Bauman Moscow State Technical University
Moscow, Russia
Explorer class

Technical Report
2010 MATE International ROV Competition

ROV "AKVATOR"
AKVATOR BMSTU

Team members

Stanislav Kozlov – 5 course student, capitan
Boris Hvostov – 4 course student
Dmitry Garbuzov – 6 course student
Ekaterina Arefyeva – 5 course student
Eugenia Kalinina – 6 course student
Galina Kuimova – 5 course student
Ilya Popov – 4 course student
Ivan Semin – 5 course student
Margarita Shalagina – 5 course student
Mikhail Sherbina – 6 course student
Pavel Nektorov – 5 course student
Valentin Myshkovsky – 5 course student

Team mentor

Stanislav Severov, PhD, Professor of Bauman Moscow State Technical University

Table of Contents

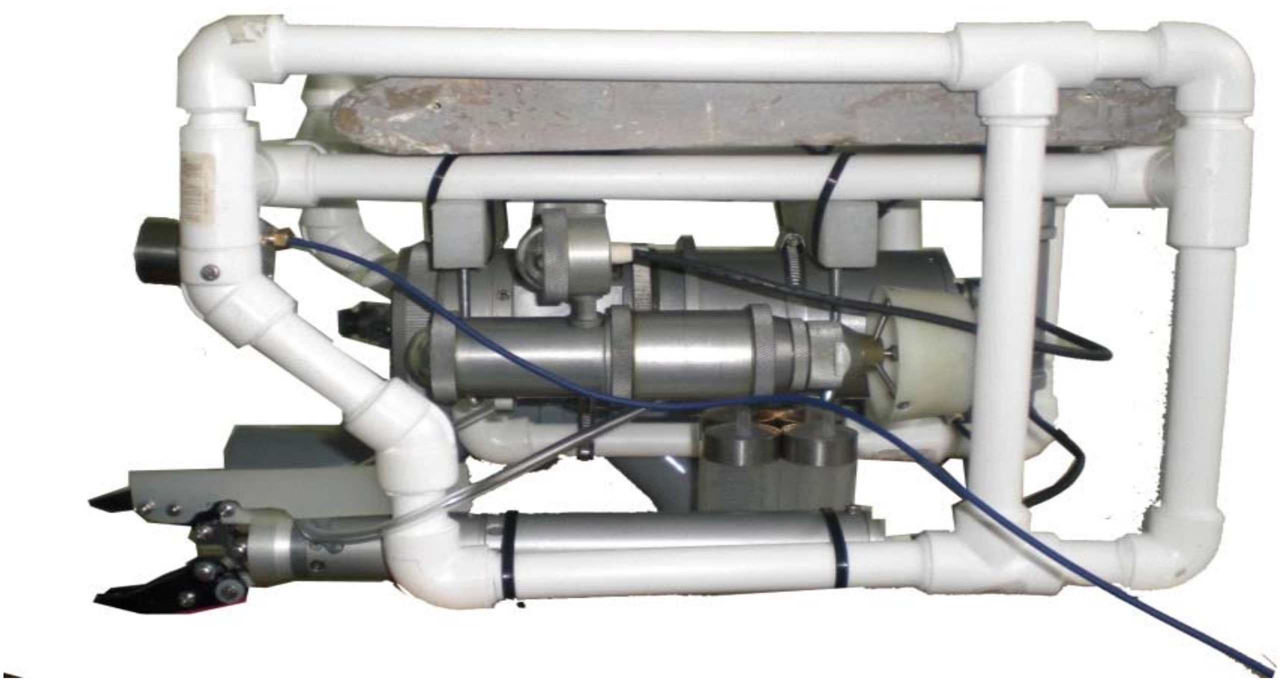
Abbreviations .... Error! Bookmark not defined.
Abstract 4
Design rationale 6
Project essence 7
Frame construction 7
Frame construction .... Error! Bookmark not defined.
ROV systems 8
Propulsion system 8
Video system 8
Sensor system 8
Tether 10
Control system 10
Devices for the competition missions performance 12
Task #1: Resurrect HUGO 12
Task #2: Collect samples of a new species of crustacean 12
Task #3: Sample a new vent site 13
Task #4: Collect a sample of a bacterial mat 13
Troubleshooting technique 14
Payload of the vehicle 14
Future Improvement 14
Obtained knowledge and skills 14
Technical skills 14
Organizational skills 15
Lessons gained 15
Loihi seamount 15
Acknowledgements 19
References 19

Abbreviations

APC – Active Propelling Complex
BMSTU – Bauman Moscow State Technical University
CAD – Computer-aided design
DC – direct current
FEBRAS – Far Eastern Branch of the Russian Academy of sciences
MATEC – Marine Advanced Technology Education Center
PAP – Package of Applied Programs
ROV – Remotely Operated Vehicle

Abstract

The report describes ROV "AKVATOR" created by the student team "Hydronautic ROV" to perform the missions of International Competition MATEC-2010. The ROV chassis base is a polypropylene frame. The pressure hull and the propulsion system are attached to it. The propulsion system is based on 8 thrusters of MAXON company (Switzerland). Quantity of thrusters and their mounting arrangement give an opportunity to control the ROV at all 6 degrees of freedom. Such a maneuverability is connected with small dimensions of the vehicle and unability of installation of a complicated (heavy) manipulation complex. Taking into account the vehicle maneuverability, a one- (two) degree-of-freedom manipulator and special extra equipment (for 4th mission performance - described below) are enough to accomplish all the missions of MATEC-2010. The control system provides vehicle handling both in manual and semiautomantic (with one or several coordinate fixation) modes. The video system consists of a rotatable high resolution camera and an additional camera for a special mission performance. The average project cost, which includes development expenditures, vehicle building and participation expenses, doesn't exceed sums spent by competitive teams (even taking into account donated materials and components cost).



BMSTU ROV TEAM EXPENSE REPORT

Item Description	Source	Donated	Cost
Travel Stipends	BMSTU	$	$ 18000-
Fiber Optic Video Link	SIO RAS	$ 5,050	$ -
Main Camera & Housing	SIO RAS	$ 3,000	
25 Student Versions of SolidWorks	Dasso Systems	$ 2,500	$ -
Thrusters (5)	SIO RAS	$ 1,937	$
Printed Circuit Boards	SIO RAS	$ 1,485	
Underwater Connectors	SIO	$ 908	$ -
Foundation Grant	BMSTU	$ 700	
Rapid Prototype Camera Housings	TETIS	$ 550	
Tether	EDBOERAS	$ 550	
Waterjet Services	TETIS	$ 500	$ -
LED Lamps	EDBOE RAS	$ 360	
IP68 Rated Cabling & Connectors	SIO RAS	$ 350	$ -
Plastic & PVC sheets	TETIS	$ 300	$ -
Aluminum Hard Anodizing	EDBOE RAS	$ 300	
16 ea PIC18F4431 Processors	BMSTU	$ 132	
Acrylic Tubing	BMSTU	$ -	$ 95.00
Batteries	BMSTU	$ -	$ 76.00
CNC work for aluminum parts	EDBOE RAS	$ 27-	$ -
Electronic Components	BMSTU	$ -	$ 375.86
Fiber Optic Cable	SIO RAS	100$ -	$ -
Foam Float Material	BMSTU	$ -	$ 125.00
Misc Supplies	BMSTU	$ -	$ 276.00
Motors (2)	BMSTU	$ -	$ 15.50
O-Rings, shaft seals & sealant	EDBOE RAS	$ -	$ 35.75
Pulleys and cog belts	BMSTU	$ -	$ 75.00
Salvage Parts - Hydraulics & Pneumatics	EDBOE RAS	$23 -	$ -
Salvage Parts - Video Mixer	TETIS	$45 -	$ -
Salvage Parts - Video Selector Box (2006)	SIO RAS	$34 -	$ -
Salvage Video Cameras	EDBOE RAS	$56 -	$ -
Solenoids (left over from 2006)	EDBOE RAS	$ 18-	$
Stainless Fasteners	BMSTU	$ -	$ 126.00
Travel Costs		$	$ 18000
Student input to travel costs		$ 1,500	$
Student Fundraising on Ebay		$(4,000.00)	$
Total Donations		$29,000	$
Total Cost		$	$14,200
		Total Project Cost: $ 43,200	

The major part of the project expenditures is compensated by gratuitous help of academic and commercial organizatons engaged in underwater robotics technology. They are presented in the second column of the table. Travel, meals and lodging expenses are paid by Federal Youth Agency,

Основная часть проектных расходов компенсируется безвозмездной помощью академических и коммерческих организаций, связанных с подводной робототехникой. Они представлены во втором столбце таблицы. Расходы по командировке, питанию и проживанию оплачивает Федеральное агентство по делам молодежи РФ.

Design rationale

Circuitry

Initial circuitry of AkvaTOR ROV is the result of sequential evolutionary increase of the functionality of control systems. It was completed in the form of course projects and diploma design by previous years' students.

Before determining circuitry of AkvaTOR ROV, BMSTU team has developed and built circuits for a test ROV TAM-Test Akvator Modified. This ROV turned out to be very useful for mastering soldening, assembling and installation techniques. It also helped to improve operating skills, which are needed for working with bottom equipment in the reservoir. Later crustacean obtaining device, temperature sensor, hydrophone and other circuit units were installed. These units are correspondent to AkvaTOR ROV mounted devices.

The following components will be presented on MATEC-2010:

SHEMA PRINCIPIALNAY BEREG-V134 – ROV-shore principal circuit.

BEREG CAM BOT – diode bridge circuits for system protection in case of polarity misconnection.

BEREG CAM TOP – 48V power supply connection circuit; joystick; I/O video sockets.

CPU MODULE – temperature sensor, camera rotation, pressure sensor and I2C bus connection circuit.

CPU MODULE VIDEO – video processing circuit.

STANDART BORT V10.37 – first on-board circuit unit.

STANDART DC V10.37 – second on-board circuit unit.

SOEDINENIE BLOKOV KAMERY 2-2 – camera units, power supply sockets, fuse, work mode indicator connection circuits. Indicator information: 1 led – ROV connection, 2 led – control menu entered, 3 led – system overload.

Microprocessor Atmega128 is used in on-board and on-shore parts of control system. For example here is the most informative circuit layout of on-board ROV AkvaTOR CPU circuit.

.

Fig. 1. Most informative circuit layout of on-board ROV AkvaTOR CPU circuit.

Project essence

AkvaTOR was designed and built by BMSTU team as a compact mobile remotely operated underwater robot capable of performing simple underwater operations including assembling and dismantling, water temperature measuring, collection of hydrothermal vents, collection of crustaceans, hydroacoustic emission sources detection, collection of bacterial mat samples. We consider AkvaTOR ROV’s capability of performing more than 10 functionally different tasks a preliminary project study of a bigger ROV for sea mountain research and sea bottom gas and oil extraction wells maintance (including damaged, such as BP Mexican gulf oil well). During AkvaTOR development a number of original technical solutions was proposed and implemented.

Frame construction

As a material of a framework there were selected polypropylene pipes of 1 inch (2.54 mm) and fittings to them. Density of a material of a framework is 980 kg/м3. The shape of a framework was selected due to optimal placement of all units and systems of the ROV under condition of minimization of overall dimensions.

During the seafloor equipment construction we used weld technology. Making the frame of the vehicle we used gluing technology, which is more accurate.

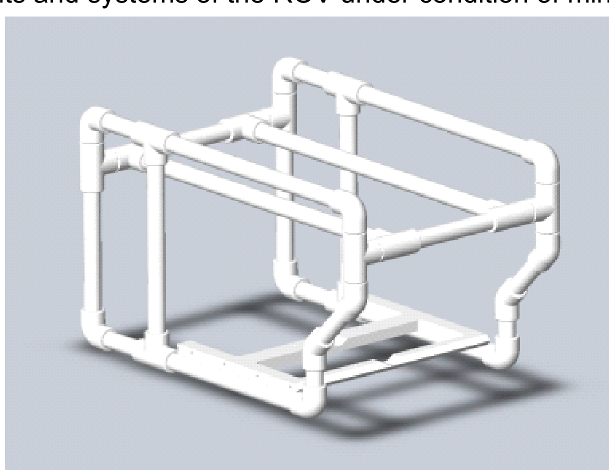


Figure 2 Model of the frame of "AKVATOR

ROV systems

Propulsion system

AkvaTOR is equipped with 4 propulsors – 2 horizontal and 2 vertical. Main parts of each propulsor are Maxon engine and magnetic couplings. Similar propulsors are used in the injector, used to crustacean obtaining.

Video system

AkvaTOR is equipped with a standart modular analog videocamera (composite video signal) installed on a movable platform. The platform is controlled by a servo, steering device, commonly used in RC-models. Enlarged area of the survey can be achieved via a mirror, similar to the rear view mirror in cars.

Sensor system

Temperature sensor Microchip MCP9804 is installed on Akvator. This digital sensor uses I2C communication protocol. Sensor's small size allows to measure temperature in hardly accessible places.

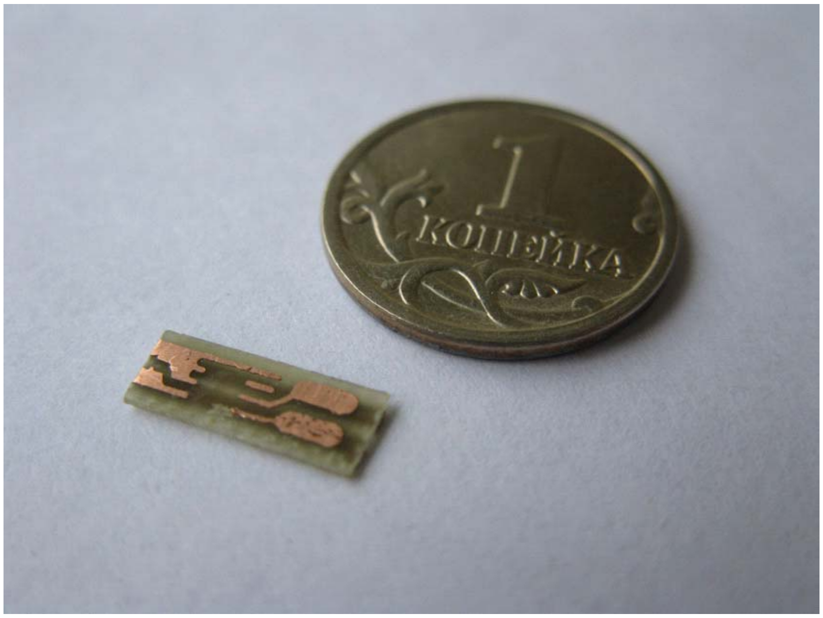


Fig.3. Thermo sensor circuit board

A special device for sound frequency measurement was created for AkvaTOR ROV - a hydrophone. It is a hermetically sealed metal case with a thin membrane. Inside the case an electret microphone with amplifier is placed. The amplifier consists of 2 operational amplifiers connected in series, one in the mode of amplification, the second as a repeater, to prevent amplification of noise. To receive a signal of the hydrophone a special microphone wire is used, going directly to the shore. Amplifier power supply and the signal from the hydrophone pass through this wire. Data from the hydrophone, allowing to determine the frequency of the signal recorded, is transmitted on a laptop via a microphone input using free software.

Fig.4. Hydrophone

Fig.5. Sensor circuit board

A special device for sound frequency measurement was created for AkvaTOR ROV - a hydrophone. It is a hermetically sealed metal case with a thin membrane. Inside the case an electret microphone with amplifier is placed. The amplifier consists of 2 operational amplifiers connected in series, one in the mode of amplification, the second as a repeater, to prevent amplification of noise. To receive a signal of the hydrophone a special microphone wire is used, going directly to the shore. Amplifier power supply and the signal from the hydrophone pass through this wire. Data from the hydrophone, allowing to determine the frequency of the signal recorded, is transmitted on a laptop via a microphone input using free software.

Tether

Fig. 6. Single-wire stranded cable connection

Single-wire stranded cable connection, shown in Figure 3, was effective in a test version of “TAM” ROV, powered by the source voltage - 180V. After changing, according to the requirements of MATEC, 180V to 48V, and due to the equipping contest ROV with hydrophone, temperature sensors and other onboard devices we had to switch to 3-wire cable connection.

Control system

When developing control system of AkvaTOR ROV, BMSTU team at first followed the architecture of a well-known prototype, shown below.

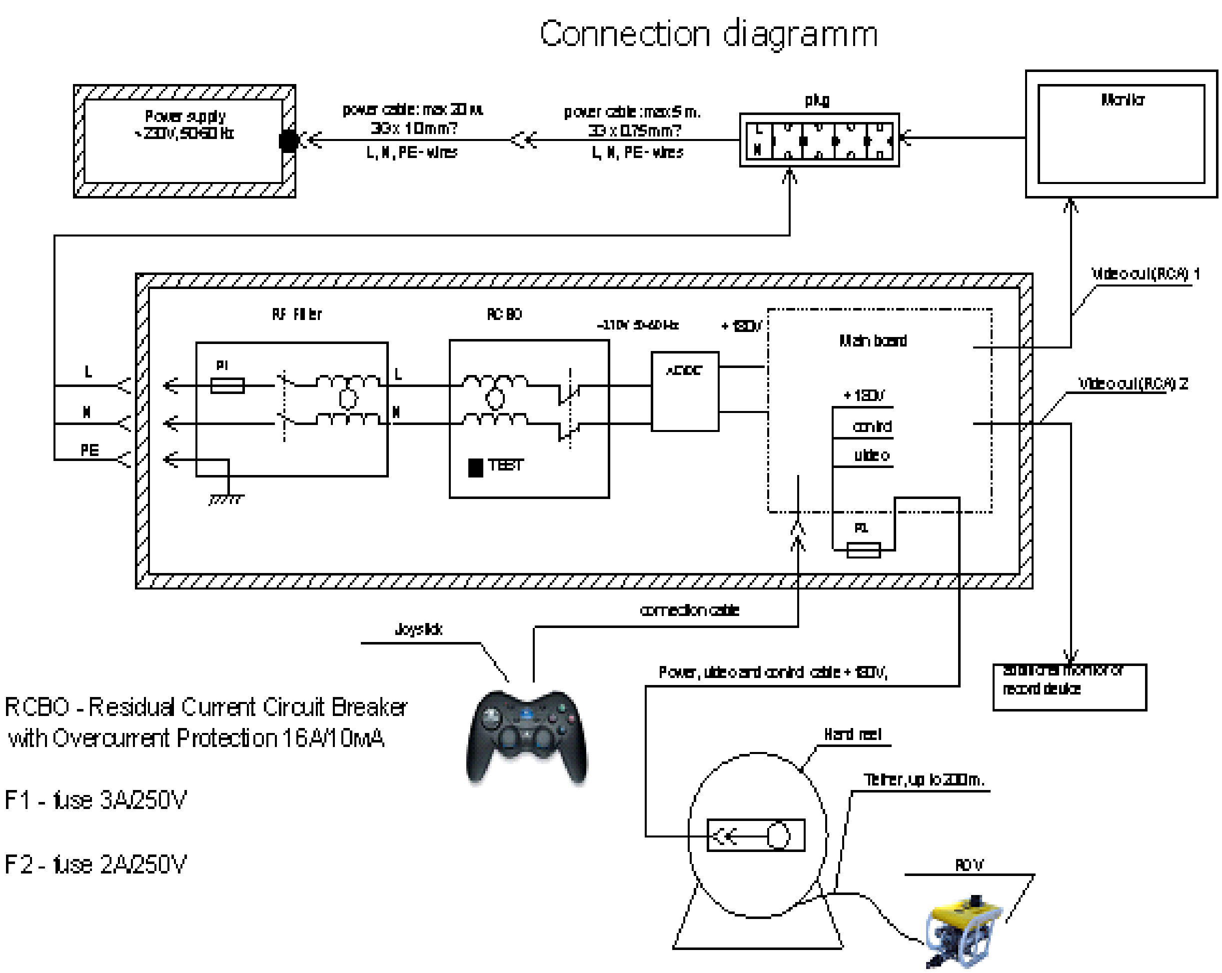


Fig. 7. Control system architecture of a ROV

Main subsystems of this architecture are: ROV. Tether. Shore control unit. Control panel.

Further decomposition is determined by the objectives of consideration. Because of many functional and structural differences between the AkvaTOR ROV and his prototype its control system of has a number of significant differences. Some of them can be seen in the section "Circuitry". The other part of the differences represented in the photos of components of on-board complex.

Fig. 8. Power module and desk control console

Shore control unit represented in form of general purpose construction, which uses 180V and 48V power supply, for test and contest ROVs respectively. The latter, because of the uselessness of lowering transformation of the current, power system is simplified and reduced to a single board, green, shown at the bottom front of the box.

Fig.9 AkvaTOR ROV control unit mini screen

Here is shown the mini screen of the control unit, which was used during developing skills of ROV operating AkvaTOR ROV, while performing specified underwater tasks. During the contest, using of a laptop is supposed.

Devices for the competition missions performance

Special devices were developed for missions 1-4 of the competition.

Task #1: Resurrect HUGO

A common microphone is used as a hydrophone. It is placed in a hermetic unit with a low-frequency filter. Signal from it is transmitted via separate cable straight to the laptop.

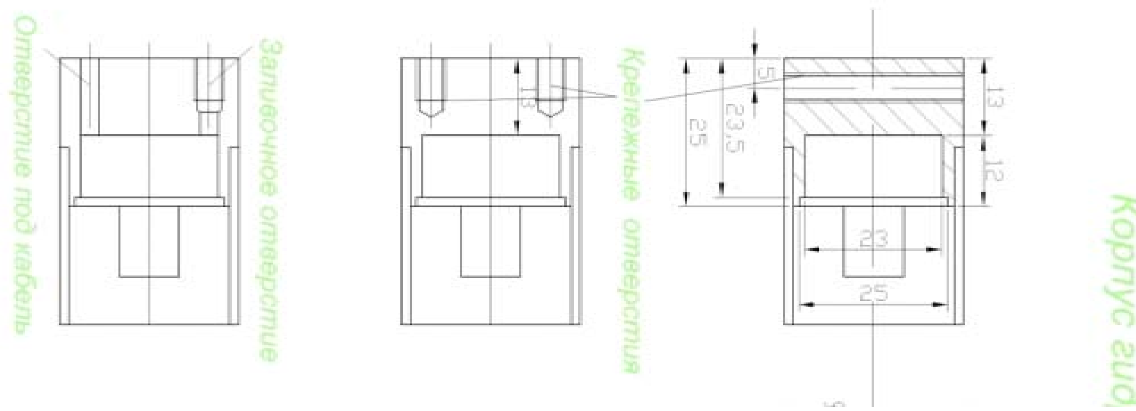


Fig. 10 Microphone using as a hydrophone

Task #2: Collect samples of a new species of crustacean

A special attachment was developed for collecting crustacean samples. Operating principle: jet propeller sucks down water with crustaceans, which accumulate in a special netting.

Figure 11. Diffuser and water cannon of crustacean collecting device.

Figure 12. Jet propeller of crustacean collecting device.

Task #3: Sample a new vent site

To accomplish the 3d mission of competition a special device was developed. It is based on a thermode (MCP9804 0,25C Typ. Accuracy Digital Temperature Sensor). Thermode signal is transmitted to the board, placed on the vehicle.

Task #4: Collect a sample of a bacterial mat

Operating principle of the sampler is based on low tensility of water. The device consists of solid pipes (50 ml syringes are used), elastic rubber pipes and foundation on which said solid and elastic pipes are mounted. Operating order of the sampler:

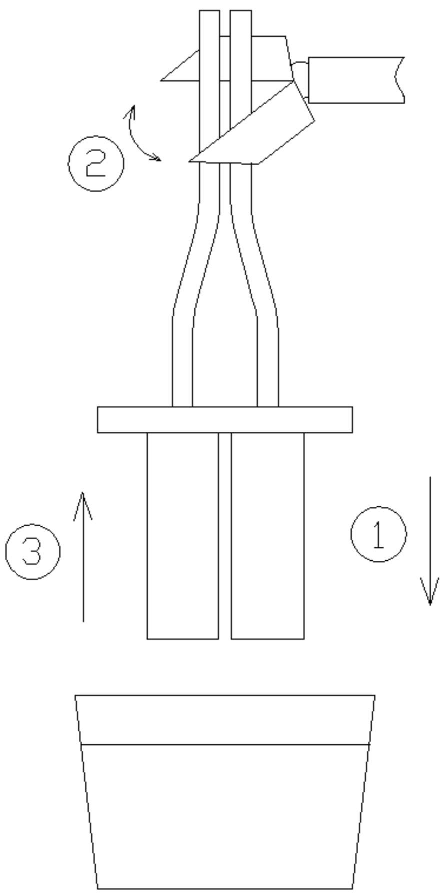


Fig. 13. Collector a sample of a bacterial mat

- Sink part of device with solid pipes in container with bacterial mat, using vertical thrusters.
- Squeeze elastic pipes with manipulator and block access for water to solid pipes.
- Lift the device and vehicle itself.

Fig. 14. Collector's element for a sample of a bacterial mat

Challenges and problems

During realization of the project "AKVATOR" team members have faced with a number of challenges and problems:

- Related to construction:
  - Firstly configuration of a frame was selected incorrectly.
  - a problem with fixing devices and adaptations to the frame
  - Low mobility of manipulator construction.
- Related to the electronic part:
  - onboard power stabilization
  - Video signal Transmission
  - Power stabilization on "a coastal part"
  - Output of a teletext to the screen
- Related to the software

    - Realization of the protocols of data exchange
- Management problems
    - Absence of programmers in the team
    - Delay in delivery

Perhaps, overcoming of management barriers became one of the most difficult problems, which our team has successfully resolved.

We have overcome, apparently, an impenetrable wall of indifference from outside our university management, we have awoken interest of investors by our enthusiasm and well co-ordinated work, we have organized the student's society which is engaged in designing of devices for various competitions on a robotics, and also have acquainted many and many people with MATEC competition.

Troubleshooting technique

There were some technical problems during customization and debugging. For example, the onboard converter of power intended for power supply of thrusters permanently overheated. After long search of solution, we have understood that stabilizer should be taking out on a coastal part. Also there were problems with video signal transmission, but the problem has been solved by selection of necessary amplifier of video signal.

Payload of the vehicle

Payload of the vehicle includes all the components of the on-board complex, mounted on the framework, notably: buoyancy control system, manipulator, hydrophone, device for crustacean collecting, bacterial mat sampler, thermode, lighters, video camera.

Future Improvement

- **Manipulator**
  Improve fastenings, provide an opportunity of manipulator position control (pull out or push into as much as possible), as well as opportunity of installation of manipulator at a small angle for better view of the clamp.
- **Framework**
  Make the framework wider to place all the components, including manipulator, inside.
- **Electronics and control system**
  In perspective develop and make new “stuffing” of the vehicle, i.e. develop, make and test boards of thrusters, lighter and manipulator control. This is an effortful, but feasible task.
- **Buoyancy**
  Leave everything on its place: buoyancy control system (BCS), constructed from pipes with an opportunity of volume and buoyancy force control, which makes development and testing of the vehicle easy. But we would like to increase construction reliability and decrease motion drag of BCS pipes
  Make an alternative buoyancy for the vehicle: cut it out from a light material, drill holes for the thrusters, shape the buoyancy, putty, ground and colour it.

Obtained knowledge and skills

Technical skills

Developing of real underwater robotic objects
Board equipment adjustment
Electrical circuits testing

Adjustment of video signal transmitting channels
Working with microprocessor
Writing and debugging of software for control subsystems
Document preparation for the developed objects and systems

Organizational skills

We've learned how to work in a team, to distribute roles and duties among the team members.
We've obtained a skill of interaction with sponsors and stakeholders in the university.
We've worked out forms of interaction with equipment suppliers.
We've mastered the technique of decision making in project critical moments under lack of time, components and other sources.

Lessons gained

- It is necessary to provide plug-in elements (resistors, fuses, diodes etc.) to prevent fusing of critical components such as camera etc. in case of short-circuit.
- Place the construction units of an attachment in a way they don't obstruct the camera and lighters.
- All the preliminary work (thrusters adjustment, video control, debugging) should be carried out in an aquarium, not during the testings in an experimental basin that the pilots have more time to train in missions performance.
- Bear in mind that during the transportation of the vehicle wire breaks and other faults can take place as well as during the vehicle operating flowing and equipment and devices failures are possible.

Loihi seamount

The bulk of information about Loihi comes from dives made in response to the 1996 eruption. In a dive conducted almost immediately after seismic activity was reported, visibility was greatly reduced by high concentrations of displaced minerals and large floating mats of bacteria in the water.

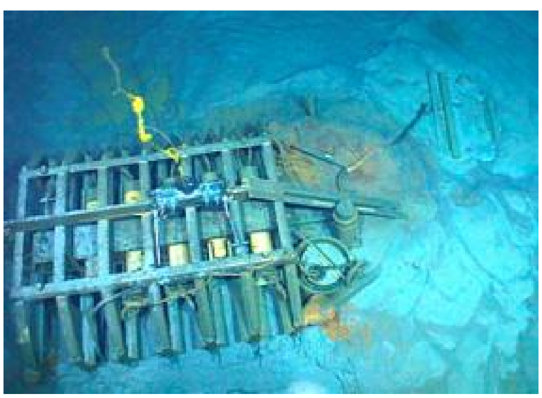


Figure 15 .The HUGO junction box almost ready to be retrieved from the ocean floor. The box monitored activity on Loihi Seamount.

In 1997, scientists from the University of Hawaii installed an ocean bottom observatory on the summit of Loihi Seamount. The submarine observatory was nicknamed HUGO, (Hawaii Undersea Geological Observatory). HUGO was connected to the shore, 34 km away, by a fiber optic cable. It gave scientists real-time seismic, chemical and visual data about the state of Loihi, which had by then become an international laboratory for the study of undersea volcanism. The cable that provided HUGO with power and communications broke in October 1998, effectively shutting it down.

It was highly desirable to visit the HUGO Junction Box to perform the following tasks:

1. Cut off the anchor cable
2. Adjust the attitude of the Junction Box if necessary and survey the area, remove the Power Regulator connector to see if the system begins operating again.
3. If so, test all optical and electrical circuits in the HUGO connectors with a new test connector designed to evaluate all connector functions
4. Replace the High-Rate Hydrophone with a new unit, and return the other to the surface, deploy the sea-water return electrode

5. Return the Experiment module to the surface and replace the connector and cable to the experiment package, then return the unit on the following dive and re-install it.
6. Install a new connector designed to allow voice conversation between the submersible and HUGO Shore Station via acoustic link.
7. Attach the Power Regulator Module and connector to the Junction Box float and release the float to be picked up by the Kaimikai-o-Kanaloa.

On January 19 of the following year, HUGO was visited by Pisces V. Methods to prevent the leaks in the connectors were tested and two new hydrophones, a test connector, and experiment connector –cable were built up. Four dives were planned to accomplish the above tasks and to attach cable protection to the main cable at "hard spots" where it shows attenuation near shore, and where it passes through very rough territory towards the north end of Loihi. The observatory functioned for four years before it went dead again in 2002.

Loihi's mid-Pacific location and its well-sustained hydrothermal system contribute to a rich oasis for a microbial ecosystem. Areas of extensive hydrothermal venting are found on Loihi's crater floor and north slope, and along the summit of Loihi itself. Active hydrothermal vents were first discovered at Loihi in the late 1980s. The two most prominent vent fields are at the summit: Pele's Pit and Kapo's Vents. These vents were considered "low temperature vents" because their waters were only about 30 °C. The volcanic eruption of 1996 and the creation of Pele's Pit changed this, and initiated high temperature venting; exit temperatures were measured at 77 °C in 1996.

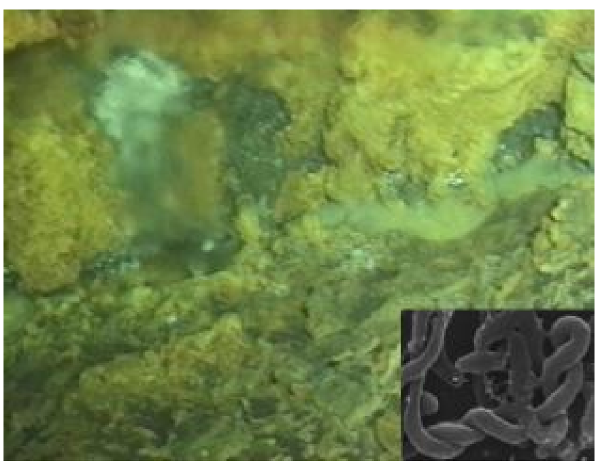


Figure 16. Bacterial mat on a 160 °C vent. Inset shows micrograph of bacteria.

The vents lie 1,100 m to 1,325 below the surface, and range in temperature from 10 to over 200 °C. The vent fluids are characterized by a high concentration of CO2 and Fe (Iron), but low in sulfide. Low oxygen and pH levels are important factors in supporting the high amounts of Fe (iron), one of the hallmark features of Loihi. These characteristics make a perfect environment for iron-oxidizing bacteria, called FeOB, to thrive in.

A diverse community of microbial mats surround the vents and virtually cover Pele's Pit. The Hawaii Undersea Research Laboratory (HURL), NOAA's Research Center for Hawaii and the Western Pacific, monitors and researches the hydrothermal systems and studies the local community. The National Science Foundation (NSF) funded an extremophile sampling expedition to Loihi in 1999. Microbial mats surrounded the 160 °C vents, and included a novel jelly-like organism. In 2001, Pisces V collected samples of the organisms and brought them to the surface for study.

Marine life inhabiting the waters around Loihi is not as diverse as life at other, less active seamounts. Fish found living near Loihi include the Celebes monkfish (Sladenia remiger), and members of the Cutthroat eel family, Synaphobranchidae. Invertebrates identified in the area include two species endemic to the hydrothermal vents, a bresiliid shrimp (Opaepele loihi) of the family Alvinocarididae (described in 1995), and a tube or pogonophoran worm.

Figure 17. Pisces V operated by NURP's Hawaii center dives to 2000 m.

Figure 18. Bresiliid shrimp (Photo courtesy of Verena Tunnicliffe)

Dives conducted after the 1996 earthquake swarms were unable to find either the shrimp or the worm, and it is not known if there are lasting effects on these species.

Reflections

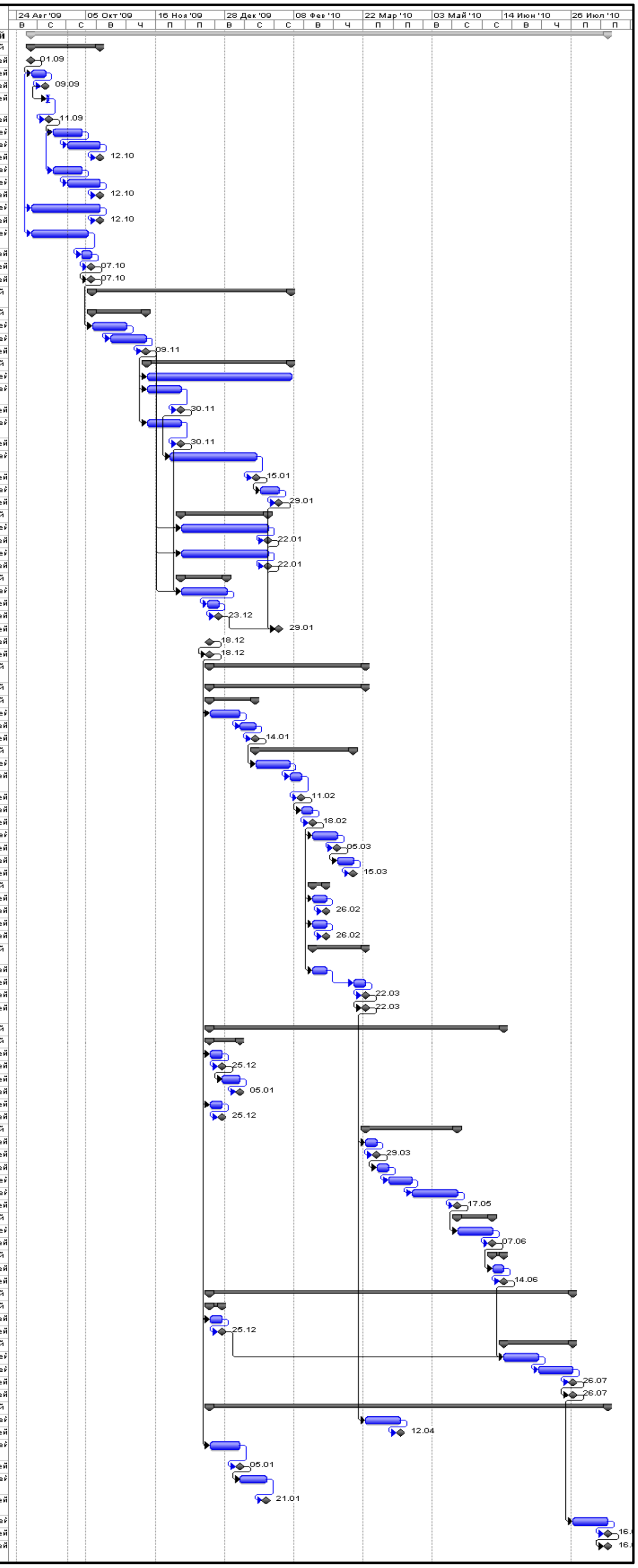
At the beginning of the project of participation in MATEC competitions the BMSTU team had very a poor ground for success. Primarily the MATEC-2010 project was considered as a common student research work. But as students' interest increased lessons transformed to studying real MATEC missions. Student groups were made into teams, coming one after another (5th and 4th courses). The Far East State Technical University team has given us an essential advisory assistance. Their mentor, Ph.D., professor A.F.Scherbatyuk has an experience of successful participation in MATEC-2008 and MATEC-2009. FESTU and BMSTU experience in preparing for the competition attract interest of other Russian universities, e.g. in Moscow and Saint-Petersburg

Team work

The main success factor in realization of our project became competent planning. The team captain developed a time schedule of execution phases, where key roles in project teams were determined and risks were described. Besides the calendar schedule we developed a finance plan, alteration plan and risk plan. Team work was organized according to ANSI PMI

Appendix

Ид.		Название задачи	Рабочие дни
0		**Проект АкваТОР**	**242,88 дней**
1		Подготовительные работы	30 дней
2		Задание выдано	0 дней
3		Формирование команды проекта	7 дней
4		Команда проекта создана	0 дней
5		Формирование единого инфокоммуникационного пространства команды проекта	2 дней
6		Инфокоммуникационное пространство налажено	0 дней
7		Разработка КП проекта	14 дней
8		Согласование КП проекта	14 дней
9		КП проекта разработан	0 дней
10		Разработка Устава проекта	14 дней
11		Согласование устава проекта	14 дней
12		Устав проекта разработан	0 дней
13		Поиск спонсора проекта	30 дней
14		Спонсор найден	0 дней
15		Анализ РТС прошлых лет с целью определения наиболее перспективной модели	25 дней
16		Согласование модели	5 дней
17		Анализ завершен - выбрана модель	0 дней
18		Подготовительные работы завершены	0 дней
19		ПИР (проектно-изыскательские работы)	82 дней
20		Разработка Технического Задания	22 дней
21		Подготовка ТЗ	15 дней
22		Согласование ТЗ	15 дней
23		ТЗ подготовлено	0 дней
24		Разработка Технического Проекта	60 дней
25		Разработка ТП	60 дней
26		Подготовка спецификации оборудования и ПО из которого будет состоять аппарат	15 дней
27		Спецификация необходимого оборудования утверждена	0 дней
28		Подготовка сметы оборудования и ПО из которого будет состоять аппарат	15 дней
29		Смета оборудования и ПО утверждена	0 дней
30		подготовка 3D модели аппарата в одном из инженерных пакетов	35 дней
31		3D модель подготовлена	0 дней
32		Согласование ТП	10 дней
33		ТП подготовлен	0 дней
34		Подготовка Рабочей Документации	35 дней
35		Подготовка эксплуатационной документации	35 дней
36		Эксплуатационная документация подготовлена	0 дней
37		Подготовка регламентирующей документации	35 дней
38		Регламентирующая документация подготовлена	0 дней
39		Разработка Программы и Методики Испытаний	20 дней
40		Подготовка ПМИ	20 дней
41		Согласование ПМИ	5 дней
42		ПМИ подготовлено	0 дней
43		Цикл ПИР завершен	0 дней
44		Получение исходных данных по конкурсному проекту	0 дней
45		Исходные конкурсные данные получены	0 дней
46		Реинжениринг запроектированного аппарата с учетом конкурсных условий	60 дней
47		ПИР	60 дней
48		Доработка Технического Задания	15 дней
49		Подготовка ТЗ	10 дней
50		Согласование ТЗ	5 дней
51		ТЗ подготовлено	0 дней
52		Доработка Технического Проекта	40 дней
53		Доработка ТП	15 дней
54		Внесение изменений в спецификацию оборудования и ПО из которого будет состоять аппарат	5 дней
55		Спецификация необходимого оборудования утверждена	0 дней
56		Доработка сметы оборудования и ПО из которого будет	5 дней
57		Смета оборудования и ПО утверждена	0 дней
58		Доработка 3D модели аппарата в одном из инженерных	10 дней
59		3D модель подготовлена	0 дней
60		Согласование обновленного ТП	5 дней
61		ТП подготовлен	0 дней
62		Доработка Рабочей Документации	5 дней
63		Внесение изменений в эксплуатационную документаци	5 дней
64		Эксплуатационная документация подготовлена	0 дней
65		Внесение изменений в регламентирующую документаци	5 дней
66		Регламентирующая документация подготовлена	0 дней
67		Доработка Программы и Методики Испытаний	20 дней
68		Доработка ПМИ	5 дней
69		Согласование ПМИ	5 дней
70		ПМИ подготовлено	0 дней
71		Цикл Реинжениринга завершен	0 дней
72		Строительно-монтажные работы	120 дней
73		Подготовка помещений	10 дней
74		Поиск помещения для сборки аппарата	5 дней
75		Помещение найдено	0 дней
76		Подготовка помещения	5 дней
77		Помещение подготовлено	0 дней
78		Поиск вспомогательного оборудования	5 дней
79		Вспмомогательное оборудование подготовлено	0 дней
80		Закупка оборудования согласно ТП	40 дней
81		Выбор поставщиков	5 дней
82		Список поставщиков утвержден	0 дней
83		Разработка логистической схемы доставки оборудования	5 дней
84		Закупка оборудования	10 дней
85		Доставка оборудования	20 дней
86		Оборудование получено	0 дней
87		Сборка аппарата на основе ТП	15 дней
88		Непосредственно сборка аппарата	15 дней
89		Аппарат собран	0 дней
90		Настройка аппарата согласно ТП	5 дней
91		Заливка ПО	5 дней
92		ПО залито	0 дней
93		Тестирование аппарата согласно ПМИ	150 дней
94		Подготовка помещений	5 дней
95		Поиск помещения для тестирования аппарата	5 дней
96		Помещение найдено	0 дней
97		Процедуры тестирования в бассеине	30 дней
98		Тестирование аппарата	15 дней
99		Доводочные испытания	15 дней
100		Тестирование пройдено	0 дней
101		Аппарат к участию в конкурсе готов	0 дней
102		Подготовка к выезду на соревнования - Завершение проекта	165 дней
103		Получение разрешения на вывоз оборудования	15 дней
104		Разрешение на вывоз получено	0 дней
105		Сбор всей необходимой информации о поездке на соревновани команды проекта	10 дней
106		Информация получена	0 дней
107		Согласование вопросов проживания и доставки членов команды проекта к месту соревнований	10 дней
108		Вопросы проживания и доставки членов команды проекта к месту соревнований согласованы	0 дней
109		Проведение обучающих семинаров по возможным вопросам и за	15 дней
110		Цикл семинаров завершен	0 дней
111		Доставка аппарата и членов команды до места соревнований	0 дней



Acknowledgements

A number of institutions have enthusiastically contributed to creation of ROV AKVATOR:

Far Eastern Branch of the Russian Academy of sciences Institute of Marine Technology Problems - technical consultations, advices about organization, warnings about possible mistakes, peer reviews, participation in trial design testing.

Russian Academy of Sciences Experimental Design Bureau of Oceanological Engineering - expressed willingness to share with us components, laboratories, instruments and other services for creation of AKVATOR. Here, according to MATEC conditions, our team was interested in small ROVs, which meet dimension requirements of MATEC. Russian Academy of Sciences Experimental Design Bureau of Oceanological Engineering deals with larger ROVs.

Close corporation "TETIS" - gave us testing equipment, components, consultation and other services. Only consultations about Seabotix manipulatior turned out to be practically valuable (in minimal degree).

Institute of Oceanology of the Russian Academy of Sciences **-** possesses the most valuable, from students' point of view, prototype. AKVATOR was created by developing of this prototype.

An essential influence on AKVATOR project was exerted by: Underwater Robotic Systems department, Special Machine-Building faculty and BMSTU in the person of its president I.B. Fedorov and in the person of chancellor A.A. Alexandrov.

References

1. http://www.marinetech.org/ MATEC official site.
2. http://akvator.studenthost.ru/ Student project "AkvaTOR" site.
3. http:// An informational portal for CAD professionals. The site has an extensive forum, containing advices in the field of different CAD packages application.
4. http://www.gnom-rov.ru/ ROV "GNOM" official site.
5. Fe-Oxidizing Microbial Observatory, http://earthref.org/cgi-bin/er.cgi?s=http://earthref.org/FEMO/loihi.htm
6. Hawaii Undersea Research Laboratory at the University of Hawaii at Manoa, www.soest.hawaii.edu/HURL
7. HUGO, www.soest.hawaii.edu/HUGO/hugo.html
8. Loihi seamount, http://en.wikipedia.org/wiki/Loihi_Seamount