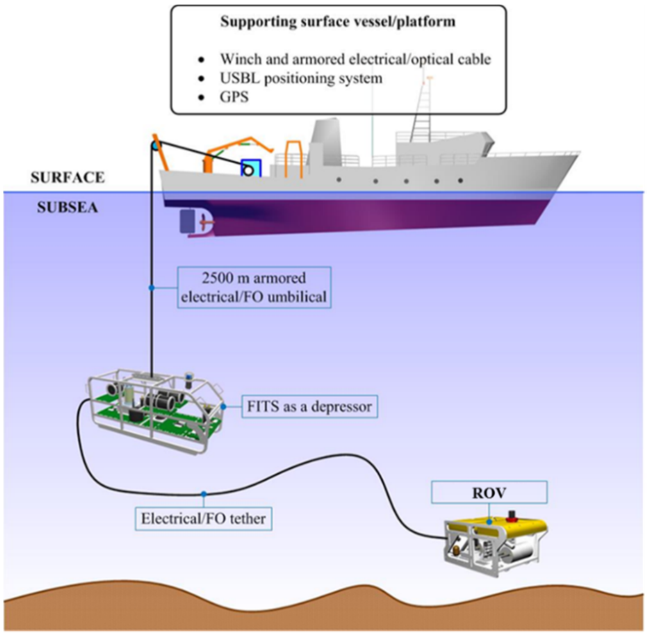


Fig. 4 Deepsea ROV operation with FITS as the depressor.

## IV. PROROTYPE AUTOMATIC PUSH CORER OF IUT

Inspired by the automatic tool changer (ATC) and tool spindle of a computer numerical control (CNC) machine [4], the IUT developed a prototype automatic push corer (APC), as shown in Fig. 5(left part), which could be integrated with an ROV as a payload device for sediment sampling purposes. The design concept of the IUT prototype APC is to decouple the operation of sediment sampling into a rotational motion and a linear motion. The IUT prototype APC has four main components, including a vertical sampler, a rotating tube changer, an actuator, and a protective frame. Electrical energy and control signals required to drive the actuator are supplied from the surface mothership and delivered to the actuator through the ROV.

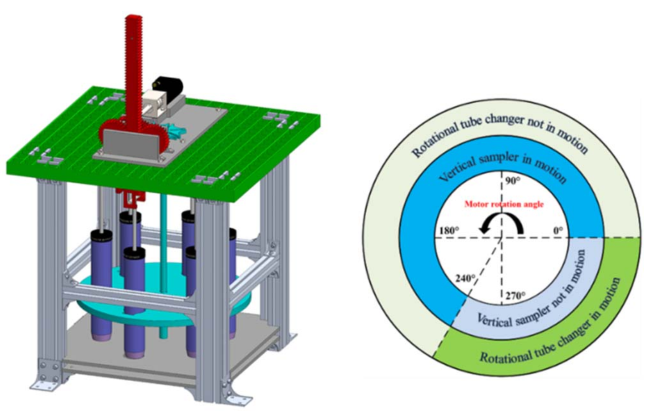


Fig. 5 IUT prototype APC (left) and its intermittent motions (right).

Intermittent motions for the vertical sampler and the rotational tube changer are shown in Fig. 5(right part). In each revolution of the actuator, the vertical sampler is in motion for 240°, while the rotational tube changer is held in place; the rotational tube changer is in motion for 120°, while the vertical sampler is held in place. With this design, the single actuator can drive these two mechanisms to perform the sampling and tube changing sequentially.

## V. VIDEO-GUIDED SEAFLOOR SAMPLING OFF TAIWAN

The V-Corer and the TVG have been utilized to perform video-guided seafloor sampling for mineral resource investigation off NE Taiwan. Fig. 6 shows several important survey sites off NE Taiwan for mineral resource investigation in years 2016 and 2017.

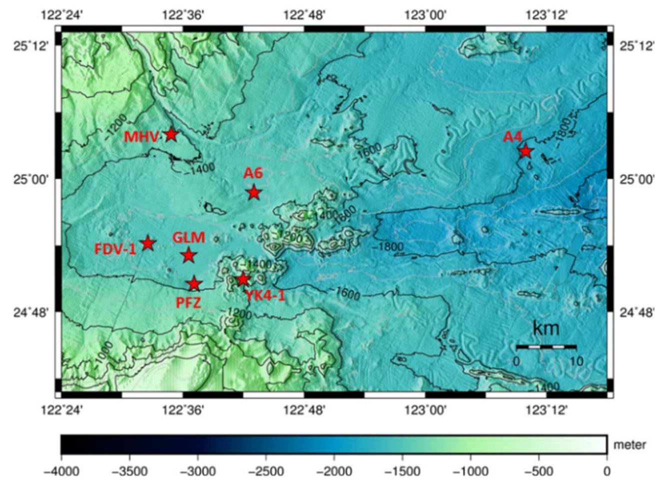


Fig. 6 Mineral resource investigation area off NE Taiwan.

In 2016, the V-Corer was used for seafloor sampling at sites A6 and A4. Based on the real-time seafloor video displayed and recorded during the survey, the seafloor at site A6 was considered to have a soft bottom, as shown in Fig. 7. At site A6, the V-Corer was equipped with twelve core tubes and carried out sediment coring one time. Eleven sediment cores were obtained in this operation, as shown in Fig. 8. Site A4 is a background site. Based on the real-time seafloor video displayed and recorded during the survey, the seafloor at site A4 was also considered to have a soft bottom. At site A4, the V-Corer was equipped with ten core tubes and carried out sediment coring one time; seven sediment cores were obtained in this operation.

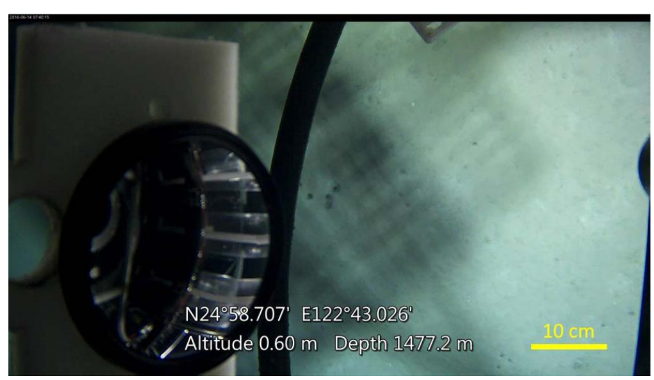


Fig. 7 Seafloor surface observed through V-Corer at site A6 off NE Taiwan.

Fig. 8 Sediment cores obtained through V-Corer at site A6 off NE Taiwan.

In 2017, the TVG was deployed for seafloor sampling at site PFZ. During the survey, the TVG collided with the mounds several times near the location with coordinates (N24°50'58.86", E122°37'15.42") and brought back several small mound samples, which were found to have metallic or crystal reflections, as shown in Fig. 9.

Fig. 9 Mound samples obtained at site PFZ off NE Taiwan.

In 2017, the TVG was deployed for seafloor biological sampling at Four Way Closure Ridge off SW Taiwan, as shown in Fig. 10. In this cruise, lots of mussels and different kinds of deep-sea animals were collected by the TVG at a depth of 1350 meters, as shown in Fig. 11.

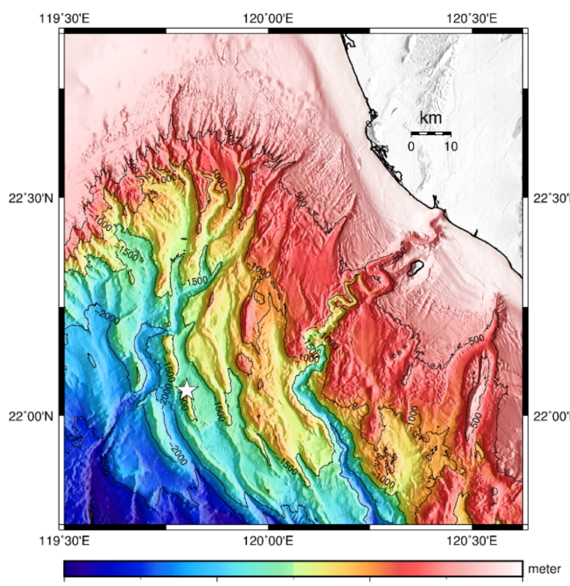


Fig. 10 Seafloor sampling through TVG off SW Taiwan.

Fig. 11 Biological samples obtained through TVG off SW Taiwan.

## VI. Functional Test of IUT Prototype APC

The sampling and tube-changing functions of the IUT prototype APC were tested using single-machine mode of the APC. In other words, the IUT prototype APC was a self-sustaining system equipped with the electric power and communication systems, as shown in Fig. 12(left part). The sampling and tube-changing functions of the IUT prototype APC were tested in Kaohsiung harbor, Taiwan, with a depth of 6 meters, as shown in Fig. 12(right part).

Fig. 13(A) and Fig. 13(B) show that a core tube is pushed down into the seafloor to begin the sampling operation. Fig. 13(C) and Fig. 13(D) show that the same core tube is pulled back from the seafloor to finish the sampling operation. The sampling and tube-changing functions of the IUT prototype APC were verified using single-machine mode of the APC in Kaohsiung harbor, Taiwan.

Fig. 12 Self-sustaining version of IUT prototype APC (left) and functional test of IUT prototype APC in Kaohsiung harbor (right).

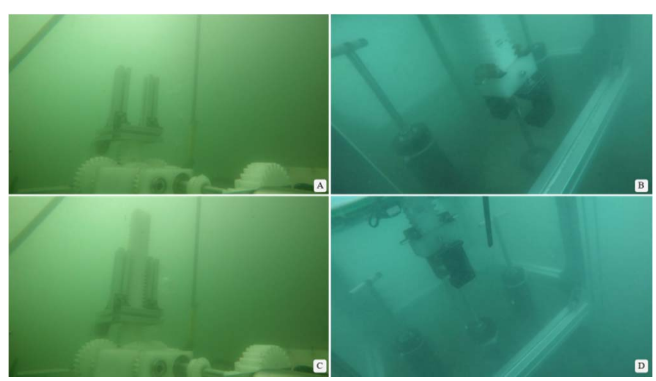


Fig. 13 Screenshots of IUT prototype APC performing sediment sampling.

## VII. CONCLUSIONS

Two deep-towed vehicles, including the Video-guided Multi-Corer (V-Corer) and the TV-Grabber (TVG), have been presented in the paper. The V-Corer and the TVG were both developed by the IUT, NSYSU, for video-guided seafloor sampling operations through a small research vessel, such as RV Ocean Researcher III in Taiwan. Some sampling results obtained using the V-Corer and the TVG off NE and SW Taiwan have been presented in the paper as well.

In addition to the V-Corer and the TVG operated by the CTD winch system, the IUT has also developed the Fiber-optical Instrumentation Towed System (FITS) that is operated by a multipurpose winch equipped with an armored hybrid cable. The concept of using the FITS as a depressor for an ROV close-up seafloor inspection and sampling through a small research vessel has been illustrated in the paper.

Moreover, a prototype automatic push corer (APC) developed by the IUT, NSYSU, has been introduced as well. The IUT prototype APC was designed to be integrated with an ROV as a payload device for seafloor sediment sampling without the need of using manipulators. The sampling and tube-changing functions of the IUT prototype APC were verified through a self-sustaining version of the APC in Kaohsiung harbor, Taiwan.

## ACKNOWLEDGMENTS

This research is supported by the Ministry of Science and Technology (Taiwan), under grants 108-2218-E-110-003, 108-2218-E-110-002, 108-2218-E-110-004, 107-2218-E-110-005, 107-2218-E-110-004, 107-2218-E-110-006, and 107-3113-M-110-001.

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