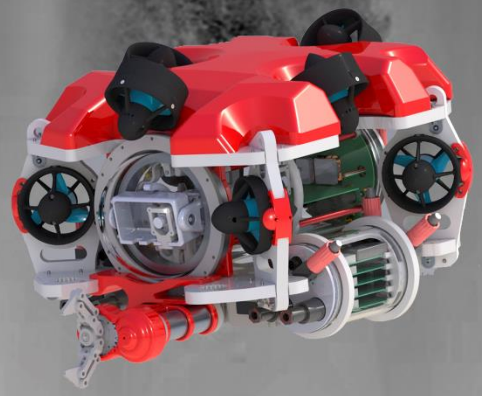
COUSTEAU

HYDRONAUTICS
BAUMAN MOSCOW STATE TECHNICAL UNIVERSITY



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EXPLORER CLASS
2017 MATE INTERNATIONAL ROV COMPETITION
MOSCOW, RUSSIA

1. ABSTRACTION

Educational and scientific center «Hydronautics» was founded in 2010 at the Bauman Moscow State Technical University. The aim of the center is to develop student initiative and new educational technologies for training engineering personnel in the field of underwater robotics and the marine industry. Students build underwater vehicles using knowledge and skills obtained at the Underwater Robots and Vehicles department. There are also students from Mechatronics and Computer Sciences departments that are heavily involved in the company's operation.

Fig. 1.1. Hydronautics company

This year our company is devoted to Long Beach Port Service and Environmental Issues. We thought for a long time about the name of our vehicle and decided that we would name it in honor of the man who did a lot for the ecology of the sea - Jacques-Yves Cousteau. So we have designed ROV «Cousteau».

Fig. 1.2. ROV «Cousteau»

«Cousteau» is a modular construction that provides high maintainability and the ability to quickly change functional units. We kept within strict deadlines due to the division of roles and precise scheduling of work by using a Gantt chart and mind maps. In our work, we use modern methods of design and modeling: Solidworks CAD and Altium Designer.

For the production of parts, we used the latest technologies: milling using CNC machines, 3D printing, laser-cutting. Our vehicle is made from easily processed and cost-effective materials: polypropylene, Plexiglas, aluminum, ABS-plastic.

The vehicle can be used for full-scale underwater research, as it is capable of carrying additional equipment for a wider range of tasks.

2. TABLE OF CONTENTS

3. STEP-BY-STEP DEVELOPMENT

3.1. CONCEPT AND PRINCIPLES

Designing an ROV requires lots of time, a good knowledge of robotics, high financial spending and, of course, a solid team of workers with their endless flow of ideas. The development process was done in several consecutive steps:

1) Compiling the ROV specifications
2) Choosing the number of thrusters and their arrangement
3) Design of the pressure hulls
4) Software development
5) Design of the microprocessor control unit
6) Development and testing of auxiliary tools
7) Assembly of the ROV
8) Testing and troubleshooting of all systems
9) Aesthetic decoration and design

The development timeline is shown in Fig. 3.1.1.

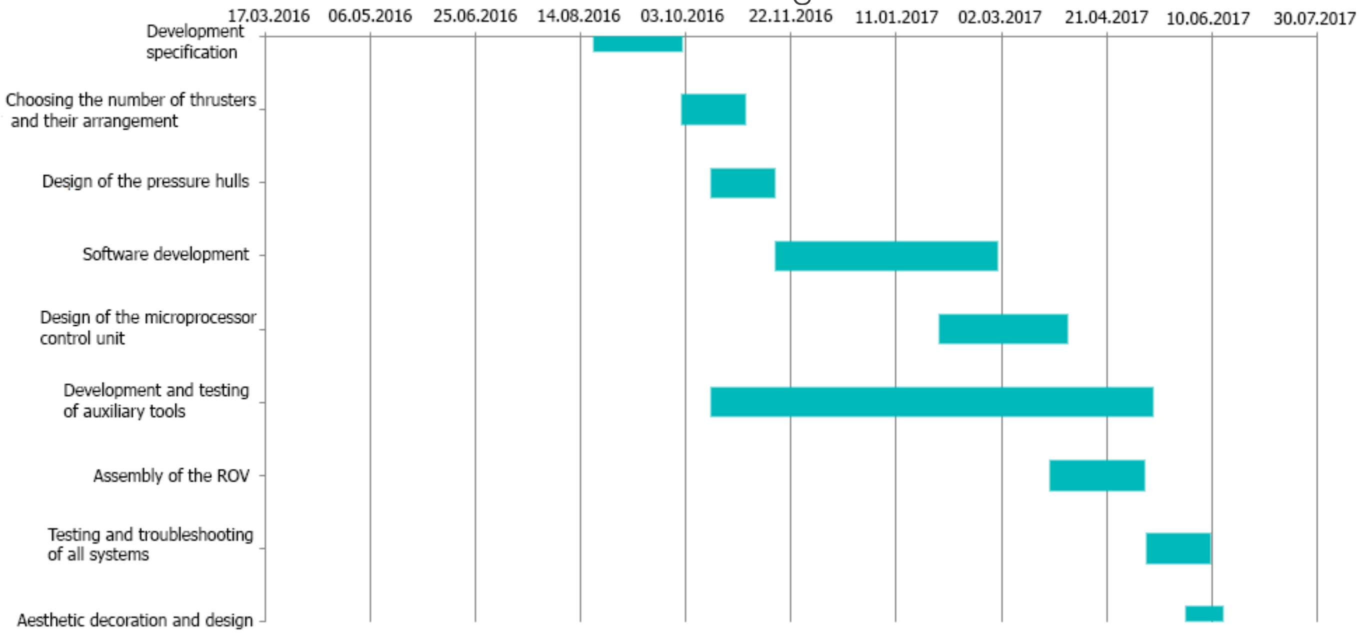


Fig. 3.1.1. The development timeline.

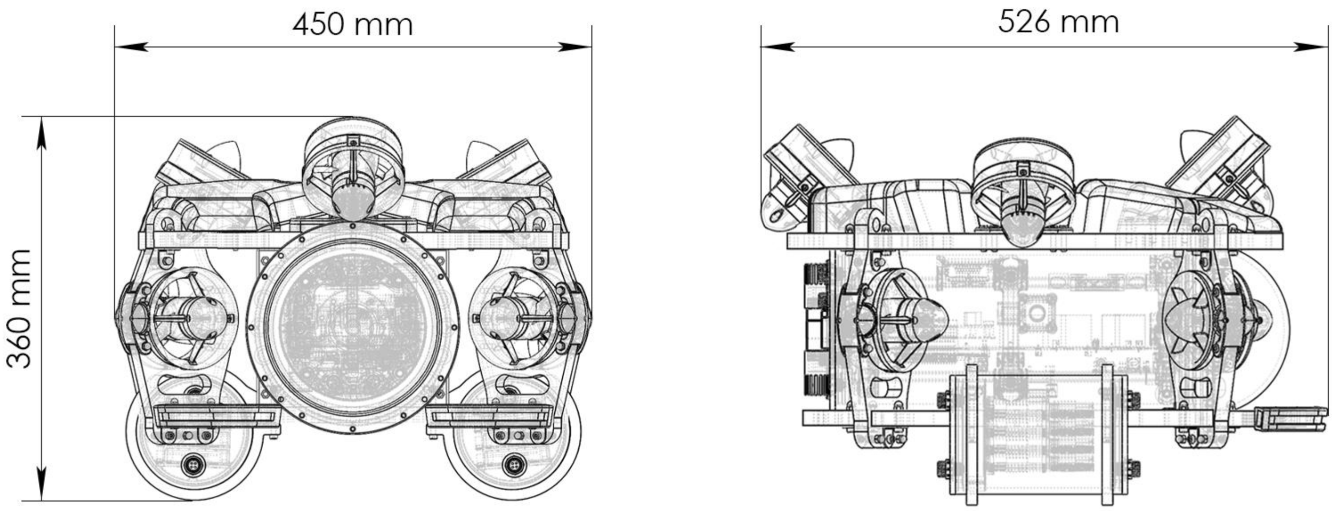


Fig. 3.1.2. Drawings of «Cousteau»

3.2. SAFETY IN THE ROV

When working on the Cousteau project, in addition to directly creating the ROV, much attention was paid to compliance with safety rules.

1) The company members in the laboratory who work directly with the equipment were dressed in gowns, protective gloves and goggles (Fig. 3.2.1.). When working with harmful substances workers are protected by respirators and gloves.
2) Before working with tools and machines, employees are instructed.
3) The load-lifting device (telpher) can only be used by trained participants in the project, in special protective suits and helmets (Fig. 3.2.2.).
4) The telpher has an emergency power-off button in case of failure of the device.
5) On the inside of the door there is a reminder to switch off all electrical devices.
6) In the laboratory there are first aid kits. Their content is refreshed from time to time.
7) The team has a safety check list to start the device during the competitions (in the application).

Fig. *3.2.1. Company member* in gowns, gloves and goggles

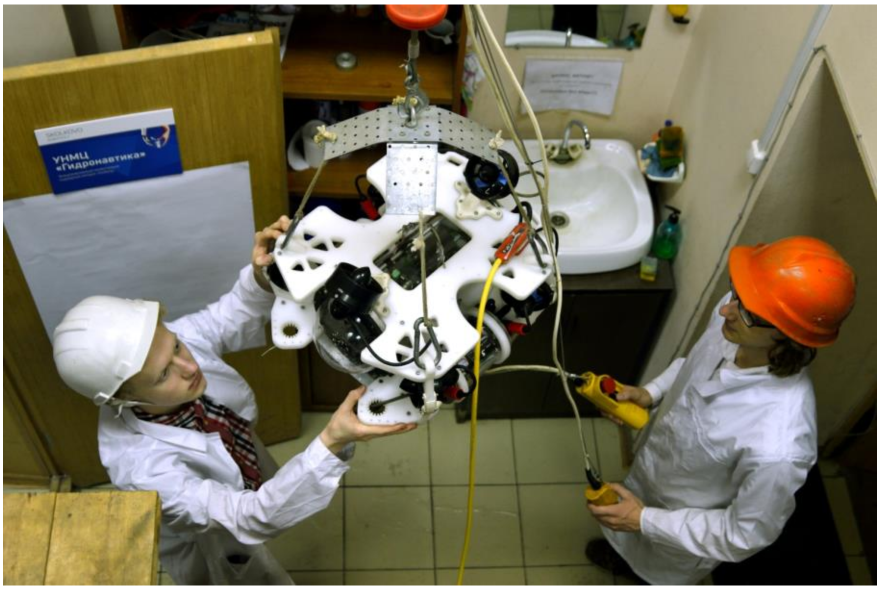


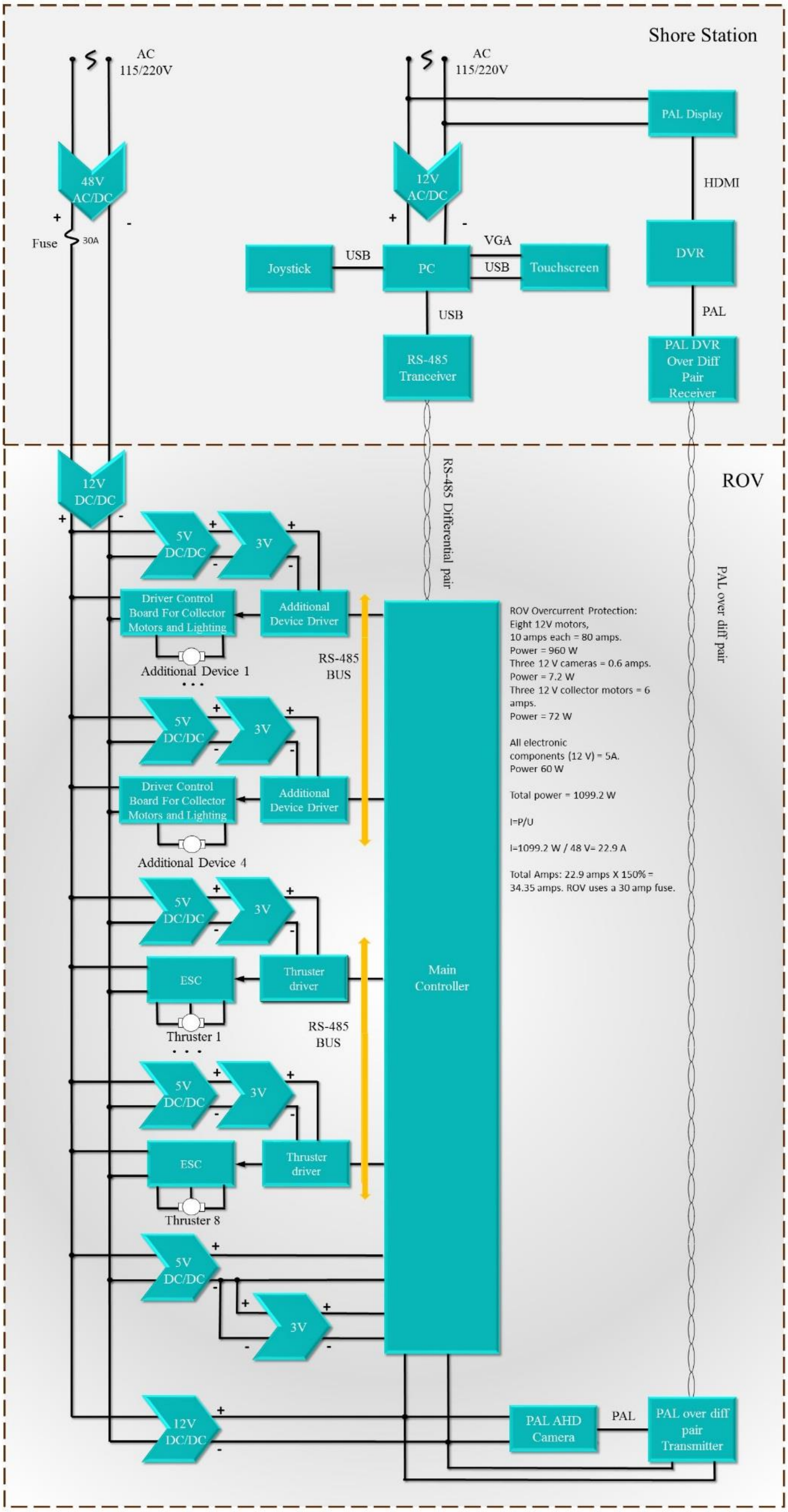
Fig. *3.2.2. Trained participants in special protective suits and helmets use the telpher*

During the tests of the magnetic clutch the magnets were torn off with rapid rotation and there was a danger of injury, considering that a special protective device was assembled.

Initially, the ROV did not have emergency shutdown of the motors during the loss of communications, and during the tests the communication disappeared and the ROV crashed into the pool wall, breaking some equipment. Subsequently, this problem was eliminated. More information is in the JSA.

4. ELECTRONICS

4.1. SID



4.2. COMMUNICATION CHANNEL

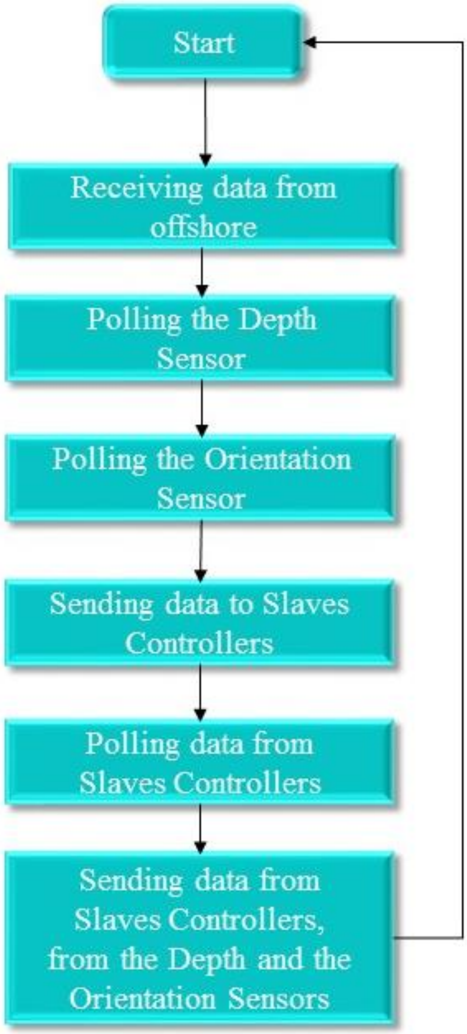


Fig. 4.2.1. Software logic scheme

Communications channel consists of 3 subsystems (Fig.4.2.1.):

- Connection between vehicle and shore via interface RS-485.
- Connection between auxiliary measuring equipment on board via bus 12C.
- Connection between controllers of thrusters and onboard equipment via bus RS-485.

Shore-to-vehicle communication channel

Whilst organizing this type of connection, we had to provide adequate transmission speed with limitations of tether (current length of tether is 20 m). Implementation of RS-485 allows us to organize half-duplex link with speed up to 57600 baud/s.

Judging by simplicity of topology of this network, we have decided not to use industrial network-level protocols but, instead, to develop our own asynchronous protocol, which allows to extend length of tether up to several hundreds of meters and decrease baud rate without reducing protocol efficiency. Main controller receives data via interruption routine and transmits by separate stream. On shore side, role of transceiver is performed by x86 architecture computer.

Role of shore side transceiver is performed by x86 architecture computer.

Software was developed in QT Creator environment, which allows us not only to create graphic interface but, in addition, to work with periphery of computer. We also used processing library to work with Saitek joysticks. From shore data is transmitted with frequency of 20Hz, which is limited only by capacity of computer.

Onboard communication channel

To connect main controller with auxiliary devices and thrusters we have chosen RS-485 interface. This allows to construct electronics block in stack form.

Main controller (Bus Master) sends data to supplementary controllers (Slaves). Data is received with interruption routine, while transmission proceeds in separate stream.

Logic scheme of software is presented in Fig.4.2.2.

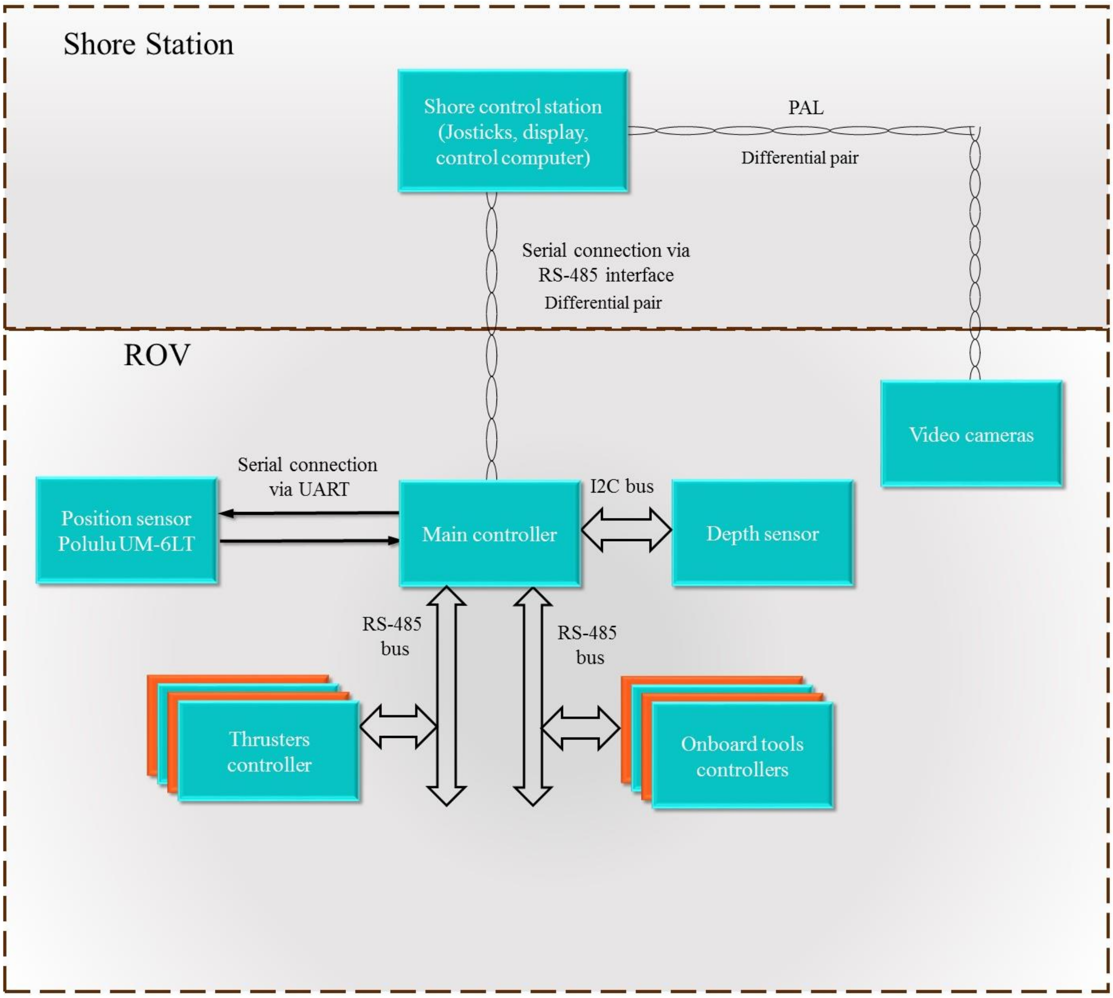


Fig. 4.2.2. Communication channel of the vehicle

4.3. CONTROL SYSTEM

To simplify the underwater vehicle operator's work, the automatic control system for 4 degrees of freedom - course, roll, pitch and depth – was implemented. Its principle of operation is shown in Fig.4.3.1. Simulation in Matlab Simulink allowed us to determine coefficients for converting the system error in the control voltage. In the automatic control system, a proportional integral controller is used that allows to perform a constant external action and to ensure a constant positioning of the device at one or several degrees of freedom simultaneously. To coordinate the control systems, a signal distribution block for the thruster was written to each other. The principle of its operation consists in the joint processing of signals from several system processes. The principle of its operation is presented in Fig. 4.3.2.

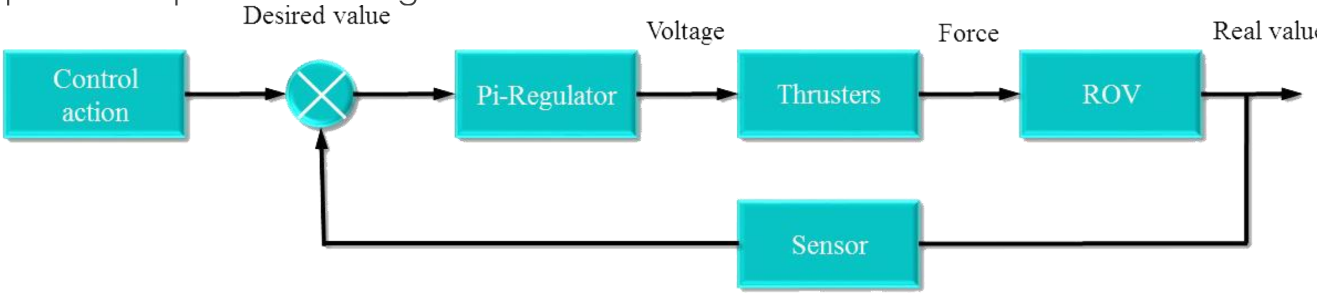


FIG. 4.3.1. Block diagram of the algorithm of the stabilization system

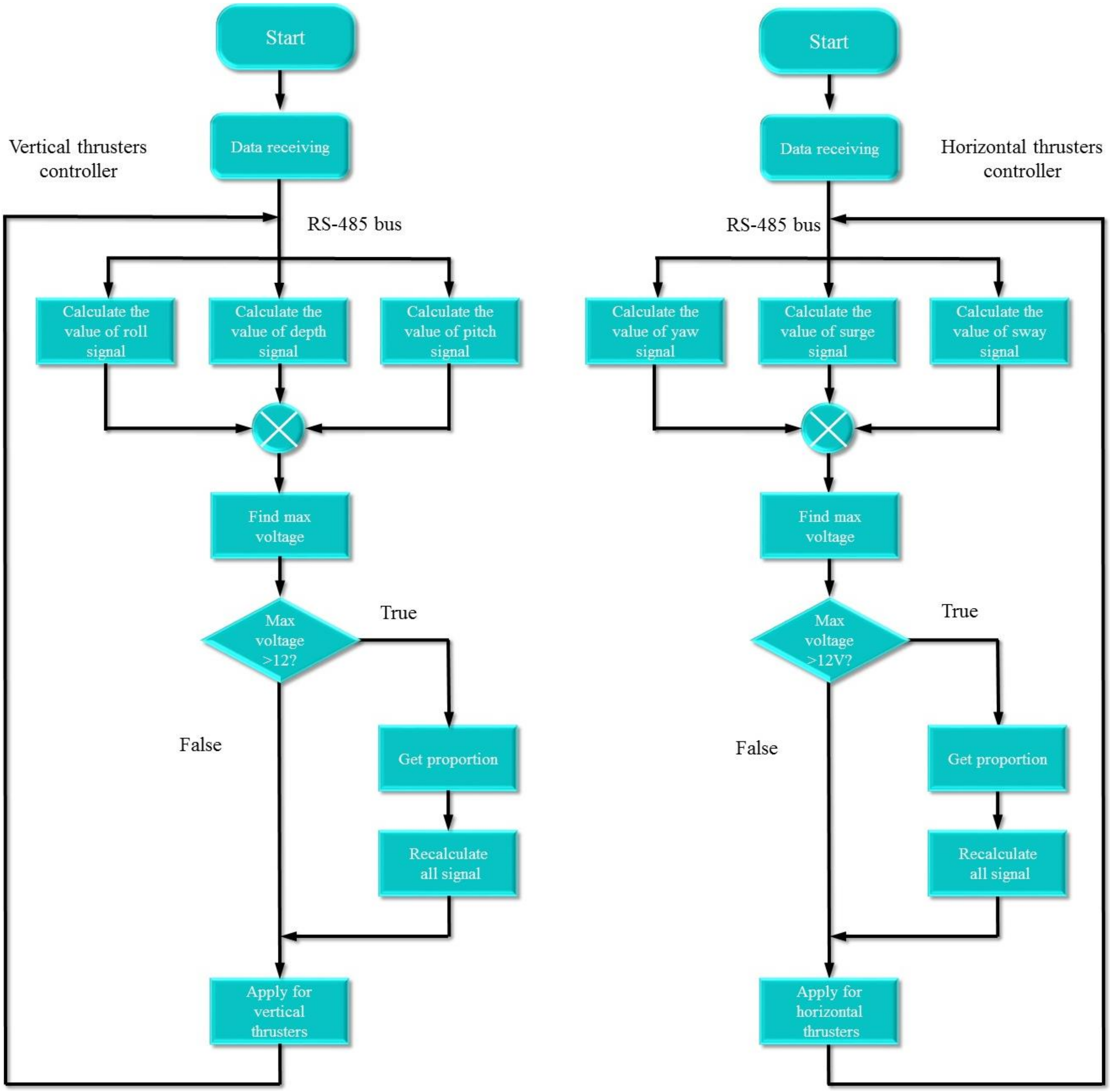


FIG. 4.3.2. Block diagram of the control algorithm for vertical and horizontal thrusters

4.4. CABLE

A special submarine cable from Novacavi is used to connect the device with the control panel and power supply to the device. The cable contains 4 twisted pairs and two power lines, placed in a strong shell, reinforced with Kevlar fiber.

We decided to use the purchased cable, not homemade for the sake of reducing the weight of the structure. This cable has no buoyancy blocks and is designed so that it initially has a neutral buoyancy. The cable characteristics are shown in Table 1.

Length	20 meters
Diameter in water	8 mm
Buoyancy	Neutral
Operating temperature	-30°+45° C
Breaking force	220 kg

Tab. 4.4.1. Cable specifications

4.5. MAIN PRESSURE HOUSING

Main pressure housing of electronics (Fig. 4.5.1.) contains 11 boards.

- Main boar
- Cross-board
- Central Controller Board
- Driver boards for additional devices 4 pcs
- Power driver 4 pcs

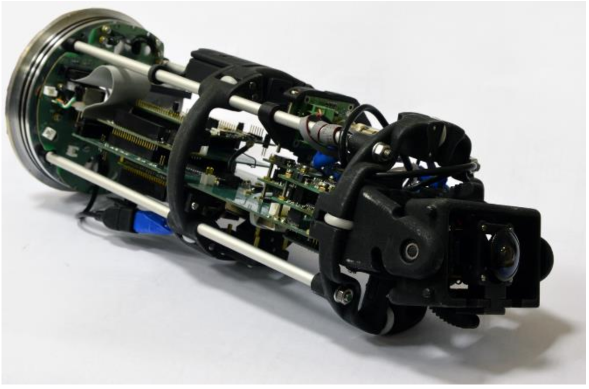


Fig. 4.5.1. Electronics in the pressure housing

4.5.1. MAIN BOARD

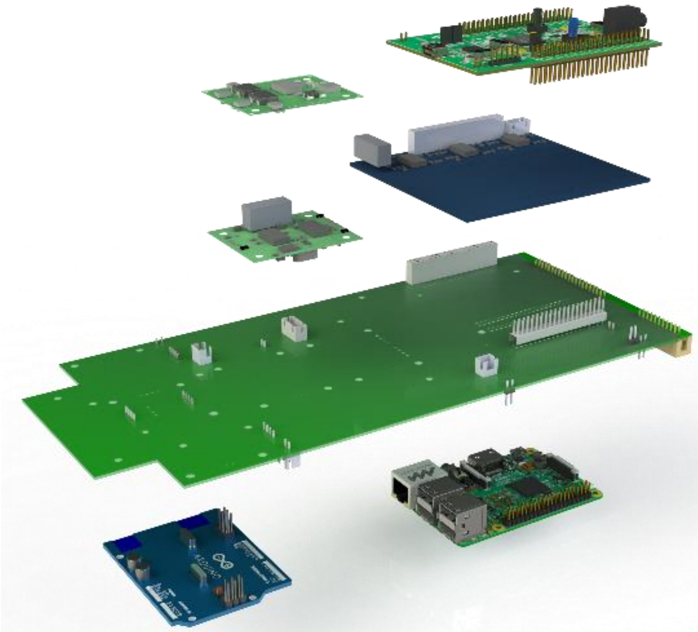


Fig. 4.5.1.1. Main board arrangement

Motherboard serves to simplify the tracing and compact placement of all other boards in the main body (Fig. ...). In addition to the signal lines, there are power lines along the board, so the board is made of foil 105 microns thick. The design of the main building went simultaneously with the PCBs layout, the designers and electronic engineers worked in constant contact, the export of the step model from the Altium Designer to SolidWorks was used extensively to estimate the dimensions, as a result, the optimum positioning was obtained.

4.5.2. CROSS-BOARD

Cross-board is designed to simplify the layout of communication lines to the connectors. Also on it is a DC-DC converter with 12 to 12 for cameras and a cooler for air circulation. The board is connected to motherboard by flexible plumes and also made with a foil thickness of 105 microns.

4.5.3. CENTRAL CONTROLLER BOARD

The stm32f3 discovery board is installed on the central controller board. The controller board has 3 decoupled RS-485 transceivers through which stm32f3 discovery receives and transmits data from the shore via RS-485 interface and sends control commands to the drivers of the motors and the drivers of the additional devices. The STM32f3 discovery controller closes the machine control system

4.5.4. DRIVER BOARD FOR ADDITIONAL DEVICES

To control the power drivers of additional devices, 4 identical boards are used (Fig. 4.5.4.1.) which are installed on the motherboard in the sturdy housing of the main bank.

The boards are equipped with 32-bit microcontrollers from STM to control drivers. To provide communication with the head controller via the RS-485 interface and additional devices, for example an encoder, two MAXIM chips are used on the RS-422 interface. The board forms a control action for power drivers, which consists of two antiphase PWM signals, between pulses of which there is always a time interval not exceeding the programmed value.

Fig. 4.5.4.1. Driver board for additional devices

4.5.5. DRIVER CONTROL BOARD FOR COLLECTOR MOTORS AND LIGHTING

To control the collector motors of additional equipment in the TNPA Cousteau, the H-bridge circuit used. It consists of two half-bridge circuits, which individually can control lighting of the underwater vehicle. Driver disign is based on the IR2113SPBF chip, which manages power keys represented by the MOSFET transistors IRF Z44EPBF . The board provides protection against overcurrent. Control signals coming to the board are solated from the power part, using an optocoupler. The main advantages of driver are: low cost, convenient form factor, high maintainability, the process of manufacturing one card takes less time than waiting for the delivery of a purchased analog.

4.5.6. RASPBERRY PI 3.

The motherboard has a raspberry pi 3 single-board computer. For future implementation of the autonomous operation algorithms of the device, it is connected to STM32f3 discovery via the SPI interface, at the moment this connection is not used. Raspberry pi 3 is equipped with a built-in wifi module. It runs the raspbian operating system. When we are connecting to raspberry pi 3 via wifi, it is possible to flip the main controller via USB-cable and the other cards via RS-485 interface from it (For this, bootloader is loaded in them). All this allows us to debug and reflash all microcontrollers of the device without disassembling the case and even on the surface of the water.

4.5.7. DRIVER CONTROL BOARD FOR SCREW MOTORS

To control motor drivers, 8 identical own designed boards are used, which are installed for 4 pieces in a rack in 2 separate sturdy housing. The boards are equipped with 48/12 V voltage converters for powering all PA electronics and VMA drivers, STM controllers to operate the drivers, serial interface chip rs485 from MAXIM company to provide controller communication with the head controller and remote firmware, DIP switch for setting the address of the controller, also a circuit for measuring the amperage, power circuit and hardware protection for the current of the power drivers VMA.

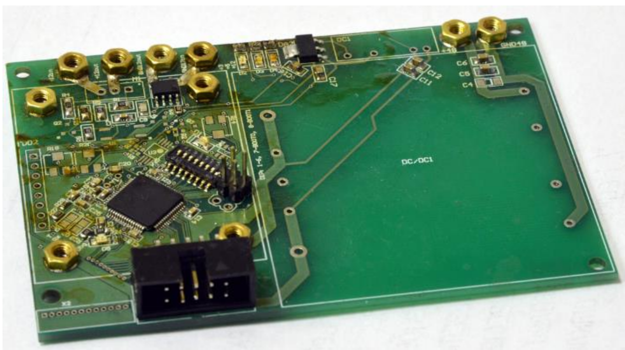


Fig. 4.5.5.1. Driver control board for screw motors

5. *DESIGN RATIONALE*

Cousteau's design conception is based on good features of previous generations of Akvator ROVs and supplemented with new ideas of our current team. There are three basic principles that have guided us through Cousteau's designing - safety, reliability, usability.

5.1. FRAME

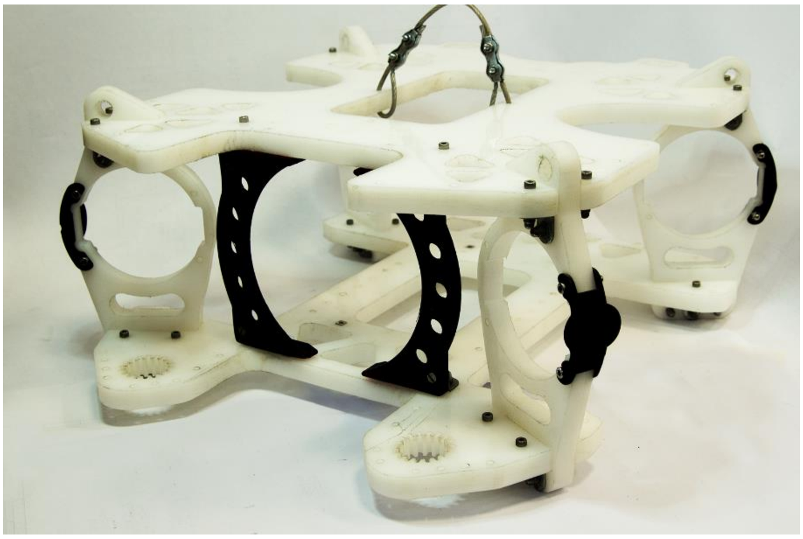


Fig. 5.1.1. Cousteau's frame

Frame is completely designed and built by us, as like in the our previous ROV - Iceberg. It is modular, easy to assemble and disassemble. Rigidity of frame is provided with horizontal thruster's fixtures with stainless steel fasteners. There are cut-outs in non-loaded areas to easier wiring and to make the frame lighter. There are also fixing holes for additional equipment and payload.

Due to these features, total disassembling of Cousteau takes about 15 minutes.

Frame is made of 15 mm polypropylene. This material is durable, corrosion-resistant and has good buoyancy. All corners and sharp edges are rounded to meet the safety requirements. Fixing screws are tighten with cap nuts so accidental stacks isn't possible.

5.2. BUYONACY

Cousteau is designed that way to provide positive buoyancy without additional floats. That is achieved by using polypropylene as main frame material, by big volume of main pressure hull and by low weight of ROV. Cousteau could have maximum displacement about 18000 cm³. At the density of water 1 g/cm³ we have maximum weight about 18 kg. Assembled ROV weights 17,3 kg in current configuration.

There are holes on the frame for additional weights to provide neutral buoyancy and correct position in space.

5.3. CAMERAS

Cousteau is equipped with three AHD cameras MDC-AH2290FTN produced by Microdigital. Cameras are powered by separated 12V to 12V DC/DC converter to minimize the interferences and provide good quality of picture.

Fig. 5.3.1. MDC-AH2290FTN Camera

Video signal format	AHD (1080p) / CVBS (960H)
Matrix type	2.0 Megapixel SONY 1/2.8"(diagonal 6,35 mm) Progressive CMOS
Resolution	1920x1080
Signal-to-Noise-Ratio	more then 50 dB
Minimal Luminance	0.2 lx (Color) / 0.02 lx (white/black)
Voltage	12V±10% DC
Current	200 mA
Working temperature	-10 ~ +50 C
Working humidity	90%

Tab. 5.3.1. Characteristics of MDC-AH2290FTN camera

Main camera is mounted to the tilt unit. Wide-angle 180° lens BL0220M23 produced by Beward is located on the camera.

Type	Fixed
Focus length	2 mm
Lens speed	F2.0
Horizontal angle	195° (2/3")
Compatible Matrix Format	Up to 2/3"
Focus	Manual

Tab. 5.3.2. BL0220M23 lens characteristics

Fig. 5.3.2. BL0220M23 lens

5.3.1. TILT UNIT

Tilt unit has fastenings for two cameras. In our current configuration only one MDC-AH2290FTN camera is used. There also Bluetooth module nearby camera. Tilt unit can move from -90° to +60°. Main part of tilt unit is gear motor that transmit rotation through gear. Tilt angle is measures with encoder.

Fig.5.3.1.1. Assembled tilt unit in SolidWorks

Fig.5.3.1.2. Assembled tilt unit

5.4. PRESSURE HOUSINGS

All Cousteau's electronics is located in three pressure cases: main one and two identical thruster's drivers cases. This way of housing caused by different reasons, and the main one is temperature distribution. Blue Robotics Thrusters require DC-DC converters from 48V to 12V, which emit a large amount of heat in usual mode of operation. These converters are located in driver's cases and also used for supplying main case's electronics.

In this way of housing, usual temperature is established in main case. This is very important for normal functioning of electronic. The second reason for this way of housing is ergonomics. In contrast to previous generations of Akvator ROVs there is minimal number of hermetic connectors on cases. This is makes maintenance easier and construction more tightly and reliable.

The main controller, additional device drivers, Bluetooth module, Raspberry Pi, tilt unit with main camera, additional cameras, orientation sensor are located in main case.

The main controller, additional device drivers and Bluetooth module are mounted on motherboard to decrease the number of wires. Motherboard connected by buses with cross-board, which is provide correct communication and power lines to connectors.

To ensure normal temperature and air moving in main case cooler located there. It is also cooling the additional device drivers.

The feature of this case is construction that most convenient for service. All electronics are located on frame, which can come forward from pressure case if it is necessary. This allows us not to disassemble the whole case.

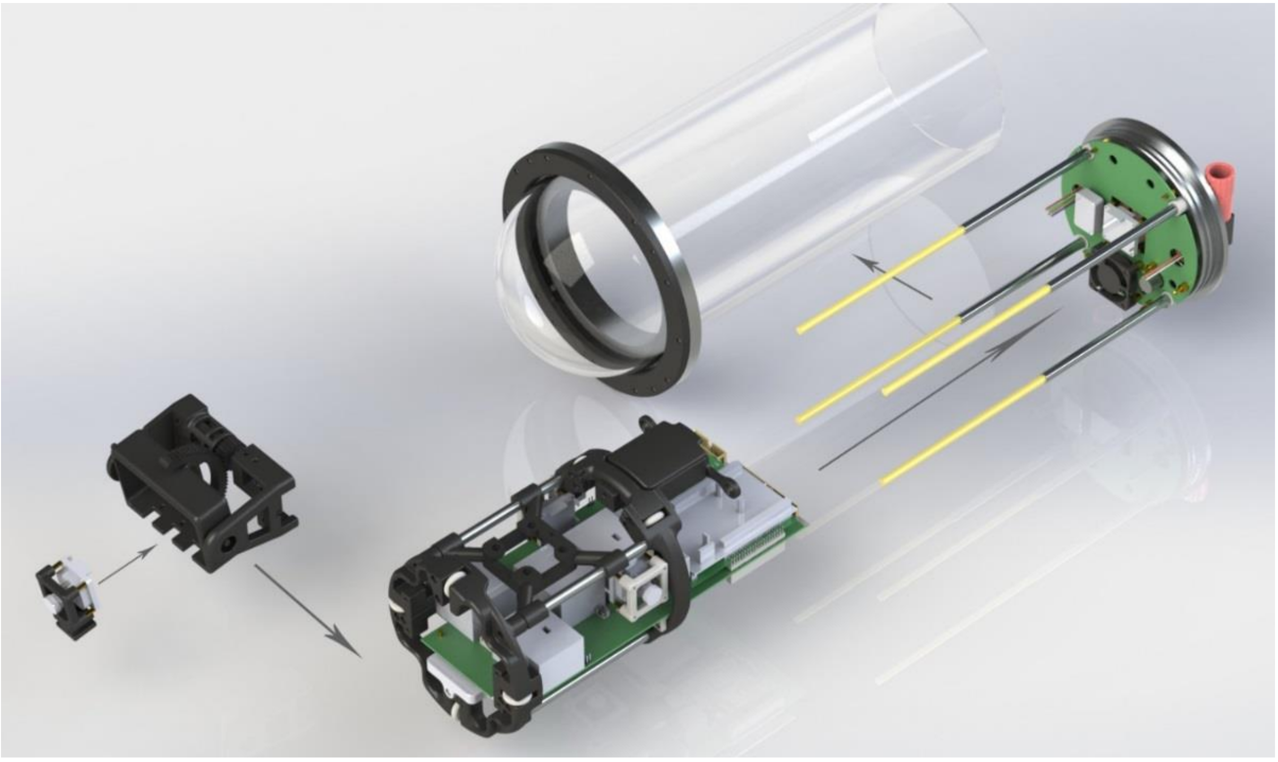


Fig. 5.4.1. Main pressure case with electronics

To decrease hydrodynamical resistance forces and improve the field of vision there is an acrylic dome end cap in front of main case.

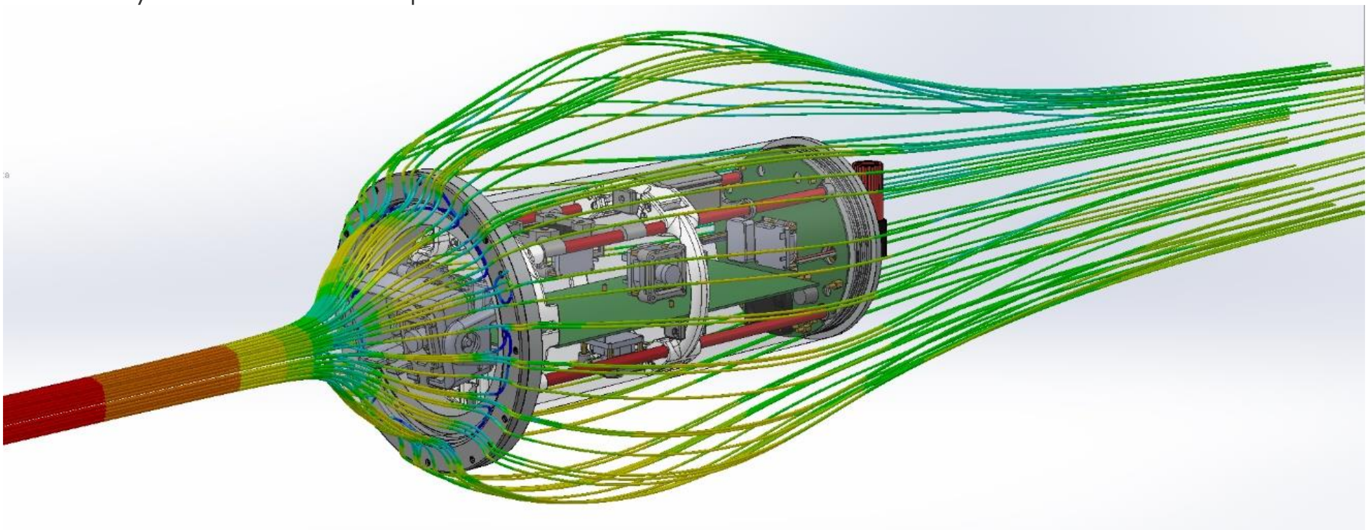


Fig. 5.4.2. Flow motion lines

Cousteau's pressure housings are made of Plexiglas tubes (outside diameters Ø160mm for main case and Ø110mm for driver's cases) and sealed with custom built duralumin caps. It is optimal combination in point of ergonomics, light weight and heat sink. Light and clear Plexiglas allow us to mount cameras in any place of case and visual inspect components. Duralumin with his great heat conductivity hosts all electronics that releases heat.

Sealing is provided by rubber O-rings with radial way and face way of placing. O-rings sizes are regulated by GOST – Russian analogue of ANSI. Subconn connectors and HYF connectors are used for sealing wires.

All the sharp edges are rounded to avoid scratches and cuts.

5.5. PROPULSION SYSTEM

Cousteau uses eight Blue robotics T200 thrusters. We decided to use T200 thrusters because of their lightness and power. Also, these thrusters are based on brushless motors and it is good for Cousteau's reliability.

All the characteristics of Blue Robotics T200 are additionally measured with our thrusters testing and measurement bench.

	Thrust	Weight
Blue Robotics T200	3.0 kgf	344g
Previous thrusters	2.5 kgf	530g

Tab. 5.5.1 Comparison of old thrusters and T200

Fig. 5.5.2. Thrusters testing and

Traditionally for our last Akvator ROVs, Cousteau's horizontal thrusters are placed by vectored arrangement which is better for maneuvering than traditional. Vertical thrusters are used for depth changing and, by pairs, for yaw and roll.

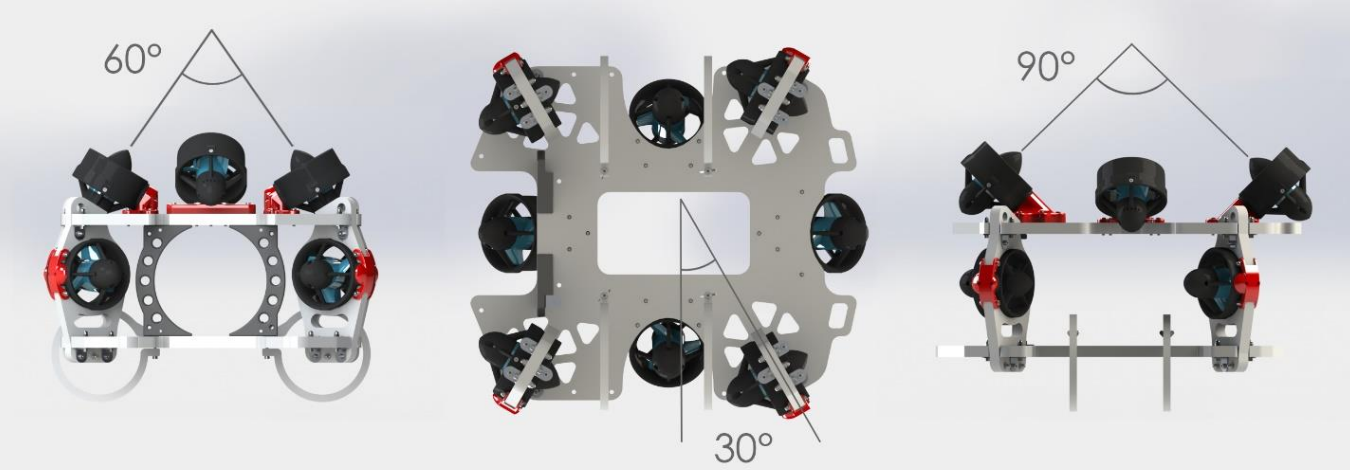


Fig. 5.5.3. Thrusters angles and arrangement

Starboard and port thrusters are mounted with 60° angle to frame to provide faster heave. Front and rear thrusters are mounted with 45° angle to frame for more accurate pitch motion. Also, this arrangement allows us to meet the minimal size requirements. Horizontal thrusters are mounted with 30° angle to centerline. This way of arrangement allows Cousteau to move by surge faster than by sway.

5.6. LIGHTING

Our ROV uses two 15W LED IP68 strips for lighting. Using LED strips as lighting source allows us to reach more lighted area with less lighter size.

LED strips are mounted in 3D-printed holders and additionally sealed with compound.

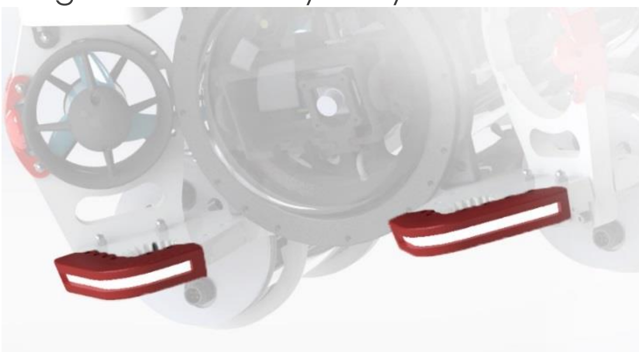


Fig. 5.6.1 Cousteau's lighters

5.7. ORIENTATION SENSOR

For determining the orientation of the vehicle we use CH Robotics UM6 (Fig. 5.7.1.). It provides absolute values of Euler angles (yaw, pitch, raw), circular velocities, linear accelerations along the X, Y and Z axis, quaternions, IMU also has magnetometer. Using a built-in Extended Calman Filter, we can ensure that these readings are highly accurate.

IMU sends information packets with up to 300 Hz frequency. That allows us to design control system that includes several types of passive and active stabilization. Smooth ROV movement and convenient control allows it to perform the tasks of MATE 2017 underwater missions.

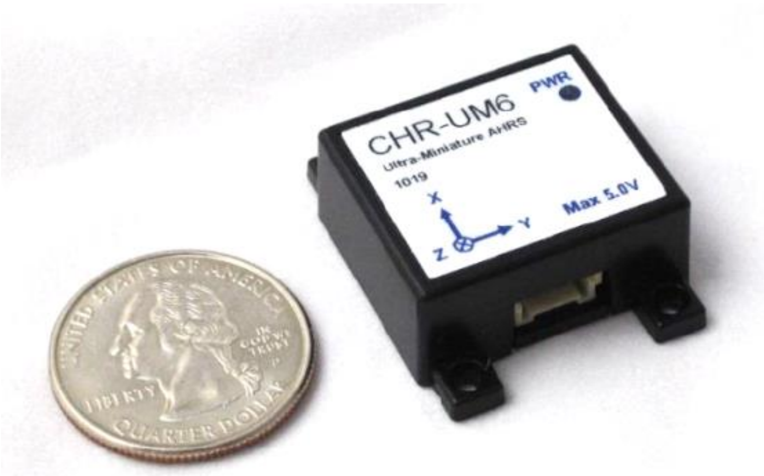


Fig. 5.7.1. CH Robotics UM6 Orientation sensor

5.8. ROV CONTROL STATION

We designed mobile control station for ROV (Figure 5.8.1.). It ensures quick and easy deployment of the whole system. It contains:

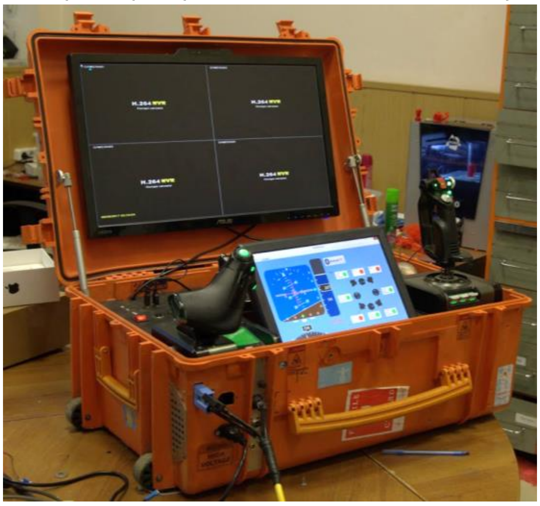


Fig. 5.8.1. ROV control station

- Shockproof equipment box
- 30" wide display
- 16" touchscreen for displaying onboard sensor's data
- Saitek X50 Joysticks for ROV controlling
- 2kW power supply unit for all ROV complex
- 48V to 12V AC-DC converter for DVR and touchscreen supplying.
- Mini-PC for connecting peripheral devices to the ROV
- USB to RS-485 connector produced RealLab! to connecting ROV with PC.
- Microdigital MDR-AH4000 DVR for real-time video translation and recording from Cousteau's cameras.
- Analog video converter

User interface is displayed on 16" touchscreen which is mounted on the control panel. GUI indicates state of Cousteau's equipment and sensor's reading.

Cousteau's position is described on UI elements which is designed in the image of flight instruments such as attitude indicator and compass. This type of indication is comfortable for pilot and informative.

Simplified model of Cousteau is displayed on the right side of the screen. Directions of thrust and current of each thruster are displayed on that model. There is a color indication of current values in each motor. When current value becomes higher than the critical limit, the thruster picture starts to blink with red color, which means that something prevents motor from rotating.

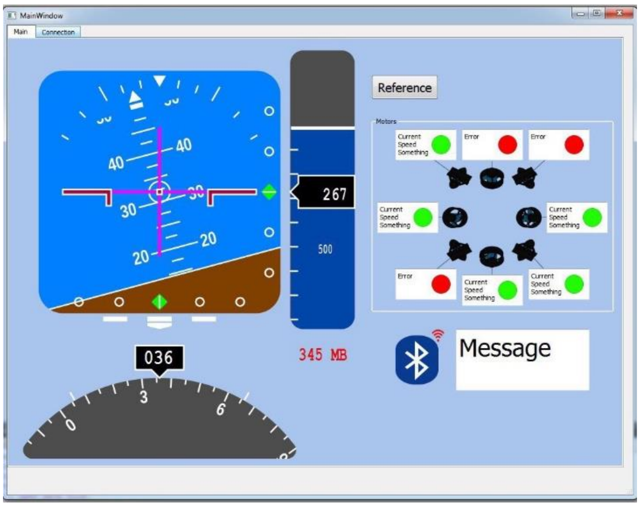


Fig. 5.8.2. Graphical interface of the status indication program

Data from depth sensor is displayed between information about thrusters and information about Cousteau's position.

At the bottom right displays last message from Bluetooth module.

To control the vehicle we designed several interaction protocols:
1. Main, whitch used to complete to perform tasks.
2. Configurational, which allows us to adjust paramaters of vehicle electronics.
3. Direct thrusters control protocol, used as debug instrument and in case of failure any of vehicle systems

Connecting is built by client-server model with onboard controller as server. Client (control box) sends requests with control commands to server and server performs them and sends answers.

6. PAYLOAD

6.1. BUOYANT BEACON

For marking the container that contains high danger cargo is used buoyant beacon, manufactured from plastic bottle painted in orange, durable lace and carbine (Fig. 6.1.1).

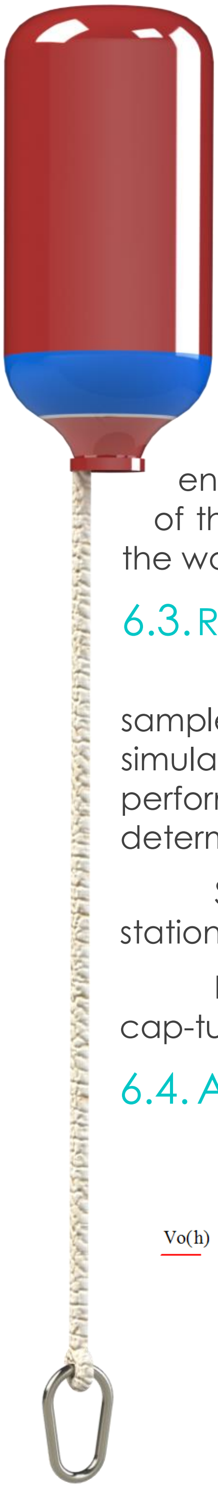


Fig. 6.1.1. Buoyant beacon

6.2. BLUETOOTH

For performing task №4 we designed the complex containing an HC-06 Bluetooth-module (Fig. 6.2.1) and Arduino Uno microcontroller board. Information from Bluetooth-module working in "slave" mode transmitting with UART to Arduino Uno, where results are stored and waiting for transmission to the main MCU.

Fig. 6.2.1. Bluetooth-module HC-06

Bluetooth-module is located in fixing of a video camera in the front-end of main pressure housing, what allows to dispose it as close to the source of the signal as possible and exclude the possibility of information loss under the water.

6.3. RAMAN SPECTROMETER

For perfoming task "environmental cleaning" (finding and collection samples of polluted bottom sediments) we using the narrow beam of light, simulating Raman laser. Laser is implemented as two red collinear LEDs. To perform a task it is necessary to illuminate parts of bottom sediments to determine whether they are polluted or not.

Spectrometer contains an on/off switch located on the ROV control station. LEDs is powered by control station.

For fixing the laser we use 3D-printed component – the rack in the form of cap-tube, fixed to the vehicle.

6.4. AGARATOR

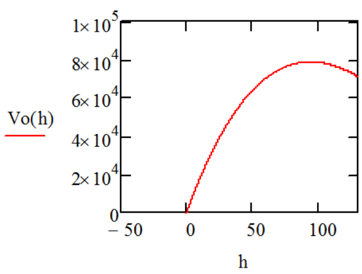


Fig. 6.3.1. Depth of a glass to capacity of a jelly plot

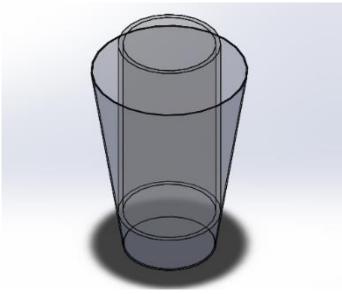


Fig. 6.3.2. View of the cup in the glass

Agar collector is a device for collecting bottom sediments. The mission goal is to collect samples of jelly from the bottom of the water.

According to the characteristics of the glass with sample provided by the organizers was calculated optimal diameter of collecting cup, providing the most capacity of collecting material.

We selected a model with flat-moving opening and closing flaps held by fixings.

Flaps presented as pointed petals on joint axis. When lowering the cup in the glass with jelly, opened flaps are cutting it with their edge and cup is filling with jelly replacing the water in it.

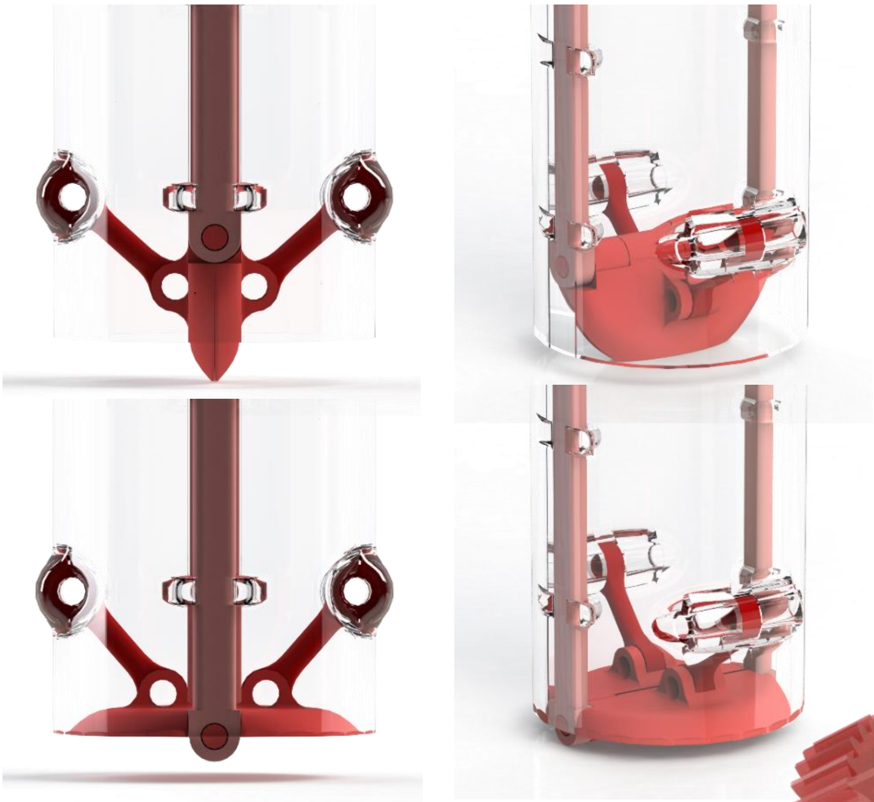


Fig. 6.3.3. View of the pointed petals

Drawings were made in the Solidworks CAD. This soft allows you to set a coupling of elements and move it with considering this coupling.

The axis on which the flaps are fitted is brought into translation motion by two vertical guides. Guides connected with rail by fixing.

The original version of a mechanism, which bringing rail into translator motion was screw-nut transfer, but due to insufficient engine rotation speed and overall constructive complexity, the different option was selected.

After further development of construction gear-rail transmission was applied. Gear-rail provides transmission of rotary motion of electric motor into translator motion of rail. With help of a Solidworks we designed the source contour, providing involute gearing with the gear.

Fig. 6.3.4. Main view of Agarator

6.5. GRABBER

This year our team decided to develop a completely new grabber, based on personal experience and applying the knowledge obtained at the university. This step helped us to save a lot on costs and make a grabber capable of fulfilling the missions set by MATE.

The grabber consists of two modules. Each module is universal and can be used for rotation and for squeezing or unfastening the claws. The module consists of a hermetic housing, a geared motor, a mounting that prevents the longitudinal and rotational movements of the geared motor.

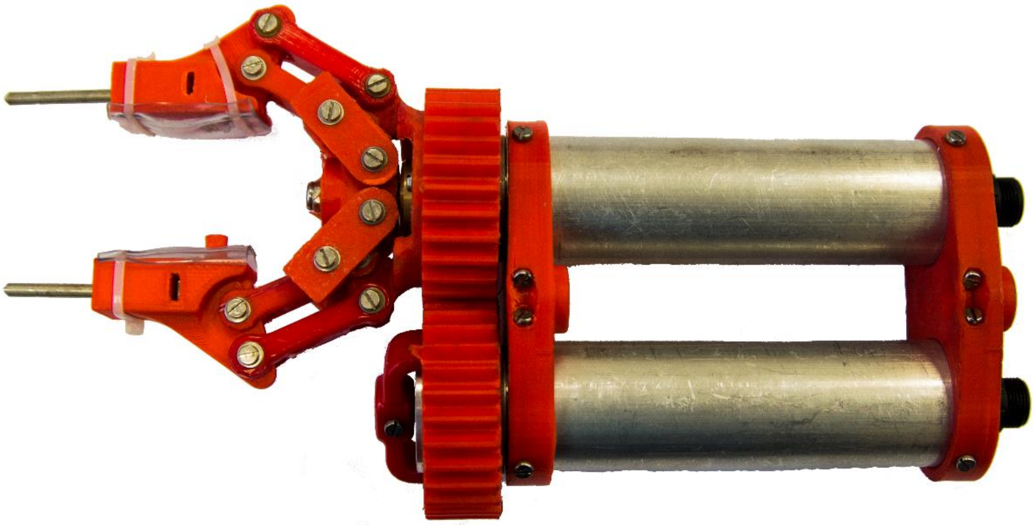


Fig. 6.4.1. Grabber

Components of the hermetic case:

1) Aluminum pipe with holes for fixing the covers.
2) Back cover, which include a hermetic connector, on which comes the control signal to the motor-reducer. In the cover there are two grooves, in which there are two sealing rings for sealing.
3) Front cover.

Both of covers are made by hand on a lathe and made of aluminum alloy with magnesium and copper. Such material is one of the most demanded duralumin alloys in the shipbuilding industry, since it has high strength and is light enough.

The output shaft of the engine is sealed by two cuffs, which serves as a seal.

Compression and unfastening of the claw is carried out by translational movement, which is performed by the transfer of the screw-nut.

The pusher is not rigidly connected to the claws. The moment is transferred by means of a transition piece, which has the possibility of axial rotation. Thanks to this, we are able to rotate endlessly with claws, while retaining the position of the fingers of grabber. The torque is transmitted through a gear train.

The grabber has only two purchased elements: the geared motor and the hermetic connector.

The gears are insulated with a protective cover.

Manipulators have current cutoffs. This allows you to eliminate jamming in extreme positions and avoiding excessive compression of a foreign body by grabbing, for example, a human finger!

7. ROV TESTING

Cousteau was designed to operate at depths up to 50 meters. The durability of the framework and the pressure hulls was calculated and modeled using Solidworks CAD. The ROV itself has been successfully tested at 20 meters.

Safety is one of the most important principles for our company, therefore the ROV was subjected to a number of tests before first launching. The tests included but were not limited to: tests for loss of connection and tests of insulation. After that, it was launched in our lab's pool (Fig. 7.1).

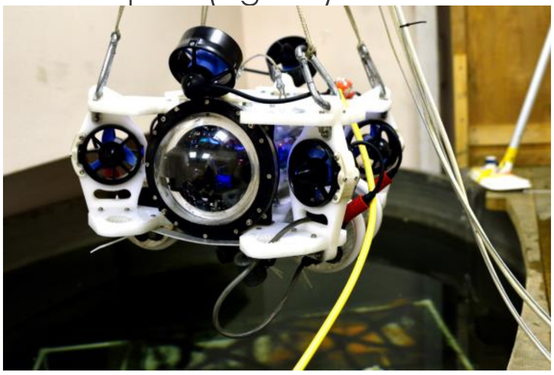


Fig. 7.1.ROV Testing

Fig. 7.2. Work with bottom equipment

For a long time, the Cousteau could not pass the leak test. Unfortunately, there was a leakage in the power housing of electronics due to the use of substandard connectors. The leak was eliminated to the next test. On tests with a duration of 12 hours no leakage was observed.

DC/DC converters 48 to 12 for some inexplicable reasons left the protective cutoff from time to time, as it turned out during the installation of the "pole" of the foot output voltage closed on the ground on the housing of each other. This problem was eliminated by cutting and blunting the legs and an additional layer of insulation. For the successful fulfillment of MATE's tasks, we simulated all the bottom equipment (Fig. 7.2.).

8. CHALLENGES

8.1. TECHNICAL CHALLENGES

1. Dormant DC/DC converters. Initially, the project of the ROV should use external DC/DC with 48 to 12 converters with IP68 protection level, additionally hermetically sealed with a radiator, put out for water for better cooling, however, during the tests in our 2 meter pool, it became clear that they are leaking, and we were forced to use additional DC/DC, inside the power casing seats for which we have provided.

2. Buoyancy. At the first launching of the Cousteau we found that the vehicle has a strong positive, due to the absence of external DC/DC converters. We decided to place additional loads on the base of the ROV.

3. The main controller of the ROV from time to time began to hang. As it turned out, the code on the controller was corrected, but on the console there is no: in the parcel from the shore there was one extra byte, the defect was quickly eliminated.

8.2. NON-TECHNICAL CHALLENGES

Our team faced big financial problems this year. We were forced to launch a crowdfunding to raise funds for the assembly of the new ROV «Cousteau». We conducted a lot of outreach activities and eventually collected more than the required amount.

9. FUTURE IMPROVEMENTS

In the future, we plan to develop a multi-stage electromechanical manipulator (Fig. 9.1.). Such a device will greatly facilitate the implementation of operations such as the docking of various connectors, the stabilization of the apparatus relative to floating platforms, the collection of soil samples and also the mounting operations.

Fig. 9.1. Multi-stage electromechanical manipulator

It is also planned to develop screw-type motor with a magnetic clutch (Fig. 9.2.). In the EMSworks package, a magnetic coupling was modeled (Fig. 9.3.) for subsequent bench tests.

Fig. 9.2. Screw-type motor with a magnetic clutch

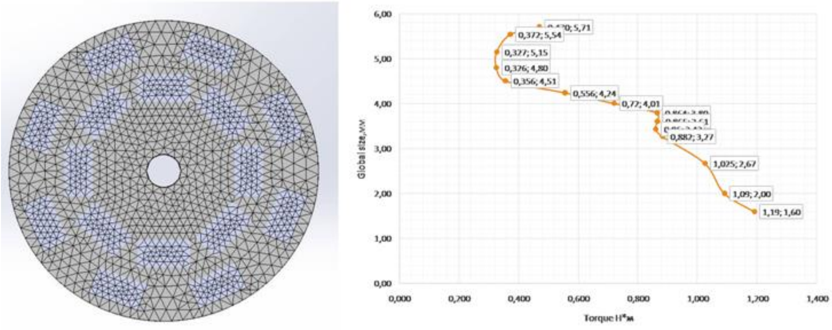


Fig. 9.3. Modeling of magnetic clutch in the EMSworks

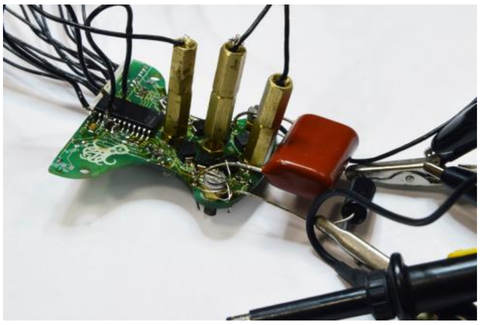


Fig. 9.4. Brushless motor driver

Now our company is finishing debugging its own brushless motor driver with feedback on the counter-EMP. The driver will be manufactured on a special board for subsequent attachment to the covers of the power casing for cooling (Fig. 9.4.).

10. REFLECTIONS AND LESSONS LEARNED

Artem Tkachuk

First of all, the Hydronautics is a laboratory, where we got practical skills and new knowledges. And it does not happen with teachers, but with the guys who are always ready to share it. It teaches some things like teamwork, self-development, setting goals and objectives.

Kirill Tiniakov

I received extensive knowledge and skills. I learned a lot about power electronics and microcontrollers, received big experience in developing and debugging boards. Also, ROVs are not my specialty and thanks to Hydronautics team I was able to discover the marine technologies world.

Solodijkina Anna

In the Hydronautics, I got a broad idea of the activities of the robotics engineer and got practical skills in many areas. During my participation in the project I learned how to distribute the efforts that are needed to solve a particular problem. I got experience of creative approach to solving technical problems and team work experience.

11. ACKNOWLEDGEMENTS

We want to thank MATE Center for an amazing opportunity to take part in this competition. Thanks to you, we receive a new challenge every year and learn how to approach that challenge creatively.

PICASO 3D For a free 3d printer service (9)

Mir for financial support(10)

ROVBUILDER for special tether and Umbilical winch(7)

HYDROBOT-X for providing connector (5)

MICRODIGITAL for their video equipment and video expertis (6)

Bauman Moscow State Technical University for financial and administrative support, as well as the provided laboratory and a pool for testing our vehicles. (8)

Underwater Robots and Vehicles Department for the knowledge and skills they gave us

Rezonit for their free PCB (3)

Yandex for cloud storage

Acrylice for acrylic underwater camera's head (2)

MISiS fablab for their equipment we used to make PP chassis (1)

Eltech for electronic parts (4)

These people have also been invaluable to the project success: Anatoly Alexandrov, Dmitry Shekhovtsov, Vadim Veltishev, Evgeny Nishkov, Svetlana Semenyuk

All our moms, dads, grandparents for the support and faith in us!

Stanislav Severov, Anatoly Strelnitsky, Alexander Vylegzhanin for their time, creativity, knowledge, and guidance.

We're also very grateful to the Boomstarter's bakers and other supporters which have made great financial support for us.

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13. APPENDIX A. PROJECT COSTING AND BUDGET LAYOUT

Hydronautics 2017 Project Budget		
	Budget item	Amount
Operational Expenses	Hardware vehicle parts	$2 500,00
	Electronic components	$1 500,00
	Circuit boards	$500,00
	Grabber cost	$400,00
	Teather cable	$200,00
	Upgrading of a control station	$500,00
	Miscellanious consumables	$500,00
	Capital expenses	-
	Total expenses	$6 100,00
Income	Boomstarter crowdfunding	$1 800,00
	"MIR"	$1 800,00
	BMSTU	$14 075,00
	Donated parts	$2 500,00
	Total income	$20 175,00
2017 Employee Expenses		
Estimated Travel	Airplane tickets	$9 500,00
	Car rent	$900,00
	Residence rent	$1 700,00
	Medical insurance	$175,00
	Visa fees	$1 800,00
	Total Travel Expenses	$14 075,00
	Surplus/(Deficit)	$0,00 / ($0,00)

Project costing

Category	Expense	Amount	Amount	Balance
Parts donated			$19 774,49	
Hardware(1)	Polypropylene cutting	1	$175,94	$0,00
Hardware(2)	Acrylic domes	2	$175,94	$0,00
Electronics(3)	Manufacturing of circuit boards	2	$175,94	$0,00
Electronics(4)	Electronic components	12	$211,13	$0,00
Hardware(5)	Sealed connectors	20	$1 231,58	$0,00
Electronics(6)	AHD Camera	3	$263,91	$0,00
Electronics(6)	Digital video recorder	1	$263,91	$0,00
Electronics(6)	Video transmitter	2	$140,75	$0,00
Electronics(7)	Teather cable	1	$879,70	$0,00
Hardware(8)	Underwater thrusters	8	$1 403,44	$0,00
Hardware(9)	3D printer service	1	$175,94	$0,00
Electronics(8)	DC-DC convertors	10	$232,24	$0,00
Travel expenses(8)	Airplane tickets	1	$9 676,10	$0,00
Travel expenses(8)	Car rent	1	$985,26	$0,00
Travel expenses(8)	Residence rent	1	$1 759,40	$0,00
Travel expenses(8)	Medical insurance	1	$175,94	$0,00
Travel expenses(8)	Visa fees	1	$1 847,37	$0,00
Re-used			$1 671,94	
Hardware	Acrylic sheets	1	$175,94	$0,00
Hardware	Box of the mobile control station	1	$462,00	$0,00
Electronics	120 Hz 30" display	1	$677,00	$0,00
Electronics	Car display	1	$357,00	$0,00
Cash donated			$3 441,00	
General(10)	Donated by "MIR"		$1 765,00	$1 765,00
General(11)	Raised on Boomstarter		$1 676,00	$3 441,00
Purchased			$3 428,61	
Hardware	Aluminum caps	6	$424,00	$3 017,00
Hardware	ABS plastic coils	3	$84,00	$2 933,00
Electronics	Electronic components	1	$1 055,00	$1 878,00
Electronics	DC-DC convertors	10	$275,00	$1 603,00
Electronics	Thruster drivers	8	$200,00	$1 403,00
Electronics	Sealed connectrs	25	$202,00	$1 201,00
Hardware	Acrylic tube	1	$300,00	$901,00
Hardware	DC motors	2	$123,16	$777,84
Hardware	Aluminum Pipes	2	$228,72	$549,12
Electronics	Raspberry Pi	1	$61,57	$487,55
Electronics	USB - RS-485 converter	1	$76,76	$410,79
Electronics	STM32 Discovery	1	$23,40	$387,39
Hardware	Fixture parts	50	$300,00	$87,39
General	Miscellaneous	-	$75,00	$12,39
			Total Vehicle Cost	$10 430,97
			Total Expenses	$24 875,04

14. APPENDIX B. SAFETY CHECKLIST

Before the launching the ROV in the water:

1. Check if all cables are securely fastened to the frame
2. Check if all sealed connectors are inserted correctly. Use markings of the electronics unit cover as a reference.
3. Check insulation of all cables.
4. Check if all thrusters have their protective gratings installed.
5. Check if fuse is installed in the positive power line.
6. Check if the ROV control station is properly grounded.
7. Power up the ROV control station and measure voltage on metallic parts relative to the ground. The voltage should be zero volts.
8. Check if 48V DC voltage source used for powering the ROV is isolated.
9. Before powering up the ROV all joysticks should be in the neutral position.
10. Make sure, that the ROV control station is not too close to the water. It should be at least two meters away to avoid damaging its electronics by splashing water.
11. Make sure that manipulator is not in one of extreme positions, which can cause jamming.
12. Make sure, that no one is touching moving parts of the ROV.
13. Power up the ROV and measure voltage on aluminum covers of pressure hulls and thrusters relative to negative power line of the DC voltage source. The voltage should be zero volts.

Before retrieving the ROV from the water:

1. Power off the ROV to avoid electric shocking in case of leaking hulls.
2. Retrieving the vehicle should be performed by at least two people or using a lifting mechanism.

After retrieving the ROV from the water:

1. Check transparent pressure hulls for signs of leakage and cracks.
2. Check if payload of the vehicle is intact.
3. Check if thrusters' propellers are secured on the shaft and are not slipping