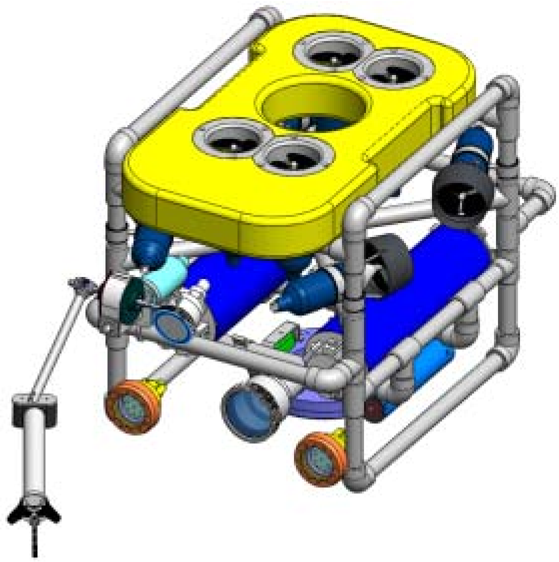
Institute for Marine Technology Problems presents

The ROV «Junior» from «Primorye Coast» Team



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Abstract

In this work the description of remotely operated vehicle “Junior” is represented. This vehicle was created due to missions that will be conducted on the MATE/MTS ROV Competition in the year of 2009.

“Junior” has polypropylene framework, propulsion system of 8 thrusters, manipulator providing object capturing up to 40 mm in diameter with the 6,5 kg strength, vertical docking color video camera, wide-angle light-sensitive navigation camera of high resolution and rotary color camera placed on the same axis with manipulator, two clustered lamps, two hermetic containers for electronics, foam buoyancy, sensors of temperature, depth, water flowing and current.

The upgrading for this year competitions includes: development of the catcher, just for the accomplishment missions, modification the video system, replacement the buoyancy with the change of vertical thrusters’ positions, and also a significant modification the autopilot (replacement the magnetic compass TCM2 with more accurate, more fast-responsive and quick-acting and less exposed to the noise effect ID-6, and also the usage of the multi-channel 16-bits ADC).

This year our team from Russia will take part in these competitions for the second time. The members of our team are the students from FENTU, FENU and the lyceum of FENTU. Although, the team itself is assembled on the base of Institute for Marine Technology Problems FEB RAS.

Budget and financial statement

Expenses

Item	Quantity	Price, $USD	Total,$USD
Framework			
Polypropylene pipe, m 23	10	0.95	9.50
Clamp,	15	1.64	24.60
Accessory power system			
Current source,	1	1,015	1,015
Cable, m	50	1.25	62.50
PVC pipe, kg	2	0.25	0.5
Movement-steering complex			
Electric motor ДП-40-430-3-24,	8	67.00	536.00
Propeller screw ∅75,	8	50	400.00
Management system			
Board	2	12.50	25.00
Chip At90CAN128,	2	9.7	19.40
Chip ADXRS401EB,	1	86.40	86.40
Chip ADXL203EB,	1	51.80	51.80
Complex sensor TCM-2	1	833.40	833.4
Pressure sensor KPT-55,	1	125.00	125.00
Temperature sensor AD-592,	1	5.40	5.40
Joy stick Saitek Aviator,	1	57.50	57.50
Rover book	1	1,500	1500
Manipulation complex			

Manipulator Seabotix TJG300,	1	3,937.50	3,937.50
Electric motor MC-146,	1	311.25	311.25
Optic relay PVG-612,	10	13.10	131.00
Information-measurement complex			
Module CDD FARB of CTCM-2723 camera,	2	234.10	468.20
Black-and-white TV camera QN-B309,	1	337.75	337.75
Objective Computar 2.6 мм 1:1.0 ½” CS,	1	249.70	249.70
Light diode cluster XL7090,	2	60.80	121.60
Coaxial cable PK-50, m	25	0.39	9.75
Pressurized volumes			
Control blocks container	2	100	200
Compensator	2	100	200
Container of lights	2	100	200
Container of camera	3	100	300
Traveling expenses			
Visa	6	160	960
Air ticket	6	2285	13,710
Cost of living	6	412	2,472
TOTAL	**$28,360.50**		

Donation

Company	Value, $USD
Institute of Marine Technology Problems	16,932.50
Far Eastern National Technical University	5,714
Far Eastern National University	5,714
TOTAL	**$28,360.50**

Design rationale

Framework

As a material of a framework there were selected polypropylene pipes of 1 inch (25,4 mms) and fittings to them. Density of a material of a framework is 980 kg/м^3. 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. For improvement of floatation the framework is made pressurized. The attachment to a framework of units of ROV is through standard clamps. In SolidWorks the model of a framework (Figure 1) with the following characteristics was made: weight - 1,9 kgs, displacement - 2,3 liters.

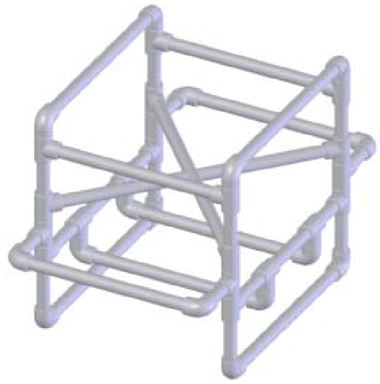
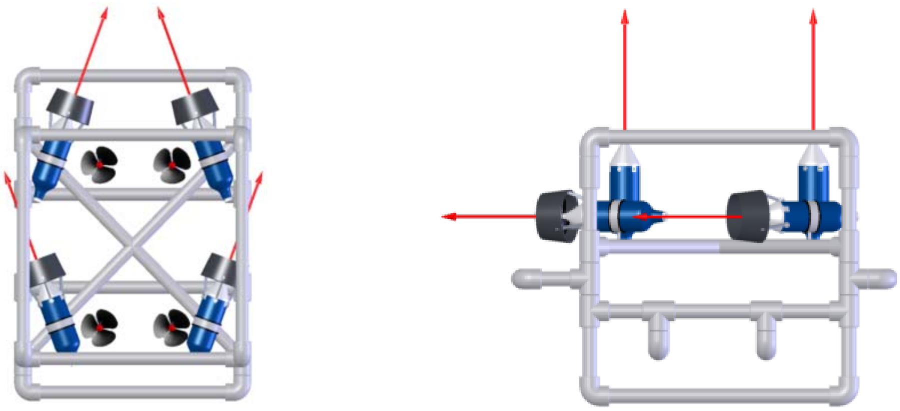


Figure 1. Framework

Thrust-steering system

The thrust-steering system (TSS) of underwater vehicle is based on effective layout of eight (8) thrusters. This number was accepted with purpose of ensuring of execution of mission targets.

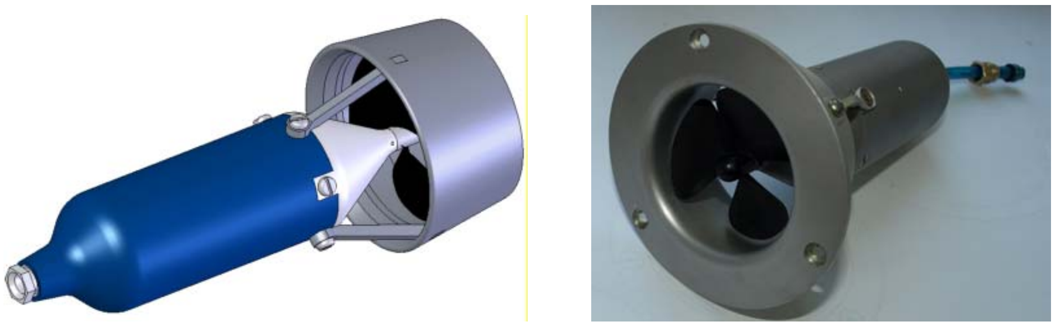
Chosen configuration of horizontal thrusters for the creating of forward and lateral movement, as well as yaw control, is shown at fig. 2a. Layout design and scheme of tractive force vectors of vertical thrusters, represented at fig.2b, was chosen with intention to ensure vertical movement of vehicle with trim control and depth stabilization.



a b

Fig. 2. Scheme of propulsors placement: a – view from above; b– side view

Thruster is brush motor, placed in pressurised volume, with 75 mm diameter screw propeller, protected by nozzle and mounted at the end of output shaft. Screws of the vertical thrusters are arranged in water ducts, placed in foam buoyancy of ROV (fig.7). The model of designed thruster is represented at fig.3a, external appearance photograph is shown at fig. 3b.



a b

Fig. 3. Propulsor: a – model of horizontal propulsor (with nozzle); b – photo of vertical propulsor (with sluice)

Strong cases

One of the most responsible units in the vehicle are two pressurized containers. Inside the first container the engines power controllers are arranged. The second container comprises control cards by the vehicle units. Both containers have cylindrical shape by a minor diameter of 100 mms and length of 350 mms and are calculated on strength for immersion on depth up to 200 m.

There are also specially projected strong containers, with arranged inside them by the following equipment:

1. Sensor of depth.
2. Lights.
4. Vertical docking color-video camera
5. Black-and-white wide-angle navigational video camera
6. Rotatable color-video camera

All indicated strong containers are calculated on a diving depth up to 200 m.

Manipulation complex

The function of collecting and management objects is possible for ROV only with availability of a manipulation complex.

The structure of manipulation complex has:

1. Motor - reduction gearbox and worm reduction gearbox arranged in a pressurized body allow making smoothly varying turn of the manipulator with an angle up to 220º.
2. Pipe of the grubber magnifies service zone of the manipulator and allows collecting the objects without landing.
3. Grubber TJG300 of the corporation SEABOTIX. Allows to make acquisition of object from 1,45 up to 40 mms in diameter, thus the force of compression makes up to 6,5 KGF.

Arrangement of the projected manipulator of the ROV in a work is shown in a fig. 4.

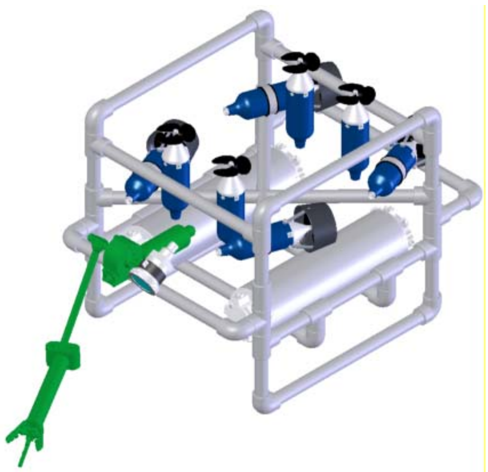


Fig. 4. Manipulation complex

Video system

In process of ROV construction the special attention was paid to designing of it's video system. There are following components in composition of video system:

1. Lighting fittings (two pieces) (the light source is cluster XLD-AC-007WHT, consisting of 7 high-brightness white LEDs (light emitting diodes) XL7090 with brightness belonging to the range of 56,8…62,0 lm (current consumption is 350 mA).
2. Wide-angle navigational video camera QNB209 (110^0, 0,003 lux, 570 lines).
3. Vertical docking color video camera and rotatable video camera CTCM-2723 (3.0 lux, resolution of 340 lines, viewing angle is 58˚).

The video system's cameras are shown at Fig. 5.

Fig. 5. Video cameras: a) survey and rotatable; b) navigational

Arrangement of the lighting fittings and cameras was designed with purposes of maximal visual angle and directional lighting in working area. Lights are arranged stationary in lower stern-part of frame.

Wide-angle camera makes it possible to enlarge the underwater coverage area from vehicle stem, which helps for operator to perform the controlled moving of vehicle and operations of manipulator. Fig.13 illustrates mutual alignment of lighting fittings flux and viewing angle of stationary wide-angle video camera.

Arrangement of the enumerated elements is shown at Fig. 6.

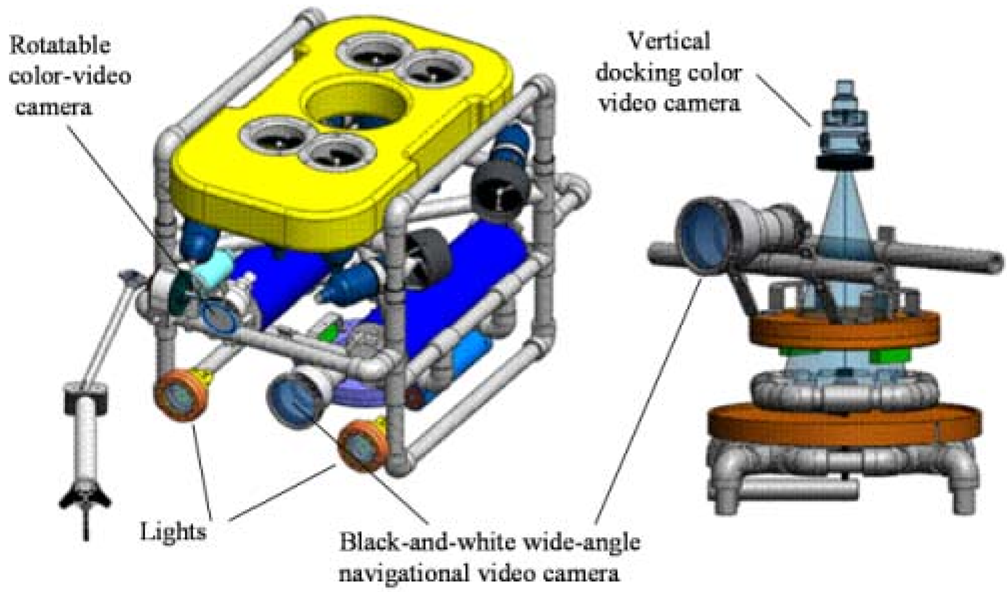


Fig. 6. The model of video system

It is obvious from fig.6, that viewing field of wide-angle video camera may be found insufficient for execution of objects collection, and for this purpose rotatable video camera is used, arranged in-line with manipulator, that allows to track at any time the behavior of manipulator's gripper and its position relatively underwater objects (in limited viewing field).

Vertical docking color video camera provides the view of the docking area from above that helps by the accomplishment missions.

Foam buoyancy

The program of automated designing SolidWorks enables to perform not only configurating of vehicle's systems, but makes it possible to carry out the calculation their mass characteristic. It allows of estimating the mass and displacement of designed vehicle. On basis of this data ROV's buoyancy was analyzed and computed subject to use requirement of negligible positive resultant vehicle's buoyancy. The model of foam buoyancy is shown at fig.7. It is made of foam plastic solid plate of 75 mm thickness and 150 kg/m3 density.

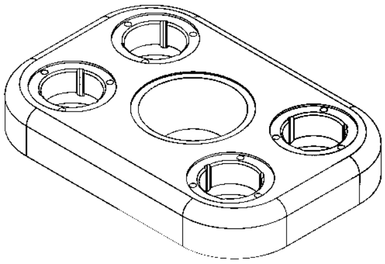


Fig. 7. Model of buoyancy;

Sensors

Depth sensor

The pressure sensor KPT5-33, ensuring the pressure measurement at the depth of 40 m with the accuracy of ±1% , is used as the depth sensor. It is according to the operation range of measuring submergence depths of 40±0.4 m. Analog signal from the sensor is received by the control unit. Depth sensor appearance and placement on the ROV are shown at the fig. 8.

Fig. 8. The depth sensor

Sensors of water flowing into ROV's container

Sensor of water flowing is the copper conductor, isolated from container hull. The conductor pose with respect to the hull may be seen at the fig. 10. The conductor is the copper foil, placed on the glass fiber plastic substrate. Gap between conductor and hull is 1 mm. When water flowing into this gap the short circuit occurs between the plate and container, and appropriate comparator of electronic circuit is actuated.

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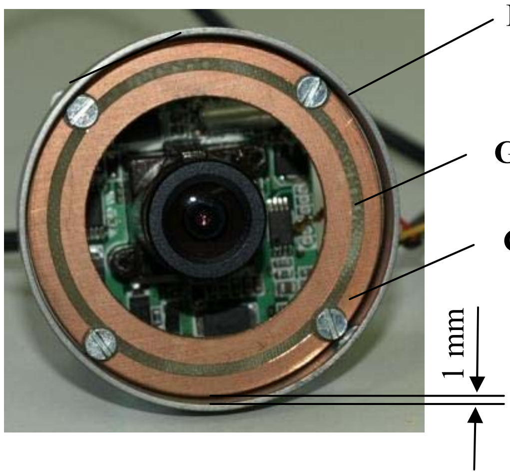


Fig. 10. Sensor of water flowing into video cameras container

Control system

The management system "Junior" consists of units arranged in the ROV operator complex:
- Joystick (specifying body),
- Notebook (operator console),

And onboard the vehicle:
- Controller of the autopilot and controller of a power module
- Sensors

The functional diagram of a management system is in the Appendix A.

Joystick

As a specifying body in remotely-operated vehicle "Junior" the joystick Saitek Aviator AV8R-01 was selected. Fulfillment of missions needs 9 buttons: acquisition of the manipulator (1), switching of video cameras (1), on/off lamps (2), motion of the manipulator upwards/downwards (2), mode of auto course (1), auto trim difference (1) and auto depth (1); and 4 axes: course forwards/back, to the right/to the left, change a course and depths. The joystick, selected by us, has necessary quantity of buttons and axes. For activity with the joystick the functions Windows API and structure Windows were used. Frequency of the reference to the joystick is 10 Hz.

Operator console

For processing and mapping of pilot signal from joystick, videodata and indications of sensors on the notebook, the program «Junior's Control Panel», written on C ++ Builder 6 with usage of libraries and files DirectX and WinAPI is used.

The program is written so that as much as possible to facilitate activity of the operator, majority of components (mapping of depth, course, roll and different) are outwardly approximate to substantial devices. In a fig. 12 the interface of the program is shown. It allows easily enough receiving the required information during fulfillment of mission. The control can be executed both by joystick, and with the help of mouse. Such reduplication allows two operators working in difficult situation, and also safeguards the system from loss of a specifying body in case of incapacitation of the joystick.

The program has two main modes and one optional. The main operational modes are: mode of guidance of the vehicle on the purpose («on devices») and full-screen mode, for more fine control. As targeting is an important operation in fulfillment of missions, in this mode there are shown indications of all sensors, full information of different malfunctions both on board, and "overhead". In a full-screen mode there are only data that can be necessary for measurement of temperature, correct activity with the manipulator and precise positioning.

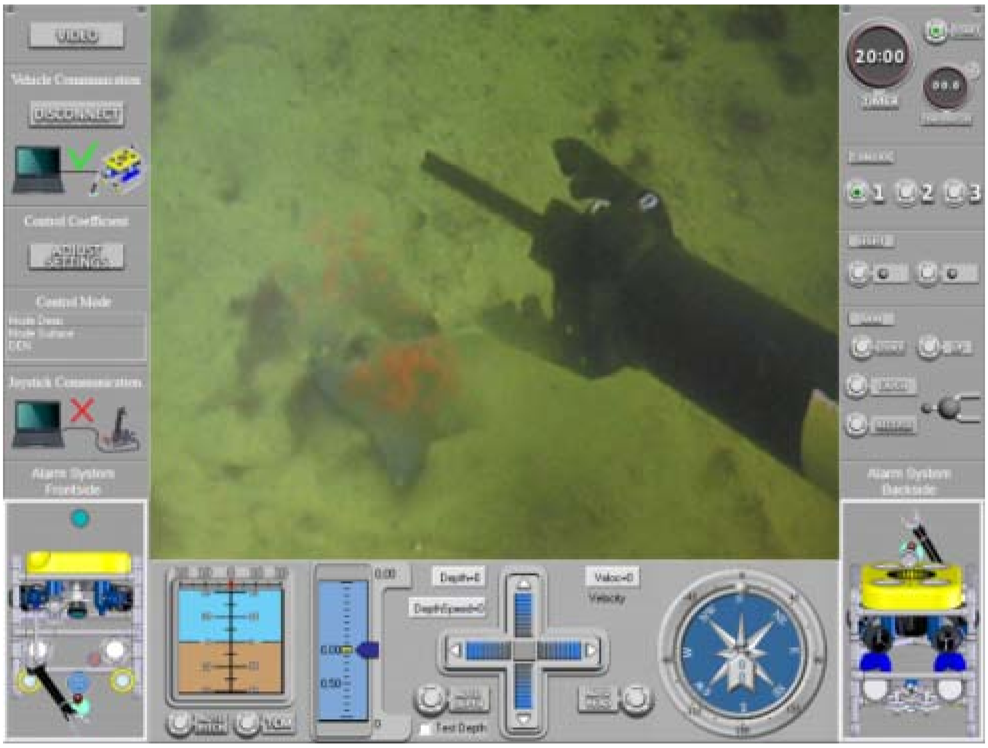


Fig. 12. Interfaces of time schedule control by the vehicle Junior

Electronic control means

Electronic control means are divided into switching unit, control block container and power container.

Switching unit

Switching unit is intended for separation of wires of ROV cable on power supply voltage, management interface and video signal. Switching unit also provides protection against current overload (more 20A), indication of consumed current, turning the power on and off of the vehicle, PC connection through USB-port and video transmission on TV tuner.

Through the terminals of accumulator battery supply voltage comes to the safety device, designed for 20A of current and fulfilling the current protection, following which power is supplying to the switching unit through the slot. Observation of current is performing by ammeter, incorporated into the switching unit.

Control signals come to the switching unit from PC through the USB-port. The switching unit by the use of USB – RS-485 bridge changes the interface of data transmission from USB to RS-485 , which possesses better noise stability and requires only three lines for the data transmission. Then the signals through the slot RS-485 are propagated via the interface by cable to the container of control unit. The data from the sensors are transmitted backwards via the same interface.

The container of control unit

There are the autopilot card, digital compass TCM2 and two sensors of water flowing in the hermetic container of control unit.

The autopilot card receives the commands incoming via the interface RS-485, analog signals from sensors of pressure, angular velocity, water (5 pieces), compensator, three video signals from video cameras.

The information processing device from the autopilot is made on basis of microcontroller (MC) AT90CAN128. It is energy-efficient 8-bits CMOS MC with AVR RISC architecture. Data input and output are fulfilled via the USART and CAN interface.

After the scaling by operational amplifiers the analog signals enter the 8-ports 10-bits analog-digital converter, embedded in microcontroller AT90CAN128, where their digitization and further data transfer to the control console are accomplished.

The processing of the analog signals from water sensors is performed by analog comparators, from which the logic signals are enter the port of microcontroller for the following sending to the control console.

Microcontroller turns on optorelay-assisted power supply of selected by operator video camera and commutates the appropriate video signal via the video multiplexer. Video signal from the video multiplexer is transmitted to the switching unit through the video amplifier.

The button is embedded in compensator. In case of decapsulation of the oil system the spring, creating the excess pressure, disconnects the button and logic null is arrived at the entrance of microcontroller.

The digital compass TCM2 measures the course relative to the direction of the magnetic North, roll and trim difference and transmits the data to the autopilot board. This data ensure the feedback for automatic maintenance of cource and trim difference.

Power container

There are controller board of the motor control units (MCU), the board of the secondary power supply, six MCUs and two water sensors.

The MCU controller board receives the signals of motors, manipulator and lights control, coming from the interface CAN, analog signals from the four water sensors, compensator signal and signals of MCU guard functioning.

The device of data processing of MCU controller is made on basis of MC AT90CAN128. Microcontroller data input and output are fulfilled via the CAN interface.

MC generates the signals of motors actuation, PDM-signals of direction and rotary speed of each motor, turn-on signals of lights and manipulator control signals.

Lights and manipulator management is realized using the optorelay.

The processing of signals from water sensors and compensator is performed similarly to the autopilot board.

The autopilot microcontroller program

The autopilot microcontroller receives the control commands from joystick of the control board (running, lateral motion, course turn, vertical movement) and discrete signals of control modes, inquires the feedback sensors, computes the control commands for each motor and transmits via the CAN-interface to the controller of motors control unit.

The commands from the control board are sent 10 times per second; the sensors, connected to ADC (tensometric sensor of depth, vibratory gyroscope of yawing rate, sensor of temperature) are inquired hundred times per second.

After updating this data the calculation of stabilization errors in course, pitch and depth channels is fulfilled. Each 10 ms the computation of control commands for motors of TSS (thrust-steering system) is performed, and then this values are transmitted from the autopilot controller to the controller of motor control units. Here the generation of PDM- voltages of propulsion electric drive control is executed.

In addition to the computation of commands for motors the autopilot controller controls the switching of three video cameras and processes the indications of emergency system sensors (flowing into the durable box and leakage from the unloading system of outboard setup).

The vertical thrusters group control (fig.16)

Vertical group, consisting of the four thrusters, ensures the ability of semiautomatic control of the device immersion depth and stabilization of null pitch angle. The tensometric sensor of pressure KPT-33-5 and и duo-axis accelerometer. In the online mode of depth stabilization “AUTODEPTH” the deviation of the slide of the joystick vertical movement corresponds to selected depth. When the pressure sensor data about actual depth are acquired, microcontroller computes the error and multiplies it by the corresponding factor with further distribution between the vertical thrusters.

If the mode of depth stabilization is off-line, the slide of the joystick vertical movement immediately generates the control impact for vertical thrusters. With on-line stabilization of null pitch angle “AUTOPITCH” the controller receives the signal from duo-axis accelerometer, scales it and distributes between the vertical thrusters with allowance for the predetermined commands from the depth channel. Then the calculated commands of vertical thrusters control are subjected to the amplitude restriction and transmitted to the controller of movement control unit for the realization.

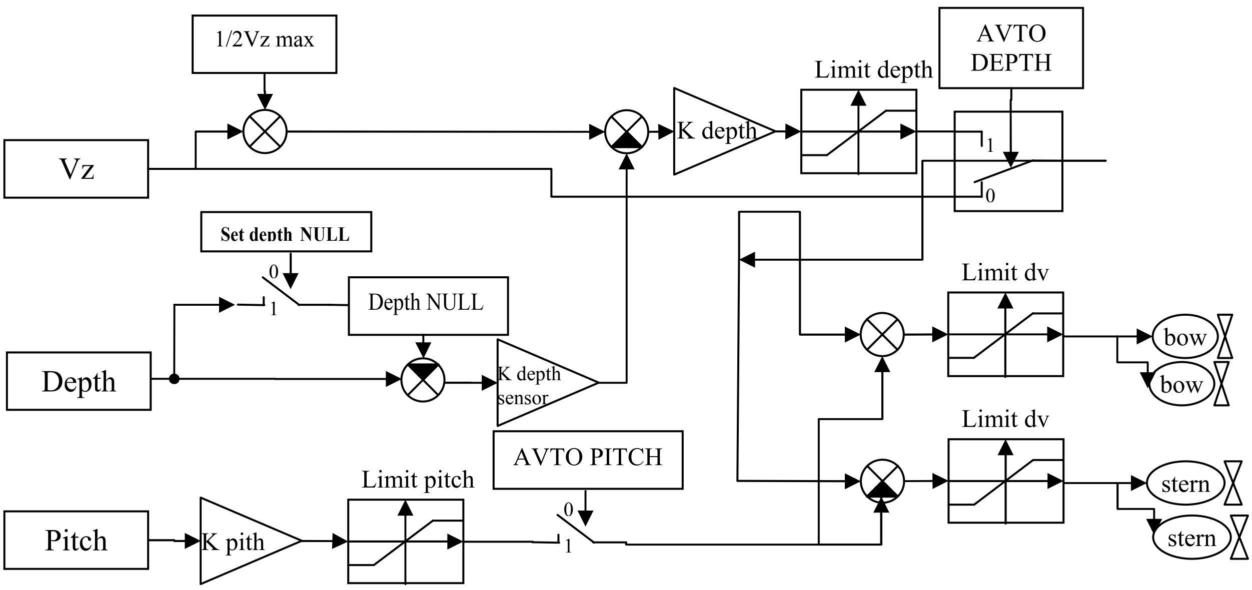


Fig. 16. Scheme of the vertical thrusters group control

The horizontal thrusters group control (fig.17-18)

Horizontal group, consisting of the four thrusters, ensures the ability of semiautomatic control of the device course, as well as manual control of running and lateral movement. Each of the horizontal thrusters takes part in forming of the control impacts for all of three mobility degrees. ROV is equipped by the magnetic compass ID-6 and gyroscopic sensor of angular speed (ADXRS402EB). With online mode of course stabilization “AUTOHEAD” and null position of course setter the magnetic course is stabilized, which corresponding the last nulling of setter. In this case the data of magnetic compass is used as well as data of angular speed sensor (ASS). If the course setter moves aside the system switch to the mode of angular speed control with only ASS feedback. Besides the course feedback from magnetic compass is switched off. Also the ability of compulsory switching off the magnetic compass stabilization by additional command «TCM-OFF». This mode was introduced for the ability of maneuvering near the objects, distorting the natural magnetic field of Earth (ferrous and magnetized objects). The joystick commands of longitudinal and lateral motion control are distributed between the horizontal group thrusters taking account of predetermined commands from the course channel. The algorithm of distribution realizes the independence of intermodulation channels control. Then the computed commands of horizontal motors control are subjected to the amplitude restriction and transmitted to the controller of movement control unit for the realization.

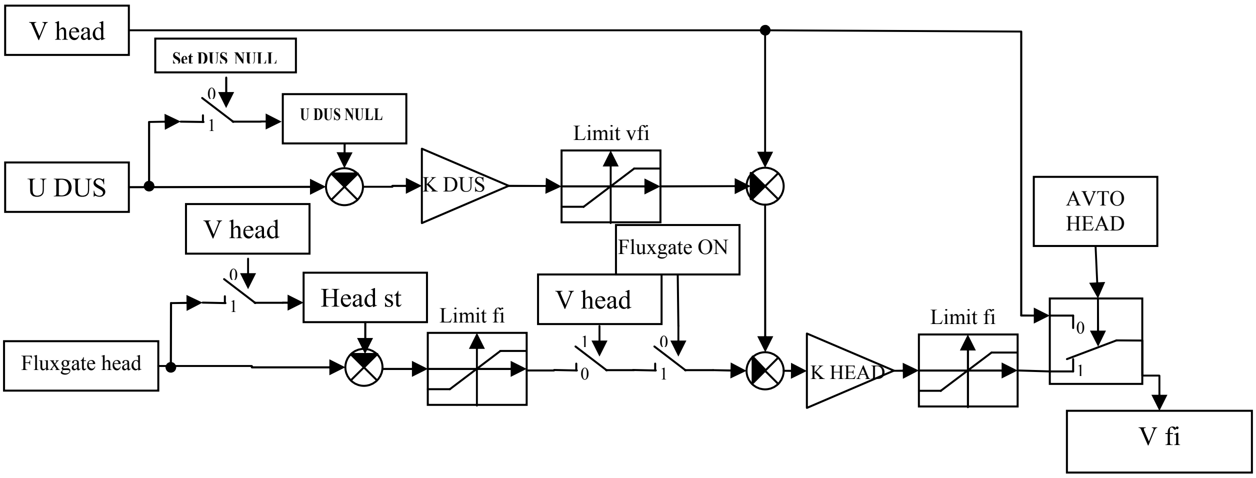


Fig. 17. Computation of the yaw control (V fi)

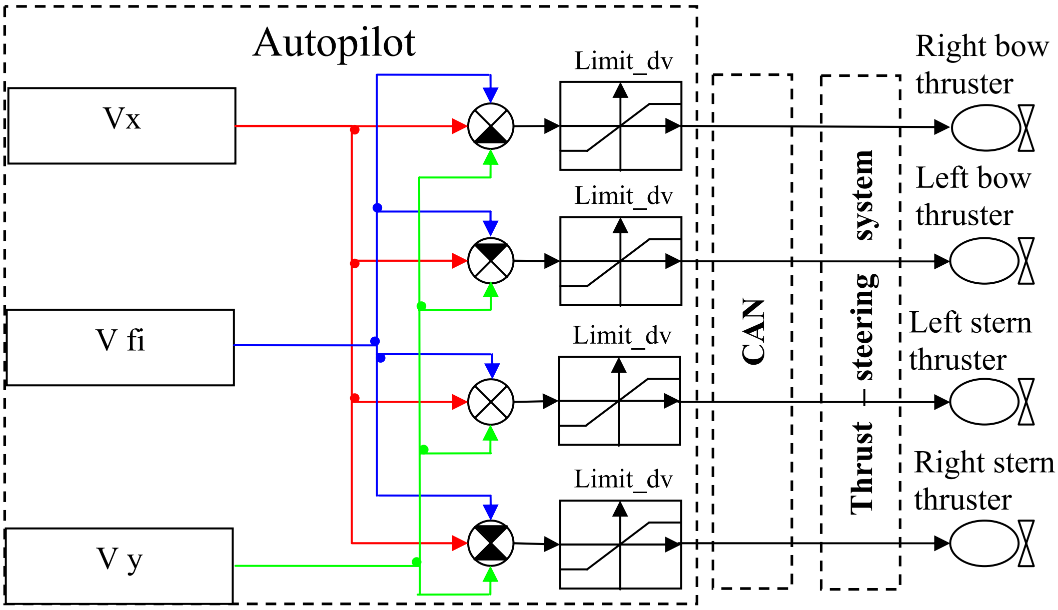


Fig. 18. Scheme of the horizontal thrusters group control

The checkout control commands

Besides the core command autopilot receives the checkout control commands. There are the factors of control laws for the regulators of depth, pitch and course here. The ability of null setting for depth and angular speed sensors has introduced, allowing to compensate the temperature drift of this sensors. This commands are used by operator at the stage of adjustment of the ROV's moving control system.

Conveniences for the accomplishment missions

Mission 1

For the accomplishment the first mission a wide-angle navigational video camera located in the front part of the ROV is used. (fig.2).

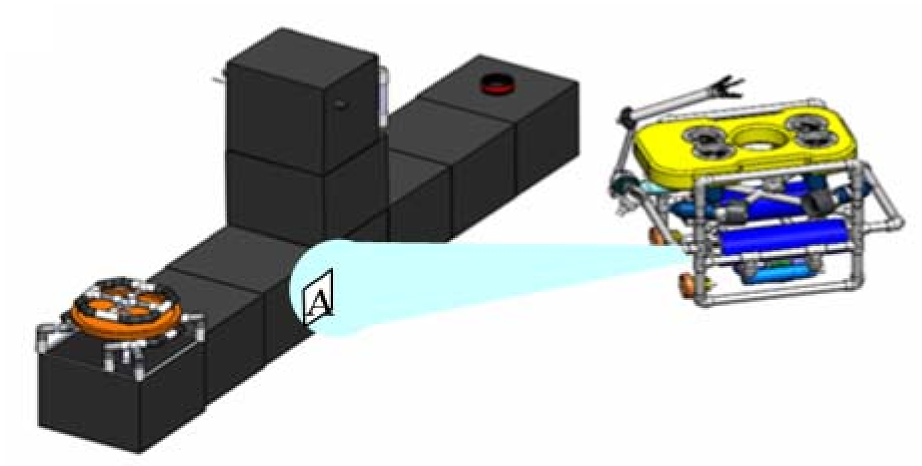
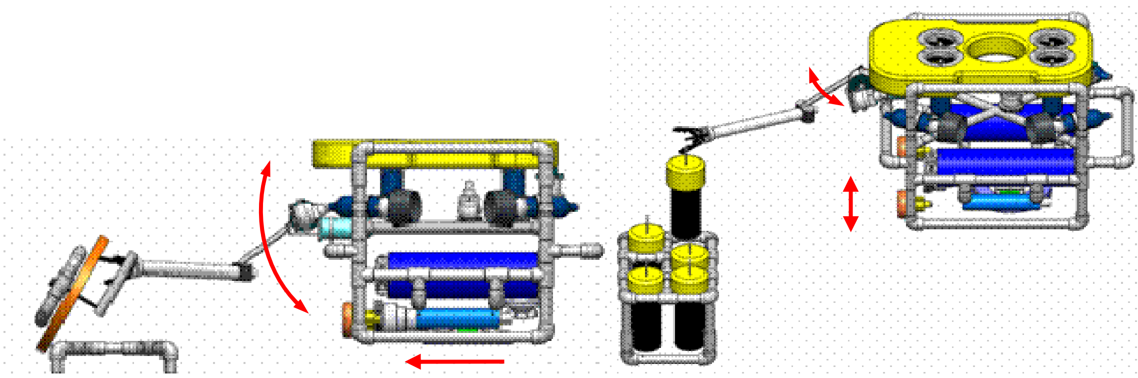


Fig. 19. Accomplishment the first mission

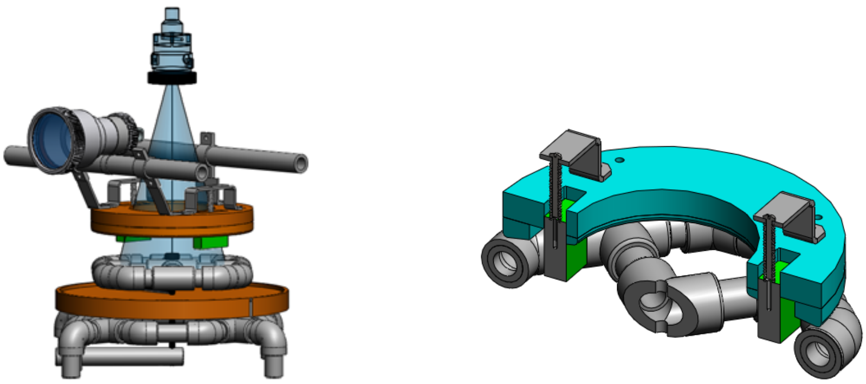
Mission 2

The figure 20a shows the opening the hatch, the figure 20b represents the removing a pod from the carousel assembly. The figure 21a illustrates the additional device “opener the hatch”, which is included in the construction of the vehicle. It is provided for the opening and closing the hatch. The figure 21b shows the construction of this device in section.



a б

Fig. 20. The accomplishment of the second mission:
a – opening the hatch; b – removing the pod



а б

Fig. 21. Additional device "opener the hatch": a – in action; b – in section

Mission 3

On the accomplishment the third mission a grubber is used. It provides transporting the airline to submarine, opening a hatch, inserting an airline into the connection and opening and closing a valve. The figure 22 represents the process of accomplishment the third mission.

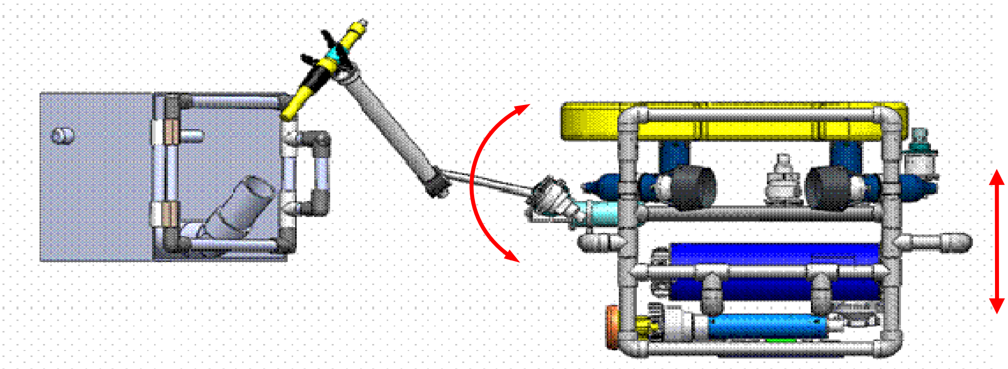


Fig. 22. The accomplishment the third mission

Mission 4

For the accomplishment the forth mission we designed the additional device – a catcher. The catcher and "opener the hatch" combined into unified device. Moreover, there is a vertical docking camera which provides aiming. Combined device is shown in the figure 23. Thanks to internal cone on the catcher, mating becomes easier.

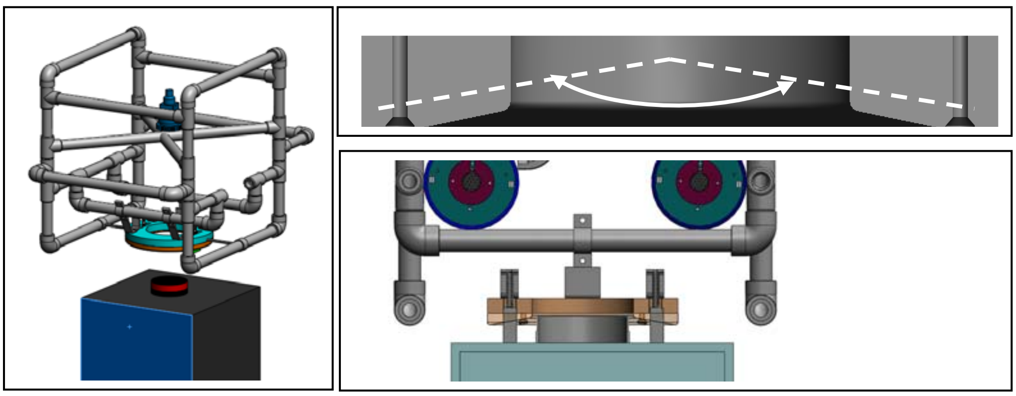


Fig. 23. Combined device

Troubleshooting Techniques

Initially, when designing the remote operator program, we make only one mode of operation, in which the application was a kind of interface board of aircraft with all major navigation and additional components, as video window. During the test team found that the composition of the elements of the interface designed is not good. For mission's fulfilling the operator is enough quite distracted by bright devices such as compass, alarm system, depthometer etc. To solve this problem we added additional mode of work – pointing mode in an annet. In this mode, the video window takes practically the entire screen, but for performance information and sensors data there is only a narrow strip at the top of the screen. This change enabled to decide the problem without changing the program finished.

During the operation the previous version of ROV "Junior" we found out the number of disadvantages concerning with the low quality of ROV's control. That is why we decided to modify the vehicle in order to make the quality of stabilization of magnetic course, depth and pitch higher.

We obtained the aim through the replacement the TCM2, used before, with the analogue inductive compass and also through the usage of the multi-channel 16-bits ADC.

Reflection and Teamwork

During the work at the apparatus we have learned to work in a team, expanded the mental outlook in area of underwater robotics and received practical experience in creating ROV. Each member of the team was given a certain part of the development of ROV, in which he was able to express himself and acquire new knowledge. With this distribution, we covered all major technical areas related to the establishment of apparatus. In doing so, each of the creators in addition to its part of the project worked in related fields.

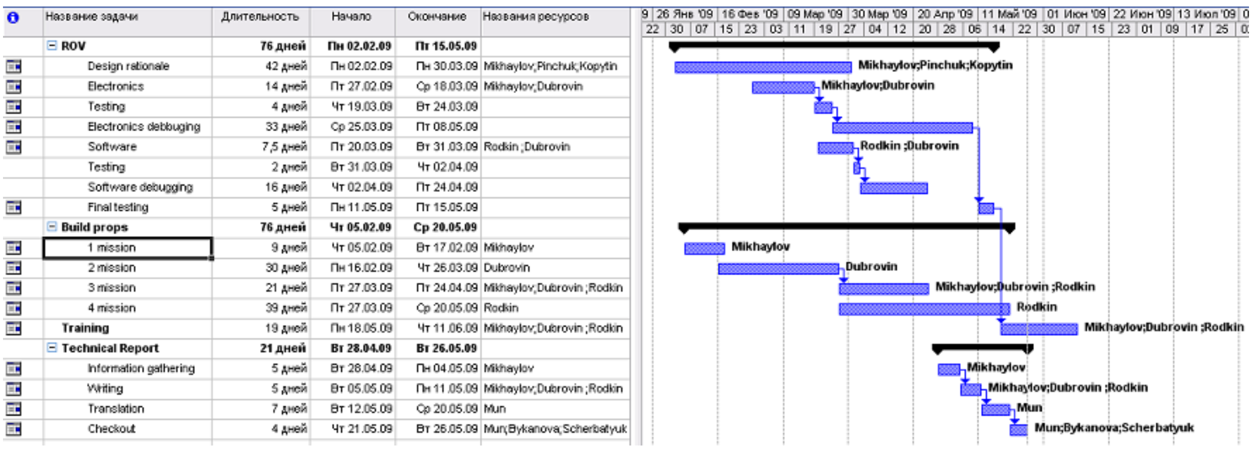
Design Rationale: Denis Michaylov, Vladimir Kopytin and Artem Pinchuk under the guidance of Anna Bykanova.

Developing, implementation and testing software for ROV's control: Denis Rodkin, Yriy Dubovoy and Alexey Kovalenko under the guidance of Sergey Mun.

Developing the electronic schemes, soldering the electronic components and assembling the containers: Denis Michaylov under the guidance of Vladimir Kostenko. Implementation and debugging the program of autopilot's microcontroller: Fyodor Dubrovin under the guidance of Nicholay Naydenko.

Coordination of problems and projects: the captain of our team Denis Michaylov under the guidance of Alexander Scherbatyuk.

The process of our team work is demonstrated on the figure 24.



Название задачи	Длительность	Начало	Окончание	Названия ресурсов
ROV	**76 дней**	**Пн 02.02.09**	**Пт 15.05.09**	
Design rationale	42 дней	Пн 02.02.09	Пн 30.03.09	Mikhaylov;Pinchuk;Kopytin
Electronics	14 дней	Пт 27.02.09	Ср 18.03.09	Mikhaylov;Dubrovin
Testing	4 дней	Чт 19.03.09	Вт 24.03.09	
Electronics debbuging	33 дней	Ср 25.03.09	Пт 08.05.09	
Software	7,5 дней	Пт 20.03.09	Вт 31.03.09	Rodkin ;Dubrovin
Testing	2 дней	Вт 31.03.09	Чт 02.04.09	
Software debugging	16 дней	Чт 02.04.09	Пт 24.04.09	
Final testing	5 дней	Пн 11.05.09	Пт 15.05.09	
Build props	**76 дней**	**Чт 05.02.09**	**Ср 20.05.09**	
1 mission	9 дней	Чт 05.02.09	Вт 17.02.09	Mikhaylov
2 mission	30 дней	Пн 16.02.09	Чт 26.03.09	Dubrovin
3 mission	21 дней	Пт 27.03.09	Пт 24.04.09	Mikhaylov;Dubrovin ;Rodkin
4 mission	39 дней	Пт 27.03.09	Ср 20.05.09	Rodkin
Training	19 дней	Пн 18.05.09	Чт 11.06.09	Mikhaylov;Dubrovin ;Rodkin
Technical Report	**21 дней**	**Вт 28.04.09**	**Вт 26.05.09**	
Information gathering	5 дней	Вт 28.04.09	Пн 04.05.09	Mikhaylov
Writing	5 дней	Вт 05.05.09	Пн 11.05.09	Mikhaylov;Dubrovin ;Rodkin
Translation	7 дней	Вт 12.05.09	Ср 20.05.09	Mun
Checkout	4 дней	Чт 21.05.09	Вт 26.05.09	Mun;Bykanova;Scherbatyuk

Fig. 24. Working process of our team

Experience we can use gained for creating another underwater robotics team, which will include the members "Primorye Coast". Besides, we plan to continue to enhance our skills in the area of ROV, so that in future to take part in competitions already as instructors.

Team Photo Album


Piloting of the “Junior”


Tool construction


Working on electronics

Challenges

Besides preparing for the ROV competitions and study in the university, most member of our team are engaged in science activity. Therefore, it was not easy to gather all together and work at the developing and designing the ROV. Sometimes we had to meet at nights to work together.

However, thanks to the reasonable schedule of our work, made with the support of our guides, we managed to accomplish all the preparations for the competitions in term.

Lessons Learned

By preparation the ROV for the competition our team members have raised their qualifications:

- Working with SolidWorks by the construction of the complex devices;
- Working with the object programming C++;

- Using new electronic devices (e.g., magnetic compass ID-6)
- Constructing the model of the submarine and its components.

Moreover, we have received an invaluable experience of being mentors as we were teaching new members as a team work, as a work in certain fields of ROV's developing.

Future Improvement

In reduced visibility under the water the proposed video system is not effective enough. Thus, we plan to propose the installation of forward sonar on the underwater vehicle.

For the further contribution of the vehicle we are intended to increase the number of manipulator's degrees of freedom for the expansion its capabilities.

In addition, we are going to append the controlling roll into system.

Finally, it is necessary to make the cross-transmission of video signals.

Description of a submarine rescue

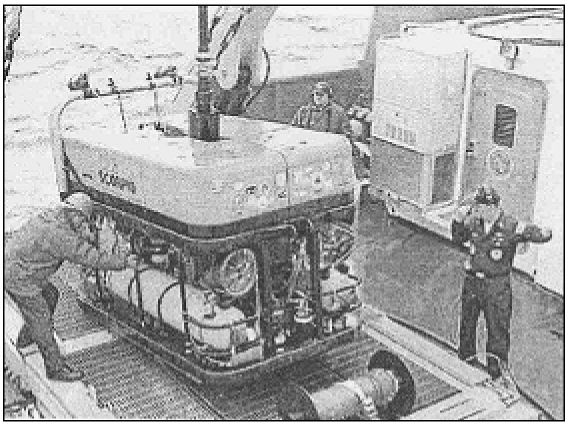
There are 5115 submarines that have been constructed for the last century. Nearly the third of them were destroyed during the battles, and 227 submarines – in peacetime. In postwar time 27 submarines were destroyed in USSR and Russia. Human casualties and losses are huge ("Introduction in Underwater Robotics", Y.K. Alekseev, 2008).

Searching and rescuing actions are very important and essential in usage of ROV.

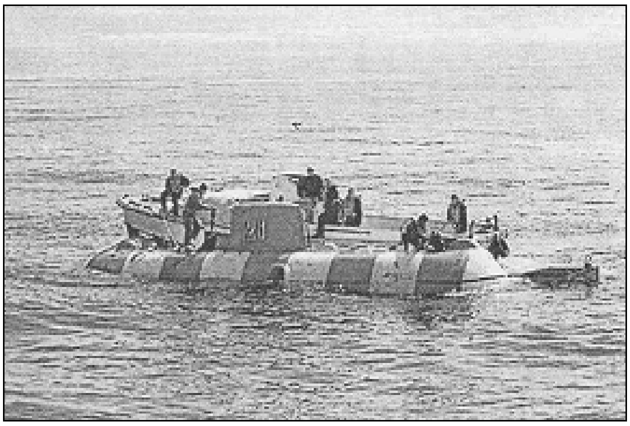
On preparing to this year competitions our team has studied a lot of literature about rescue of submarines by ROVs. What struck us most was the event, which took place in Berezovaya bay in 2005.

On August 4, 2005 in Berezovaya bay the AS-28 submarine signaled about the accident: their submarine could not move. The submarine was determined to be caught in cribs. Two up-to-date ROVs were sent for rescuing: Venom and Tiger. The crews of both ROVs didn't manage to accomplish their missions. "The technicians just broke the Venom. The technical crew of Tiger didn't accomplish the mission as well", commented on that accident the admiral Vladimir Masorin ("Experience from Berezovaya Bay", Y.K. Alekseev, G.P. Turmov).

"Scorpio" ROV's arrival in accompany with the high quality technicians was the extreme hope for salvation the crew of the "AS-28" submarine. The "Scorpio" crew managed to rescue the submarine from the ropes which held it under the water for 3,5 hours.



a



b

Fig. 25. Submarine rescue: a – Scorpio; b– submarine AS-28

"Saved!", these words started all the news programs on August7, 2005. The undersea drama with seven submariners, captured by the ocean for 3 days, ended well.

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Appendix A. Functional scheme of the "Junior" control system