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Remotely Operated Vehicle “ROV PHOCA“

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Abstract: The remotely operated vehicle ROV PHOCA is a deep diving platform rated for water depths of 3000 meters. The ROV is linked to a surface vessel via an umbilical cable transmitting power (copper wires) and data (3 single-mode glass fibers). As standard it comes equipped with still and video cameras and two different manipulators providing eyes and hands in the deep. Special emphasis was put on the compatibility of numerous systems with the existing ROV KIEL 6000 to facilitate the use of both systems on various research vessels with a given team of ROV pilots.

Besides this, a set of other tools may be added depending on the mission tasks, ranging from simple manipulative tools as chisels and shovels to electrically connected instruments which can send in-situ data to the ship through the ROVs network, allowing immediate decisions upon manipulation or sampling strategies.

1 Introduction

ROV PHOCA was manufactured by sub-Atlantic / Forum Energy Technologies (Aberdeen, Scotland) and was delivered to GEOMAR, Kiel in December 2010. It was funded by the German Ministry for Education and Research (BMBF) within the investment project MoLab (Modular Multidisciplinary Ocean Laboratory). The design of the ROV is based on commercially available ROVs of the Comanche series, and is number 21 in that series. It was customized to specifications aiming at a balance between system weight, capabilities of the supporting research vessels and scientific demands. In addition, special emphasis was put on the compatibility of numerous systems with the existing ROV KIEL 6000 (GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, 2017), e.g. identical cable, similar hydraulic system, similar launch and recovery system, flying mode etc.

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The system is generally used in two different configurations: one for medium ranged water depths down to 2400 m, and one for shallow water applications down to 100 meters. In case the full dive capacity of 3000 m is required, the deep sea winch of ROV KIEL 6000 may be used, which, however, requires a certain deck load-carrying capacity of the research vessel due to its size and weight. These options allow the system to be tailored to the deployment mode, keeping its weight to a minimum, both to reduce shipping costs and to permit deployment from small and medium-sized research vessels (e.g. RV "POSEIDON", RV "ALKOR"). The ROV operates in free-flying mode, without a cage or tether management system (TMS), further reducing the weight of the system. Clip-on floats just above the vehicle ensure that, even without a TMS, the cable does not lie on the seafloor or depress the ROV by its own weight.

The main tasks of the ROV include exploration, documentation and mapping of the sea floor using its own or integrated cameras (e.g. DeepSurveyCam, GEOMAR, Figure 1a). The two manipulators and a customized tool skid, which may be modified to accommodate different tools, are used for sampling, for example, rocks, fauna, fluids and sediments. Furthermore, ROV PHOCA was used to assemble and re-assemble the MoLab landers (Rovelli et al., 2015) and recover long-term sensor records from deep-sea bore hole observatories (Figure 1f).

ROV PHOCA has been deployed in various environments like the shallow waters of the North Sea (Vielstädte et al., 2015), the North Atlantic off Norway (Flögel et al., 2014; Rovelli et al., 2015) and Iceland, the Mediterranean (Jordt et al., 2015; Schmidt et al., 2015) as well as in the Pacific off Japan.

2 Technical Data

2.1 ROV PHOCA Overview

- Owner and Operator: GEOMAR Helmholtz Centre for Ocean Research Kiel
- Commissioned in 2010
- Crew: 5 pilots and technicians for normal operations
- Maximum operation depth: 3000 m
- Dimensions: length 2.1 m, height 1.85 m, width 1.3 m
- Weight in air: 2 t, in water positively buoyant or neutral
- Propulsion system: total 7 x electrical thrusters SBE 250 (sub-Atlantic/FET, Aberdeen): 4 x vector-oriented for horizontal propulsion, 3 x vertically oriented for vertical propulsion
- Auto functions: heading, depth, altitude
- Hydraulic pump: 39 lpm at max. 207 bar
- Hydraulic manipulators: 1 x ORION 7P (position controlled) and 1 x ORION 7R (rate controlled) (FMC Technologies / Schilling Robotics Ltd.)
- Cameras: 2 x SD colour cameras (Kongsberg OE14-366), 1 x HD-SDI Bullshark camera (Imenco), 1 x digital still camera (Imenco), 3 x black & white observation cameras (2 x Oktopus, 1 x Bowtech)
- Lighting: 4 dimmable LED Multi-SeaLite Matrix (DSPL), 4 dimmable halogen Deep Multi-SeaLite (4 x 250 W, DSPL), subsea flash 110 Titanium (Imenco)
- Permanent sensors: CTD (Sea-Bird), forward looking sonar (Kongsberg)

The ROV system comprises the ROV itself, a Launch and Recovery System (LARS), winches and cables as well as one control and power container depending on the configuration and the capabilities of the supporting research vessels. The system weight including the midwater winch is approximately 30 t.

Launch and Recovery System (LARS)
The LARS is mounted on each vessel's A-frame by means of a customized adapter. It consists of a frame holding underneath a plate with dampers (Figure 1b). An auxiliary winch on the A-frame is used to

lift the ROV into the dampened plate with a lift line and thus stabilize the vehicle against pitch / swing while it is being moved outboard of the vessel and lowered into the sea. When the vehicle is in the water and the auxiliary lift line is unloaded, it is detached from the vehicle which is then free to move forward away from the vessel. The power- and data –transmitting umbilical is threaded through an additional sheave to keep it load-free and clear of the LARS system itself.

Safety and Rescue Systems

In case of power loss to the ROV, its positive buoyancy provided by a large syntactic foam block will cause it to slowly float to the surface. The USBL transponder which is constantly in battery mode enables the pilots to acoustically locate the vehicle in the water column. In addition, a flasher system (Novatech) will start operating when the vehicle is shallower than 10 m, indicating the vehicle position at night. Once the vehicle is on the surface, a radio beacon (Novatech), which is also mounted on the ROV, is activated, allowing the bearing to the vehicle to be determined from the ship. As soon as the ROV has been traced either the vessel moves close enough to position the LARS above the ROV to lift it up, or a fast rescue boat may approach and attach a hook into the emergency lift line which is fixed at the central lift point of the vehicle.

Winches and Cables:

The major (midwater) winch of the ROV PHOCA system provides a diving-depth capability of max. 2400 m, with 2700 m total length of the wire. As the winch does not fit into a standard container pattern it needs to be bolted to the ships deck using special steel adapter plates. Power connection requires 400 V with 180 A. The winch has a weight of 10.5 t and is transported either as single freight or inside a container. This size and weight of the winch allow the system to be deployed off medium-sized research vehicles.

Although ROV PHOCA was intended mainly for small and medium-sized vessels using the midwater winch it is also possible to operate it with a deep-sea winch (ROV KIEL 6000) and thus reach its maximum operation depth of 3000 m. This configuration, however, may only be realized on large vessels with sufficient deck strength to support the 30 t winch.

The cable on both, the deep-water and mid-water winches is identical. It consists of sheathing composed of three steel-armored layers, protecting the core from mechanical stress and providing a breaking strength of more than 210 kN. The core consists of three single-mode glass fibers for data transmission in both directions. 2 of these fibers are used for ROV telemetry, the 3^{rd} fiber may be used for additional scientific data links (used for HD camera). Three copper wires with 4 mm^2 cross-section are used for power transmission. The weight of the cable in seawater is 1 t per 1000 m.

When operating in shallow waters a winch with 350 m of buoyant tether is used. The sheathing here consists of aramid with an outer diameter of 28 mm, the core is identical to the above-described cable. When in operation the winch is used as a capstan.

Containers: Control & Power Van

The PHOCA system includes a 20-foot container which comprises the surface control systems and the power supply and workshop in 2 separate compartments.

In the pilot stand, 2 seats for pilots are located in front of a wall of monitors and video screens, displaying all video footage, navigation software as well as the sonar image, CTD control etc. The control “area” includes one pilot console for flying the vehicle as well as handling cameras and lights. The co-pilot usually operates manipulators and the digital still camera.

There is no dedicated spares container for ROV PHOCA. When transported containerized, two 20-foot open top containers have to be rented. In cases where the vehicle, winch and spares are shipped as single freight, one 40-foot truck is necessary. The system weight including the midwater winch is approximately 30 t.

2.2 Sensors and Tools

2.2.1 Owned by and provided within the ROV PHOCA system

- CTD Fast Cat SBE 49 (Sea-Bird) real-time probe
- Sonar MS 1000 (Kongsberg) high resolution, forward looking
- DVL Workhorse Navigator 1200 (RD Instruments) (for fine scale navigation)
- USBL underwater navigation (standardly ORE BATS, see below)
- cameras (see above)
- toolskid containing 2 hydraulically driven drawers in the front
- various sampling boxes / bioboxes
- 2 manipulators (see above)
- pushcores, various setups possible
- hand-nets
- Niskin bottles (2 l)
- chisel
- shovels and scoops, various
- acoustic HOMER beacon markers

2.2.2 Owned by other departments or institutions, operated by ROV PHOCA

- Bubble Box (with cameras for documenting gas bubble size, number and velocity) (GEOMAR & Univ. Kiel)
- Bubble Catcher (GEOMAR & Univ. Kiel)
- DeepSurveyCam (Tom Kwasnitschka, GEOMAR)
- Echoscope (WTD 71)
- Gas samplers
- various sensors integrated into the ROV system e.g. CH_4 and CO_2 sensors (CONTROS)
- Ocean Floor Observatories (Recovery) (Marum, Bremen)
- Temperature Probe (Marum, Bremen)
- Eddy correlation system
- ADCP

2.3 Telemetry System and Navigation

Data transfer between the vehicle and the topside control van is managed by the sub-Atlantic SubCAN-System which consists of the topside SCU (Surface Control Unit) and the topside SubCan PC, which communicates with the sub-sea ROV electronics Pod and the survey pod via CAN-bus architecture.
The topside telemetry logging system ROVMon has been developed and customized to our needs by the GEOMAR ROV Team. It collects incoming data from ROV, ship, winch, CTD and underwater navigation systems (usually the ORE Offshore USBL Broadband Acoustic Tracking System (BATS)). ROVMon distributes data to several subsystems like the navigation system, the video overlay and data display clients.
The telemetry system can handle TCP/IP, UDP and serial connections. The data usually is transferred as NMEA strings; if other formats are transferred, these can be converted by specialized front-ends. The configuration of data logging is declared in advance where protocols, devices (sensors) and exports are specified for the ship and the cruise. The whole data set is written each second in comma separated values (CSV) files. For data security reasons the telemetry system starts a new file after a given interval.

For navigation and coordination with the ship during the dive, we use the navigation software OFOP (Ocean Floor Observation Protocol by Prof. Dr. J. Greinert, GEOMAR). Coordinates and course/ heading

/speed data from the ship and the ROV are displayed on a calibrated map. This navigation screen is also provided to the ship's bridge via a VNC viewer to coordinate ROV's and ship's position.

2.4 Scientific Data management

The navigation software OFOP also includes a protocol function for the scientists to describe the dive and actions like sampling and taking pictures with coordinates and timestamps. After each dive, the scientific protocol is converted into an Excel file to provide it to the scientists. The telemetry files are packed and copied onto the server for public access and post-processing. After each dive, all data sets, protocols, videos and still images (including logo and timestamp) are uploaded on a NAS (Network Attached Storage) system inside the control van for public access and backup.

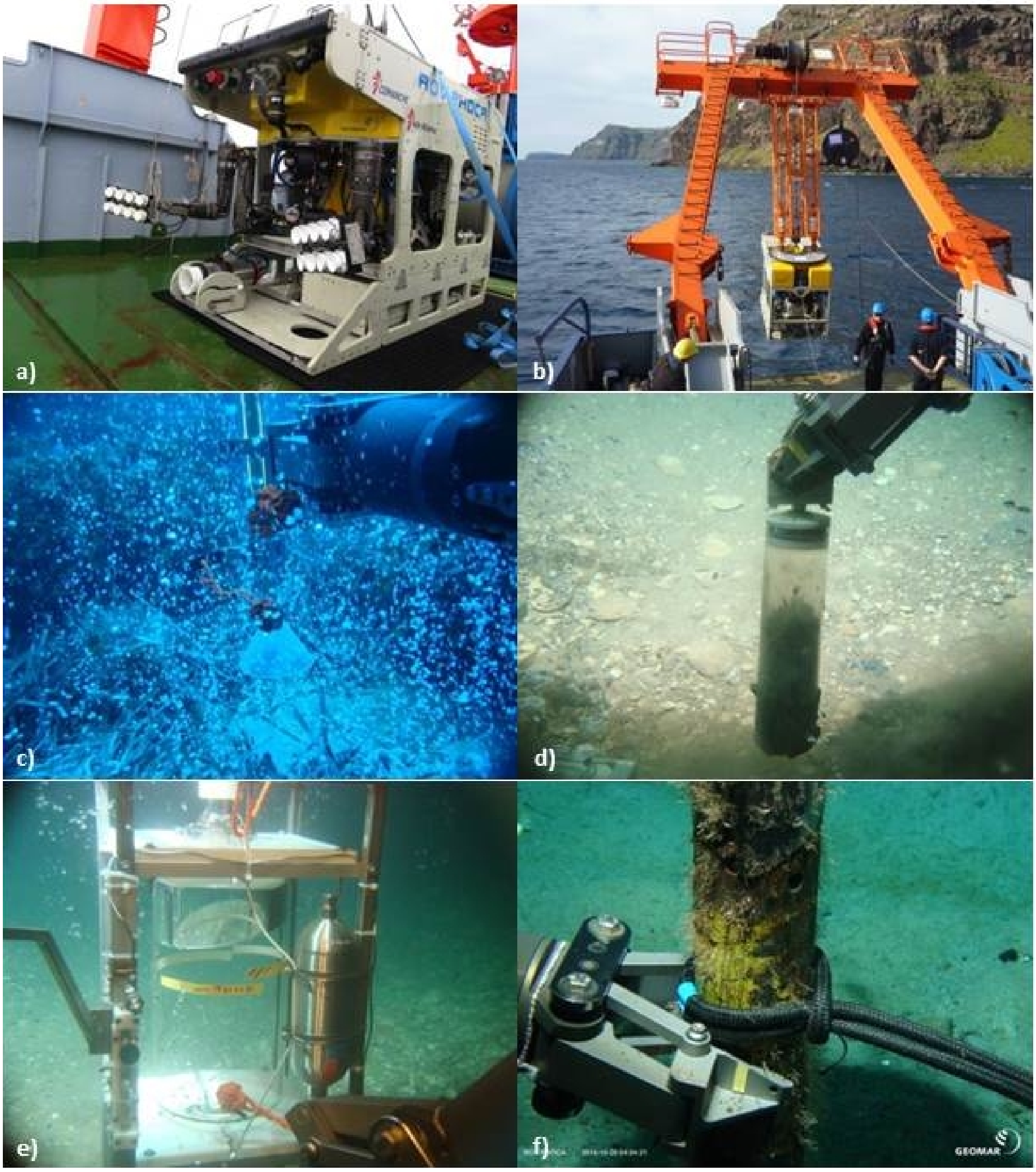

Figure 1: ROV PHOCA a) with DeepSurveyCam setup and LED light panels mounted on both manipulators, b) launched on the A-frame of RV "POSEIDON" in the Santorini Caldera, c) operating a gas sampler, d) taking a pushcore, e) operating the Bubble Catcher, f) recovery of a deep sea observatory. (Photos: a, c-f) GEOMAR ROV-Team, b) J. Geldmacher, GEOMAR).

2.5 Video System

Standard cameras on the vehicle include two colour zoom SD cameras (Kongsberg OE14-366) on pan & tilt units, one HD-SDI camera (Imenco, 720p59.9, on tilt unit), one digital still camera (Imenco), and two black and white observation cameras (Oktopus and Bowtech).
The HD video footage is recorded permanently or on demand using an Apple MacMini with an HD-Videocard and Tools On Air recording software Just:In. The HD video is standardly recorded in high quality Apple ProResLT. Other formats or uncompressed recording are possible. The video files are stored on the MacMinis' internal HDD (1 TB) and later copied to the NAS.
Both SD Cameras are permanently recorded on VisualSoft DVR. The video is recorded in Mpeg. The software automatically starts a new file each 20 minutes to generate smaller sized, thus user friendly files. The SD material contains an imprinted data overlay including date, time, depth, temperature and pan angle of the specific camera.
All SD and HD video files are uploaded into the NAS for public access and backup after each dive. The Imenco SDS1210 Digital Still camera has a resolution of 12.1 MPixel. Still images are taken on request. After each dive, images are downloaded from the camera and logo, date and time are imprinted. Images and videos are subsequently uploaded on to the NAS server. Images and videos without imprint are available on request.
At the home institute, data (videos and images) are uploaded onto the onshore ProxSys archiving system of GEOMAR. The onshore system contains all media- and data-material ever collected by ROV PHOCA.

Conclusions
Since it was put into operation, ROV PHOCA has been deployed during 10 expeditions off three different research vessels (RV "POSEIDON", RV "ALKOR", RV "SONNE") in the oceans around Europe. It has accomplished 110 dives summing up to more than 285 hours at the sea floor. Data sampled by ROV PHOCA resulted in the publications listed below.
For more details and images of the system, tools etc. please refer to our website:
http://www.geomar.de/en/centre/central-facilities/tlz/rovphoca/overview/.

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