Robocenter

Technical Report

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Оглавление

Abstract

Fig. 1 ROV "Bismark"

Our company is called Robocenter, consists of 3 employees who study in different high schools in Vladivostok, Russia. We are a subsidiary of the Center for Robotics Development. This year our company will participate in the international MATE competition for 6 years in a row.

This year we paid a lot of attention to management, we assigned responsibilities, developed two Gantt charts (more on this later), made a list of resources that needed to be managed. We worked out a system for managing resources, protocols and procedures. We made a budget and kept a careful record of finances.

After inspecting the Manual, we have drawn up a strategy for achieving the objectives of the competition. We head a vehicle that we inherited from the 2020 team. We realized that in order to complete the missions, it would be necessary to refine it.

We have designed and manufactured a set of payloads for our ROV. With its help, the device can perform all the stated tasks:

- Take the information capsule from the pipe using the Micro ROV;
- Reload Seabin and pick up the sponge with hooks;
- Collect floating debris from the water surface with a ball collector;
- Reload the eel net, kill the stars with syringes, place the coral, grab the ziplock and release the ghost net with the manipulator.

When finalizing the vehicle, we actively used brainstorming, a systems approach, various testing and testing methods, troubleshooting and problem solving techniques to generate ideas.

And, of course, as always, we paid great attention to safety. This year all precautions were added anti-covid measures.

Teamwork

Description of the company

Our company Robocenter was founded in 2014 in Vladivostok, Russia. We specialize in the development of ROV for various industrial, environmental and archaeological tasks. For 6 years we have been participating in the MATE ROV Competition and every year we develop a unique vehicle for the proposed tasks.

This year, we are developing ROV “Bismarck” for MATE, which should solve environmental and biological problems. We will talk about them below. The main goal of our company for the current year is to take the 1st place and finally get an order from MATE, we have been going for this for a long time. In 2017, we took the 4th place in the International Competitions, in 2018 - 3rd place, and 2019 - 2nd place.

In preparation for the regional MATE, we had 7 employees in 3 engineering departments: electronic, mechanical and software. But after the end of regional competitions and the termination of the issuance of US visas in Russia, only 3 people remained in the company, heads of departments. The rest of the employees left the company due to the pandemic, summer holidays or lack of motivation due to the cancellation of the trip.

Therefore, the remaining 3 people were taken on with all functions for the development, operation and management of the company. As a result, roles and positions were distributed as follows:

1. Grishchenko Andrei - Chief Programmer, co-pilot, documentation editor and Chief Executive Officer (CEO);
2. Ipatov Tikhon - Chief Electronic Engineer, pilot and Chief Financial Officer (CFO);
3. Besedin Ivan - Chief Mechanical Engineer, tether manager, designer and Chief Safety Officer (CSO)

Fig. 2 Company photo. From left to right: Tikhon Ipatov, Ivan Besedin, Andrei Grichshenko

Development schedule

In September 2020, we developed a work plan for international competitions. But after the regional competitions, we had fewer employees and the format of participation in international ones changed and we had to urgently re-plan all the work. Below we provide a plan to regional and a plan to prepare for international from May 2021.

Management of resources, procedures and protocols

Resources management

In our company we distinguish 3 categories of resources: labor, financial and means of production.

The most important of these resources is the labor, which is why we have been the most careful in managing work time. At weekly meetings, each participant reported how much time they can devote to the project for the coming week. At the next meeting, we reported and compared the amount of time actually spent with the planned one and checked which tasks were completed during this time. If there was a discrepancy between what was planned and was actually done, we looked for a way to avoid shifts in deadlines.

We have assigned a CFO position to manage financial resources. He was responsible for accounting and distribution of finances in the team. For more information on working with finance, see the "Accounting" section.

Our company has access to a limited number of production equipment. Since there were a large number of employees in the departments of our company before the regional competitions, we had to coordinate between them the hours of work with this equipment. So, for example, employees of the electronics department coordinated with each other the build order for assembling printed circuit boards and their installation on the ROV for the distribution of access times to soldering equipment.

Procedure management

In order to optimize work efficiency and increase the interchangeability of employees in the company, we have identified procedures that are easily amenable to algorithmization:

- Time tracking of employees;
- Coordination of purchases;
- Checking the tightness of the ROV;
- Launch of the ROV;
- Deployment on the side of the pool;
- Shutting down after completing missions.

For each of the selected procedures, we have developed an algorithm. For example, to start the ROV:

1	Inspect the ROV and the control panel for mechanical damage, violation of the integrity of the insulation of wires, the absence of loose components	
2	Place the ROV on a flat surface	
3	Place the control panel on a flat surface, open the cover	
4	Connect the joystick to the control panel	
5	Connect the tether cable from the ROV to the control panel	
6	Connect the control panel to the power supply	
7	Turn on the power switch on the control panel to position “1”	
8	Turn on the ROV power on the control panel to position “1”	
9	After loading the OS of the control panel, run the control program	
10	Make sure of the successful initialization of the ROV by receiving a sound signal from the ROV	
11	Make sure that there is an image from the ROV cameras in the control panel software	
12	Check for the presence of transmitted telemetry from the ROV	
13	Make a test run of the thrusters using the joystick	
	Result: the ROV is ready for operation	

Table 1 ROV startup

Protocol management

Protocols are needed to track progress, record results and spot errors in recurring events. We’ve identified three events that require accurate logging: meetings, device testing, training and cable management. We have developed our own protocol for each of them.

During each meeting, protocol is recorded, and it includes the following items:

- Personal report of the work done;
- The number of hours worked by each employee;
- Expenses per week;
- Selection of a priority task and determination of deadlines for their implementation.

We will get acquainted with the rest of the protocols in the corresponding sections.

Design rationale

The whole process of developing a device for this year can be roughly divided into 4 stages:

Development of a usage model for this year's tasks. A usage model is a document that shows how the vehicle will be able to accomplish the tasks assigned to it. It is necessary to determine the composition of the payload.

Analysis of the performance and capabilities of last year's ROV. Since last year's international competitions were canceled, we still have a fully working ROV developed by last year's team for regional MATE 2020. Based on the results of the analysis, we identified breakdowns, shortcomings and made a list of improvements.

Correction of breakdowns and shortcomings of last year's vehicle.

Development of a new payload and its integration into a new vehicle

Build vs. buy, new vs. used

When deciding the issue of buying a new one or using an old one and purchasing a finished one or making our own, we were faced, first of all, with the problem of the ratio of two resources: labor and financial.

In the first case, when we decide to buy a new one or use an old one, the contradiction is resolved by itself, since acquiring a new one turns out to be both more expensive and more labor-intensive than using last year's devices. Therefore, whenever possible, if the device performed well last year and is a good working order, we try to reuse it.

In the second case, making your own is usually cheaper, but requires more labor, and purchasing a finishing one is more expensive, but requires significantly less human resources. Since for our company labor resources are the most important and scarce of all resources (we have only 3 employees), they need to be managed very carefully. Therefore, if we had a question to buy a finished product or develop it ourselves, and at the same time the budget allowed us, then we purchased a commercial product

System approach

During the modernization of last year's ROV, we had to adhere to a system approach, since any thoughtless change in any one device could lead to the failure of the entire ROV. Our approach was to localize the changes as much as possible within a separate subsystem, test it, and only then move on to other subsystems. To do this, it was necessary to clearly understand what subsystems the vehicle consists of and what influence they have on each other.

For example, adding the MicroROV affects several subsystems at once. It is necessary to fit the device and its garage into the supporting structure and integrate it into the control system, where it will be necessary to make changes on-board and surface electronics, as well as software. A systematic understanding of the vehicle also allows us to better decompose tasks. So from the task of integrating the MicroROV we get 4 independent tasks that exclude mutual influence on each other and allow you to perform them simultaneously.

Vehicle structure

Realizing the importance of a system approach, we divided our vehicle into several main systems:

- Control system - for the pilot’s control of the ROV;
- Propulsion system - for moving the ROV;
- Carrying system - for the arrangement of the ROV elements;
- Mission payload - for completing missing assignments.
- And each system was divided into separate subsystems and devices.

Control / Electrical system

The control system of our vehicle is designed to enable the pilot to control the ROV and complete mission tasks. It includes:

- Onboard and surface electronics, allowing the supply and distribution of power and transmission of control signals;
- Software for user interaction with control electronics and in-system interaction of components;
- Cameras to provide visibility to the pilot;
- Sensors for providing the pilot with additional information and automatic stabilization of the vehicle in the water;
- Electronics connections;
- Tether cable.

Onboard electronics

The onboard electronics unit consists of three parts:

- Raspberry Pi 4 Model B;
- Driver board of our production;
- Power board of our own production.

The Raspberry Pi was taken because the Arduino boards our company previously used are not powerful enough to handle the video signal, and the Raspberry Pi does an excellent job of this task. The Raspberry Pi is also easy to use and program, making it a great onboard computer.

Fig. 3 Onboard electronic

We used the Driver Board to connect the payload, manipulator and cameras to the Raspberry Pi. It contains drivers for external motors and a manipulator, an IMU sensor and connectors.

The propulsion and power wires are connected to the Power Board. It also converts 12V to 5V to power the Raspberry Pi.

All onboard electronic boards, except for Raspberry Pi, were developed by our company for last year's competition, and are reused this year. The Raspberry Pi board had to buy a new one since last year's one went out of order.

Surface equipment

Surface equipment includes:

- ROV control box for connecting to the onboard computer, as well as for executing the necessary programs for missions. For example, for a task with a map, you need to run the program to quickly compose it. It also consists of:
    - Intel NUC computer.
    - Voltmeter and ammeter to monitor the voltage and current supplied to the device
    - Two video outputs for connecting an external monitor and outputting video video to it
    - USB connectors for connecting a joystick as well as a computer power connector
    - Monitor for displaying image from a computer
    - Cooling systems to protect against overheating and loss of performance
    - Three switches: from the computer, from the monitor and from the power supply to the ROV
    - Voltage converter 220V AC - 12V DC for powering the ROV from the outlet during training
- Power supply unit DC 12V, 50A
- Joystick to control the device. Used ThrustMaster T Flight Hotas X, as it has a suitable number of degrees of freedom, as well as additional buttons to control the payload. The joystick is connected to the control panel via USB
- Monitor that displays the image from the main camera. The image can be displayed on a computer, but its monitor is too small to display multiple images, so an additional screen is used.

Fig. 4 Surface equipment set

All surface equipment is reused.

Software

We have developed software for user interaction with electronics. It consists of two subsystems - lower and upper.

The lower subsystem is the onboard electronics software. Its task: to receive data, process it and generate signals to control electronics, as well as send data to the remote control. The onboard electronics software is written on C++. This software was developed last year. We have made minor changes to it to improve compatibility with the top software and the updated payload.

The upper subsystem is the control panel software used to process and transmit commands from the pilot to the ROV. Since one of our goals this year was to improve the ROV and reduce its cost, we decided to completely redesign the upper software. So, last year we needed a separate screen and a separate laptop to complete missions. Due to innovative solutions in the software of surface equipment, we can now use the digital screen of the surface control unit to display video from the ROV instead of an external screen. Also, the updated control unit software now allows you to quickly perform the calculations required for the mission. This can help you save money on surface equipment by eliminating a separate screen and laptop from your purchases.

To write it, we used the Qt framework on C++, it opens up great opportunities and allows us to write the most user-friendly software. The interface consists of tabs grouped by purpose.

Cameras

The vehicle has two cameras: the main one and the bottom one. The main camera is designed for the pilot to review the underwater environment in front of the vehicle. It is equipped with a servomotor, which allows you to increase the view by rotating the camera up or down. This camera is analog. The advantage of an analog camera is the minimum delay of the video signal transmitted to the surface. This is necessary for the pilot to operate in real time.

Fig. 5 Bottom digital camera

The bottom camera is located under the vehicle and is directed downward. It provides an overview under the device. This is necessary for the task with the counting of mussels and picking up sponges. This camera is digital, as the tether cable structure limits the number of analog cameras that can be connected.

We use both cameras from last year's ROV.

Fig. 6 Rear tilt camera

Sensors

Our ROV uses 2 sensors:

- IMU sensor with gyroscope and accelerometer sensors to determine the orientation of the vehicle, which is needed for the automatic roll and trim control system. This system allows the ROV to align while dragging objects such as the Powered Seabin Connector, making it easier for the pilot. Also, gyroscope orientation is used for the task "The catastrophic impact of climate change on coral reefs" when performing Fly a transect line over a coral reef.
- Pressure for determining the depth at which the vehicle is located and for the automatic depth stabilization system. We use automatic depth stabilization in the "Maintaining healthy waterways" task to move along a subway car at the same height when photographing it.

Both sensors were used from last year’s ROV.

Cabling

We distinguish three types of electronics connections on the device:

- *Interunit* for connecting the autopilot unit with external devices - external sensors and actuators. To seal the entry points into dry containers, a sealant and sealed cable entries with a rubber seal are used.
- *In-Box* - for interconnecting printed circuit boards, for example, connecting a Raspberry Pi to a distribution board inside an electronics box container. For these connections, we use wires with connectors.
- Connection to the surface via tether.

Tether

We use a 20-meter cable to power the device and communicate with it. We have chosen this length that the ROV can reach any part of the pool. According to MATE's data on the depth and length of the pool, the required cable length is calculated according to the Pythagorean theorem:

$$L = \sqrt{((4m)^2 + (10m)^2)} \approx 11m \ .$$

This length is enough for the device to swim diagonally across the entire pool. But the cable must be connected to the remote control, which is located on the pool side at some distance from the water, so we added 9 meters of reserve. If the cable was longer, the voltage drops would be greater, and a wire that is too long is more difficult to transport and store.

Fig. 7 Tether structure

The tether consists of two 12 AWG power wires and an Ethernet cable. Two twisted pairs of communication cable are used for data exchange using Fast Ethernet, providing speeds up to 100 Mbit/s. One twisted pair carries the analog video signal from the ROV, the other from the Micro ROV.

We chose the cross-section of the power cable 12 AWG, since at a current of 20 A according to the formula: U=(I*ρ*L)/S, the voltage drop is about 10%, at which the electronics of the ROV continue working.

To protect the tether from mechanical damage, we used a protective nylon braid. Since the cable has negative buoyancy, it can pull the device to the bottom. To give the cable a buoyancy close to neutral, we fixed the buoyancy elements made of expanded polystyrene along its length, whose dimensions were determined empirically.

Propulsion

Propulsion system configuration

Fig. 8 Thruster arrangement

In the task of servicing Seabin, you need to grab the induction charge with the manipulator and move it. But it is heavy and heels the vehicle. Therefore, we installed 4 vertical movement thrusters at the corners of the ROV frame to control roll and trim.

When performing a task with a subway car, we need to get a clear image of the car on each side. To do this, we need to accurately and evenly move the ROV along the car in the horizontal plane. To do this, we installed 4 horizontal propellers at an angle of 45 degrees relative to the center plane of the ROV.

ROV can move in six degrees of motion: heave, sway, surge, roll, pitch and yaw, by adjusting the thrust of specific thrusters.

Thrusters

Fig. 9 MUR Thruster 1500

In order to devote more time to development, production of payloads and software, our team decided not to develop, but to purchase ready-made propulsion systems. We have defined the criteria to be met by the thrusters:

- MATE limits the current that must be consumed by the ROV. Therefore, we were looking for such thrusters, the amount of current consumption of which does not exceed the provided current when moving in a given direction;
- MATE limits the voltage to 12V that is available for the ROV. Therefore, we were looking for such propellers that can be used with such a voltage that converters are not used;

- We were looking for hermetically sealed propellers with a ring nozzle and a propeller. Thrusters of this type are easy to control and have a focused thrust vector;
- We have tried to select the most powerful propulsion system available to ensure the vehicle has maximum mobility and power reserve. This is necessary to carry out missions where our ROV must lift and move objects;
- We made a budget limit of $250 per thruster so as not to increase the final price of our ROV;
- We were looking for a seller with a minimum delivery time to assemble the ROV and start training as soon as possible.

After studying the market, our company was able to purchase suitable propulsion units from the Center for Robotics Development.

Model	Thrust at 12V	Price per piece	Delivery cost	Delivery period
MUR Thruster 1500	15 N	$ 204,90	$ 0,00	0 days
Blue Robotics T100	23,6 N	$ 119,00	$ 150,00	20-40 days
DD TD 14	No data	$ 289,00	$ 100,00	40 days
Topping	No data	$ 85,00	$ 75,00	40 days

Table 2 Market research

Carrying system

Ballasting and buoyancy system

Fig. 10 Buoyancy blocks

Having measured the mass of the vehicle on the scales and calculated its volume in Solidworks, we learned that our ROV has negative buoyancy. If this is not corrected, then you will have to constantly turn on the thrusters in order to stay at the same depth.

We have calculated and designed polystyrene foam buoyancy blocks for our vehicle. Their density is 30 kg / m^3, which is much less than the density of water, and they make it possible to impart a small positive buoyancy to the ROV. In the event of a failure of the on-board electronics, these blocks allow the vehicle to safely float to the surface for further service.

After the final assembly and submersion of the ROV in the water, we found out that there is a roll on the nose due to the payload located there. To compensate for this roll, we attached lead weights to the rear lower part of the frame of the ROV.

Frame

All payload, thrusters and control system elements of ROV are installed on its frame. We were able to use the ROV frame from last year, but due to a change in the payload, we had to redo the lower plate of the frame. We made this plate from the same material as the frame - from low-pressure polyethylene.

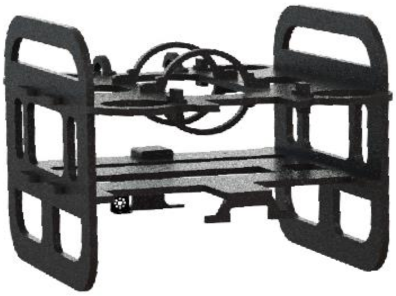

Fig. 11 Frame

Payload

MicroROV, garage and rewinder

Last year's version of the micro ROV had a problem, that this device twisted along the longitudinal axis when moving. Because of this, the image rotated and the pilot of the micro ROV could not get a view inside the drain pipe.

We have studied the reason for this phenomenon. The cause of this phenomenon was the force that occurs when the engine is running with a propeller in the water. This force twists the micro ROV in the opposite direction to the motion of the propeller. We got together as a whole team and had a brainstorming session, during which we developed a new concept. To avoid this phenomenon, we decided to install a second propeller of opposite rotation.

Fig. 14 MicroROV

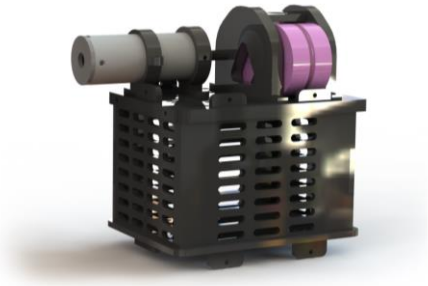

Fig. 13 Rewinder

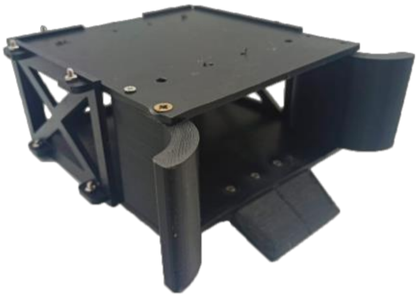

Fig. 12 Garage

A special device, a garage, was developed to place the micro ROV on the device. It allows transporting MicroROV inside the main ROV.

The rewinder is a special device that returns the Micro ROV to the garage. It consists of two silicone rollers that straighten and wind up the cable into a special box.

Manipulator

Most of the tasks in the MATE 2021 are more convenient to perform using a manipulator - a grip that can hold and move objects. We had last year’s dimensional manipulator, which had the function of rotation around the longitudinal axis.

Fig. 15 Manipulator

For the tasks facing the MATE 2021, we needed to redo the payload. Since our new MicroROV has large dimensions compared to last year’s, a new garage was created for it. Because of this, we made a compromise, abandoning last year’s large manipulator in favor of a small-sized manipulator purchased from the Center for Robotics Development. This small-sized manipulator has no disadvantages for us compared to last year’s manipulator. Also, its price is lower, which made it possible to further reduce the cost of the ROV.

Catching net

One of the objectives of the competition is to collect debris on the surface of the water. Balls are represented as debris on MATE. When testing last year's version of the net, problems were identified, namely, the inconvenience of catching balls on the surface of the pool and their loss from the net. After investigating the problem, we found out that the width and volume of last year's mesh were small. Therefore, our team decided to create a new catching net for catching balls.

Fig. 16 Catching net

During the development of the new catching net, we had two iterations, in each of which we tried new materials and changed the shape of the mesh. Thus, we came to the most optimal variant, in which the width of the (сетка) was increased, which made it possible to collect the balls faster. And also new materials were used to increase the strength of the mesh.

Hook

Among the tasks of the competition, we identified several that require the transportation of objects from the surface. Each ascent to the surface behind the load takes a long time. We decided to add a transport hook to save this time. We place additional cargo on it on the ROV. It is printed on a 3D printer and its feature is the hot plug. This means that it can be easily and quickly removed and replaced, for example in the event of a breakdown. It also makes ROV more compact for transportation.

Fig. 17 Hook

Problem solving

Throughout the project, there were problems that could not be solved using ready-made solutions and developments. In this case, it was necessary to understand whether the reason is our incompetence, lack of experience, or this problem requires an original/new solution. Therefore, at first we studied analogs, read scientific articles, and other team's technical reports of previous years. If we did not find a solution there, we turned to the mentor, but asked him to suggest not a ready answer, but to direct them in the right direction. If nothing worked out in this case, they organized a brainstorming session. Why couldn't it be organized right away? And because trying to find the answer in the literature and other sources, we were enriched with knowledge and our critical analysis in the second stage of the brainstorming became better.

As we have already written, we tried to save human resources and, if possible, buy ready-made components. But this puts an additional burden on us to choose suitable versions. Therefore, to simplify the choice, we have developed a simple tactic for ourselves:

- We formulate the technical requirements for the device.
- We set price restrictions, we are looking for suppliers that are suitable for the price, taking into account delivery.
- We filter suppliers who satisfy us by delivery time.
- We choose the best in terms of quality/price/delivery time.
- An example of using this tactic can be seen in the section "Thrusters".

Safety

Company safety philosophy

The safety philosophy of our company is to prevent all risks that may arise during the development, manufacture and operation of the ROV. According to the safety philosophy of our company, safety measures cover not only all employees of the company, but also all people who will have direct contact with the device during its operation.

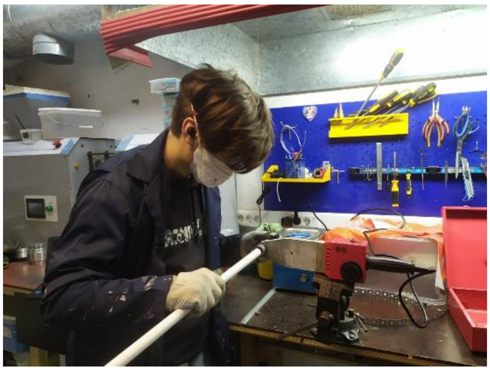

Fig. 18 Personal protective equipment used by mechanical engineer

Since the safety of every employee of the company is a priority for us, we paid special attention to it. We have developed a company safety policy that all of our employees follow. It includes a list of safety rules when working with the vehicle and equipment intended for the assembly and operation of ROV.

For example, according to this regulation, a company employee is not allowed to start working with a special machine without undergoing safety training.

To manage safety protocols, as well as develop and track the implementation of the Safety Regulation, we have appointed a dedicated employee of our company to this position. The company's safety regulations are included in the appendix.

To meet the safety requirements for the MATE ROV Competition, we have developed and added Safety Features to our ROV. These Safety Features provide a high level of safety for company employees during the operation of the machine. We were able to do this by studying the possible risks of operating the ROV, as well as recording all the incidents. A list of Safety Features is provided below.

Safety features

1. All hazardous areas of the device are marked with warning labels, which signal the need for special attention to these zones in case there is a need for direct contact of a company employee with a working device.
2. All wire connections, cameras installed on the device, all mechanisms on it, MicroROV, as well as the enclosure, which contains the main electronics of the device, have a high level of sealing, which by orders of magnitude reduces the risk of failure of the device during its operation and reduces the risk of getting an electric shock by direct contact of a company employee with a working device.
3. The enclosure of the vehicle has not only high sealing, but also strength to withstand the pressure exerted by water at the depth at which the vehicle must be to perform all tasks on the MATE ROV Competition.

Fig. 19 IP20 thruster propeller protection

4. The control panel has voltage and current indicators supplied and consumed by the ROV during its operation. Also, the control panel has the function of turning on / off the power supplied to it.
5. The control panel contains a special fuse (25A fuse), which, in the event of a short circuit on the device, immediately burns out, which leads to a power cut on the ROV.
6. The frame design does not have any sharp corners or other protrusions. This allows the employee of the company, who serves directly the device itself, to do it as safely, comfortably and efficiently as possible.
7. Some of the materials from which the components of the device are made are printed on a 3D printer, which increases the environmental friendliness of the device itself, if it works directly in a real natural reservoir, be it a lake, a bay or an ocean, our device will represent a minimum harm.
8. For the vehicle, special buoyancy blocks are provided, which help the ROV in the event of a failure of the electronics on it, it safely floats to the surface.

Critical Analysis

Testing and Troubleshooting

In the process of developing the vehicle, we tried to identify, eliminate and prevent errors that arise. To do this, we tested separately the components of our ROV, their interaction with each other and the assembly of the vehicle.

1. The worst mistakes are easier to identify and fix at the component level. Before installing a purchased or manufactured component on the ROV, we checked its operability and functional characteristics.

Checking the components helps prevent the error from affecting the entire system. In particular, each pressurized ROV unit was pressurized in a chamber under pressure. Lack of tightness in one of the units can lead to a short circuit, which can lead to equipment failure in the other unit.

In addition to identifying errors, testing can determine the characteristics of the developed component. For example, we measured the current of the MicroROV thruster, for which we designed propellers. This information was useful in calculating the fuse for our MicroROV.

Software testing at the level of individual components is performed using built-in functions of Integrated Drive Electronics (IDE).

2. Testing the interaction of components with each other. Our experience shows that when components are combined, their behavior does not always match to the expected result. Therefore, we have always checked the build results at all stages.

   a. Mechanical compatibility test of manufactured components. For example, when assembling our MicroROV, a design error was detected, which was that the shrinkage of parts printed on a 3D printer was not taken into account. As a result, we made it mandatory to check 3D models for shrinkage compensation.

   b. We checked the results of combining electronic components with each other. So, before packing electronic boards in sealed cases, we checked their assembly performance. Checks of this kind allow you to check the subsystems of the ROV without carrying out a complete assembly of the vehicle, and, thus, save effort on installation and dismantling.

   c. Software testing. This testing of interfaces between software modules (between the upper and lower software), as well as the interaction of software with equipment.

   d. Also, the assembled device was tested in a small pool in order to check the basic functionality.

3. Testing ROV as a finished product. Since the main goal of our work is to create a complete device for performing tasks, we conducted its operational testing. This testing consisted of the pilot performing the competition tasks using the tools we developed. For

example, we checked whether the ROV can lift the model with a servo grip, whether the ascent rate changes with the lifted model, how fast the ROV can swim, how the MicroROV behaves in the pipe.

Troubleshooting strategies and techniques

In the process of development, testing and operation, we constantly faced problems, so we needed to develop for ourselves an effective strategy and tactics to fix them.

As a template, we used the experience of our mentors, who are able to fix problems very quickly and efficiently. Then they worked out their methods for a long time on their mistakes, including both cognitive models and engineering life hacks.

The first step in the strategy is to isolate the problem. It is necessary to pinpoint where the failure occurred, find and isolate the problematic system and subsystem, if possible.

The second stage, if the cause of the problem is not obvious and includes both software and electronics with a design, then we assume that the failure occurred due to software. Since changes to the code can be done the fastest.

If it's not about the software, or not just about it, then we assume that the problem is in the electronics and do a comprehensive check of the boards and connectors, trying to localize the problem even more.

And last but not least, we turn to the constructive part.

When a problem is found and it can be equally effectively solved either by interfering with software, or with electronics or mechanics, then we follow the same path as when searching for an error: from software to mechanics. We took this tactic from a TV series about doctors, where they try to treat a patient with minimal surgical intervention.

That is why this year we decided to keep all the software operation logs and their subsequent analysis to identify the malfunction of the ROV.

Prototyping

Fig. 20 MicroROV prototype

Before designing some of the complex assemblies, we tested our hypotheses by prototyping. For example, last year there was only one motor on MicroROV, and a reactive moment was created. We thought that installing a second counter-rotating motor would eliminate this problem. To test this concept, we created a test Micro ROV from a plastic bottle. After the tests, the reactive moment was eliminated, and we began to develop Micro ROV according to this concept.

We learned to work and used both for prototyping and for manufacturing a 3D printer, a CNC milling machine and a laser machine.

Accounting

Budget planning

After creating the General Work Plan, our company has drawn up a budget plan. This budget plan is included in the appendix. Our CFO has reviewed our company's technical reporting costs from previous years of participation in MATE competitions.

The biggest expense for our company every year is a business trip to the United States. This year we have budgeted $ 8,500 for 5 US tickets and hotel accommodations. We also added the following items to the budget: $ 887 to buy materials to upgrade the payload and repair the device and $ 300 for a taxi to the pool.

The main goal of our company is to make the device more affordable for the consumer. This can be done by reducing the costs of the company. Our company was preparing for the MATE competition last year. The theme of this year's competition is similar to the theme of last year's competition. We decided not to develop the device from scratch, but to refine last year's one. This made it possible to cut the budget.

We agreed that we can contribute $ 55.39 each month from pocket funds to the budget, which will give us $ 3333.04 in total.

Having created a budget plan, we realized that we would need another $ 6353.96. With him, we turned to our sponsor - the Center for the Development of Robotics. After receiving the funds, we started working on the ROV.

In April, we realized that we would not be able to fly to the United States due to coronavirus restrictions. Because of this, we have a budget surplus. Also, in April, the propulsion devices began to work worse due to wear and tear. We bought new ones to improve the reliability of the device. We have purchased and integrated a new, lighter and more compact manipulator. With this we were able to reduce the budget surplus.

Cost accounting

For a more rational use of the budget allocated to us, we carefully approached the acquisition of components. We have detailed our experience in the section “**Build vs. buy, new vs. used**”.

Our CFO meticulously took into account all our company's expenses. He collected the checks weekly and entered them into the Project Cost sheet. This table is indicated in the appendix. It lists all reused and purchased components.

It was important for us to take into account not only financial costs, but also to assess the intangible contribution to the project: mentors' time, pool rent, parental assistance, equipment provided. And although this contribution is certainly invaluable for accurate accounting, we tried to find the market value of each help point and also included them in our Project Cost.

Acknowledgements

We thank our sponsor, the Center for Robotics Development, who also helped us with materials, equipment, facilities, and a test aquarium.

We express our deep gratitude to Sergey Mun for organizing the MATE Russia-Far East ROV Competition.

We thank our mentors for the transfer of knowledge and experience, as well as for helping in the implementation of the project. We are grateful to Angelina Borovskaia for mentoring in design, Vadim Sorin for mentoring in electronics and in organizing our team, Alexander Omelyanenko for help in the design and development of technical documentation, Vitalii Shevchenko for mentoring in programming.

We would like to thank the Robotics Center for the provided components, as well as employee Maksim Grinevskii for help with the production of components. We would like to thank Anton Osipov for his help in printing 3D components.

We thank the Maritime State University named after admiral G.I. Nevelskoy for access to the pool for training.

We were also morally supported by our parents and helped with the transportation of the ROV and props to the pool.

And, of course, thanks to the MATE Center for their invaluable contribution to underwater robotics and the opportunities provided.

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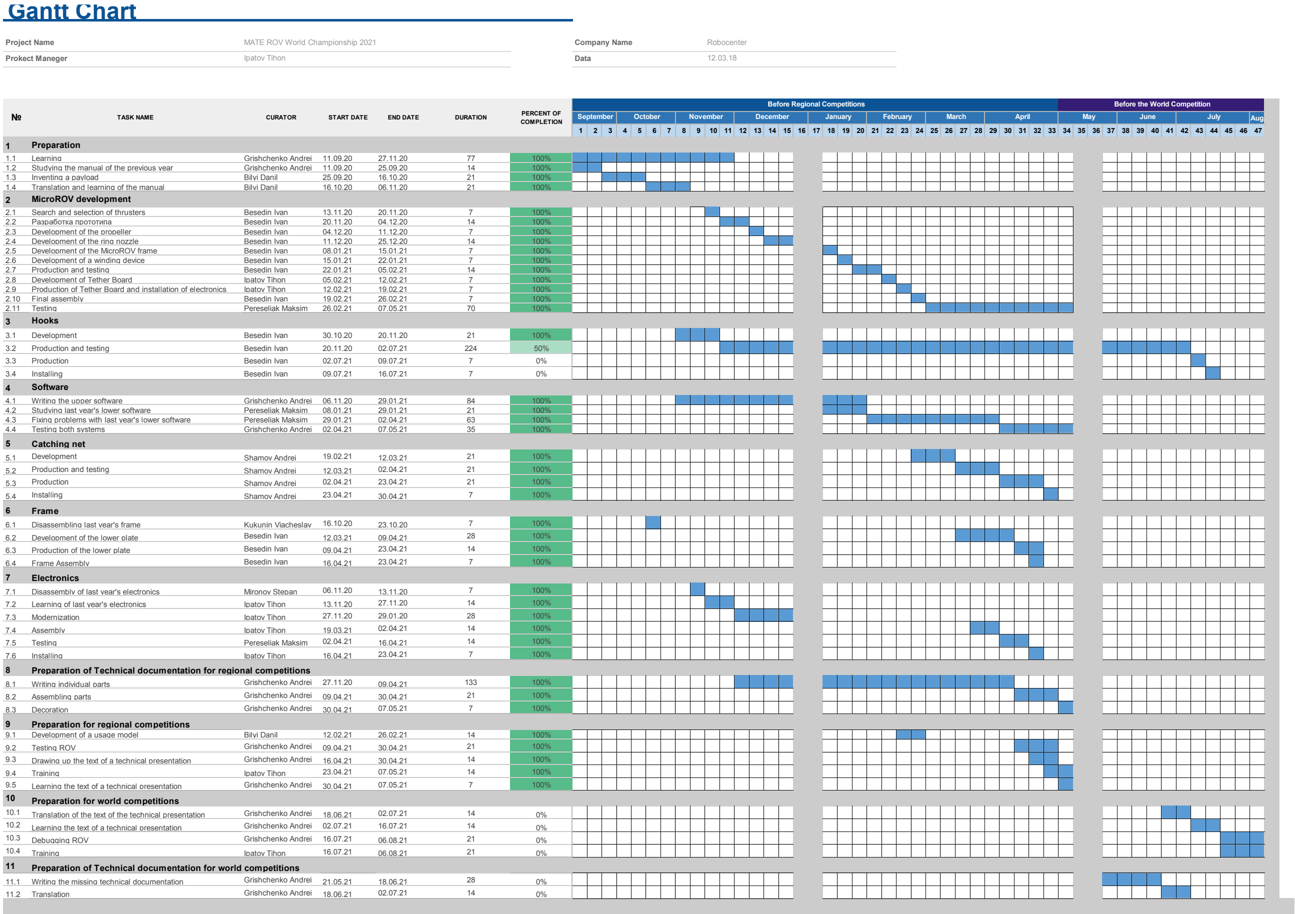
Appendix A. Gantt Charts



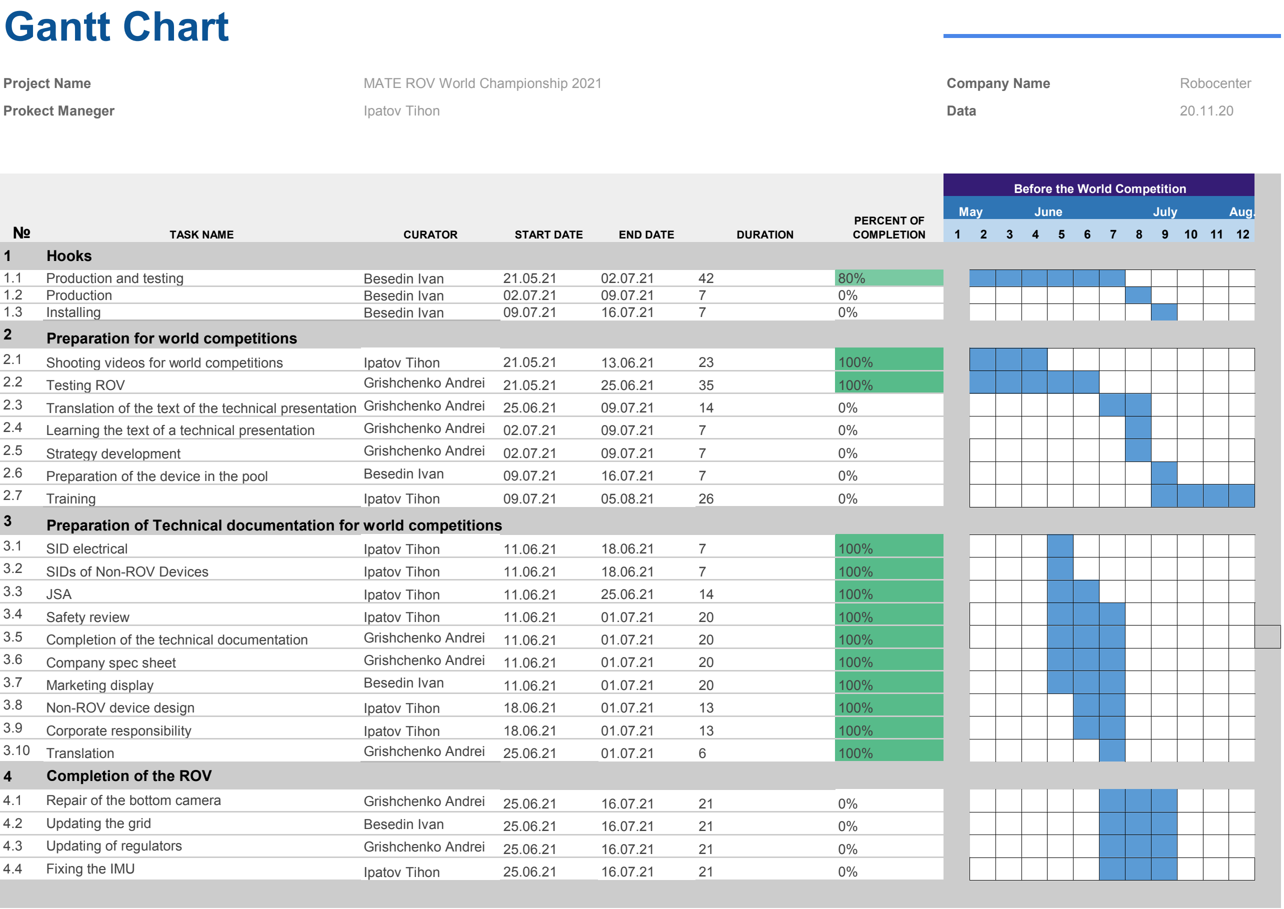
Gantt Chart

Project Name	MATE ROV World Championship 2021	**Company Name**	Robocenter
Prokect Maneger	Ipatov Tihon	**Data**	12.03.18

Before Regional Competitions: September, October, November, December, January, February, March, April (weeks 1–33)
Before the World Competition: May, June, July, Aug. (weeks 34–47)

№	TASK NAME	CURATOR	START DATE	END DATE	DURATION	PERCENT OF COMPLETION
1	**Preparation**					
1.1	Learning	Grishchenko Andrei	11.09.20	27.11.20	77	100%
1.2	Studying the manual of the previous year	Grishchenko Andrei	11.09.20	25.09.20	14	100%
1.3	Inventing a payload	Bilyi Danil	25.09.20	16.10.20	21	100%
1.4	Translation and learning of the manual	Bilyi Danil	16.10.20	06.11.20	21	100%
2	**MicroROV development**					
2.1	Search and selection of thrusters	Besedin Ivan	13.11.20	20.11.20	7	100%
2.2	Разработка прототипа	Besedin Ivan	20.11.20	04.12.20	14	100%
2.3	Development of the propeller	Besedin Ivan	04.12.20	11.12.20	7	100%
2.4	Development of the ring nozzle	Besedin Ivan	11.12.20	25.12.20	14	100%
2.5	Development of the MicroROV frame	Besedin Ivan	08.01.21	15.01.21	7	100%
2.6	Development of a winding device	Besedin Ivan	15.01.21	22.01.21	7	100%
2.7	Production and testing	Besedin Ivan	22.01.21	05.02.21	14	100%
2.8	Development of Tether Board	Ipatov Tihon	05.02.21	12.02.21	7	100%
2.9	Production of Tether Board and installation of electronics	Ipatov Tihon	12.02.21	19.02.21	7	100%
2.10	Final assembly	Besedin Ivan	19.02.21	26.02.21	7	100%
2.11	Testing	Pereseliak Maksim	26.02.21	07.05.21	70	100%
3	**Hooks**					
3.1	Development	Besedin Ivan	30.10.20	20.11.20	21	100%
3.2	Production and testing	Besedin Ivan	20.11.20	02.07.21	224	50%
3.3	Production	Besedin Ivan	02.07.21	09.07.21	7	0%
3.4	Installing	Besedin Ivan	09.07.21	16.07.21	7	0%
4	**Software**					
4.1	Writing the upper software	Grishchenko Andrei	06.11.20	29.01.21	84	100%
4.2	Studying last year's lower software	Pereseliak Maksim	08.01.21	29.01.21	21	100%
4.3	Fixing problems with last year's lower software	Pereseliak Maksim	29.01.21	02.04.21	63	100%
4.4	Testing both systems	Grishchenko Andrei	02.04.21	07.05.21	35	100%
5	**Catching net**					
5.1	Development	Shamov Andrei	19.02.21	12.03.21	21	100%
5.2	Production and testing	Shamov Andrei	12.03.21	02.04.21	21	100%
5.3	Production	Shamov Andrei	02.04.21	23.04.21	21	100%
5.4	Installing	Shamov Andrei	23.04.21	30.04.21	7	100%
6	**Frame**					
6.1	Disassembling last year's frame	Kukunin Viacheslav	16.10.20	23.10.20	7	100%
6.2	Development of the lower plate	Besedin Ivan	12.03.21	09.04.21	28	100%
6.3	Production of the lower plate	Besedin Ivan	09.04.21	23.04.21	14	100%
6.4	Frame Assembly	Besedin Ivan	16.04.21	23.04.21	7	100%
7	**Electronics**					
7.1	Disassembly of last year's electronics	Mironov Stepan	06.11.20	13.11.20	7	100%
7.2	Learning of last year's electronics	Ipatov Tihon	13.11.20	27.11.20	14	100%
7.3	Modernization	Ipatov Tihon	27.11.20	29.01.20	28	100%
7.4	Assembly	Ipatov Tihon	19.03.21	02.04.21	14	100%
7.5	Testing	Pereseliak Maksim	02.04.21	16.04.21	14	100%
7.6	Installing	Ipatov Tihon	16.04.21	23.04.21	7	100%
8	**Preparation of Technical documentation for regional competitions**					
8.1	Writing individual parts	Grishchenko Andrei	27.11.20	09.04.21	133	100%
8.2	Assembling parts	Grishchenko Andrei	09.04.21	30.04.21	21	100%
8.3	Decoration	Grishchenko Andrei	30.04.21	07.05.21	7	100%
9	**Preparation for regional competitions**					
9.1	Development of a usage model	Bilyi Danil	12.02.21	26.02.21	14	100%
9.2	Testing ROV	Grishchenko Andrei	09.04.21	30.04.21	21	100%
9.3	Drawing up the text of a technical presentation	Grishchenko Andrei	16.04.21	30.04.21	14	100%
9.4	Training	Ipatov Tihon	23.04.21	07.05.21	14	100%
9.5	Learning the text of a technical presentation	Grishchenko Andrei	30.04.21	07.05.21	7	100%
10	**Preparation for world competitions**					
10.1	Translation of the text of the technical presentation	Grishchenko Andrei	18.06.21	02.07.21	14	0%
10.2	Learning the text of a technical presentation	Grishchenko Andrei	02.07.21	16.07.21	14	0%
10.3	Debugging ROV	Grishchenko Andrei	16.07.21	06.08.21	21	0%
10.4	Training	Ipatov Tihon	16.07.21	06.08.21	21	0%
11	**Preparation of Technical documentation for world competitions**					
11.1	Writing the missing technical documentation	Grishchenko Andrei	21.05.21	18.06.21	28	0%
11.2	Translation	Grishchenko Andrei	18.06.21	02.07.21	14	0%

Gantt chart 1 - before regionals



Gantt Chart

Project Name	MATE ROV World Championship 2021	**Company Name**	Robocenter
Prokect Maneger	Ipatov Tihon	**Data**	20.11.20

Before the World Competition: May, June, July, Aug. (weeks 1–12)

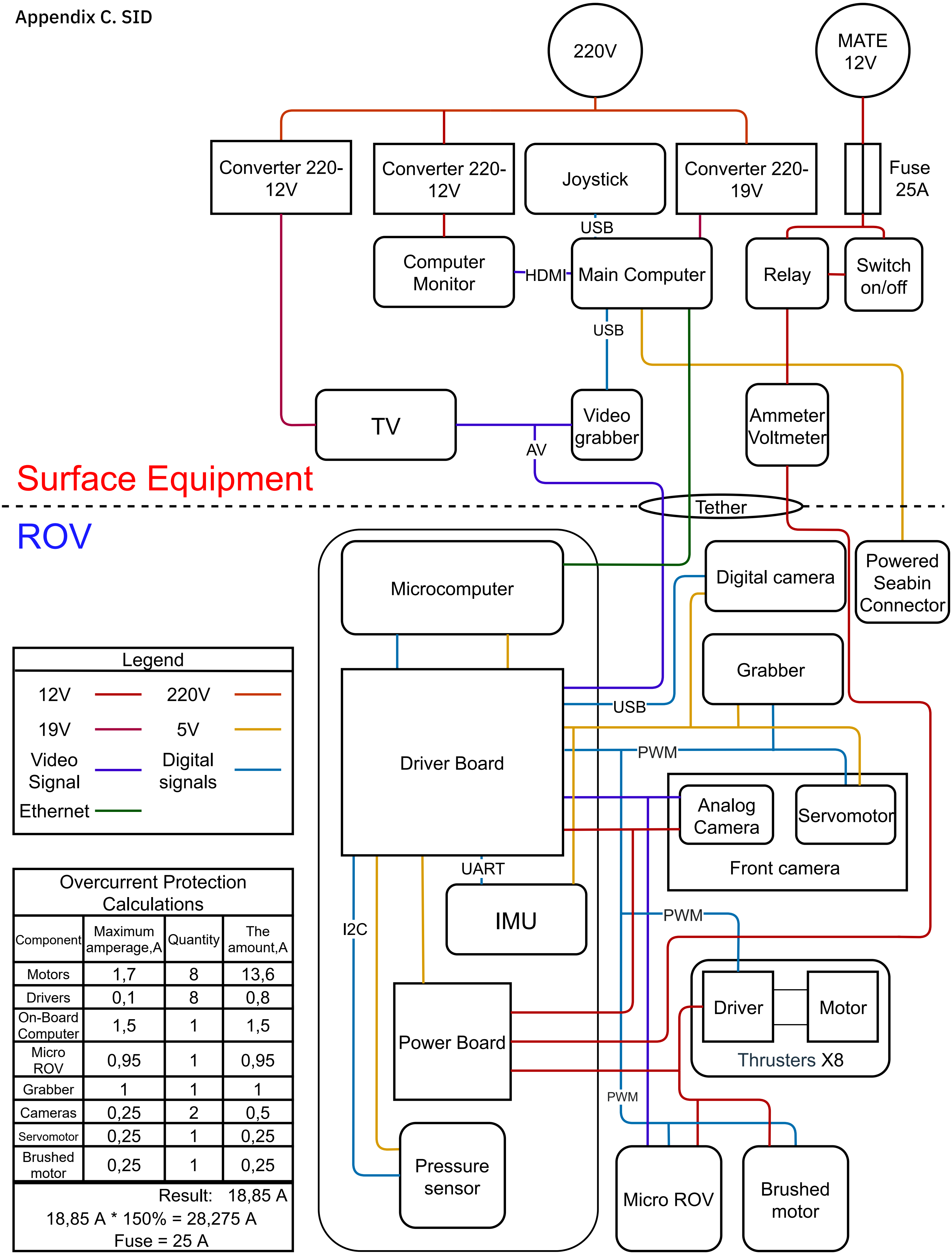
№	TASK NAME	CURATOR	START DATE	END DATE	DURATION	PERCENT OF COMPLETION
1	**Hooks**					
1.1	Production and testing	Besedin Ivan	21.05.21	02.07.21	42	80%
1.2	Production	Besedin Ivan	02.07.21	09.07.21	7	0%
1.3	Installing	Besedin Ivan	09.07.21	16.07.21	7	0%
2	**Preparation for world competitions**					
2.1	Shooting videos for world competitions	Ipatov Tihon	21.05.21	13.06.21	23	100%
2.2	Testing ROV	Grishchenko Andrei	21.05.21	25.06.21	35	100%
2.3	Translation of the text of the technical presentation	Grishchenko Andrei	25.06.21	09.07.21	14	0%
2.4	Learning the text of a technical presentation	Grishchenko Andrei	02.07.21	09.07.21	7	0%
2.5	Strategy development	Grishchenko Andrei	02.07.21	09.07.21	7	0%
2.6	Preparation of the device in the pool	Besedin Ivan	09.07.21	16.07.21	7	0%
2.7	Training	Ipatov Tihon	09.07.21	05.08.21	26	0%
3	**Preparation of Technical documentation for world competitions**					
3.1	SID electrical	Ipatov Tihon	11.06.21	18.06.21	7	100%
3.2	SIDs of Non-ROV Devices	Ipatov Tihon	11.06.21	18.06.21	7	100%
3.3	JSA	Ipatov Tihon	11.06.21	25.06.21	14	100%
3.4	Safety review	Ipatov Tihon	11.06.21	01.07.21	20	100%
3.5	Completion of the technical documentation	Grishchenko Andrei	11.06.21	01.07.21	20	100%
3.6	Company spec sheet	Grishchenko Andrei	11.06.21	01.07.21	20	100%
3.7	Marketing display	Besedin Ivan	11.06.21	01.07.21	20	100%
3.8	Non-ROV device design	Ipatov Tihon	18.06.21	01.07.21	13	100%
3.9	Corporate responsibility	Ipatov Tihon	18.06.21	01.07.21	13	100%
3.10	Translation	Grishchenko Andrei	25.06.21	01.07.21	6	100%
4	**Completion of the ROV**					
4.1	Repair of the bottom camera	Grishchenko Andrei	25.06.21	16.07.21	21	0%
4.2	Updating the grid	Besedin Ivan	25.06.21	16.07.21	21	0%
4.3	Updating of regulators	Grishchenko Andrei	25.06.21	16.07.21	21	0%
4.4	Fixing the IMU	Ipatov Tihon	25.06.21	16.07.21	21	0%

Gantt chart 2 - after regionals

Appendix B. Usage model

№ of dive	Plan	Points
0	We install a frame for counting mussels(Grabber) and a net for eels(hooks)on the device	0P
1	We dive into the depth of the field with mussels	
	We install the device above the field	
	We dive until the frame touches the field	
	We loosen the grip of the grabber, we dive in parallel, slightly pushing back to put the frame	
	We open the grabber and throw out the frame	5P
	We float above the frame, install the device so that it is in the field of view of the bottom camera	
	We count mussels	5P
	We turn the device towards the eels	
	We swim up to the field with eels	
	We dive until the moment when the grabber will be able to grab the net with blackheads for a metal earring	
	We pick up the grid with blackheads with the grabber and remove it	10P
	We float a short distance above the frame of the eel field	
	We install the device so that the net attached to the hook is in the middle of the eel field	
	We lower the device until the net touches the bottom	
	Guided by the bottom chamber, we lower the device until the hook lowers the trap with eels	
	We pass back, leaving the field for eels and installing a new net	
	We turn around and swim backwards to the pipe	
	We aim and launch the Micro ROV into the pipe	
	We hook the capsule with the information and pull it out of the pipe using Micro ROV	25P
	We climb to a depth just above the height of the corals (around 0,5 m)	
	We swim up to the field with corals	
	Switching to autonomous control	
	In automatic mode, we swim over the field of corals	20P
	Mapping the sights on the reef	5P
	We float to the surface and remove the device together with the capsule and the grid attached to it	10P
	We determine the polluting substance	5P
	The result of the first dive	95P
Side of pool	We install syringes for killing stars on the ROV's grabber and lower the vehicle into the water when ready	
2	We dive into the depth of the props	
	We install the device above the subway car and scan it with a bottom camera	20P
	We go down and scan the subway car from all 4 sides. We draw a scan on the side of pool	
	We turn around and enter the coral reef zone	
	We are approaching the first star	
	We open the grabber and put the syringes NEAR the star	
	We pick up one syringe and install it on the star	5P
	We take the second syringe and swim to the second star	
	If there is a sponge layout on the route	
	1) We rise above the sponges (around 0,6-0,7 m), they were not dumped by the flow	
	2)Install ROV over the sponge so that it can be grabbed with a hook	
	3) Slowly lower the device to the sponge, trying not to knock it down	
	4) We pick up the sponge and gently float to a small height to remove it	10P
	5)We go to the side and swim to the second star	
	6)Kill the star	5P
	Else:	
	We swim up to the second star and install a syringe on it	5P
	We repeat the described actions (1-4)	10P
	We turn around and swim up to a large coral	
	We install the device in front of the coral, so that it all falls into the field of view of the camera	
	We determine the areas on the coral	10-20P
	We go around the coral from any side	
	We swim up to the coral nursery	
	We take the coral and transfer it to the landing site	10P
	Repeat the action with the second coral	10P
	We turn around in the direction of Seabin and swim to the ZipLock located near it	
	Open the claws of the grabber and grab the first Zip Lock	5P
	We turn around in the direction of the second ZipLock and swim to it	
	We swim as close as possible, open the grabber and put the first and second ZipLocks next to each other	
	Using the grabber, we grab the first and second ZipLocks	5P
	We pop up to the level of the frame with balls	
	Carefully moving, we collect the maximum number of balls	5-15P
	We turn around and swim out of the field with the balls	
	We swim to the board and take out the vehicle + collect all the collected props	5P
	The result of the second dive	95P
Side of pool	We remove props from ROV and immerse it in water	
3	We dive to the depth of Seabin	
	We put the device opposite the induction charger	
	We grab the induction charging with the grabber	
	Remove the charger from the socket	5P
	We hook up the net with hooks and remove it	10P
	We swim to the surface and give the props to the coastal team. We insert a new grid and charging into ROV	
	Back to Seabin	
	We install the device so that the grid is over the landing site, and the charger is over the socket	
	We lower the vehicle until we touch the landing place with the grid. Then it will detach itself from the hook and install	10P
	We check that the charger still gets into the socket. If not, then we correct it	
	We go down and set the charger	20P
	We swim back from Seabin	
	We turn around and swim to the ghost grid	
	We swim up from above so that it is perpendicular to the grabber	
	We grab the free part of the pin and, moving sideways, take it out	10P
	We swim to the surface behind the grid	
	We grab the net with the payload (hook or grabber) and pull it to the side of pool	10P
	We take out ROV	
	The result of the third dive	65P
	The performance is completed. Result	270P

Appendix C. SID



Overcurrent Protection Calculations

Component	Maximum amperage,A	Quantity	The amount,A
Motors	1,7	8	13,6
Drivers	0,1	8	0,8
On-Board Computer	1,5	1	1,5
Micro ROV	0,95	1	0,95
Grabber	1	1	1
Cameras	0,25	2	0,5
Servomotor	0,25	1	0,25
Brushed motor	0,25	1	0,25

Result: 18,85 A

18,85 A * 150% = 28,275 A

Fuse = 25 A

Appendix D. Safety Check Lists

Safety Check List for ROV development
Security measures of the company's employees during the design and manufacture of ROV
A) When working on the machine
1. When working on the machine, persons with experience and knowledge of working on this machine are allowed
2. When working on the machine, an employee of the company must have gloves, protective glasses and special protective clothing
3. Upon completion of work on the machine, it is necessary to restore order in the workplace
B) In the production of components and mechanisms on the ROV
1. All manufactured parts must be stored strictly in a certain place
2. Parts with roughness must be protected with special tools and means
3. The manufactured mechanisms must be maintained in optimal condition, lubricated and checked for operability
C) When assembling the main device to the company's employees
1. The device must be assembled by several employees of the company
2. The assembly of the device must be carried out under strict compliance with the drawings and prototyped models

If an employee of the company receives an electric shock
1. It is necessary to pull the employee of the company away from the current source, using objects and things that do not conduct electricity
2. It is necessary to check the breathing and pulse of an employee of the company
3. It is necessary to report this incident to the mentor and call a doctor if necessary

If an employee of the company receives a physical injury
1. It is necessary to provide a safe area around the injured employee
2. It is necessary to provide first aid to the injured employee
3. It is necessary to report this incident to the mentor and call a doctor if necessary

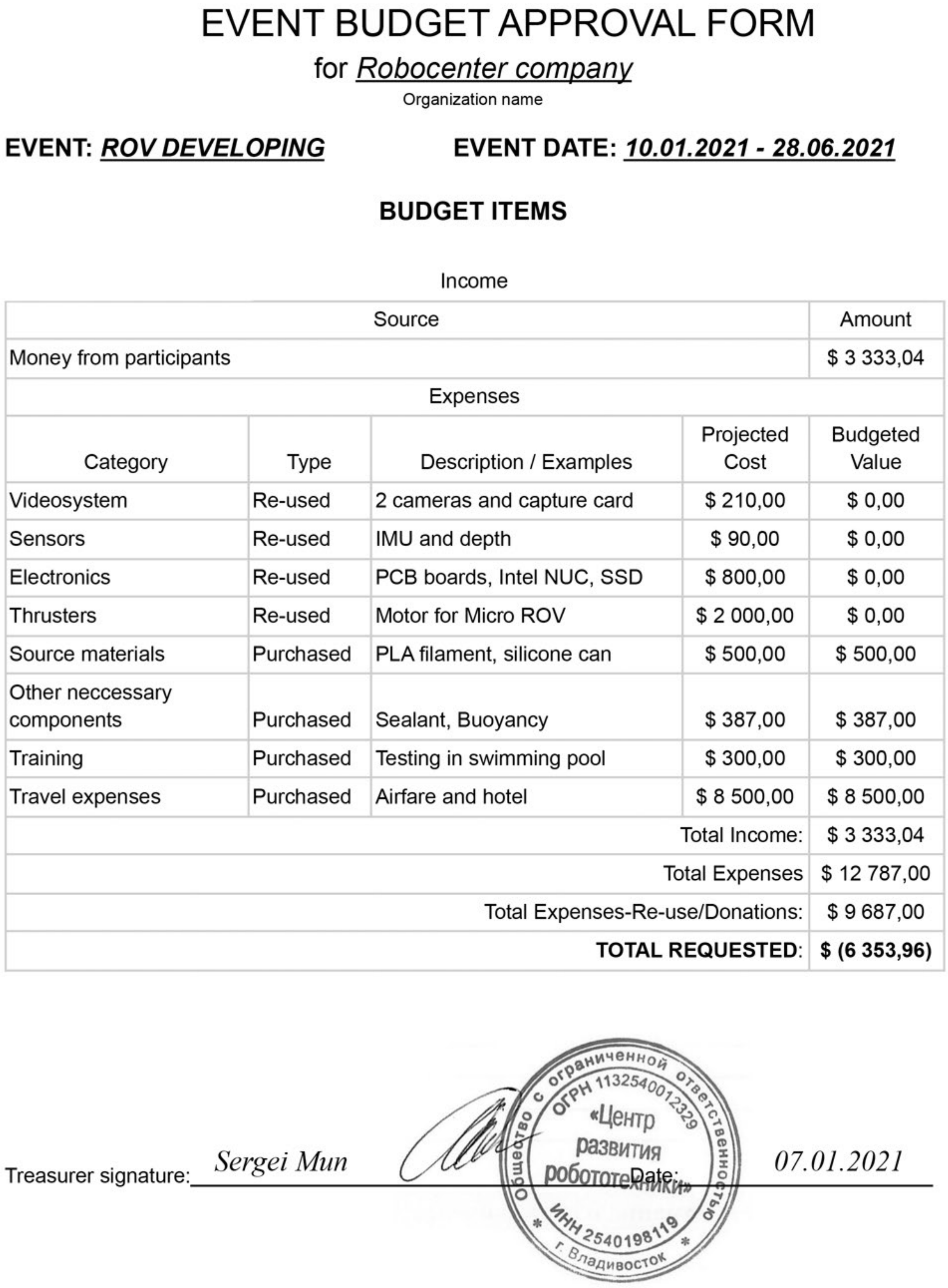
Safety Check List for ROV operation
Safety measures of the company's employees when the ROV is first connected to the power supply on land
1. Check the design of the device for the integrity and correctness of the assembly, check the drawings
2. Check the electronics on the device, make sure that it is connected correctly
3. Supply power to the device through the ROV control unit, while making sure that there is no danger of electric shock to the company's employees
4. In case of problems, identify a problem when the power is turned off from the device

Safety measures of the company's employees during the first ROV connections in the water
A) Before starting to connect the power supply to the ROV
1. Check the integrity of the ROV construction
2. Check the sealing of all components and units of the ROV
3. Check the buoyancy of the ROV and its balancing in the water environment
4. Apply power to the ROV, making sure that none of the company's employees has contact with the water in which the device is located
5. Check the device for operability, in case of a malfunction of the ROV, it is necessary to turn off the power and bring it to the surface for its diagnosis

Safety measures when connecting the ROV in water
1. Check the sealing of the ROV wire connections
2. Check the ROV construction for integrity
4. Apply power to the ROV, making sure that none of the company's employees has contact with the water in which the device is located
4. Check the performance of the device in the water, setting in motion each of its mechanisms in turn

If an employee of the company drowns
1. Quickly get the injured person out of the water
2. Check his pulse and breathing
3. It is necessary to provide first aid to the injured employee
4. It is necessary to report this incident to the mentor and call a doctor if necessary

Appendix E. Event Budget Approval Form



EVENT BUDGET APPROVAL FORM

for *Robocenter company*
Organization name

EVENT: ***ROV DEVELOPING*** **EVENT DATE:** ***10.01.2021 - 28.06.2021***

BUDGET ITEMS

Income

Source				Amount
Money from participants				$ 3 333,04
Expenses				
Category	Type	Description / Examples	Projected Cost	Budgeted Value
Videosystem	Re-used	2 cameras and capture card	$ 210,00	$ 0,00
Sensors	Re-used	IMU and depth	$ 90,00	$ 0,00
Electronics	Re-used	PCB boards, Intel NUC, SSD	$ 800,00	$ 0,00
Thrusters	Re-used	Motor for Micro ROV	$ 2 000,00	$ 0,00
Source materials	Purchased	PLA filament, silicone can	$ 500,00	$ 500,00
Other neccessary components	Purchased	Sealant, Buoyancy	$ 387,00	$ 387,00
Training	Purchased	Testing in swimming pool	$ 300,00	$ 300,00
Travel expenses	Purchased	Airfare and hotel	$ 8 500,00	$ 8 500,00
			Total Income:	$ 3 333,04
			Total Expenses	$ 12 787,00
			Total Expenses-Re-use/Donations:	$ 9 687,00
			TOTAL REQUESTED:	**$ (6 353,96)**

Treasurer signature: *Sergei Mun* Date: *07.01.2021*

ОГРН 1132540012329
«Центр развития робототехники»
ИНН 2540198119

Appendix F. Budget and Project costing

Budget

Reporting period

School Name:		The Center for Robotics Development	From:	10.01.2021
Instruction/Sponsor:		Sergey Mun	To:	28.06.2021

Income

Source	Amount
Money from participants	$ 3 333,04

Expenses

Category	Type	Description / Examples	Projected Cost	Budgeted Value
Videosystem	Re-used	2 cameras and capture card	$ 210,00	$ 0,00
Sensors	Re-used	IMU and depth	$ 90,00	$ 0,00
Electronics	Re-used	PCB boards, Intel NUC, SSD	$ 800,00	$ 0,00
Thrusters	Re-used	Motor for Micro ROV	$ 2 000,00	$ 0,00
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Other neccessary components	Purchased	Sealant, Buoyancy	$ 387,00	$ 387,00
Training	Purchased	Testing in swimming pool	$ 300,00	$ 300,00
Travel expenses	Purchased	Airfare and hotel	$ 8 500,00	$ 8 500,00

Total Income:	$ 3 333,04
Total Expenses	$ 12 787,00
Total Expenses-Re-use/Donations:	$ 9 687,00
Total Fundraising Needed:	$ (6 353,96)

Project costing

Reporting period

School Name:	The Center for Robotics Development	From:	10.01.2021
Instructor/Sponsor	Sergey Mun	To:	28.06.2021
Funds			

Date	Type	Category	Expense	Description	Sources / Notes	Amount	Running Balance
10.01.2021	Re-used	Autopilot	Watertight enclosure	MUR Autopilot watertight enclosure	From the last year	$ (60,00)	$ (60,00)
10.01.2021	Re-used	Electronic Control Unit	Joystick	Thrustmater T-Flight Hotas X	From the last year	$ (100,00)	$ (160,00)
10.01.2021	Re-used	Vehicle frame	Frame	HDPE 1000x1000x10 mm sheet	From the last year	$ (200,00)	$ (360,00)
10.01.2021	Re-used	Electronics	Electronic boards	Raspberry Pi 4 Model B, Autopilot controller PCB	From the last year	$ (170,00)	$ (530,00)
10.01.2021	Re-used	Videosystem	2 cameras and capture card	Analog and digital cameras and AVerMedia	From the last year	$ (210,00)	$ (740,00)
10.01.2021	Re-used	Cable	4 cables and wires	12 AWG	From the last year	$ (135,00)	$ (875,00)
10.01.2021	Re-used	Sensors	IMU and depth	IMU Hipnuc HI226 & MUR Depth sensor	From the last year	$ (90,00)	$ (965,00)
10.01.2021	Re-used	Sealant	Sealing components	Sealant, penetrators, cable gland, inlet seals	Used for tightness	$ (187,00)	$ (1 152,00)
10.01.2021	Re-used	Electronic Control Unit	Waterproof case	MUR Medium case	For surface PC	$ (30,00)	$ (1 182,00)
10.01.2021	Re-used	Electronic Control Unit	Voltage converter	220V AC to 12V DC	For surface PC	$ (10,00)	$ (1 192,00)
10.01.2021	Re-used	Electronic Control Unit	Surface PC	Intel NUC i7	For surface PC	$ (266,36)	$ (1 458,36)
10.01.2021	Re-used	Electronic Control Unit	SSD	Adata 256 Gb	For surface PC	$ (19,11)	$ (1 477,47)
10.01.2021	Re-used	Buoyancy	Buoyancy	1200x600x30 Penoplex 1 sheet	Extruded foamed polystyrene	$ (10,00)	$ (1 487,47)
19.01.2021	Purchased	Mission specific Features	Motors for Micro Rov	BLDC drone motors 24 mm	Ordered from Internet	$ (16,00)	$ (1 503,47)
12.02.2021	Purchased	Mission specific Features	PLA filament	PLA filament 1kg	For 3D printing	$ (27,32)	$ (1 530,79)
05.04.2021	Purchased	Mission specific Features	Silicone rollers	Smooth-On Mold Max silicone 1l can	Used for rewinder	$ (28,69)	$ (1 559,48)
10.04.2021	Purchased	Mission Specific Features	Manipulator	MUR gripper	Light and compact underwater gripper for tasks performing	$ (163,98)	$ (1 723,46)
26.04.2021	Purchased	Thrusters system	8 thrusters	MUR Thruster 1500	Instead weared out	$ (1 639,20)	$ (3 362,66)
21.04.2021	Purchased	Vehicle frame	Bottom plate	HDPE 1000x1000x10 mm sheet	Built new for new improvements*	$ (100,00)	$ (3 462,66)
30.05.2021	Purchased	Work of mentors	Salaries for mentors	To control our work and teach us	Employees of Center for Robotics Development	$ (3 278,40)	$ (6 741,06)
28.06.2021	Purchased	Training	Swimming pool	To test our vehicle	Maritime State University G.I. Nevelskoy	$ (204,90)	$ (6 945,96)
28.06.2021	Purchased	Training	Taxi to the pool	Round-trip	From our organization	$ (82,90)	$ (7 028,86)

Total Raised	$ 0,00
Total Spent	$ (7 028,86)
Final Balance	$ (7 028,86)