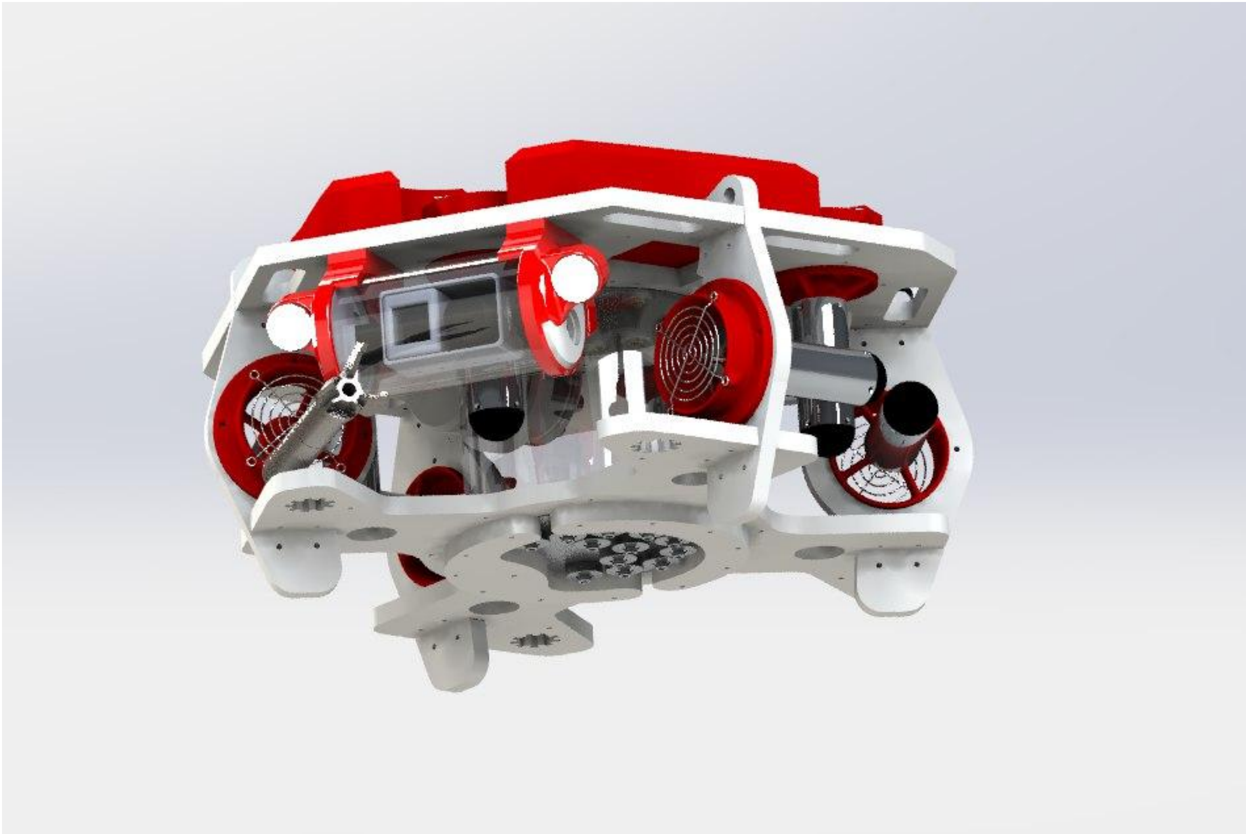

Team mentor: Stanislav Severov
Team supervisor, Risk manager: Anatoliy Strelnitskiy
CEO, CTO: Alexey Nekrasov
Team members:
Anton Nochnoi: 2nd pilot, assembling engineer
Danila Matyushevsky: 2nd Pilot, Designer
Ivan Semenyuk: Main pilot, Computer Vision Engineer
Aleksey Volf: Chief mechanical engineer
Ilya Litik: Chief Electronics Designer, embeded programming engineer
Ann Terehova: Second software engineer
Ilya Morev: Chief software engineer
Ivan Remizov: technical reporter, travel manager, CFO

1.Abstract

The Bauman Hydronautics team was founded in 2010 at the Bauman Moscow State Technical University. We build underwater vehicles using knowledge and skills obtained at the Underwater Robots and Vehicles department, using modern production technologies. There are also students from Mechatronics, Power engineering and Computer Sciences departments that are involved in our team operations.

This year our company is devoted to Europa ocean mission: operate in the ocean Measure the temperature of water emerging from a vent; take pressure measurements to determine the thickness of the ice and depth of the ocean; use serial numbers to identify mission-critical equipment and transport the equipment to a collection basket for later recovery; collect samples of oil from the sea floor, return the samples to the surface; take still photographs of coral colonies, attach a flange to the top of a decommissioned wellhead, install a wellhead cap to the top of the flange.

For performing these tasks, we have designed the low-cost underwater vehicle “IceBerg”. Its main advantages are small size, field of view angle of 270 degrees, and gripper. We have also designed fully replaceable tool: in-house designed depth sensor.

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. For example, Solidworks CAD, was used for structural design. Altium Designer was used for electrical circuit design. These student versions of software were provided by Bauman Moscow State Technical University.

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.

AKVATOR IceBerg can serve as a prototype for industrial grade ROV that can explore the wrecks in the rivers and lakes of Russia

Fig. 1.1. AKVATOR IceBerg ROV

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.

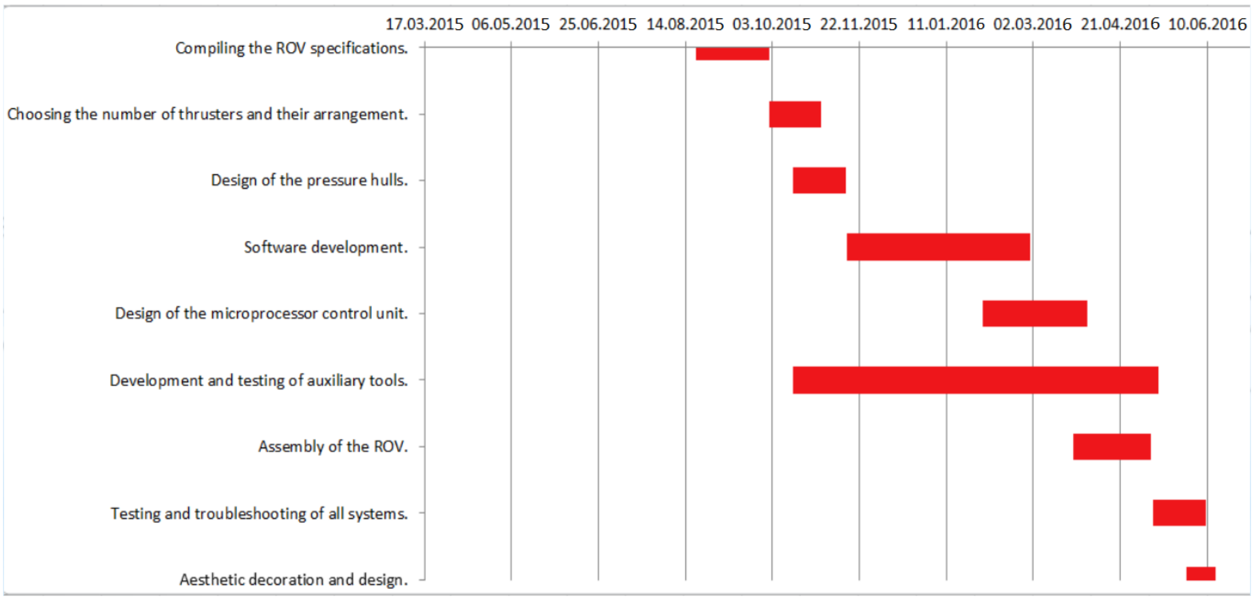

Fig. 3.1.1. The development timeline.

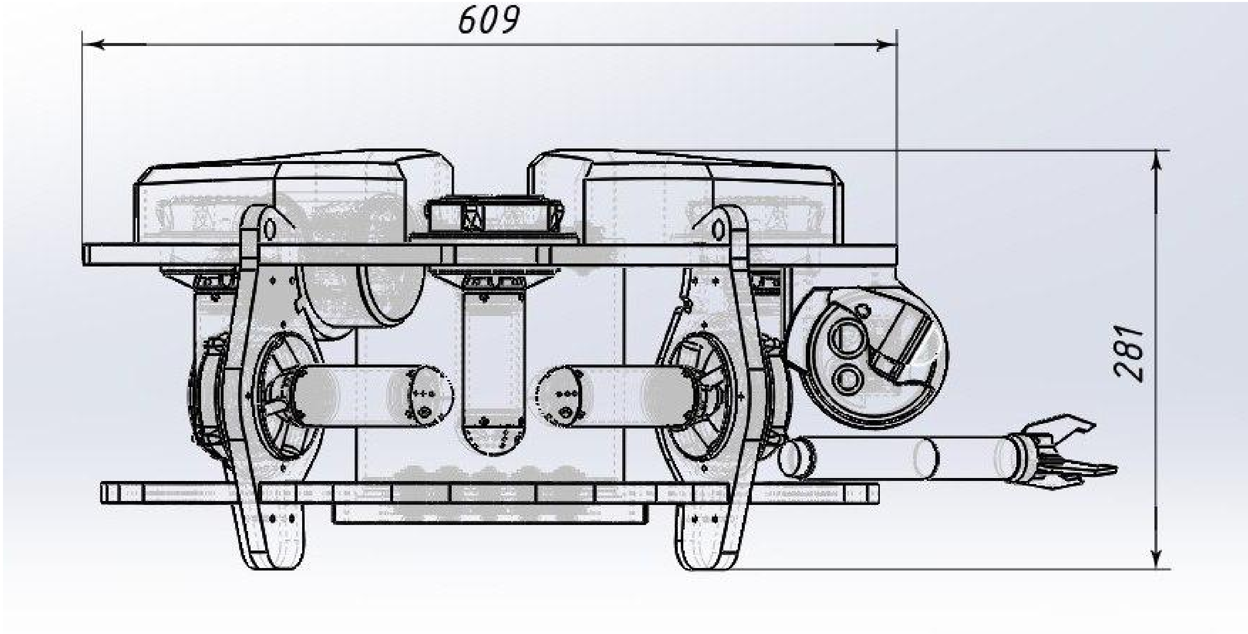

Fig. 3.1.2. Dimensional drawing of AKVATOR IceBerg

3.2 Safety

While working on the AKVATOR IceBerg we concentrated our efforts not only on development and assembly, but also on many safety issues and concerns. A set of rules was applied to everyone working on a project in the lab.

1) Team members working with mechanical tools and machinery were required to wear protective coats, gloves and glasses. (Fig. 3.2.1)

2) Before getting access to any machinery everyone had to listen to a short operating briefing.

3) Operation of the lifting mechanism (electric hoist) was only allowed by at least two people at the same time. (Fig. 3.2.2.)

4) The electric hoist was equipped with an emergency off-switch to prevent an accident in case of any mechanic failure.

5) All electrical equipment is shut off before closing the lab, thanks to many reminding placards. Still from time to time, some minor incidents happened. For example, first time the ROV Control Station was used, it shocked the operator! The cause of that was a cheap ungrounded power strip. Once it was replaced, the problem was solved.

Fig.3.2.1. Working at the laboratory

Safety Features of AKVATOR IceBerg

- Warning stickers on moving parts
- No sharp edges

- A safety fuse in the main power line
- Metal gratings on thrusters, making them 100% safe
- Software indication of different hardware faults, that can occur during the ROV operation, such as loss of connection

4. Electronics

4.1. Electronics Systems Layout

4.1.1. Functional scheme

There are seven boards inside of the electronics housing:

• Board with sealed connectors

• Power supply board

• Main controller board

• Depth and Orientation sensor board

Power supply board.

The voltage converter board contains 3 DC-DC converters. Two TEN-40-4811WI modules convert the input voltage from 48 volts to 5 volts for powering the main controller; another module (SMB60) transforms 48 volts to 5 volts for powering the and PWM controller, which (Light, Grabs and camera servo), the last one transforms 48 volts to 12 volts for camera powering. Power consumption of the whole system is limited by 2 Kilowatts, and to ensure that, a 40 ampere current fuse is used. Power supply diagram is shown on Fig. 4.1.1.

Main controller board

Main controller board (Fig 4.1.2) provides connection with the shore, control loops of stabilization system, sensors poll, control the light, grab, servo drive and additional devices. Connection with shore is through galvanic isolated RS-485 transceiver/receiver.

Board includes STM32L with Core 407VE shield board - main controller (Fig 4.1.3), PWM controller, based on Atmega1280 (Fig 4.1.4). It connected through SPI interface with main controller. This system generates PWM signals on 3 driver boards, based on STL 6207D, each one can control 2 engines. PWM signals are galvanic isolated for protection main controller in case of leakage loss .

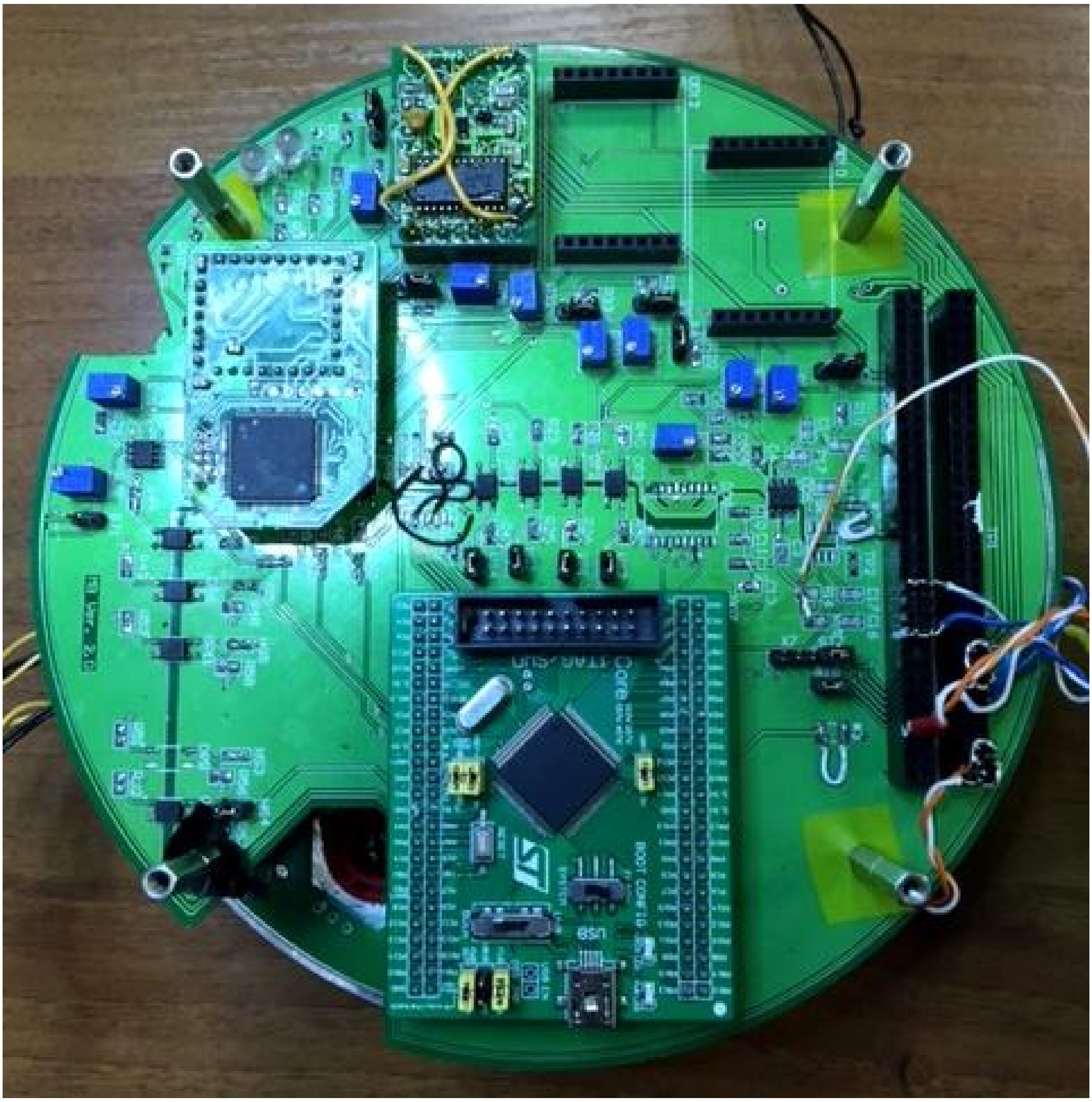

Fig.4.1.2. Main controller board prototype

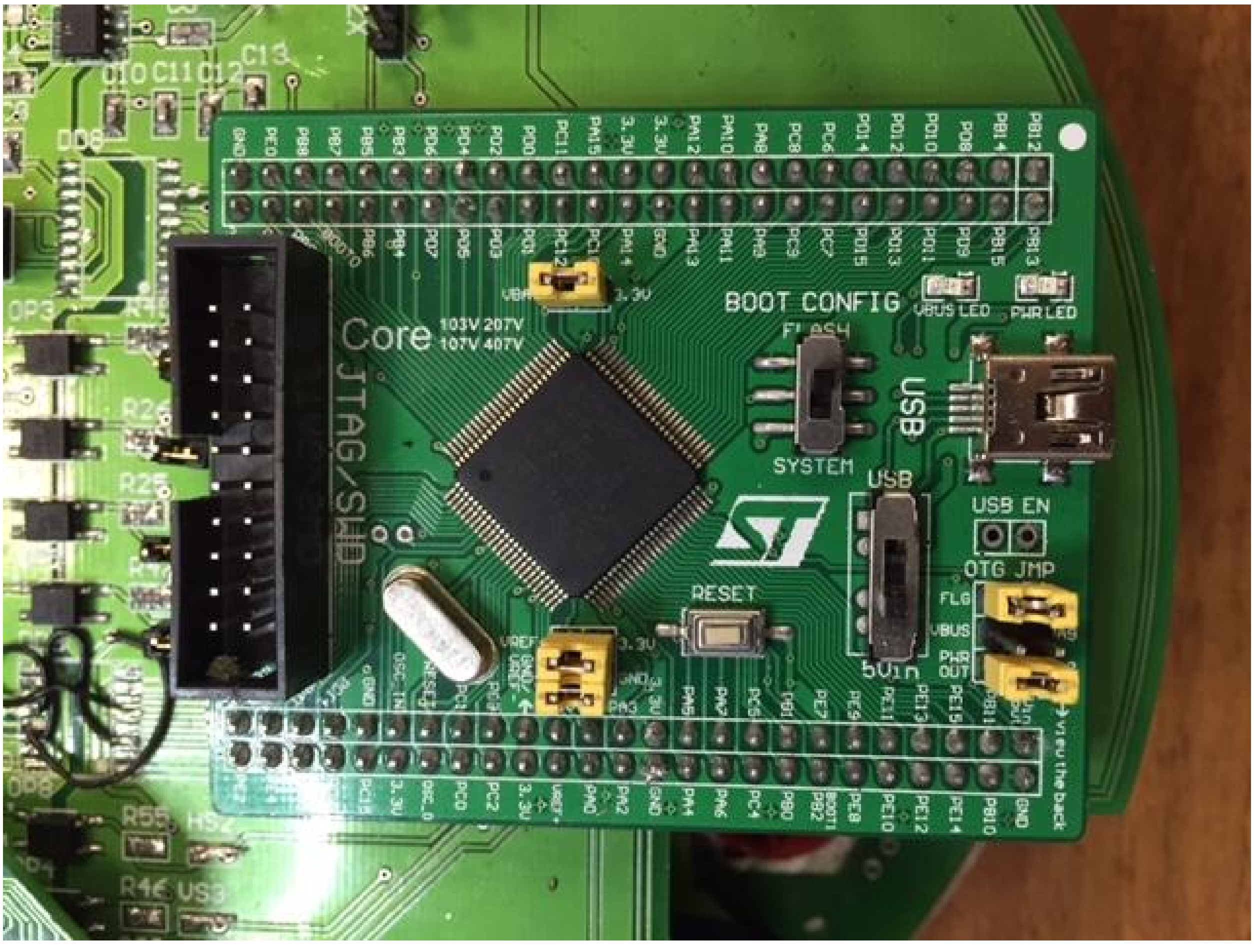

Fig.4.1.3. STM32L shield board

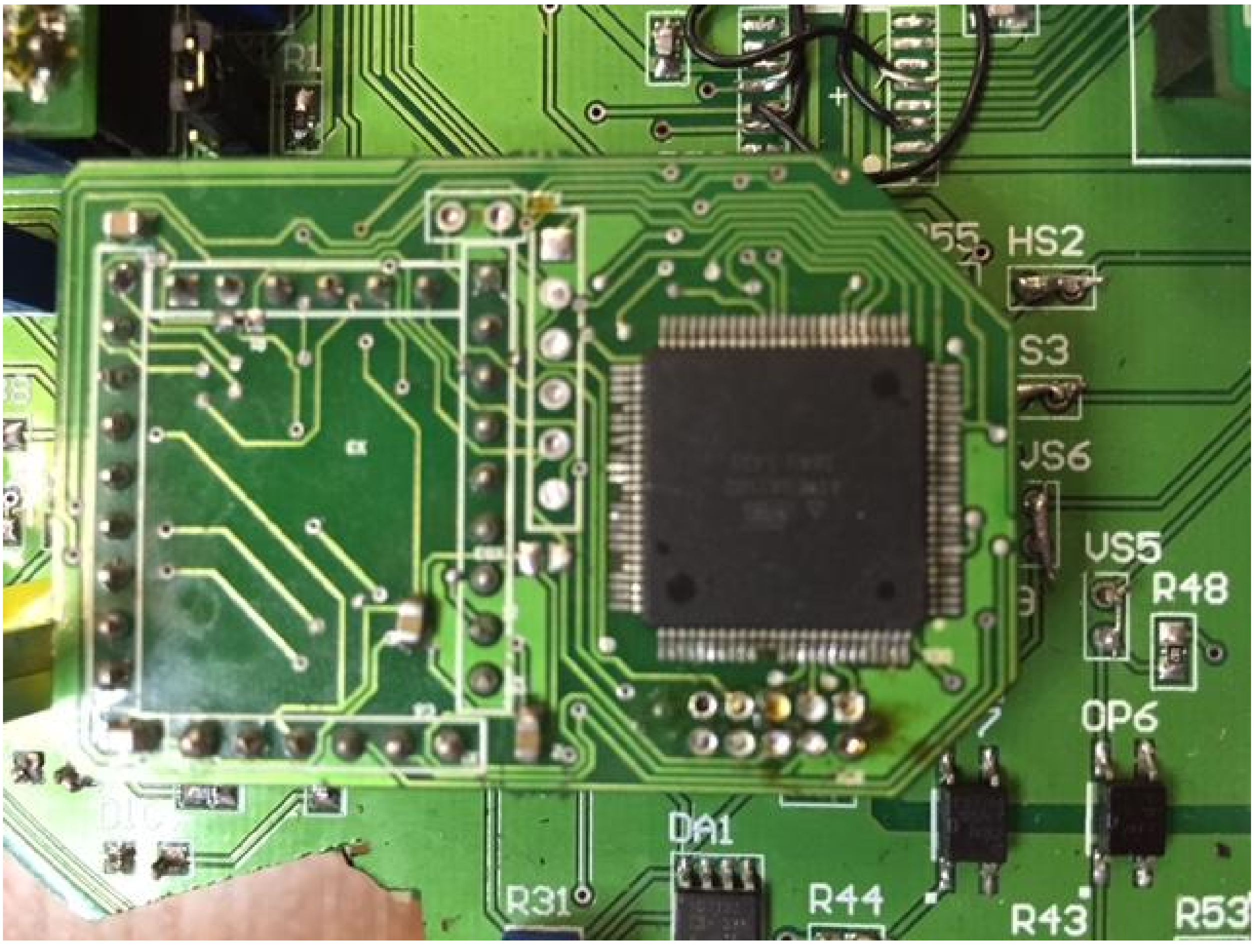

Fig.4.1.4. PWM controller

Board with sealed connectors

This board provides signals income and outcome from ROV to the ROV control station. All signals from board with sealed connectors to the other boards comes through PC104 type bus (Fig.4.1.5.).

Fig.4.1.5. Bus

Fig. 4.1.6. System Interconnection Diagram

Fuse value calculation:

To calculate the fuse value will calculate the maximum operating current consumed by the ROV using the following formula:

$$I_{FLC} = 8 \cdot I_T + 2 \cdot I_G + 4 \cdot I_L + I_{ED}, \text{ where}$$

$I_T = 2.5\ A$ – a maximum operating current of one propeller

$I_G = 0.5\ A$ – a maximum operating current of grab

$I_L = 0.5A$ - a maximum operating current of the lamp

$I_{ED} = 3A$ - the maximum operating current of all electronic devices (determined experimentally).

$$I_{FLC} = 8 \cdot 2.5 + 2 \cdot 0.5 + 4 \cdot 0.5 + 3 = 26\ A$$

We calculate the nominal value of the protective guard according to the formula:

$$I_{OP} = I_{FLC} \cdot 150\% = 39 \text{ A}$$

Rounding up the value of the standard, we get $I_{OP} =$ 40A

Safety notes!

Each Pololu driver had a built-in current sensor. This way we can monitor motors currents. High motor current can tell us that the thruster is blocked and needs to be stopped. Therefore, Thrusters Controllers are programmed to shut down the motor when it has a current exceeding four amperes.

Depth sensor board

Depth sensor is based on strain gauge pressure sensor. Signal processing board is an easy to remove module, connected to vehicle's network via UART interface. This approach allowed us to perform a number of experiments using different kinds of schematics for the processing of the signal.

4.2. Depth Sensor

Depth sensor was designed using a strain gauge pressure sensor (Fig. 4.2.1) with additional signal processing schematic. It can measure pressure with a value up to 60 MPascal, which is the approximate value of pressure at a depth of 60 meters below the water's surface.

Signal processing board (Fig.4.2.2) contains power supply unit for the sensor and a low-pass filter to eliminate noise in the signal.

A 14-bit analog-to-digital converter is used to send the signal to STM32 controller, which then performs additional software filtering of the digital signal.

The output value of the depth sensor can be accurate up to 10 mm.

4.3 Board with sealed connectors

Fig.4.2.1. Strain gauge pressure sensor

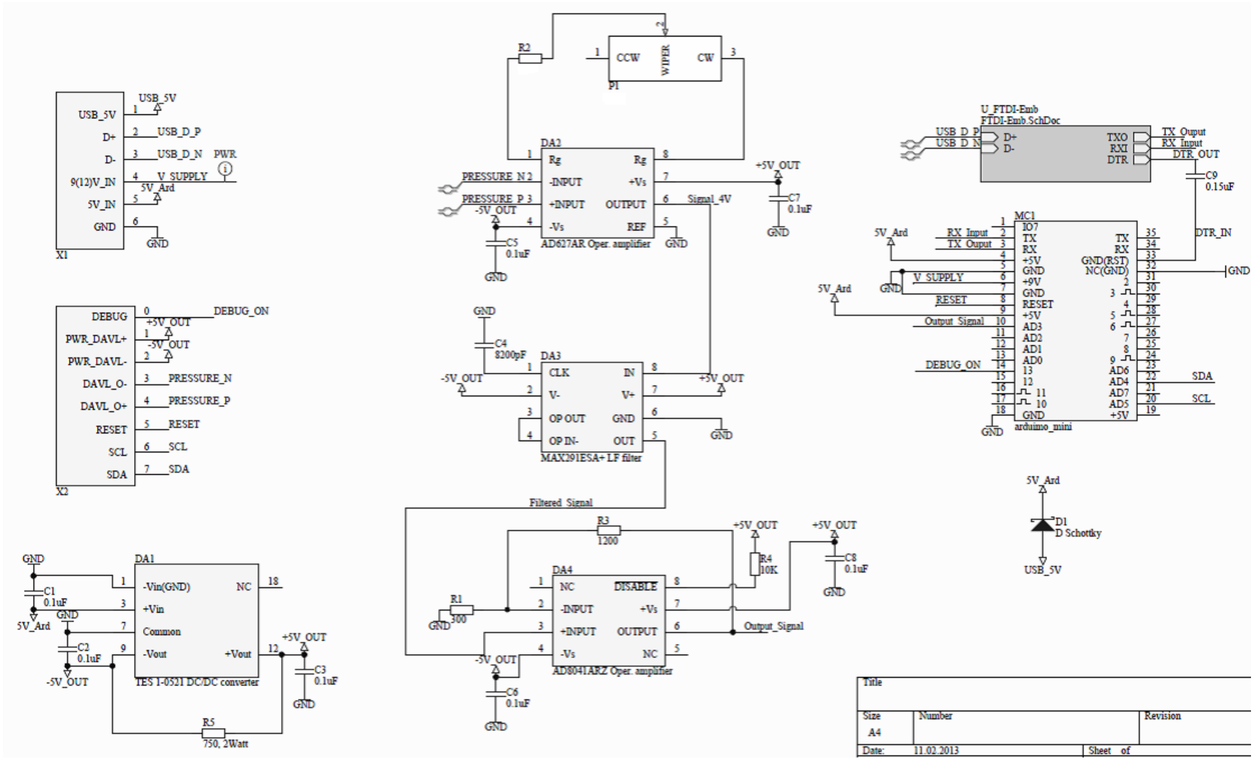

Fig.4.2.2. Signal processing board

4.4 Calculation of the gain of the differential amplifier DA2

We calculate the gain of the op-amp DA2

As mentioned above the output pressure sensor is a differential signal and ranges from 0 to 200 mV, while the input voltage range DA3 filter to which it is applied is in the range from 0 to 4V. For scaling the measured voltage to a predetermined range project used high-precision instrumentation amplifier AD627 Analog Devices. The main characteristics of the amplifier:

Power supply voltage	from + 2.2V to ± 18V
The range of the gain	from 5 to 1000

The apparatus unit connected in the following scheme:

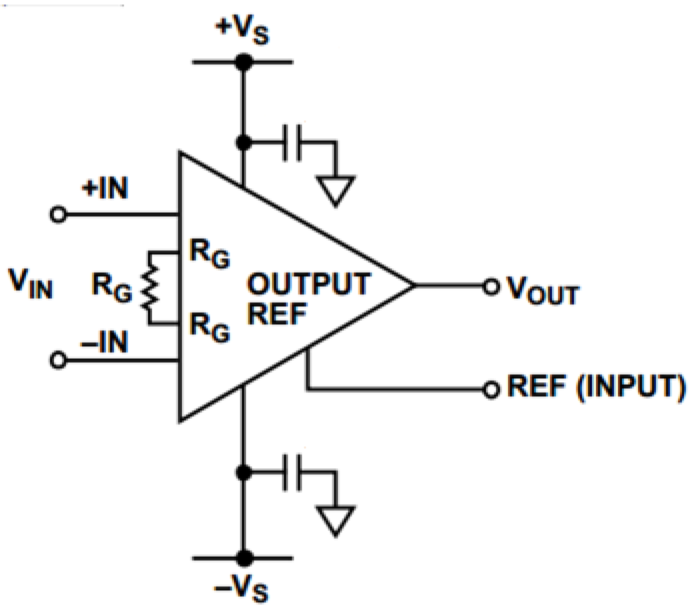

Fig.4.2.3. Differential amplifier

It sets the REF signal input voltage range of the middle and is calculated as follows:

$$V_{OUT} = [V_{IN}(+) - V_{IN}(-)] \times (5 + \frac{200\,k\Omega}{RG}) + V_{REF}$$

In our system, at equal potentials at the inputs VIN (+) and VIN (-), at the

output should be formed at ground potential, so the output REF should be connected to GND.

The expression for the gain is determined by the formula:

$$GAIN = 5 + \frac{200\,k\Omega}{RG}$$

, where

RG - the resistance of the external resistor.

Obviously, the required gain is determined from the formula:

$$GAIN = \frac{4V}{(200*10^{-3})} = 20$$

Then, the resistance of the external resistor is equal to

$$RG = \frac{200*10^{3}}{(20-5)} = 13333\ Ohm$$

Since the maximum permissible voltage at the filter inlet DA3 in the documentation may reach supply voltage, so we round this value down to the matching of the face value of a number of standard RG = 13 kOhm.

On the concept of this resistance consists of resistors R2 and P1

The resistance of the resistor R2 is equal 13khOm as calculated above. Trimmer P1 is required for precise gain control range. We calculate it using the formula resistance:

$$P1 \geq 13333\text{-}13000 = 333\ Ohm$$

Round this value to match the standard range: P1 = 500 Ohm

4.3. Orientation Sensor

For determining the orientation of the vehicle, we use Pololu UM6-LT Orientation Sensor (Fig. 4.3.1). It uses rate gyros, accelerometers, magnetic sensors, and an on-board 32-bit ARM Cortex processor to estimate the absolute sensor orientation 500 times per second. Sensor orientation is reported using Euler angles over serial interface at user-customizable rates. Clocking signal from the UM6-LT sets stabilization system working frequency. This sensor can provide up to 300Hz data update rate, which allows us to create a fast-responding ROV 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 2016 underwater missions.

Fig.4.3.1. Orientation sensor Pololu UM6-LT

4.4. ROV connections**.**

There are two communication systems on the AKVATOR IceBerg ROV (Figure 4.4.1.):

•Connection between shore and ROV via RS485 interface

•Connection between onboard controllers via UART

ROV to shore communication.

This connection should provide a satisfactory bandwidth along the 20 meter tether. We decided to use RS-485 interface that allows us to have a half-duplex connection with speed up to 115200 baud per second. As the network topology is primitive (point-to-point), we decided not to use any of the existing "high-level" industrial standard network protocols and to write our own instead. With this simple asynchronous protocol, we can elongate tether up to hundreds of meters without losing channel efficiency. On the shore side x86 PC is used to communicate with the ROV. To be exact, it is an embedded PC board inside of the ROV control station. The shore side software was created in QTcreator as a powerful IDE, which makes possible to create a Cross-Platform graphical interfaces. The shore side software sends data to the ROV with a frequency of about 20-30 Hz. This frequency is only limited by the performance of the PC Onboard communication channel. For inter-controller communications we chose UART interface, which is supported by the AVR microcontrollers by design. The communication controller as the Bus Master exchanges data with other controllers (Slaves). This exchange takes place inside of an Interrupt Service Routine that is called on with a fixed frequency of 50 Hz. Software logic diagram is represented on Figure 4.4.2.

Fig. 4.4.2. Software logic diagram

Safety notes!

Safety features of the AKVATOR IceBerg ROV electronics, communications and control systems:

•All additional connectors placed on the boards are asymmetrical and have different shapes. That makes it impossible to mix connectors or plug detachable modules on the wrong side.

•Fuse in the 48V power circuit protects electronics from damage in case of a short circuit.

•Modular implementation of the main electronic boards allows placing the boards in any order while assembling the electronics unit thus preventing possible mistakes.

•All voltage converters used in the vehicle have short circuit protection.

•Humidity sensor inside of the electronics housing can monitor even the slightest changes in the humidity value. If the value exceeds the dangerous level, it sends a signal to the ROV control station and lights an LED.

•Both onboard and shore side software constantly check for data link validity. In the case of a lost connection, all ROV systems are automatically shut down.

5. Software and Algorithms

5.1. Stabilization system algorithms

To make pilot's work easier our embedded systems programmer **Ilya Litik** developed an automatic system of stabilization on 4 degrees of freedom: yaw, pitch, roll angles and depth position. The model of the feedback control system is shown in Fig. 5.1.1. A proportional-integral controller is used to compensate for external perturbations and ensure stability of the vehicle on several degrees of freedom. We determined parameters of the regulator using system modeling in Matlab Simulink. To coordinate stabilization contours we have written algorithms that process control signals from the shore to calculate the amount of thrust on each motor. The flowcharts of the algorithms are shown in Fig. 5.1.2.

Fig. 5.1.1. The model of the feedback control system

Fig. 5.1.2. The flowcharts of the stabilization algorithms

Fig. 5.1.3. Main controller software block diagram

6. Construction Rationale

6. 1. Framework

The main feature AKVATOR IceBerg it that it has a modular structure, with separate units performing different tasks. Each unit can be easily removed from the main frame for repair and maintenance.

Polypropylene framework is what holds everything together: thrusters, pressure hulls, buoyancy, etc. We use Polypropylene because of its durable nature, rigidity and innate positive buoyancy. We decided that a frame made of plates is much better than frame made of tubes, because of less hydrodynamic resistance and inertia.

The frame was manufactured using CNC milling machine (Figure 6.1.1) by the company Chief mechanical engineer **Aleksey Volf** with the support of construction engineers **Ivan Semenyuk, Ivan Remizov and Danila Matyushevsky**. After preliminarily training, they could perform all steps of manufacturing frame components without any help.

It is necessary to note that we had created a 3D model of the entire ROV in Solid Works before we started to fabricate parts for it. Later, while assembling, we were strictly guided by this 3D model.

To achieve the best maneuverability, stability and velocity in all directions we have decided to design the frame to be of symmetrical shape along X and Y axis, so both sides of the ROV can serve as a “front” side. This way we can place several video cameras on the vehicle’s perimeter to achieve a wide field of view. Aside from that, this allows for the placement of additional tools on the vehicle without obstructing any cameras or thrusters. It requires only 16 screws to assemble the frame, which makes it easy to maintain the ROV.

Compared to the previous model AKVATOR-3D, developed by the Bauman Hydronautics company for the 2013 MATE competition, AKVATOR IceBerg is has smaller external dimensions and weight, as well as better maneuverability and durability.

Safety notes!

The frame does not have any sharp corners and edges, to prevent even the slightest harm to the personnel.

Fig.6.1.1. Framework manufacturing (on the left).

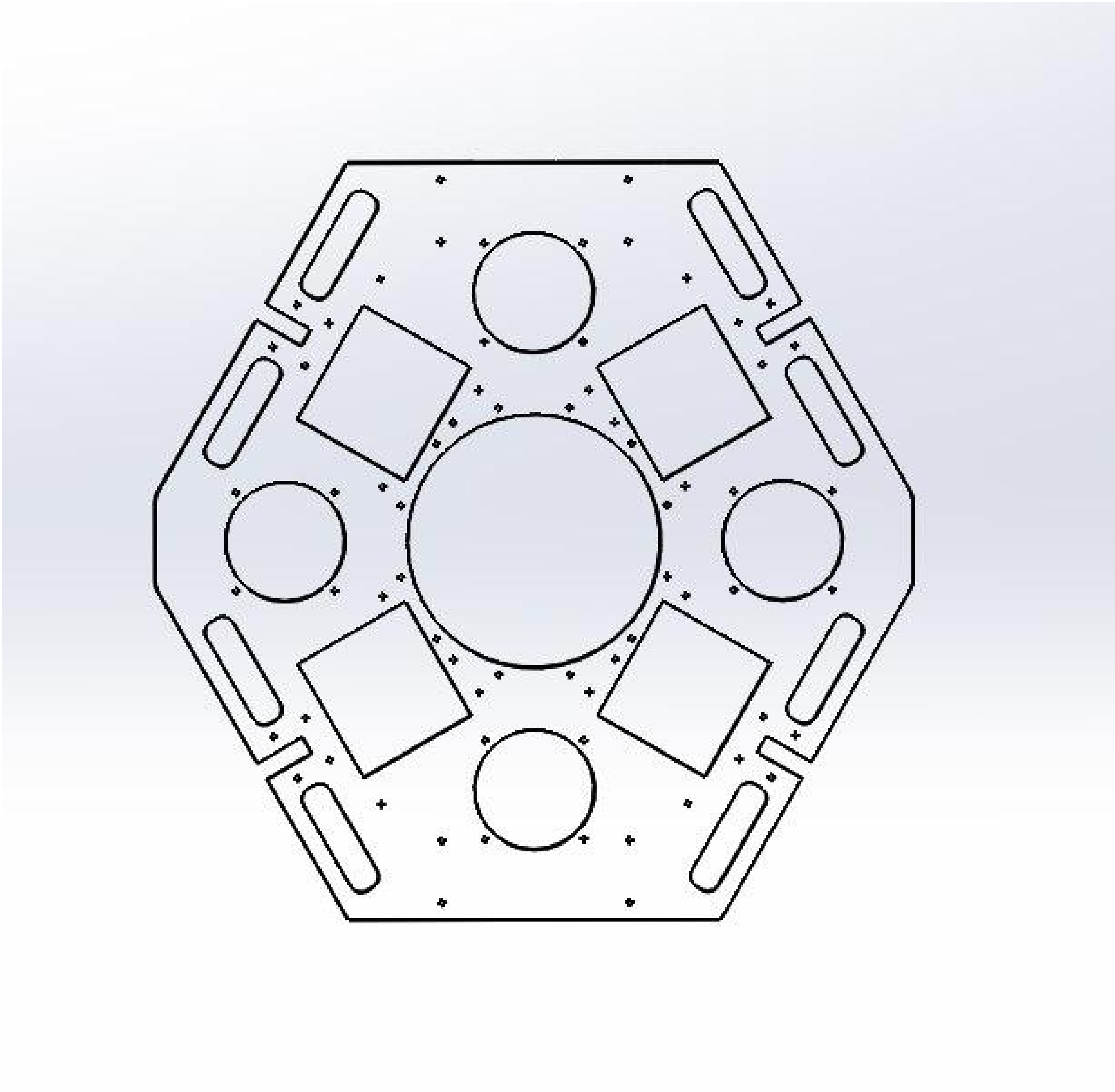

Fig.6.1.2. Drawing of the framework

6.2. Tether

The AKVATOR IceBerg tether is twenty meters long and consists of 4 twisted pairs and power copper. Cable cross section is 2.5 mm^2 .

Tether functions:

- Transmits differential signals from 3 cameras
- Communicate over RS485
- Powers ROV

6.3. Buoyancy

Buoyancy units are fastened on the frame along with other equipment (Figure 6.3.1). These elements balance residual buoyancy of the ROV. Their shape and dimensions were computed in Solid Works software as well. Their geometry was chosen to provide neutral buoyancy of whole vehicle and absence of any torque about the pitch and roll axis. The resulting positive buoyancy of the vehicle varied from 20% after initial assembly to 5-10% with the entire payload installed. We used diving weights to adjust the vehicle's buoyancy and balance. As a result, the slightly positive buoyancy of the AKVATOR IceBerg ensures its return to the water surface even in the case of thruster failure.

Fig.6.3.1. Buoyancy units Fig.

6.4. Cameras

For our visual systems, we use three KPC-VSN700PHB analog cameras (Figure 6.4.1). Two of our cameras located symmetrically inside of the front side pressure hull are, and one additional camera placed on the vehicle's backside in order to achieve maximum field of vision of 270°.

The first camera pressure hull performs observation and sends video feed to the main screen. The second camera is used to implement video capture algorithms (determining the ship dimensions, stitching a panorama, counting zebra mussels). For these tasks, we used camera lens with a small angle of view 63° to avoid aberrations. There is a servo drive inside of the hull that allows rotating the cameras along the horizontal axis. Rotating range is 180° (from -90° to +90°).

Each 'front' camera has the angle of view of 120°, because the refraction in the water reduces the viewing angle.

Fig.6.4.1. Analog camera KPC-VSN700PHB

6.5. Pressure Hulls

AKVATOR IceBerg has a module structure. There are several hermetic cases with different purposes installed onboard.

Electronics hull (Fig. 6.5.1) is made of a transparent Plexiglas tube, 180 mm diameter that is closed on both sides by aluminum covers, manufactured using CNC milling machines. The cables are connected to the hull using industrial-grade waterproof connectors with IP68 degree of protection that are fully dismountable, reliable and affordable. Electronics case contains all printed-circuit boards of the vehicle: connection controller, thrusters' drivers, tools controller etc.

Cameras' hull was specially designed for IceBerg and also made of transparent Plexiglas (Fig. 6.5.2). It has a diameter of 100mm and thickness of 4 mm. There are two waterproof connectors in the hull. It is closed from both sides with covers made from ABS plastic using molding into silicone forms.

There are rubber O-rings on the covers' perimeters to provide to make them watertight. To disassemble the hull you only need to pull out a case from the slot in the vehicle's frame and pull out its covers. This feature greatly simplifies maintenance and reparability of the vehicle.

There are also several hulls for different elements of the system, which were placed outside of the main two hulls for different reasons. Among them are two hulls for the side video cameras and a case for the orientation sensor which was manufactured using 3D-printing (Fig. 6.5.3).

All hulls can withstand pressure up to 106 Pascal that approximately corresponds to 100 meters depth. All calculations were performed in Solid Works software and obtained results completely satisfied our needs.

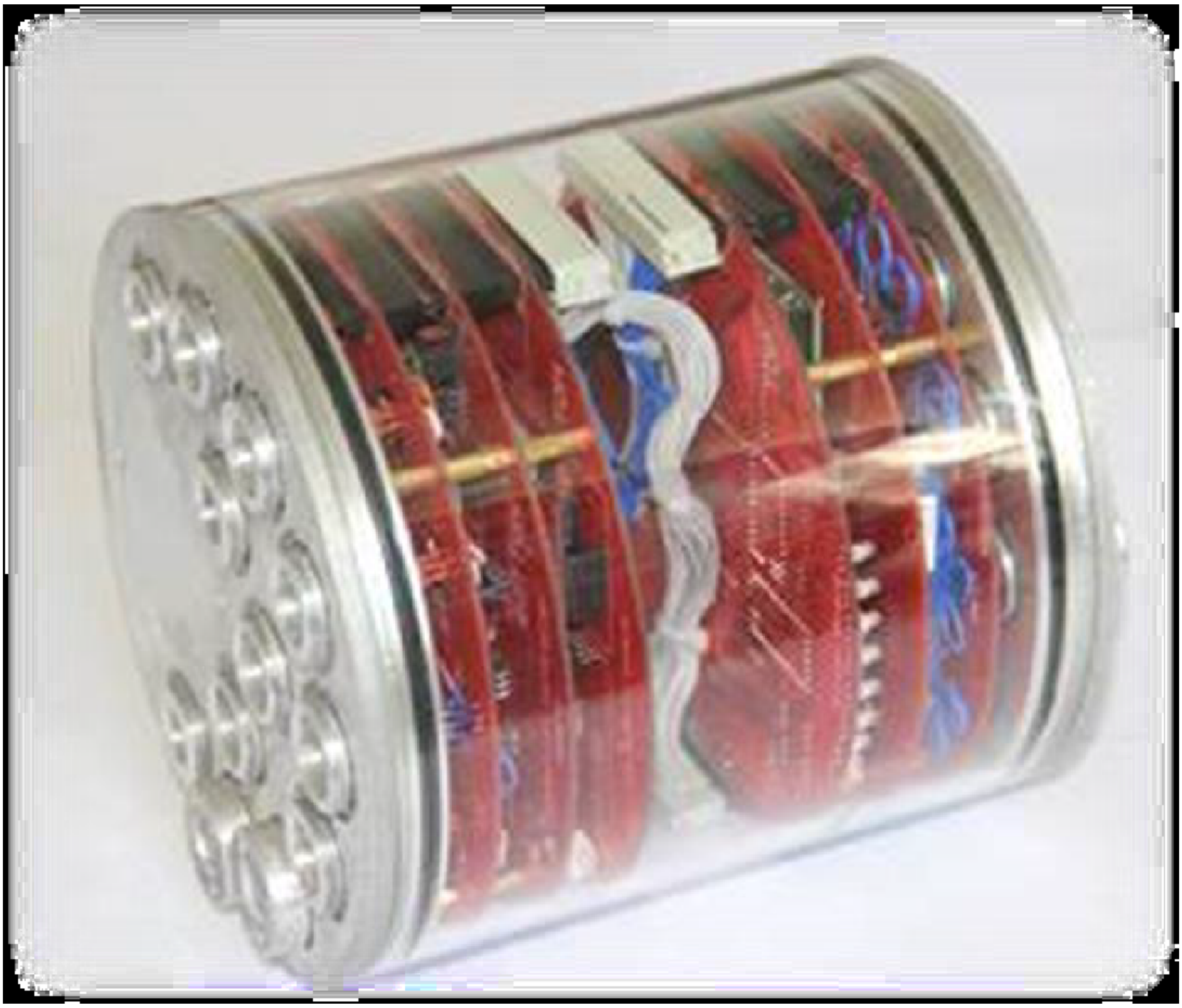

Fig. 6.5.1. Electronics case

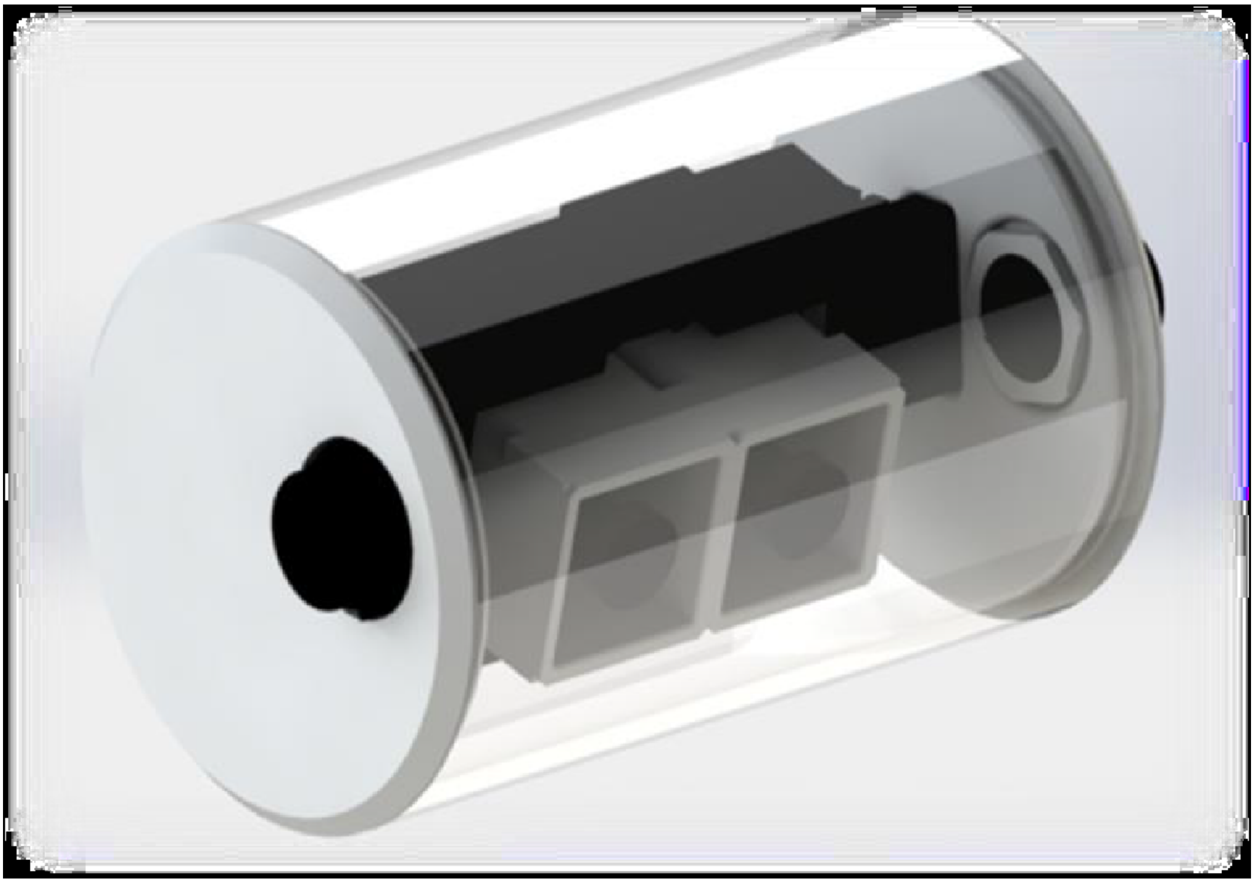

Fig.6.5.2. Frontal observe cameras hull

Safety notes!

Transparency of the pressure hulls allows us to easily see if there is a leakage in the hull. We also can observe LEDs inside the electronics hull that can indicate possible failures.

6. 6. Propulsion System

Eight in-house designed thrusters make up the propulsion system. They are designed to be as simple as possible: brushed MAXON motor of the RE 40 series with 150W power is placed in aluminum waterproof case and rotates double-bladed 80mm diameter propeller using an elongated shaft. Shaft sealing is provided by two reinforced aluminum cups and rubber O-rings with silicone lubricant. Propellers are placed in special fairings, made on a 3D-printer, that decrease loss of water flow on blade edges and increase the thrust.

Our thrusters (Figure 6.6.1) produce up to 3kg of thrust. This construction showed good results on the previous competitions, and we decided to reuse them. However, we have added a couple of minor improvements regarding sealing mechanism.

There are 4 thrusters that provide horizontal motion and another 4 provide vertical motion, i.e. vectored arrangement. This thruster arrangement allows the vehicle to maneuver in all directions; also it allows minimizing mutual interference between stabilization systems (yaw, pitch, roll angles and depth stabilization).

Fig.6.6.1. Thruster

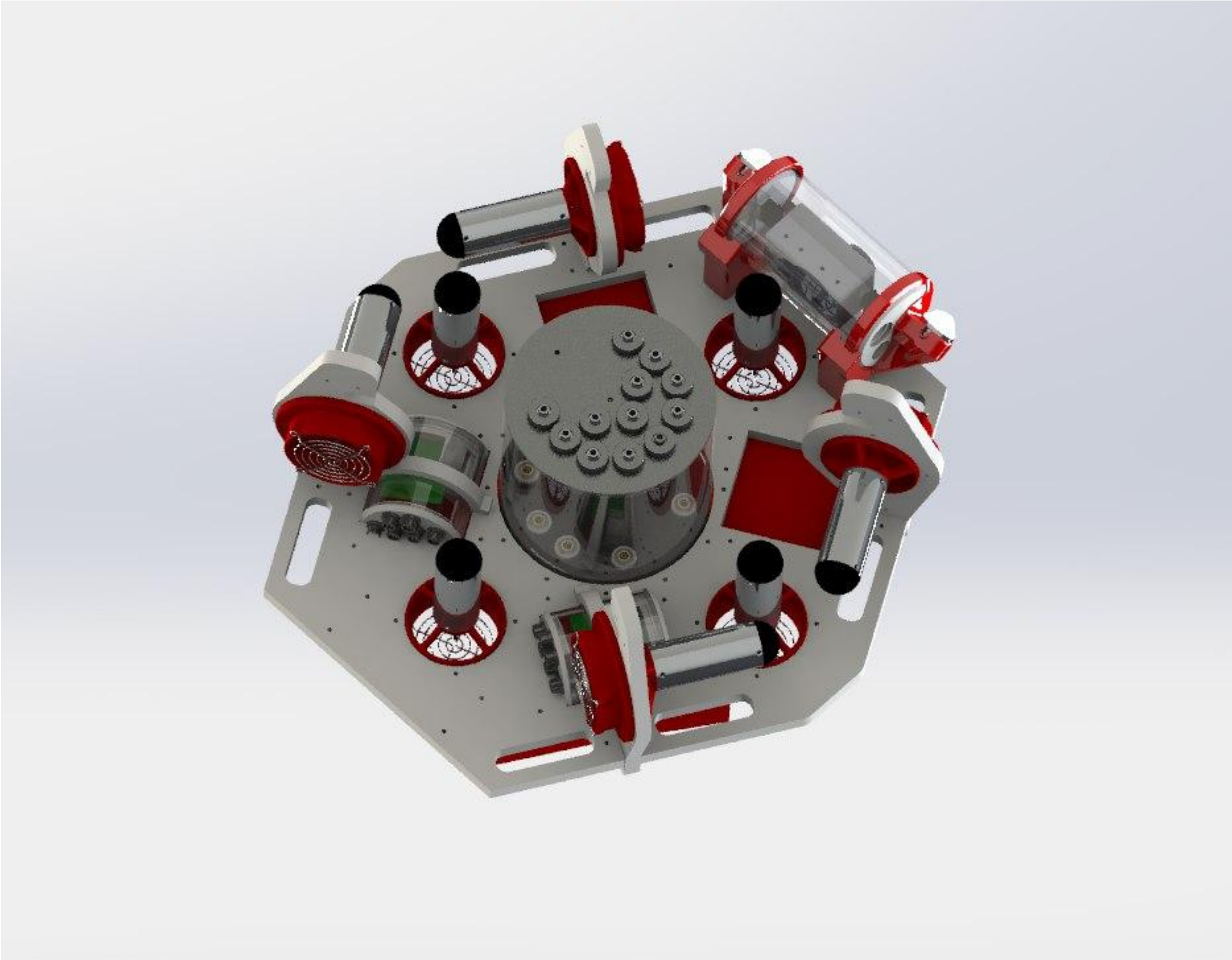

Fig.6.6.2. Arrangement of the thrusters

Active moving complex system control

System consists of two sealed hulls. One of this hulls controls four engine. Each hull contains driver board with two ATMega16 and four Pololu drivers. All hulls are connected to RS-485 bus, where they receive control commands. (Fig.6.6.3.).

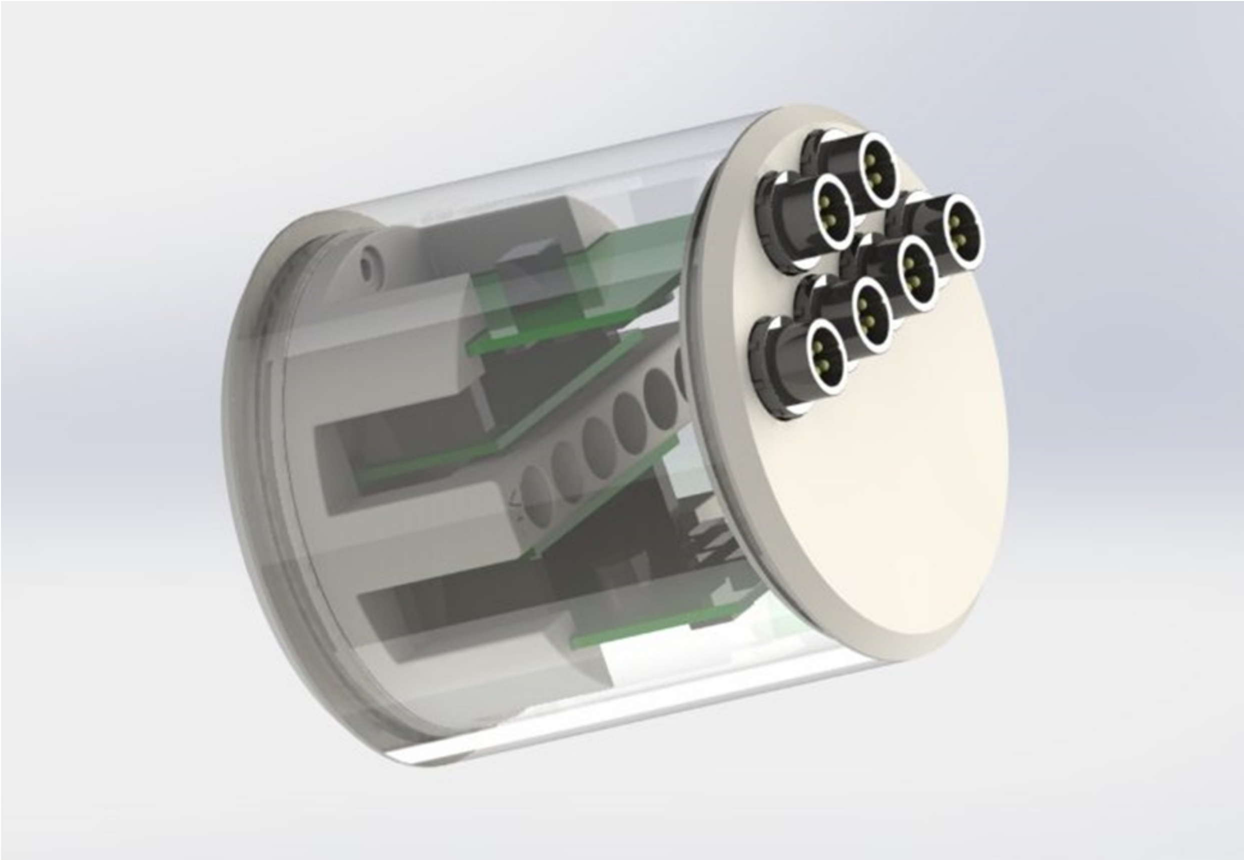

Fig.6.6.3. Sealed drivers hull

Safety notes!

Our thrusters are covered with metal gratings, which prevent any objects from touching the propellers thus preventing possible injuries.

6.7. Lighting

Our vehicle uses two 20W LED lamps for lighting (Fig. 6.7.1). They are directed forward, on the camera block. To provide with better heat dissipation the lamps cases were filled with biodegradable mineral oil. Lenticular shaped glass of the lamps disperses the light from LEDs that provide excellent working zone illumination.

Fig.6.7.1. LED Lamp

6.8. ROV Control Station

Our company designed a mobile control station for the ROV (Figure 6.8.1) which ensures quick and easy deployment of the whole system. It contains:

1)Shockproof equipment box

2)30” wide display

3)Saitek X50 joysticks for ROV controlling

4)2kW power supply unit for all ROV complex

5)Small informational screen for real-time indication of ROV sensors values

6)Analog video converter

7) Analog video splitter

8)Mini-PC for connecting peripheral devices to the ROV

Fig.6.8.1. ROV Control Station

User interface.

User interface is shown on an additional screen, which is located on the control panel (Fig.6.8.2.).

This GUI was designed by company programmer, **Ilya Morev**.

For software writing was used QTcreator.

It indicates the number of the vehicles thrusters, its speed, and direction. Its conveniently for debugging, testing and collecting information for the researches.

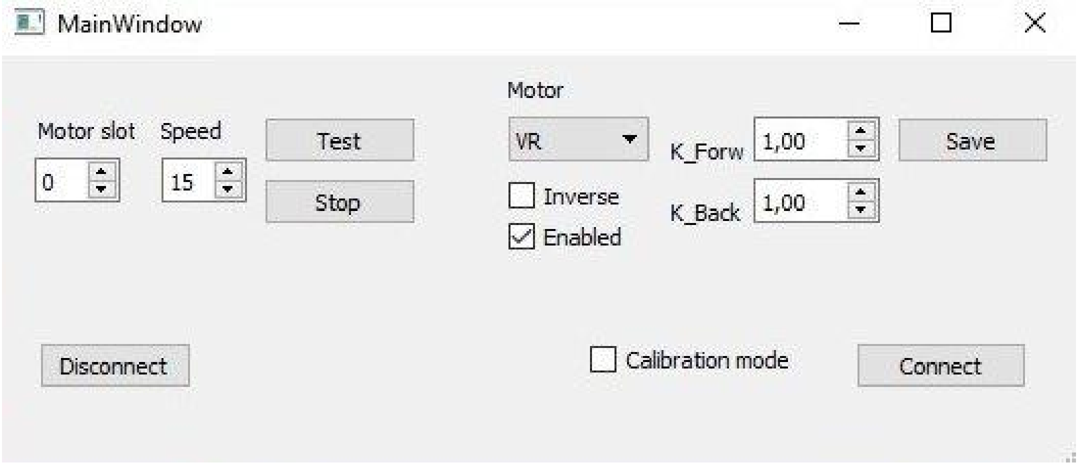

Fig. 6.8.2. GUI

7. Payload for the mission

7.1. Manipulators

The IceBerg ROV is equipped with two electromechanical manipulators.

One was a Seabotix manipulator, which was then modified by the company engineer **Alexey Volf** (Fig. 7.4.1).

One of the modifications made, was that the ball screw actuator was reduced in size, decreasing the size of the entire manipulator by 60%. Three corrugated fingers allow the manipulator to handle small objects. This gripper has a modular design that allows it to be used and attached to other vehicles, which was designed by the Hydronautics team.

The other manipulator on the AKVATOR IceBerg was bought from a Russian manufacturer (Fig. 7.4.2). It has the same principle of operation, but it has a longer housing, which allows for a larger range of manipulation. The manipulator also has the ability of holding larger objects, at the expense of dexterity.

Both manipulators are powered by 48 volt motors. The manipulators are needed for performing mission tasks as a multi-functional device. They are used for carrying equipment, open doors, e.g.

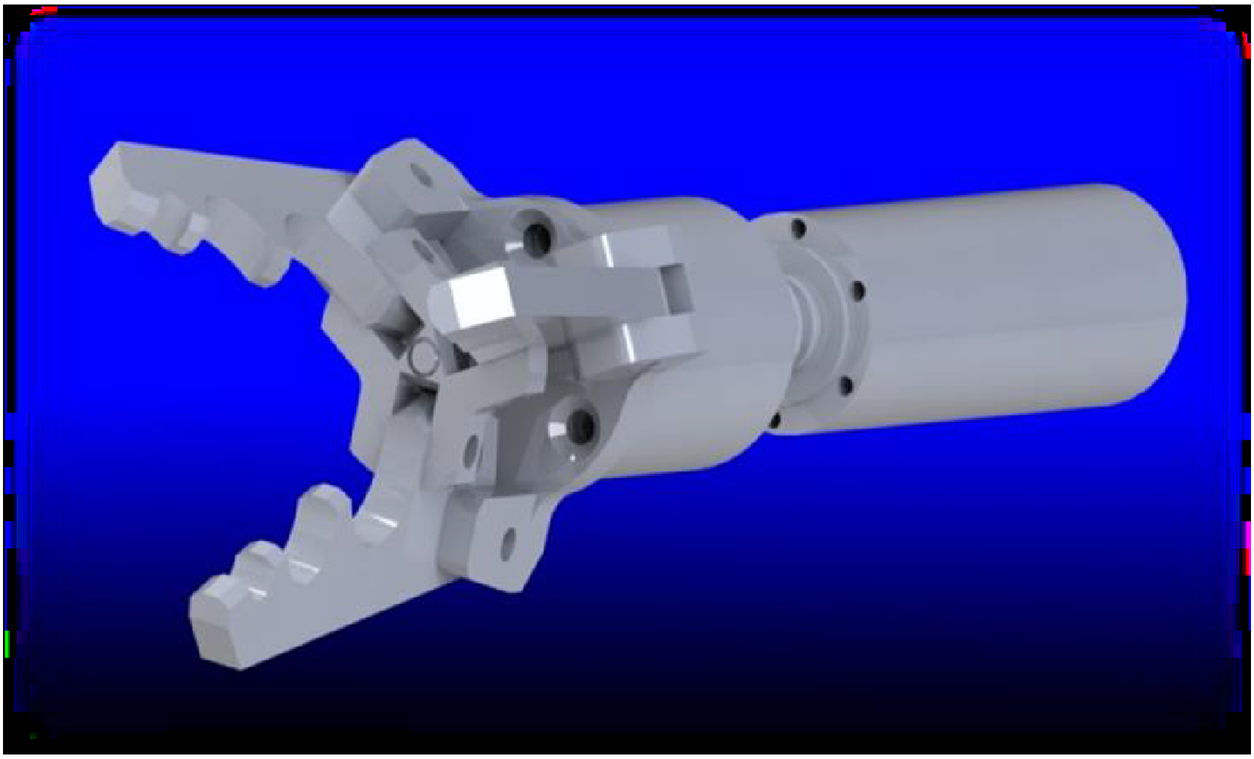

Fig.7.4.1. Manipulator №1

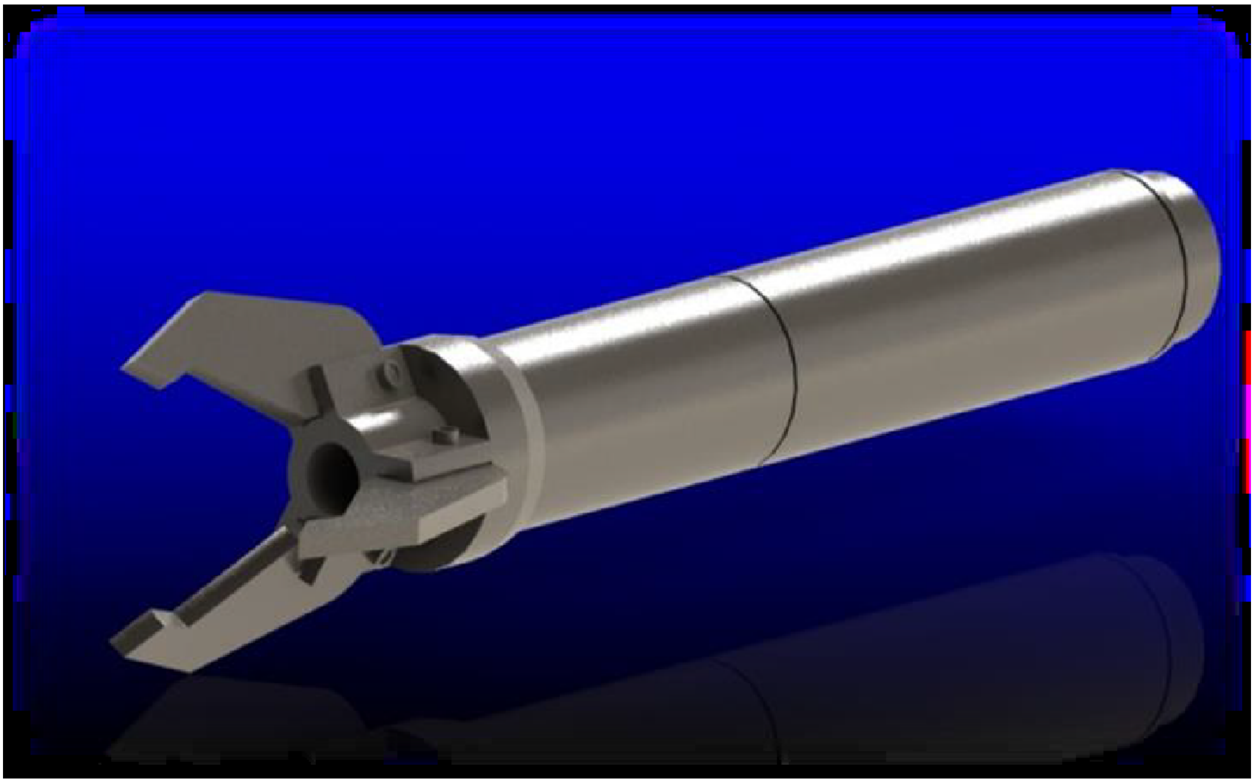

Fig.7.4.2. Manipulator №2

Safety notes!

Manipulators' drivers have built-in current sensors. This allows us to monitor the strength of a grip to prevent jamming or trapping someone's finger!

8. ROV Testing

AKVATOR IceBerg ROV was designed to operate at depths up to 20 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.

Because safety is what matters the most at our company, 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. 8.1). The pool is 3x2 meters and it is 2 meters deep. Instructions about potential safety issues were given to all team members before the ROV could launch (Appendix B).

For the first test, the vehicle was brought to the pool bottom for 10 minutes. Unfortunately, a leak in the Electronics Unit occurred due to faulty sealed connector. The issue was addressed, and at the next two tests the vehicle stayed 2 meters underwater in intervals of 30 minutes and 1 hour respectively.

First testing of the vehicle movement demonstrated its unsatisfactory maneuverability. We decided to change the arrangement of thrusters to prevent undesirable interactions of the water currents.

The test for weight capacity showed that AKVATOR IceBerg can lift a load up to 2.5 kg.

To prepare ourselves for the mission, we have constructed equipment for the pool training (Fig. 8.2). We used it to test the vehicle mobility and image processing software and stabilization systems (Fig. 8.3).

Fig.8.1. Preparing the ROV for testing

Fig.8.2. Carrying pool training equipment

9. Challenges

9.1. Technical Challenges

1) Weight. During the first launch of the ROV we discovered that it weights too much (>40kg), and we decided to change frame construction. The metal part of the frame was removed, and the new elements arrangement was applied. After that the vehicle showed good stability, maneuverability and lost about 15kg. **2)** We actively use 3D printing in this project. On one of the testing iterations we have found out that FDM technology printed parts are easily pass the water through. So we decided to try the new one – SLS technology. This technology is much more expensive, but quality is better the FDM. SLS printed parts practically don't pass the water.

9.2. Non-technical Challenges

The main non-technical issue of the project this year was fundraising. Due to administrative problems it was very difficult to obtain more than minimal funding from the university. It looked like we were on our own but luckily we have found out about the "Polytechnic 2016" exhibition. In included a competition of Bauman Moscow State Technical University students projects. We presented the prototype of AKVATOR IceBerg, developed by the team in early 2015 and won a grant. This allowed us to keep working on the project and implement every feature we planned.

Significant in solving the financial problem was a 20% discount made by PICASO company, on one of their product – 3D printer. We have printed a lot of components on this printer, and we could not afford the full price so it really helped us out.

10. Future improvements

We are planning to improve other elements of the vehicle and add new ones:

1)Development of a detachable structure with additional tools, which is connected to ROV controller using I2C bus. This structue will have standard mountings for different kinds of equipment.

2)Changing the electronics of the vehicle. We plan to use a single-board computer to control all systems of the vehicle instead of several microcontrollers.

3)Adding a stereoscopic image system based on two analog video cameras.

Fig.10.1. Design of the thruster

Fig.10.2. The propeller

11. Reflections and Lessons Learned

While working on the project, we have obtained and improved upon a variety of skills in mechanics engineering, electronics and programming. Teamwork provides an invaluable experience that could not be taught in class.

Projects of this scale require not just enthusiasm, but efficient managing of the workflow and planning. For example, company technical reporter **Ivan Remizov** compiled an overview of the mission tasks that was put on the wall in the lab, so the company members didn’t have to look them up in the mission manual (Fig. 11.1).

One of the achievements, this year, was that we decided not to use 3D-printing for the most important parts of the vehicle and used CNC milling of polypropylene instead. This is how we made the framework of the ROV and mounting mechanisms for manipulators and payload.

These are the reflections that company members wanted to share:

Ivan Semenyk: Main pilot, Computer Vision Engineer :

“Working as a team, we constantly share our experience and constantly learning something new from each other. In Hydronautics team, I have learned the basics of microcontroller programming in C language, learned to improve my CAD skills, became interested in the technical vision, and started to learn OpenCV library to QT platform. And of course participate in the competition - an invaluable experience in stressful situations in a rigid time constraints. **“**

Alexey Volf - Chief mechanical engineer :

“Participation in this project is a rewarding experience. I've learned how to work in a team, how to create a project and make a plan of working. I've improved my skills in drawing, 3D-modeling, mechanics and electronics. Working in a team taught me how to cope with engineering problems and find creative solutions. I'm sure, that such experience will be useful in my future job. **“**

Alexey Nekrasov, CEO, CTO :

“I learned how to apply my skills as a mechanical, electonics engineer and manager. I also improved my knowledge of programming on C++. Working with the team taught me how to find unusual solutions to engineering problems, how to discuss and analyze them and to find a compromise.”

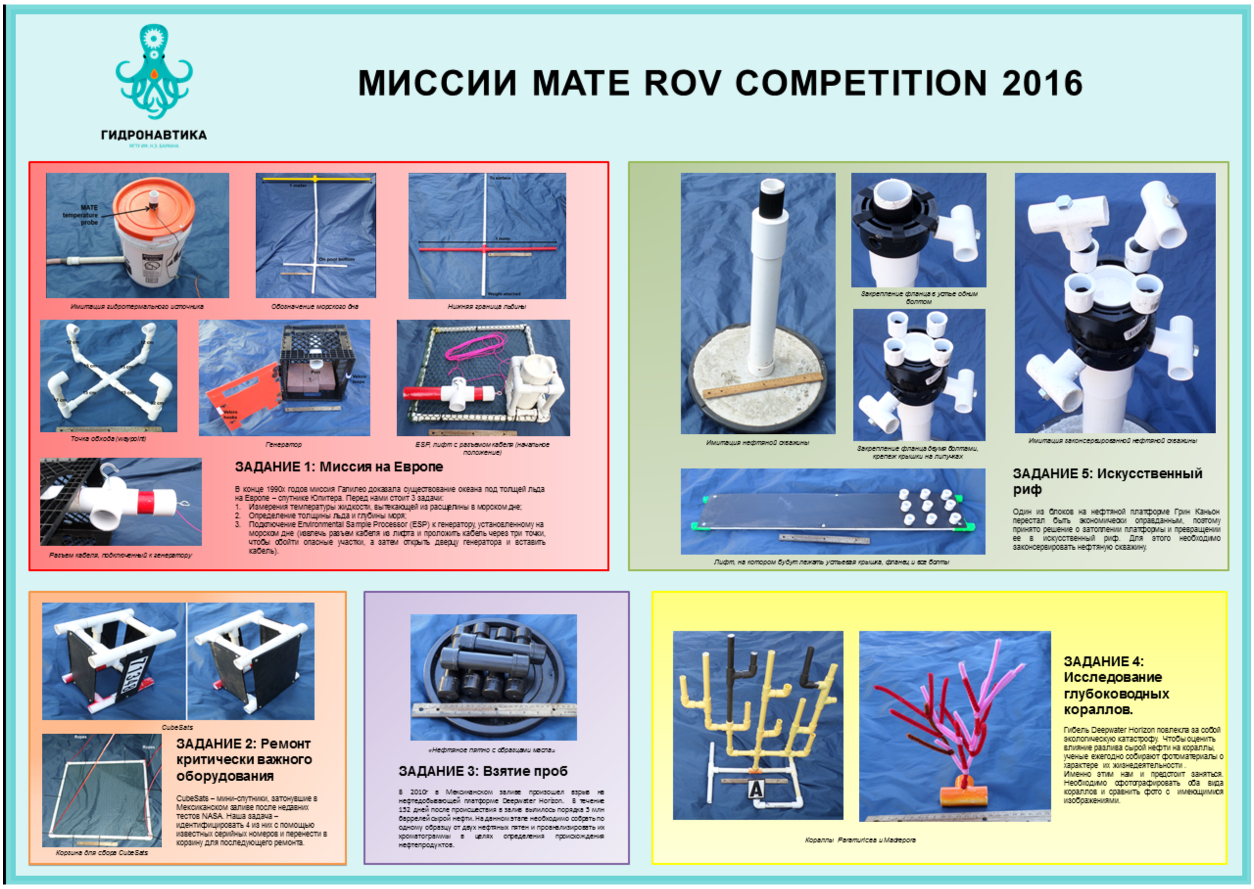

Fig.11.1. Overview of the mission tasks

12. Acknowledgements

MARINE ADVANCED TECHNOLOGY EDUCATION CENTER

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.

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For financial and administrative support, as well as the provided laboratory and a pool for testing our vehicles.

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For the knowledge and skills they gave us.

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For the free of discount made on their product line.

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Ivan Semenyk

Alexey Volf

Ilya Litik

Anna Terehova

Ilya Morev

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14. Appendix A. Project Budget Layout

Reporting period: 01.09.2015 – 20.05.2016

School name: Bauman Moscow State Technical University

Mentor: Stanislav Severov

Funds: BMSTU

№	Element	Numder of	Price, US Dollars per item	Cost, us dollars
1	purchased			
2	stm32 board	1	20	20
3	IMU "Pololu UM6"	1	130	130
4	Electronics pressure hull	1	600	600
5	PCB plates and electronics parts	1	415	615
6	ROV framework, polypropylene cutting	1	246	246
7	HYF sealed connectors	20	8	160
8	Computer for control station	1	308	308
9	Analog video cameras	4	100	400
				2479
10	re-used			
11	box for the mobile control station	1	462	462
12	120HZ 30" Display	1	677	677
13	19" Touchscreen display	1	307	307
14	20W LED lamps	2	24	48
15	Camera rotating servos	1	22	22
16	In-house designed neutrally buoyant tether	1	171	171
17	DC/DC converters	3	165	492
18	MAXON motors	8	357	2857

19	GNOM Manipulator	1	527	527
20	Seabotix Manipulator	1	800	800
				6363
	Donated			
21	BIRNS sealed connector	1	750	750
22	3d printed parts	17	600	600
				1350
				10192

15. 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.