Journal of large-scale research facilities, 3, A117 (2017) http://dx.doi.org/10.17815/jlsrf-3-160

Published: 23.08.2017

Remotely Operated Vehicle “ROV KIEL 6000“

GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel *

Facilities Coordinators:
- Dr. Friedrich Abegg, GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Germany, phone: +49(0) 431 600 2134, email: fabegg@geomar.de
- Dr. Peter Linke, GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Germany, phone: +49(0) 431 600 2115, email: plinke@geomar.de

Abstract: The remotely operated vehicle ROV KIEL 6000 is a deep diving platform rated for water depths of 6000 meters. It 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. Besides this a set of other tools may be added depending on the mission tasks, ranging from simple manipulative tools such 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 KIEL 6000 was manufactured by FMCTI / Schilling Robotics LLC (CA/USA) and was delivered to GEOMAR, Kiel in 2007. Funding came from the German state of Schleswig-Holstein, whose capital city Kiel provided the name. The ROV was designed and built to specifications which aimed at a balance between system weight, capabilities of the supporting research vessels and the scientific demands. It is one of the most versatile ROV systems world-wide, rated for 6000 m water depth, reaching approx. 95% of the world’s seafloor. The system may be used in three different configurations: one for the deep sea, one for the mid-range down to 2400 m and one for shallow water applications down to 100 m. This allows the system to be tailored to the deployment, keeping its weight to a minimum, both to reduce shipping costs and to permit deployment from even medium-sized research vessels. 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 on the cable 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 seafloor using its cameras (Anderson

*Cite article as: GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel . (2017). Remotely Operated Vehicle “ROV KIEL 6000“ . *Journal of large-scale research facilities, 3*, A117. http://dx.doi.org/10.17815/jlsrf-3-160

et al., 2016). 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. The ROV can also be used to carry out in-situ experiments by, for example, precisely placing experimental chambers on the seafloor and manipulating valves etc. attached to them. ROV KIEL 6000 has been deployed in numerous environments such as e.g. the shallow waters of the North Sea (McGinnis et al., 2014; Rovelli, 2014; von Deimling et al., 2011), at Mid-Ocean Ridges with hot and cold seeps (Perner et al., 2011, 2010), in the artic region close to Spitzbergen (Lehmenhecker & Wulff, 2012), various region of the Atlantic, Indian (Amon et al., 2017; Chen et al., 2015), and Pacific Oceans (Schmidt et al., 2017).

2 Technical Data

2.1 ROV KIEL 6000 Overview

- Owner and Operator: GEOMAR Helmholtz Centre for Ocean Research Kiel
- Commissioned in 2007
- Crew: 8 pilots and technicians for normal operations.
- Maximum operation depth: 6000 m
- Dimensions: length 3.5 m, height 2.4 m, width 1.9 m
- Weight in air: 3.5 t, in water positively buoyant
- Propulsion system: total 7 x electrical thrusters SBE 380 (sub-Atlantic/FET, Aberdeen): 4 x vector-oriented for horizontal propulsion, 3 x oriented vertically for vertical propulsion, maximum tractive power 530 kg forth/back, 340 kg lateral, 300/380 kg up/down
- Auto functions: heading, depth, altitude, station keep, displacement, trim
- Hydraulic pump: 39 lpm at max. 207 bar
- Hydraulic manipulators: 1 x ORION 7PE, position controlled, and 1 x RigMaster, rate controlled (FMC Technologies / Schilling Robotics)
- Cameras: 2 x SD colour cameras Kongsberg OE14-366 MKII, 1 x Alpha Cam HD video (1080p50) & still camera (with lasers) (SubC Imaging), 1 x HD camera with IO Industries Flare 2K SDI camera head (running in 1080p25-mode, upgrade to 1080p50 soon) (designed by GEOMAR ROV Team), 4 x black & white observation cameras (Oktopus)
- Lighting: 2 DSPL (Deep-Sea Power & Light) HMIs (2 x 400 W), DSPL 2 HIDs (2 x 70 W), 8 x DSPL dimmable halogens Multi SeaLite (8 x 250 W), one LED / flash light AQUOREA LED (SubC Imaging)
- 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 several containers depending on the configuration and the capabilities of the supporting research vessels. The system weight in the 6000 m deep-sea configuration sums up to approximately 67 t. The mid-water configuration saves decks space during operation and sails with a total weight of approximately 50 t. When operated in the shallow-water configuration it uses only 4 containers and sails with a total weight of approx. 40 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 modular frame holding underneath a plate with dampers (Figure 1b). An auxiliary winch on the A-Frame is used to lift the ROV against 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 away from the vessel. The power- and data-carrying 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 onboard underwater navigation transponder will switch into battery mode enabling still the acoustic detection of the vehicle's position. In addition, a flasher system (Novatech) will start operating when the vehicle is shallower than 10 m water depth, 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.

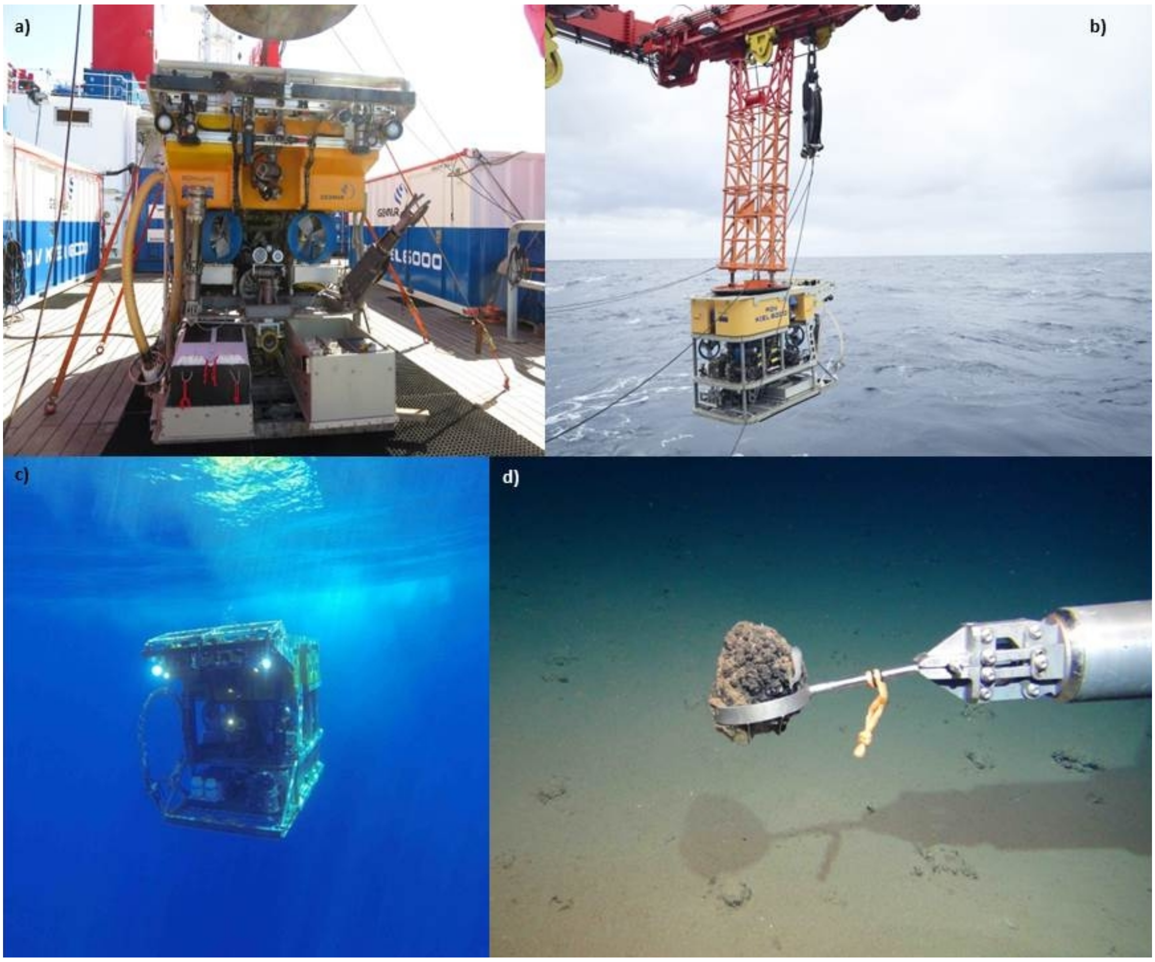

Figure 1: ROV KIEL 6000, a) front view of the vehicle on deck of RV "SONNE", b) deployed with A-frame and LARS, c) underwater, d) using the ORION manipulator to sample a manganese nodule. (Photos: a, c, d) GEOMAR ROV Team, b) Sven Sindt).

Winches and Cables: The major deep-sea winch of the ROV KIEL 6000 system holds 6500 m of 19 mm cable. Redundant electrical motors are mounted together with the cable drum and the respective electronics in one high-cube 20-foot container. The winch can be mounted on the working deck either parallel or perpendicular to the ships axis, with a custom pulley system providing the necessary cable feed. This increases the versatility of the system, allowing deployments even from narrow or crowded working decks. A power supply of 400 V with 350 A is required. The winch container has a weight of 30 t and is normally fixed with its own container twist-locks on deck of the ship. In operation, it is additionally strapped down with chains.

The midwater winch holds 2700 m of 19mm cable. This winch does not fit into a standard container pattern, thus needs to be bolted on the ships deck using special steel adapter plates. The power connection also requires 400 V but with only 180 A. The winch has a weight of 10.5 t and has to be transported as loose single freight or inside a container.
The cable on both the deep-water and mid-water winches is identical. It consists of a 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 glass fibers are used for ROV telemetry, the 3^{rd} fiber may be used for additional scientific data links (8-channel multiplex, 2 channels used for HD cameras). 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

1. The Control Van contains all surface control systems (SCU) where all data to and from the ROV are coordinated. Two pilot consoles with touchscreens are located in front of a set of monitors displaying all cameras, including the HD-SDI and observation cameras. One screen displays the sonar image, various control software (e.g. for the CTD and the AlphaC HD camera) and several "controlling" screens with ship's data, and VNC (Virtual Network Computing) with the recording screens for the SD cameras. An additional screen is used for navigation (OFOP, Ocean Floor Observation Protocol, developed by Prof. Dr. J. Greinert, GEOMAR), displaying a calibrated map with position of ship and ROV, respectively.
   One space behind the pilot seats is reserved for the scientist who is leading the station work. This scientist follows the dive on the screens and gives directions to the ROV pilots on where to go and what to do or sample. Another space with a dedicated protocol PC (using OFOP) is also available for the scientific watch-keeper to record observations and activities. In case integrated tools need to be operated from within the container, there are two more seats available in the rear of the container. These spaces are otherwise used for post-dive editing of the video footage and data.
2. The Power Van contains the power supply system (transforming ship's power to 4 kV) and a stocked workshop, offering storage of all necessary tools and most spares.
3. The Spares Container is used for transportation of the LARS, and several boxes with large and bulky spares (e.g. spare high voltage converter) as well as ROV tools, e.g. pushcores, handnets and other tools as well as accessories and respective mounts.
4. The Vehicle Container is used for transportation of the ROV itself, floats, consumables and a decks hydraulic unit
5. Winch Container description see above

Certification The system has a certificate from DNV-GL, all containers are tested according to the Container-Safety-Certification rules (CSC).

2.2 Sensors and Tools

2.2.1 Owned by and provided within the ROV KIEL 6000 system (on demand)

- CTD SBE 49 (Sea-Bird) real-time probe
- Sonar MS 1000 (Kongsberg) high resolution, forward looking
- USBL underwater navigation (standardly Ixsea Posidonia, see below)
- DVL Workhorse Navigator 1200 (for fine scale navigation)

- Cameras (see above)
- 2 manipulators (see above)
- Toolskid containing 2 hydraulically driven drawers in the front, adaptable to scientific demands of respective cruise (each 60 x 110 x 45 cm (B x L x H))
- Various sampling boxes, to be installed in or on the drawers
- 2 pallets in the aft section for custom configuration
- Pushcores, various setups possible
- Hand-nets
- Slurpgun (suction sampler) with 8 sampling containers (2.2 l each) (by KUM, Kiel)
- Hydraulic chain saw (constructed according to our demands, integrated into the ROV hydraulic system)
- Niskin bottles
- Bioboxes (biobarrels)
- Chisel
- Shovels and scoops, various
- Acoustic HOMER beacon markers (Sonardyne), rated for 4000 (4x) and 6000 m (2x)
- Elevator landers (2 different designs allowing the extension of scientific payload)

2.2.2 Owned by other departments or institutions, operated by ROV KIEL 6000

- KIPS (Kieler Insitu Pump System) (D. Garbe-Schönberg, University of Kiel)
- ISMS (In-Situ Mass Spectrometer) (S. Hourdez, Station Biologique, Roscoff)
- Hyperspectral camera (NTNU, Norway)
- Marker Dropper (AWI)
- MEGA Cam (MPI Bremen)
- Various sensors integrated into the ROV system e.g. CH_4 and CO_2 sensors (CONTROS), temperature probes etc.
- Stereocamera system (Tom Kwasnitschka, GEOMAR)
- Gas and fluid samplers
- Autonomous: e.g. benthic chambers, profilers, eddy correlation systems, DieFast, in situ autoclaves
- Bioboxes (square boxes with sliding lids)

2.3 Telemetry System and Navigation

Data transfer between the vehicle and the topside control van is managed by the digital telemetry system (DTS) which consists of two surface and four sub-sea nodes, each representing a 16-port module. Each port may be individually configured for serial (SIM; RS232/ RS485), video (VIM; SD) or network (NIM; Ethernet) purposes.

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. It 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 received, these can be converted by specialized frontends. The configuration of data logging is declared in advance such that 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, the navigation software OFOP is used. Coordinates and course/heading/speed data from the ship and 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.
Most German research vessels are equipped with an Ixsea Posidonia ultra short baseline (USBL) underwater navigation system. While using our ROV, the positioning system is set up in a so-called responder mode (internal trigger by the PosidoniaTM system). If Posidonia is not implemented on a particular vessel (e.g. RV "CELTIC EXPLORER"), mobile transponders of other underwater navigation systems may be mounted onto the ROV and incoming data transferred to the ROV's topside telemetric system (e.g. Sonardyne or Ore).

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 be made available to the scientists promptly. The telemetry files are packed and copied onto the server for public access and post-processing. After each dive, all data and protocols are transferred to the NAS (network attached storage) for public access and backup.

2.5 Video System

Standard cameras on the vehicle include two colour zoom SD cameras (Kongsberg OE14-366) on pan & tilt units, one 2k SDI Flare HD camera (presently running in 1080p25 mode, upgrade to 1080p50 is being developed) on a tilt unit, one SubC Alpha Cam digital still camera, which also provides HD video footage (1080p50) on the lower pan & tilt unit and four black and white observation cameras mounted in the front, on top and back of the ROV.
The footage of both HD cameras is recorded permanently or on demand with Apple computers (MacPro and MacMini) using the Tools-on-Air recording software Just:In.
The HD video footage is standardly recorded in high quality Apple ProResLT. Other formats or uncompressed recording is possible. The video is stored on a RAID-System with 32 TB storage.
Both SD cameras are permanently recorded on a VisualSoft DVR. The video is recorded in Mpeg format. 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 a NAS for public access and backup after each dive. The SubC Alpha digital still camera has a maximum resolution of 24.1 MPixel. Still images are taken on demand. In addition, high definition video footage may be recorded (see above). After each dive, still images are downloaded from the cameras with logo, date and time imprinted and images uploaded onto the NAS server. Images without imprint are available on request. At the home institute, all data (protocols, videos and still images) are uploaded onto the onshore ProxSys archiving system of GEOMAR.

Conclusions
Since it was put into operation, ROV KIEL 6000 has been deployed during 21 expeditions off 8 different research vessels in almost all world oceans. It has accomplished more than 250 dives, amounting to 1404 hours at the sea floor. Data sampled by ROV KIEL 6000 resulted in more than 55 publications so far.
The following is a short list of selected publications based on data sampled by ROV KIEL 6000. A complete list can be provided upon request.
For more details and images of the system, tools etc. please refer to our webpage:
http://www.geomar.de/en/centre/central-facilities/tlz/rovkiel6000/overview/.

References

Amon, D. J., Copley, J. T., Dahlgren, T. G., Horton, T., Kemp, K. M., Rogers, A. D., & Glover, A. G. (2017). Observations of fauna attending wood and bone deployments from two seamounts on the Southwest Indian Ridge. *Deep Sea Research Part II: Topical Studies in Oceanography*, *136*, 122 - 132. http://dx.doi.org/10.1016/j.dsr2.2015.07.003

Anderson, M. O., Hannington, M. D., Haase, K., Schwarz-Schampera, U., Augustin, N., McConachy, T. F., & Allen, K. (2016). Tectonic focusing of voluminous basaltic eruptions in magma-deficient backarc rifts. *Earth and Planetary Science Letters*, *440*, 43 - 55. http://dx.doi.org/10.1016/j.epsl.2016.02.002

Chen, C., Copley, J. T., Linse, K., & Rogers, A. D. (2015). Low connectivity between 'scaly-foot gastropod' (Mollusca: Peltospiridae) populations at hydrothermal vents on the Southwest Indian Ridge and the Central Indian Ridge. *Organisms Diversity & Evolution*, *15*(4), 663–670. http://dx.doi.org/10.1007/s13127-015-0224-8

Lehmenhecker, S., & Wulff, T. (2012). ROV-based Revolver Marker Dropper for Consistent Seafloor Surveying. *Sea Technology*, *53*(7), 33-35.

McGinnis, D. F., Sommer, S., Lorke, A., Glud, R. N., & Linke, P. (2014). Quantifying tidally driven benthic oxygen exchange across permeable sediments: An aquatic eddy correlation study. *Journal of Geophysical Research: Oceans*, *119*(10), 6918–6932. http://dx.doi.org/10.1002/2014JC010303

Perner, M., Hentscher, M., Rychlik, N., Seifert, R., Strauss, H., & Bach, W. (2011). Driving forces behind the biotope structures in two low-temperature hydrothermal venting sites on the southern Mid-Atlantic Ridge. *Environmental Microbiology Reports*, *3*(6), 727–737. http://dx.doi.org/10.1111/j.1758-2229.2011.00291.x

Perner, M., Petersen, J. M., Zielinski, F., Gennerich, H.-H., & Seifert, R. (2010). Geochemical constraints on the diversity and activity of H_2-oxidizing microorganisms in diffuse hydrothermal fluids from a basalt- and an ultramafic-hosted vent. *FEMS Microbiology Ecology*, *74*(1), 55–71. http://dx.doi.org/10.1111/j.1574-6941.2010.00940.x

Rovelli, L. (2014). *Physical and geochemical controls on oxygen dynamics at continental margins and shelf seas* (Doktorarbeit/PhD, Christian-Albrechts-Universität zu Kiel). Retrieved from http://oceanrep.geomar.de/23940/

Schmidt, K., Garbe-Schönberg, D., Hannington, M. D., Anderson, M. O., Bühring, B., Haase, K., … Koschinsky, A. (2017). Boiling vapour-type fluids from the nifonea vent field (new hebrides back-arc, vanuatu, sw pacific): Geochemistry of an early-stage, post-eruptive hydrothermal system. *Geochimica et Cosmochimica Acta*, *207*, 185 - 209. http://dx.doi.org/10.1016/j.gca.2017.03.016

von Deimling, J. S., Rehder, G., Greinert, J., McGinnnis, D., Boetius, A., & Linke, P. (2011). Quantification of seep-related methane gas emissions at Tommeliten, North Sea. *Continental Shelf Research*, *31*(7), 867 - 878. http://dx.doi.org/10.1016/j.csr.2011.02.012