Cruise Report ALKOR AL391B (Test AUV TIETEK)

May 4th, 2012 (Kiel) to May 10th, 2012 (Kiel)

Test cruise for AUV "TIETEK" in the southwestern Baltic Sea

Edited by K.S. Lackschewitz

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1 Scientific Party & Crew

Scientific Party

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Ehrhardt, Michael	Fraunhofer Gesellschaft
Degel, Christian	Fraunhofer Gesellschaft
Kleffner, Bernhard	Fraunhofer Gesellschaft
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Rauschenbach, Thomas	Fraunhofer Gesellschaft
Reinecke, Andre	Fraunhofer Gesellschaft
Renkewitz, Helge	Fraunhofer Gesellschaft
Schmieger, Marc	Fraunhofer Gesellschaft
Woock, Philipp	Fraunhofer Gesellschaft

Crew

Hechler, Nobert	Captain
Nannen, Rainer	1st mate
Thürsam, Dirk	2nd mate
Mairon, Jürgen	First engineer
Stöck, Jürgen	Electrician
Falk, Volkhard	Cook
Schwieger, Hardy	Bosun
Wilga, Hans-Joachim	Seaman
Delachaux-Dit-Gay, Lucien	Ship mechanic
Riedel, Kai	Ship mechanic
Nunes Rajao, Jose	Seaman

2 Introduction

The 391st cruise of the research vessel ALKOR had purely technical aims, testing the newly-developed, Autonomous Underwater Vehicle (AUV) by the Fraunhofer Gesellschaft. The vehicle was funded by the Fraunhofer Gesellschaft MAVO-Program “Deep Sea Inspection and Exploration-Technology Concept”.

Maritime technologies will play an important economic and scientific role in the deep sea. With the general rise in raw material procurement costs will increase the importance of deep-sea deposits. Their development requires the exploration and surveying (mapping) and their operation requires a regular monitoring (inspection). The same applies to transport of raw materials to lines and cable for information and energy transfer. The study of flora and fauna and the geological structures of the oceans, especially under the influence of climate changes on earth, also requires the use of suitable deep sea autonomous underwater vehicles. The technologies needed for exploration and inspection especially in the deep sea are not yet developed enough and too expensive. Up to this point are only a few highly specialized, very expensive underwater vehicles available, although many tasks are automatically executable routine activities. It lacks cost-effective modular systems that can be adapted to the tasks to be solved. Especially lacking efficient energy storage, high-resolution sensors, effective method for evaluating the sensor data and control systems for a wide range of responsibilities of future underwater vehicles.

The aim of the MAVO project is to provide technologies for the development of pressure-neutral and therefore more cost-effective, modular AUVs for use in the deep sea to reduce the above deficits. Pressure neutrality means that all functional units (computers, sensors, energy storage device, drives) to the prevailing ambient pressure are directly exposed and no pressure resistant hull consists. Intelligent multi-sensor imaging and ultrasonic sensors, which provide information are fused, the AUV for inspection and exploration abilities. The developed new technologies to be integrated in a demonstrator that will be used as a test and acquisition platform. With the MAVO TIETeK the technological leadership will be sought in the field of development of modular, autonomous underwater vehicles for exploration and inspection tasks. The results for the achievement of the ambitious project goals per required innovation from many years experience of partners in the development and implementation of industrial components for underwater vehicles, and inspection systems.

Based on targeted strategic investment measures in advance of the complainants was an infrastructure (chamber pressure, sensor test basin, two underwater vehicles, vehicle testing pool) created that fosters the success of the project MAVO TIETeK much. The consortium now has a unique base in Germany for the proposed project, which will increase the leverage of the already made significant strategic investments.

For testing purposes working areas in the region of the Arkona Basin and the Tromper Wiek in the southwestern Baltic Sea were chosen that span water depths between 20m to 45m (Fig. 1).

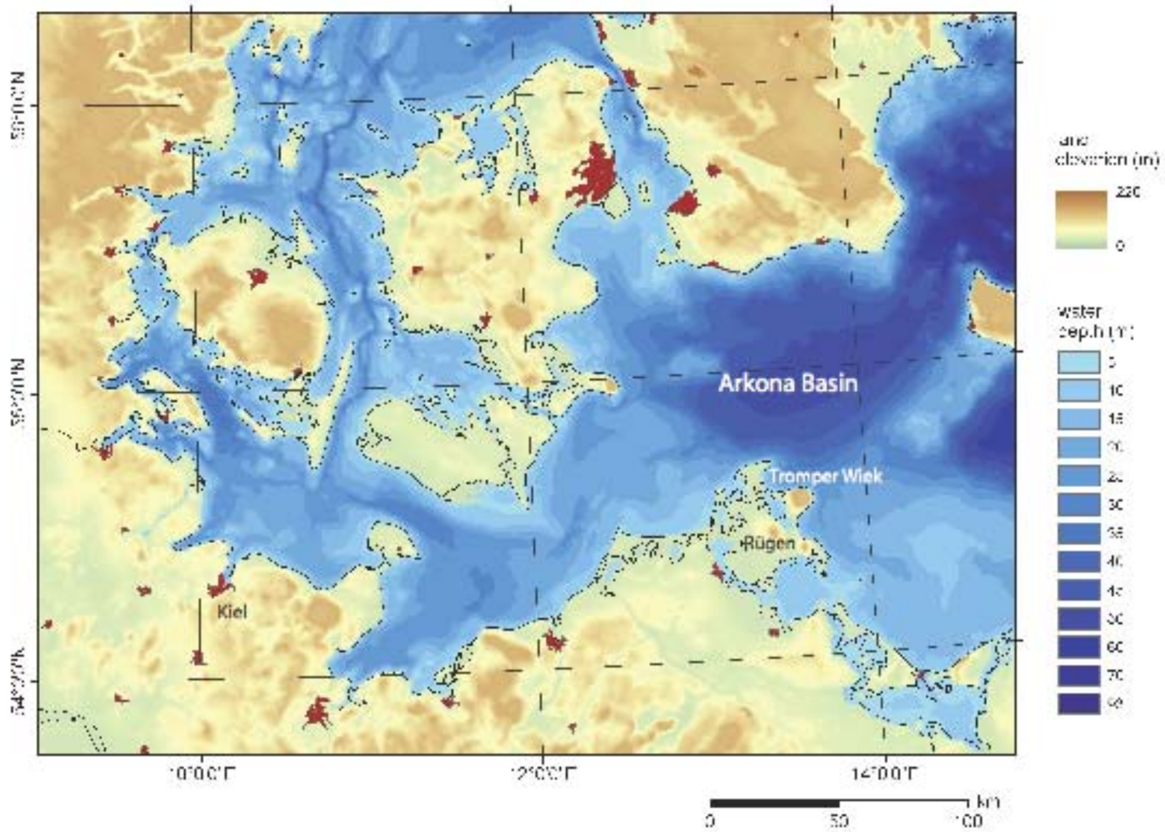


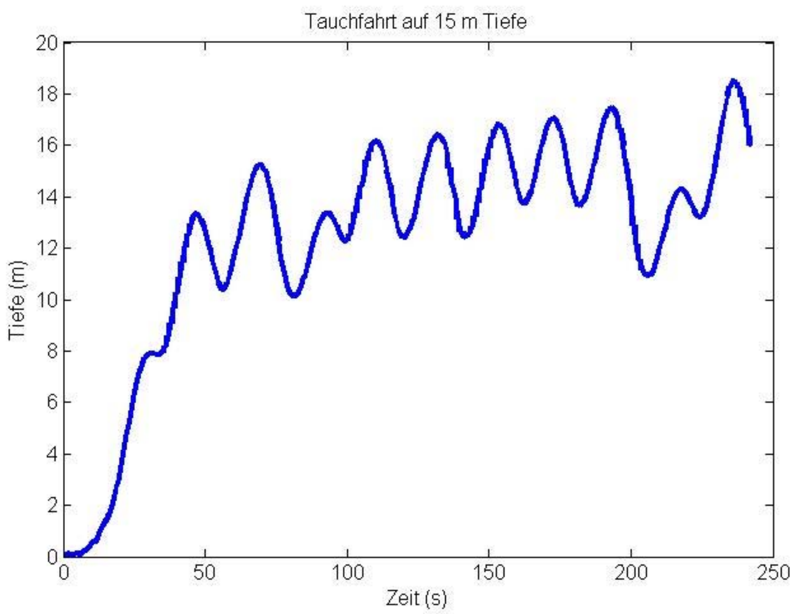
Fig. 1: Location of the shallow-water test area in the Arkona Basin and Tromper Wiek, southwestern Baltic Sea.

3 Cruise Narrative and Event List

The *ALKOR* left Kiel at 9:00 on 04.05.2012 and took course to the working area in the Arkona Basin around 54°51´N/13°43´E. The area has about 45m water depth rising to 20m. As the trimming of the AUV was the first aim work was begun already during the transit. Two deployments during the daylight hours were carried out as listed in the event table. On 05.05.12 another trim test took place in the Tromper Wiek at 54°38.58'N and 13°27.74'E. Shallow-water tests (ca. 20m water depth) were carried out for the remainder of the cruise in order to test system integrity and sensor functionality. *ALKOR* left the working area on May 9th and sailed back to Kiel where she arrived in the early morning of May 10th. The container was unloaded shortly after the arrival and the scientists left Kiel in the early afternoon of May 10th.

Event list for AL391B

Day	Time (LT)	Plan	Result
04.05.12	09:00	Leave harbour of Kiel	
	16:00	Stop during transit at 27°57´N/14°39´W for two AUV trim tests	
05.05.12	0:00	Arriving the working area at the Arkona Basin at 54°51,76'N 013°43,62'E.	
05.05.12	08:00 08:13	Start trim test Stop trim test	trim is wrong, vehicle is too heavy
	8:45	Transit to the Tromper Wiek at 54°38.58'N 013°27,74'E	
	15:44 15:52	Start trim test Stop trim test	Trim testing completed
06.05.12	11:02	**Test deployment 01**; deploy vehicle for several missions at the surface to test the control system at different engine speeds and the data recording of the different sensors. The AUV completed several straight-ahead and oscillation runs. Instruments used: Sidescan sonar, pressure sensor, DVL, GPS	Vehicle runs at different engine power. At full power (600W) the vehicle starts to dive with an angle up to 60° because of a wrong trim in the front. The vehicle has touched the bottom two times at 20m waterdepth. All sensors have recorded data.
	12:24	Recover vehicle, begin data processing	Successful.
07.05.12	08:50 09:10	Start fine trim test Stop fine trim test	trim seems correct
07.05.12	14:45	**Test deployment 02**; deploy vehicle for several missions at the surface to test the manual control with WLAN, to perform the	The vehicle has performed several runs with preset courses autonomously. There have been three uncontroled dives with the

Day	Time (LT)	Plan	Result
		directional control, to test the depth control. The course and depth control while driving various control parameters were tested.	target depth. The vehicle descends only if somebody is pushing down the bow while it accelerates. By a change of trim, the behavior can be improved. After analyzing the log files, the controller parameters are adjusted and tested during the next runs..
	16:55	Recover vehicle	Succesfull
	18:30 18:45	Start fine trim test Stop fine trim test	After the removal of a piece of foam the trim seems now correct
08.05.12	10:00	**Test dive 01**; deploy the vehicle for diving tests; at first the software update for the bow rudder control was tested; perform surface runs by given course and velocity for different time scales (90s and 180s); perform dives with depth and course control (5m waterdepths for 60s, 8m waterdepth for 90s, 10m waterdepths for 180s and 15m waterdepth for 240s) <u>Instruments used:</u> Sidescan sonar, pressure sensor, DVL, GPS, IMU, TRM (Pencil beam)	Bow rudder works correct and the vehicle dives autonomously to the preset depth..
	11:20	Recover vehicle	Succesful
		 *AUV mission depth profile lines for test dive 01 at 15m*	

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<tr><th>Day</th><th>Time (LT)</th><th>Plan</th><th>Result</th></tr>
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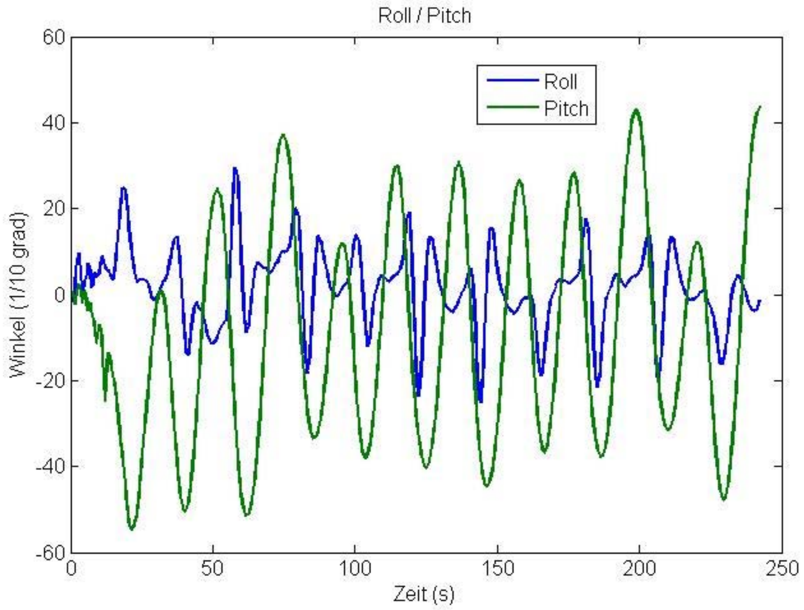

AUV pitch and roll during test dive 01 at 15m
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<tr><td>08.05.12</td><td>17:45</td><td>Test dive 02; deploy the vehicle for several dive missions without the tail rudder which is defect; software was updated for diving only with the bow rudder; run 10 dives in 8 m waterdepth; vary control parameter for course, depth and pitch;</td><td>Improving of the control parameter; vehicle touches the bottom (at 20m) each dive because of the lack of the tail rudder.</td></tr>
<tr><td></td><td>20:00</td><td>Recover vehicle</td><td>Succesful</td></tr>
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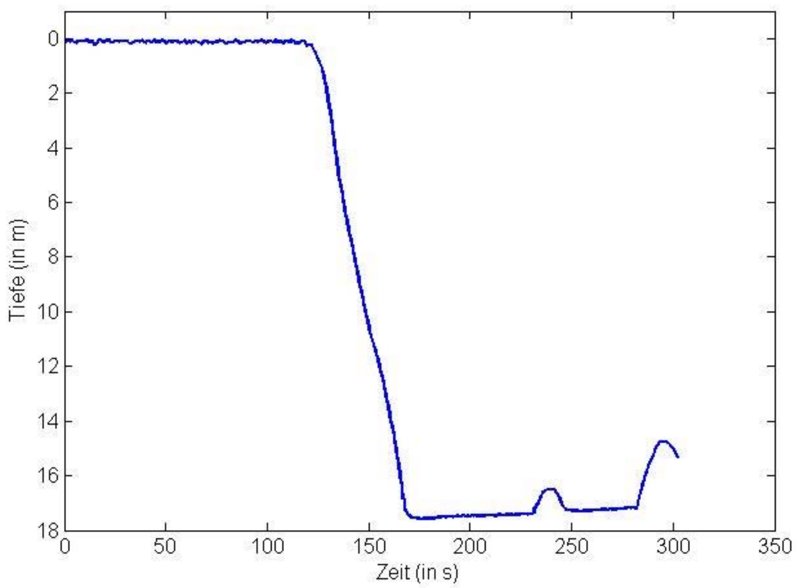

Diving profile during descent test dive 02; vehicle touch the bottom two times.
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Day	Time (LT)	Plan	Result
09.05.12	12:15	**Test dive 03**: deploy the vehicle for several dive missions without the tail rudder which is defect; realization of the experimental design to determine the controller parameters for vehicle without tail rudder; perform 9 dives with different control parameters.	Each reached the given water-depth of 9m; however, the bow rudder can't compensate the miss of the tail rudder.
	15:10	Recover vehicle	succesful
	15:30	Leaving Tromper Wiek; heading for Kiel.	
10.05.12	8:00	Arriving at Kiel	End of cruise

4 AUV Functions and Capabilities

The AUV TIETEK was designed and built by the Fraunhofer-Institut für Biomedizinische Technik (IBMT), Fraunhofer Institut für Optronik, Systemtechnik und Bildauswertung (IOSB), Fraunhofer IOSB-Anwendungszentrum Systemtechnik (AST), Fraunhofer-Institut für Umwelt-, Sicherheits- und Energietechnik (UMSICHT) und Fraunhofer-Institut für Siliziumtechnologie (ISIT).

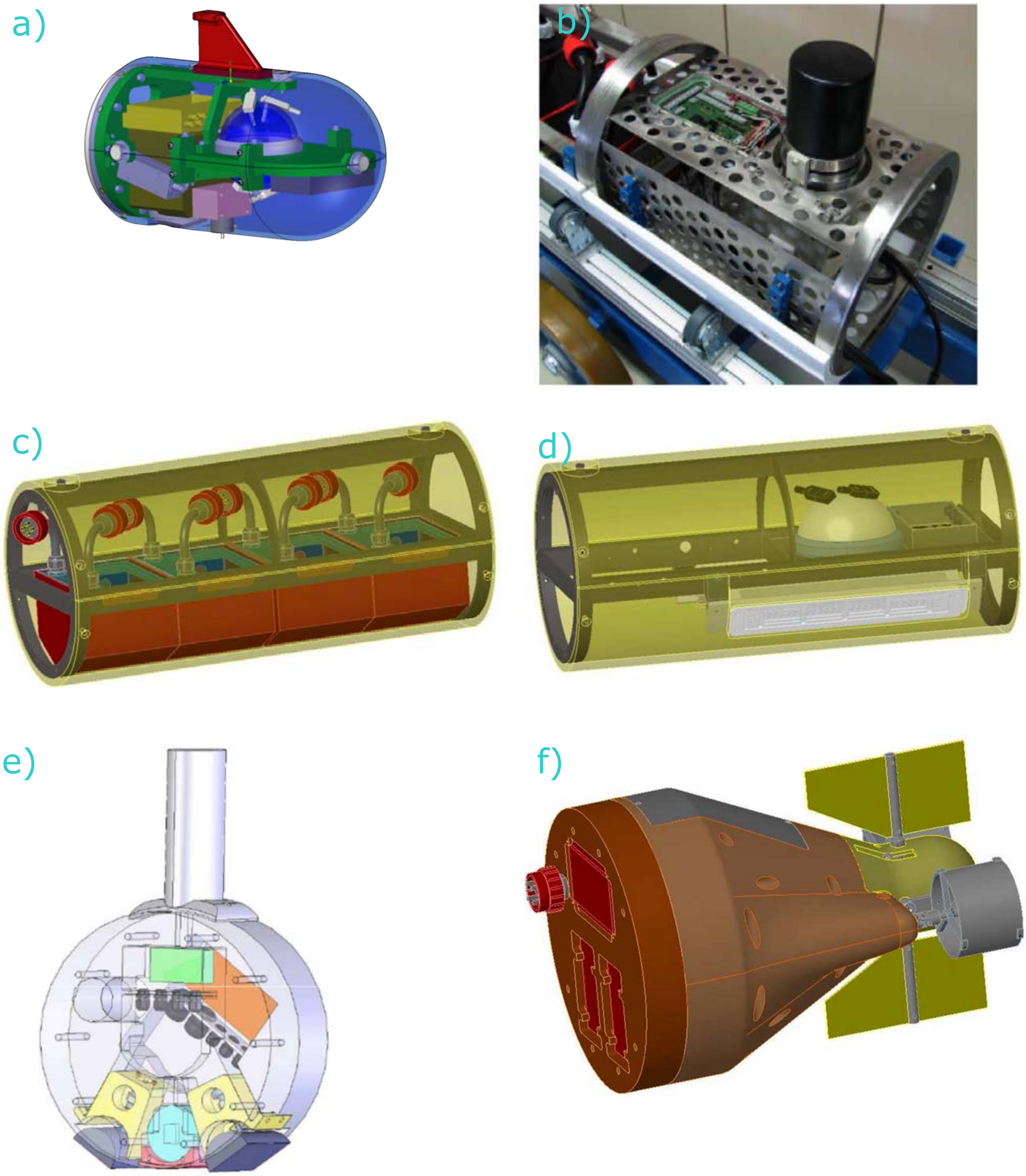

Fig. 2: Modules of AUV TIETEK. a) forward module, b) communication module, c) battery module d) sensor module, e) emergency module f) tail module.

The vehicle consists of a forward modul, a communication modul, a battery modul, a sensor modul, an emergency modul and a tail modul.
The foreward module contains the management computer, the Doppler velocity log (DVL), the pressure sensor, the inertial measurement unit (IMU), pencil beam, descent weight, WLAN and GPS (Fig. 2a). During a mission, the user interface software is in continous communication with the vehicle via the acoustic modem from Evologics which incorporated in the communication modul (fig. 2b). The battery module carries 4 battery housing each with 7 cells of Li-ion batteries. The cell voltage is 3,7 V and the capacity of each cell is 20,6 Ah (Fig. 2c). The sensor module contains a sidescan system with frequencies of 250kHz, 500Khz and 1 Mhz and a video camera (Fig. 2d). The emergency module consists of an Argos transmitter, a VHF transmitter and a drop weight (Fig. 2e). The oil-compensated propulsion and control systems are located in the tail module (Fig. 2f).

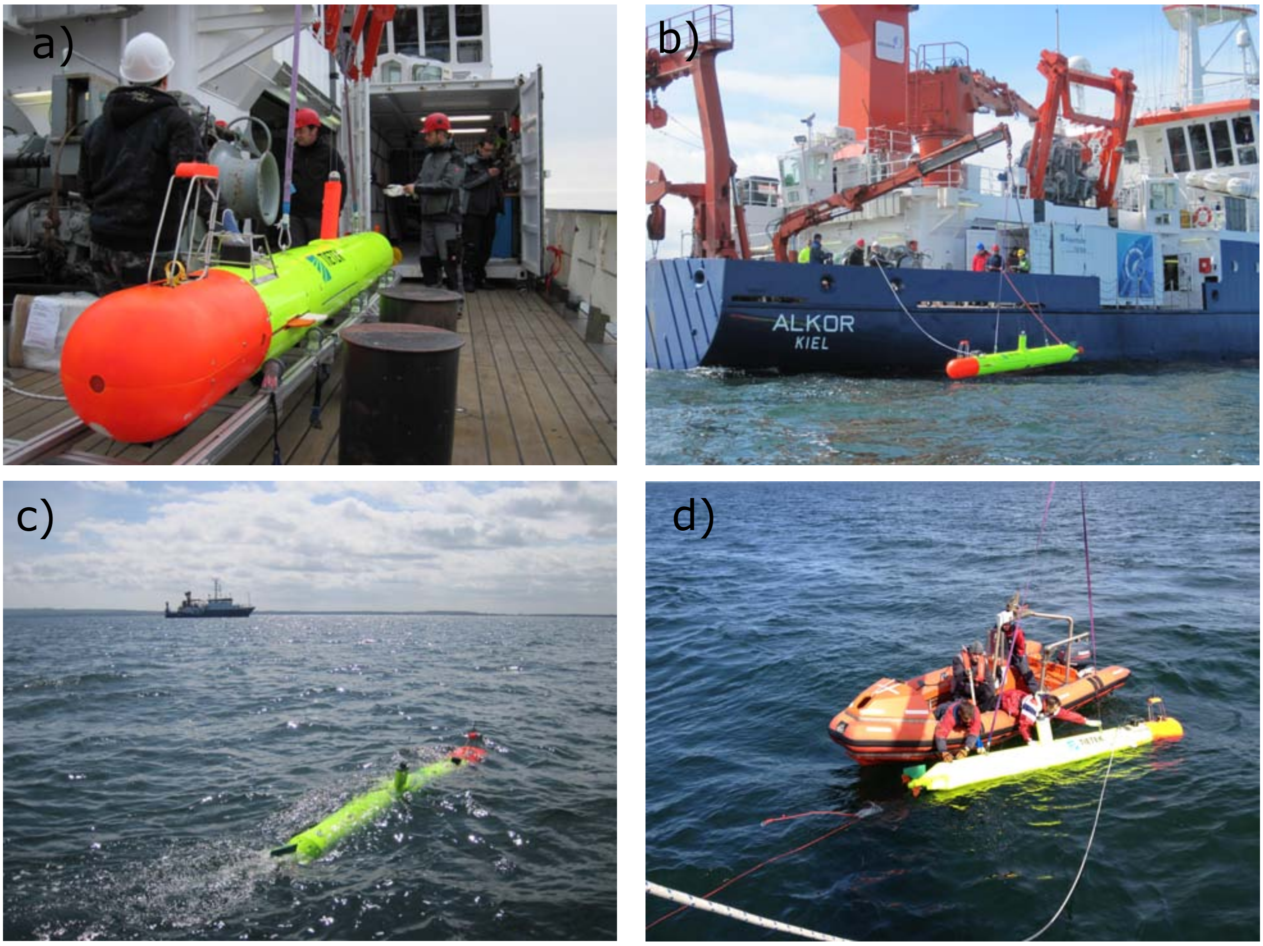

Fig. 3: AUV TIETEK operations. a) AUV shortly before launch, b) AUV is being launched, c) AUV during the test mission with RV ALKOR in the background d) The zodiac had to be used for launch and recovery of the vehicle.

The AUV TIETEK is equipped with two different wireless systems for communication with the operator when on the surface:

• WLAN networking: This system is optimized for short range, in-water communications. It will often eliminate the need to recover the vehicle between missions. Typically, ranges between the ship and vehicle of 1000 meters are achieved.

• Radio connection: XBee-PRO® 868 Long-range RF connectivity for European applications

Long-range RF connectivity for European applications

Sensors of the base vehicle include a sidescan sonar and a video camera. 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 data profiles. 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. 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.

The vehicle navigates autonomously using a combination of navigation methods, depending 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 (Xsens) - 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 must be within range of the bottom to measure altitude and provide bottom-lock for the INS.

A Vehicle Interface software, a LINUX and Windows®-based program (Fig. 5) manages every aspects 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 (from the AUV control container)
- Pre-mission system checkout
- Post-mission data analysis, mission play-back, and side-scan review

The vehicle interface program (VIP) provides a convenient means of mission planning and programming.

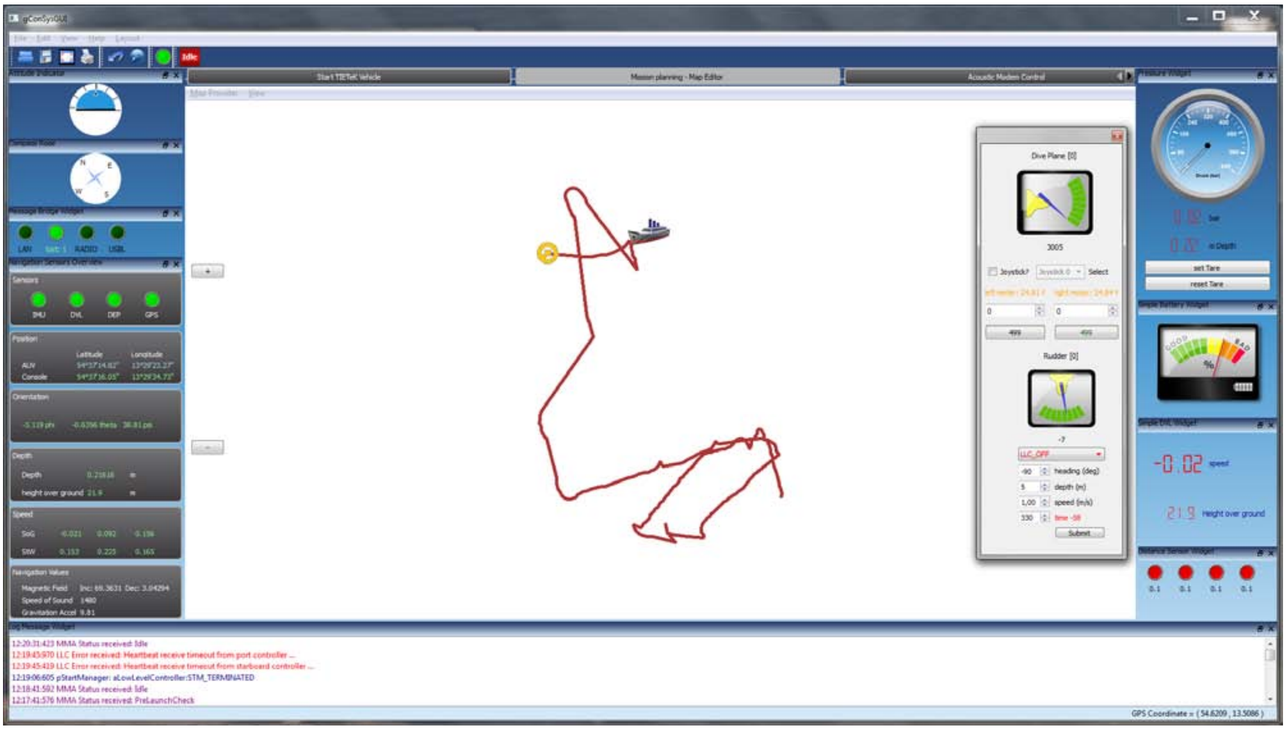

Fig. 4: Screenshot of the LINUX- and Windows®-based vehicle interface program software handling the AUV operations.

5 Acknowledgments

The AUV-team thanks the officers and crew of RV ALKOR for their help, advice and the friendly working environment during the test cruise. The entire scientific team thank the Fraunhofer Gesellschaft for providing the funds to design and built the AUV “TIETEK”.