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Autonomous Underwater Vehicle „ABYSS“

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Abstract: The Autonomous Underwater Vehicle (AUV) „ABYSS“ is a modular AUV designed to survey the ocean combining geophysical studies of the seafloor with oceanographic investigations of the overlying water column. The basic mission of ABYSS is deep-sea exploration, specifically in volcanically and tectonically active parts, such as mid-ocean ridges. With a maximum mission depth of 6000 meters, the AUV uses several technologies to map the seafloor accurately and determine its geological structure with applications from geology to biology to mineral exploration.

1 Introduction

The AUV ABYSS was built in 2008 by the US company HYDROID and was funded by the German Research Foundation. The torpedo-shaped autonomous underwater vehicle maps areas of the seafloor in high resolution using its various sonars (Haase et al., 2009; Hensen et al., 2015; Speckbacher et al., 2011, 2012; Yeo et al., 2016). Additionally, it can collect data from the water column with its physical sensors (Tippenhauer et al., 2015).

The name refers to the Abyssal, which is the term used to describe the ocean floor between depths of 2000 to 6000 meters. In this water depth, the AUV ABYSS glides close to the ocean floor with a speed of up to four knots while autonomously avoiding obstacles. It can be deployed from all middle to large research vessels (Figure 1) and uses a specially designed Launch and Recovery System (LARS) for lowering it off the side or stern of a vessel.

Before each use, a scientist programs the autonomous vehicle with a destination, course and research task. Each dive takes up to 20 hours and then the AUV ABYSS surfaces alone and is brought on board, the lithium batteries are charged for the next dive and the data is downloaded. The data is used to create three-dimensional, high-resolution maps of the seafloor. Using information from the maps allows

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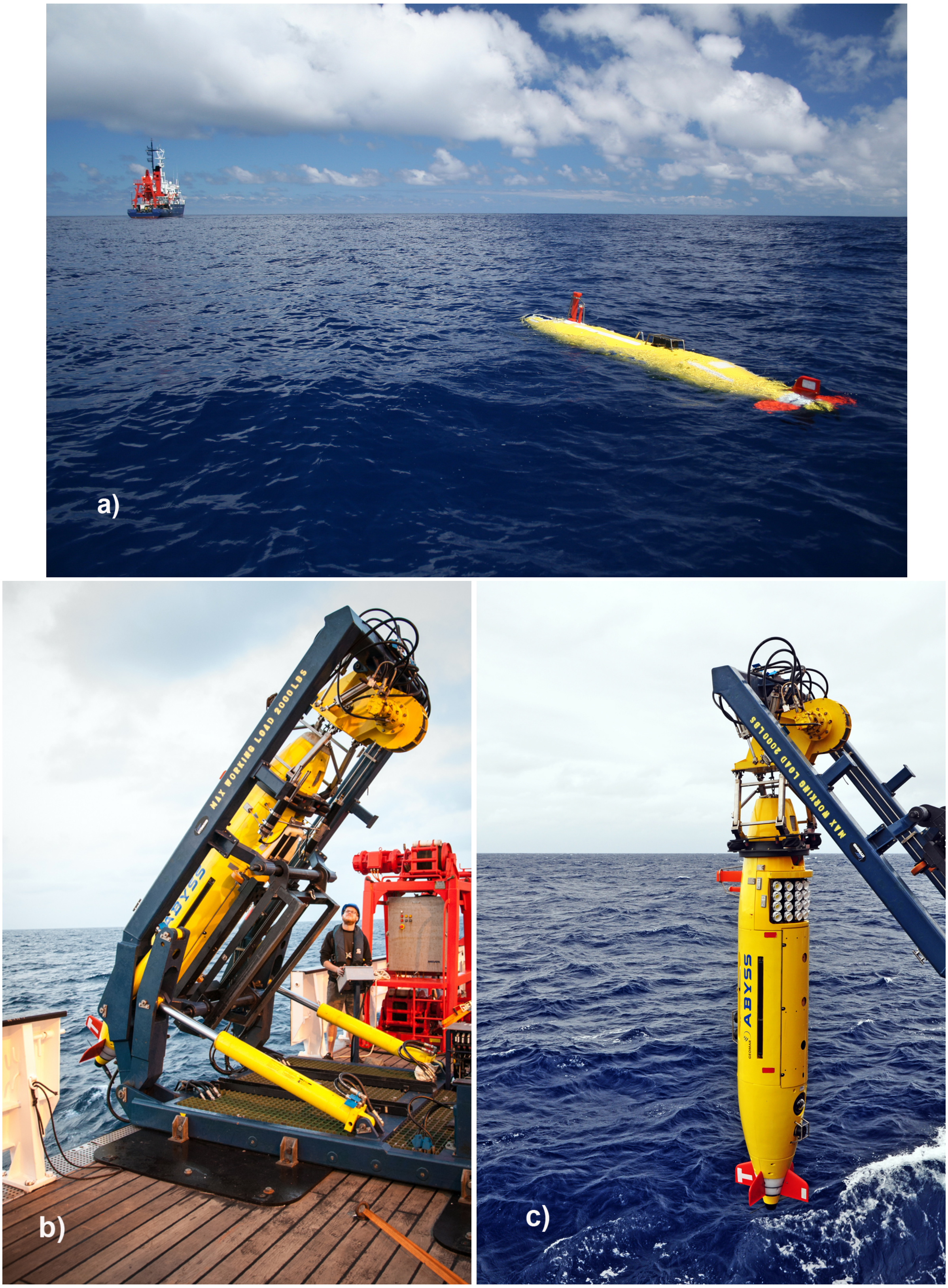

Figure 1: AUV “ABYSS“, a) at the sea surface approaching the German research vessel “POSEIDON” for recovery, b) deployed with its launch and recovery system, c) novel LED flash system in the front and the camera behind a dome port in the tail section of the vehicle.

scientists to recognize, for example, volcanoes on the seafloor or ore deposits.

2 Technical data

2.1 AUV „ABYSS“

- Owner and Operator: GEOMAR Helmholtz Centre for Ocean Research Kiel, Year: 2008
- Dimensions: Length 3.98 m, diameter 0.66 m
- Weight in air: 880 kg
- Max. depth: 6000 m
- Speed: up to 4 knots, operating time: up to 20 hrs
- Energy and Power: 11 kWh lithium-ion batteries (12 hrs charging time)
- Max range: Up to 100 km
- Standard sensors: SBE 49 CTD, fluorometer and turbidity sensor, side scan sonar 120/410 kHz multibeam echosounder 200/400 kHz
- Optional sensors: 20.2 Megapixel electronic still camera (Canon 6D) with 15 mm fish-eye lens and a cluster of 24 LED arrays with 5600 K color temperature and 4 Hz maximum operating frequency (Kwasnitschka et al., 2016), sub-bottom profiler (4-24 kHz), eH sensor (by Dr. K. Nakamura, AIST, Japan), microstructure sensor
- LARS (Launch and Recovery System) with a hydraulically operated A-frame.
- Transport: Two 20-foot containers

The ABYSS system comprises the AUV itself, a control and workshop container, and a mobile Launch and Recovery System (LARS) with a deployment frame which can be installed on the afterdeck or starboard and port side. The self-contained LARS was developed to support ship-based operations so that no Zodiac is required to launch and recover the AUV. The LARS is mounted on steel plates which are screwed on the deck of the ship. The LARS is configured in a way that the AUV can also be deployed over the port or starboard side of the German medium and big size research vessels. The LARS is stored in a 20ft. container during transport.

In general, we can deploy and recover the AUV at weather conditions with a swell up to 2.5 m and wind speeds of up to 6 beaufort. For recovery the nose float pops off when triggered through an acoustic command. The float and the ca. 25 m long recovery line drift away from the vehicle so that a grappel hook can snag the line. The line is then connected to the LARS winch, and the vehicle is pulled up.

The vehicle consists of a tapered forward section, a cylindrical midsection and a tapered tail section. An internal titanium strongback, which extends much of the vehicle length, provides the structural integrity and a mounting platform for syntactic foam, equipment housings, sensors and release mechanisms. The maximum vehicle diameter is 0.7 meters and the overall length is 3.95 meters. Vehicle weight is, depending on the payload, approximately 850 kilograms. A rectangular compartment in the midsection of the vehicle contains three pressure housings and an oil-filled junction box. Two of the pressure housings contain each one 5.75 kWhr 29-Volt lithium-ion battery pack. The third pressure housing contains the vehicle and sidescan sonar electronics. The vehicle's Inertial Navigation System (INS) and Acoustic Doppler Current Profiler (ADCP) are housed in two other independent housings that are mounted forward of the 3 main pressure housings. The propulsion and control systems are located in the tail assembly, which bolts to the aft face of the vehicle's strongback. The tail assembly consists of a pressure housing with motor controller electronics, and an oil-compensated motor housing. Propulsion is generated with a 24 VDC brushless motor driving a two-bladed propeller. Control is achieved with horizontal and vertical fins driven by 24 VDC brushless gear motors. The vehicle velocity range is .25 to 2.0 m/s, although best control is achieved at velocities above 1.0 m/s. The AUV dives descent with about 1 m/s whereas the ascent time is about 0.7 m/s or 1m/s if the ascent weight is dropped. Together with the deployment/recovery procedure the descent to the seafloor and the ascent back to the vessel takes about 3 hours at a water depth of 3500 m. Based on the sensor configuration in use the dive time varies between 16 and 20 hours. After a full dive the batteries have to be recharged which needs approximately 12-14 hours.

2.2 Sensors

Sensors of the base vehicle include a sidescan sonar; pressure, temperature, conductivity, optical backscatter and eH-sensor; and an inertial navigation system that is aided by an ADCP with bottom track capabilities. In addition, the vehicle can be reconfigured for three different modes of operation as follows:

1. Base vehicle plus RESON Seabat 7125 Multibeam echososunder, or
2. Base vehicle plus Electronic Still Camera & LED Flash System, or
3. Base vehicle plus EdgeTech Dual Frequency Side Scan Sonar and Sub-Bottom Profiler.

All sensor information collected by the vehicle is marked with time, depth and latitude, and longitude as it is collected, facilitating the rapid and highly automated generation of maps and HTML based reports. An acoustic communication system permits the vehicle to send status messages to the surface ship containing information about the vehicle's health, its location, and some sensor data while it is performing a mission at up to 6 km below the sea surface. The acoustic communication system is also used to send data and redirection commands to the vehicle. The AUV utilizes electronics, control software, and the laptop based operator interface software from the already successful REMUS 100 vehicle system.

The vehicle navigates autonomously using a combination of navigation methods which depend on the mission objectives, conditions, and optional equipment enabled.

- **GPS** - Works only on the surface, GPS determines the vehicle's location on Earth. GPS determines the "initial position" before the vehicle submerges, and verifies or corrects the vehicle's position when it surfaces during the mission. GPS also plays a critical role during INS alignment.
- **Inertial Navigation System (INS)** - After alignment on the surface, INS continuously integrates acceleration in 3 axes to calculate the vehicle's position. It uses input from the DVL and the GPS to maintain its alignment.
- **Doppler Velocity Log (DVL)** - Continuously measures altitude and speed over ground whenever the vehicle can maintain bottom-lock. The DVL receives temperature and salinity data from the CT Probe to calculate sound speed. The DVL must be within range of the bottom to measure altitude and provide bottom-track for the INS.
- **Long Baseline Acoustic Navigation (LBL)** - The vehicle navigates using Long Baseline (LBL) navigation by computing its range to a two (or more) moored acoustic transponder array covering the area of each mission. The deployment and calibration of each transponder takes approximately 2-3 hours at a waterdepth of 3000 m.

2.3 Vehicle Interface Program (VIP)

A Vehicle Interface Program (VIP), a Windows program that manages every aspect of AUV operation, including the following tasks:

- Mission planning on electronic navigation charts (customizable, multi-format).
- Real-time mission monitoring through the acoustic modem
- Real-time support-vessel position and heading through GPS and compass feeds.
- Pre-mission system checkout.
- Post-mission data analysis, mission play-back, and sidescan review.

Navigation charts show missions during planning, operation, and review. A graphic mission planner lets users build mission files using drag-and-drop to position waypoints and mission objectives on the chart window, and fine-tune missions using editable text fields. Automatic error checking verifies all aspects of planned missions, and warns operators if any mission parameters are incorrect. Communication between the vehicle and the computer runs through a standard Ethernet connection, or wirelessly, using the WiFi connection. The vehicle interface program (VIP) provides a convenient means of mission planning and programming.

3 Conclusions

Since its first deployment in 2009, the vehicle has proven to be a true work horse. At the end of year 2015, the AUV has accomplished a total of 219 dives with 2492 hrs under water on 18 expeditions and covered 13,000 km in mapping the seafloor.

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